PONTIFICIA UNIVERSIDAD CATÓLICA DEL ECUADOR

FACULTAD DE INGENIERÍA

ESCUELA DE INGENIERÍA CIVIL

DISERTACIÓN PREVIA A LA OBTENCIÓN DEL TÍTULO DE:

INGENIERO CIVIL

TEMA

Utilización del polvo de llanta en mezclas asfálticas en frío como alternativa de reciclaje

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QUITO, 2014

DEDICATORIA

Sebastián Carrasco:

Con todo mi cariño a mis padres Antonio Carrasco y Veronica Suarez; y a mis hermanos Daniel y Pedro José por su sacrificio y motivación para lograr con el objetivo, es para ustedes está tesis en agradecimiento por todo su apoyo y amor. Un especial agradecimiento a mi padre Antonio por introducirme a esta maravillosa carrera y por toda su ayuda a lo largo de la misma.

Pablo Espinosa:

Quiero dedicar este trabajo, con profundo amor,
a mis padres Pablo Espinosa y Amparo Prado,
a mis hermanos: Juan José y María Pía
y a mi novia María Cristina Ruales

AGRADECIMIENTO

El presente trabajo y el logro académico que representa no podía llegar sin contar con la preciosa y constante ayuda de nuestros padres: Antonio Carrasco y Veronica Suarez; Pablo Espinosa y Amparo Prado a quienes queremos expresarles que todo su amor y sacrificio han dado frutos.

Queremos también agradecer, por medio de este corto mensaje, a nuestros hermanos Daniel Carrasco y Pedro José Carrasco; Juan José Espinosa y María Pía Espinosa por su compañía, apoyo y cariño.

No podemos dejar de extender nuestro profundo agradecimiento a todos nuestros profesores, autoridades y trabajadores de la Universidad por todo el profesionalismo, sacrificio y abnegación que brindan a sus estudiantes en sus labores diarias.

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RESUMEN

El presente trabajo titulado “utilización del polvo de llanta en mezclas asfálticas en frío como alternativa de reciclaje” fue realizado con el fin de determinar, con base en ensayos de laboratorio, si el producto del reemplazo de agregados finos por polvo de llantas en la mezcla asfáltica cumple con las normas técnicas para el uso en calles destinadas a tránsito vehicular.

Para tal fin, primero se realizó una investigación acerca del origen del caucho y su uso para la fabricación de llantas para, posteriormente, analizar el perjuicio que supone para la naturaleza y el ser humano el desecho y almacenamiento inadecuados de los neumáticos usados. Una vez conocida esta información, se procedió a realizar los ensayos correspondientes al polvo de llantas, a la emulsión y a las briquetas de asfalto elaboradas con distintas concentraciones porcentuales de polvo de llanta en el conjunto de agregados.

Se realizaron ensayos de equivalente de arena, granulometría, abrasión, gravedad específica, peso unitario y absorción, resistencia a los sulfatos y ensayos a la emulsión; resultando en todos ellos que se cumplían las normas AASHTO y ASTM.

En las pruebas de resistencia se encontró que la mezcla con un uso de 25% de reemplazo presentaba mejores resultados; no obstante, ante pruebas de durabilidad en condiciones extremas, se produce una pérdida de resistencia en la briquetas de un 50%.

Palabras clave: asfalto – polvo de llantas – reciclaje de neumáticos

CAPÍTULO I

CAUCHOS Y NEUMÁTICOS

Antes de explicar el proceso de fabricación del neumático, es importante describir al caucho y las propiedades que posee.

El diccionario de la Real Academia Española define al caucho como "Látex producido por varias moráceas y euforbiáceas intertropicales, que, después de coagulado, es una masa impermeable muy elástica, y tiene muchas aplicaciones en la industria" (RAE, 2010). De la misma forma, Clavijo (2004) define al caucho como "un árbol de porte mediano correspondiente al género Hevea perteneciente a la familia Euphorbiacea. Este material también es conocido como caucho, hevea, hule, jebe y siringueira (Clavijo, 2004). Así mismo, en el Anuario de 2004, los autores mencionan que el caucho natural es un producto "obtenido por medio de la coagulación del látex que es emanado de algunas plantas, en especial del árbol del caucho" (Agrocadenas, 2004).

La revista Agrocadenas adicionalmente describe que el árbol de caucho utilizado para la extracción es "de tamaño mediano de 10 a 20 metros de altura y de tallo cilíndrico" (2004). El árbol de caucho puede ser encontrado en zonas que van desde 0 a 1200 metros sobre el nivel del mar (Agrocadenas, 2004). El árbol de caucho es nativo de Sudamérica y se produce en países como Brasil, Colombia, Ecuador y Perú; en estado silvestre, puede alcanzar altura de entre 25 y 30 metros de altura.

Este árbol crece en zonas tropicales húmedas donde existan posibilidades de producirse pequeñas inundaciones o presencia de lodo constante. En Latinoamérica se siembran aproximadamente 280 mil hectáreas de caucho, lo que cubre el 3,9 % de la oferta mundial (FAO, 2010). El caucho tiene varias aplicaciones desde ser aislante de sismos para estructuras hasta ser utilizado como materia prima para llantas, borradores, aditivos entre otros.

Una vez definido lo que es el caucho, es importante conocer un poco acerca de la historia de esta sustancia para, posteriormente, explicar la fabricación del neumático.

A mediados del siglo XVII, el gobierno francés envió al matemático Charles Marie Condamine a una expedición geográfica por Sudamérica. Uno de los propósitos de esta expedición era conocer la efectividad del caucho en la zona industrial. Al finalizar la expedición, los resultados mostraron que el caucho no podía mantener su forma al ser expuesto a diferentes temperaturas (Compagno, 1986). Al estar a una temperatura alta, el caucho se derretía, mientras que al exponerse a temperaturas bajas, el caucho se volvía quebradizo. Ante estos resultados, se dio por sentado que el caucho no tenía usos prácticos inmediatos. (Compagno, 1986)



Imagen 1. Extracción del caucho

En 1836, el americano Charles Goodyear descubrió que el hule o caucho, al ser calentado con azufre, se volvía un compuesto estable que podía resistir varios cambios de temperatura. Por otro lado, en 1888 Henry Ridley impulsó la exportación de las plantas de caucho, realizó experimentos de densidades de plantación así como los procesos de secado (Martines *et al.*, 2001). Así mismo, en ese año el inglés John Dunlop fabricó la primera llanta neumática que se utilizaría en una bicicleta. Sin embargo, sería en 1895 la primera vez que se usaría el neumático de Dunlop en un automóvil. Años más tarde, en 1926 Malasia crea la organización *Rubber Research of Malasia,* convirtiéndose en la máxima autoridad en la producción de hule natural.

Según el *International Rubber Study Group* el 90 % de las plantaciones de caucho se encuentran en el continente asiático. Siendo Indonesia, Malasia y Tailandia los mayores productores de hule natural. (Martines *et al.*, 2001).

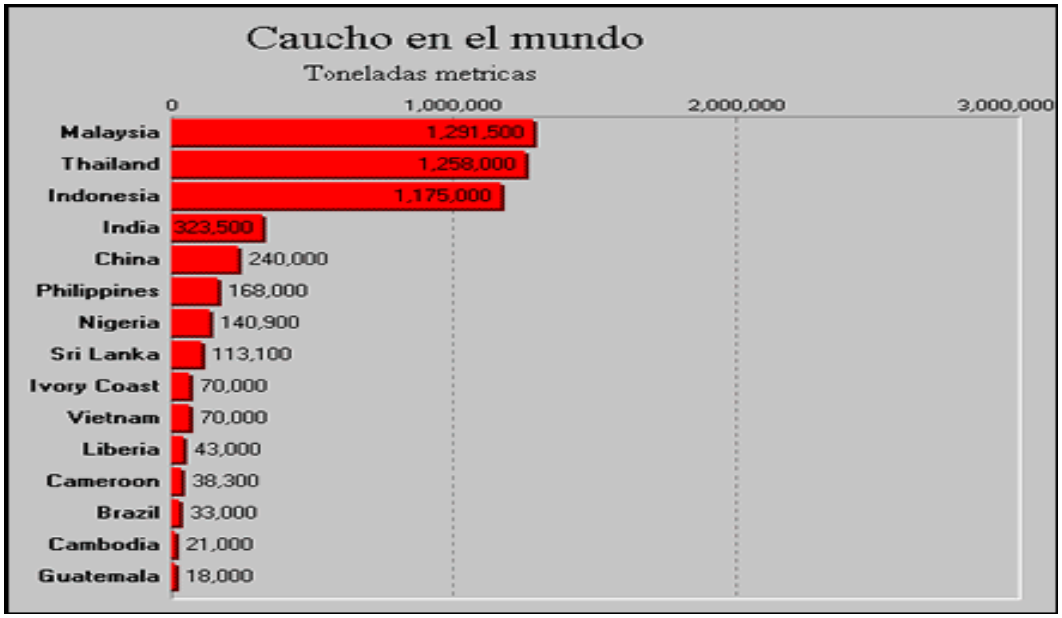


Imagen 2. Producción mundial de caucho por país

1.1 Procesos para la fabricación de neumáticos:

Según Castro (2008) "Un neumático es básicamente un elemento que permite a un vehículo desplazarse en forma suave a través de superficies lisas. Consiste en una cubierta principalmente de caucho que contiene aire el cual soporta al vehículo y su carga".

Castro (2008) señala que, según las funciones que despeña el neumático, cada material que se utiliza en su fabricación debe cumplir con los requerimientos del neumático; en su mayoría, la llanta está compuesta de caucho que representa casi el 50 % de su peso total. De esta manera se entiende por qué el 60 % del caucho producido a nivel mundial es utilizado para la fabricación de neumáticos. Adicionalmente, el caucho del neumático está compuesto por una serie de materiales como:

- **Fibras reforzantes:** que están compuestas de fibras textiles y de acero que, a su vez, forman hilos que ayudan a la resistencia del neumático. La cantidad de estas fibras varía según quién lo produce.
- **Plastificantes:** son aditivos que sirven para facilitar la preparación de la mezcla del neumático y ayudan a la flexibilidad del mismo en bajas temperaturas. Generalmente son aceites de origen mineral.
- **Varios:** además de los compuestos antes mencionados, los neumáticos contienen agentes vulcanizantes (azufre), acelerantes (sulfuros), restardantes (N-nitroso), antioxidantes, entre otros.

En la imagen 3 se presentan la composición y características de los neumáticos según la *Rubber Manufacters Association*:

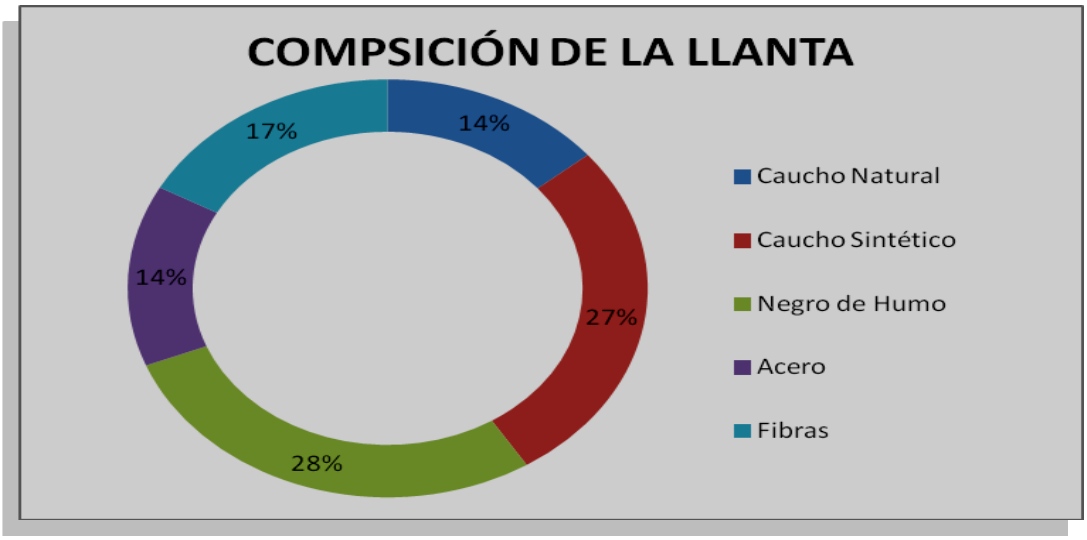


Imagen 3. Composición de los neumáticos de pasajeros (automóviles y camionetas)

1.2 Polvo de llanta

En la actualidad, el reciclaje de la llanta no está normado dentro de la Constitución vigente de nuestro país ni en otras normas legislativas; sin embargo, la realidad es que en el Ecuador existen aproximadamente 2,4 millones de neumáticos que equivalen a 55 000 toneladas que es su mayoría terminan quemándose o tirándose al mar. Las llantas se componen de un gran número de sustancias que podrían ser consideradas como peligrosas, las cuales tienen un impacto negativo en la salud si no se les da el manejo apropiado (COCEF, 2008).

Los gobiernos de todo el mundo están tratando de encontrar nuevos usos a los materiales que generalmente son desechados; por esta razón, las políticas actuales se orientan cada vez más a la reutilización de los recursos, además de sanciones más severas para quienes atenten contra el medio ambiente. Por los motivos señalados, las grandes empresas están invirtiendo ingentes sumas de dinero para encontrar alternativas para el procesamiento de sus residuos y el reciclaje de la materia que ya ha sido usada.

En la actualidad, la Corporación de Inversiones del Azuay ha entablado negociaciones con empresas europeas y nacionales para proceder a la instalación de una planta de reciclaje de llantas en el país; en esta obra se invertiría una cantidad de 3 millones de dólares, aproximadamente; lo que obligaría a los gobiernos nacional y regional a crear normas o incentivos para la producción y operación de esta planta (El Tiempo, 2011).

El inadecuado tratamiento de los neumáticos usados produce varios problemas. Cuando se queman las llantas a cielo abierto, se causa un gran impacto al medio ambiente, ya que se liberan contaminantes de referencia, tales como material particulado, monóxido de carbono (CO), óxidos de azufre (SOx), óxidos de nitrógeno (NOx), y compuestos orgánicos volátiles (COVs). Incluyen también contaminantes peligrosos tales como hidrocarburos policíclicos aromáticos (PAHs), dioxinas, furanos, cloruro de hidrógeno, benceno, bifenilos poli clorados (PCBs), y metales pesados como arsénico, cadmio, níquel, zinc, mercurio, cromo, y vanadio. Los compuestos volátiles más abundantes pertenecen a los aromáticos así como los alifáticos, olefínicos. La exposición de los humanos a este tipo de compuestos causa problemas de salud tanto a largo como a corto plazo, algunos de estos efectos pueden incluir irritación de la piel, ojos y membranas mucosas, depresión del sistema nervioso central, efectos respiratorios y cáncer entre los más graves. Las mutaciones causadas por las sustancias resultantes de la quema de las llantas son mucho más agresivas que las producidas por otro tipo de proceso como la contaminación, quema de la leña entre otros; las mencionadas mutaciones pueden provocar defectos al momento de nacer, abortos espontáneos, cáncer, o podrían influir en el aumento de enfermedades genéticas en las futuras generaciones.

En algunos casos, especialmente en zonas rurales, las llantas son utilizadas como un tipo de combustible alterno debido a su bajo costo y su alto poder energético, a lo que se suma el hecho de que no existe un control permanente por parte de una

autoridad ambiental estatal. En estos lugares se puede presentar la ausencia de una correcta ventilación con los problemas que esto conlleva.

Por otro lado, el incorrecto almacenamiento de las llantas principalmente causa cuatro tipos de impacto importantes:

- Proliferación de vectores como mosquitos y roedores debido al estancamiento de las aguas y la inaccesibilidad de zonas de almacenamiento (se recomienda perforar las llantas antes de almacenarlas a la intemperie).
- Riesgo de incendios incontrolables en lugares donde se apila gran cantidad de llantas sin la apropiada distribución y medidas de control mínimas.
- Riesgos de derrumbe cuando se apilan los neumáticos de manera inadecuada.
- Deterioro del entorno y del paisaje.

Adicionalmente, cabe resaltar el costo que representa el almacenaje de las llantas por el cual no se obtiene ningún tipo de ganancia económica.

En la actualidad, el cuidado ambiental se está abriendo campo como una de las nuevas políticas que los gobiernos están adoptando por la creciente preocupación ciudadana sobre la contaminación y especialmente el cambio de clima como resultado del efecto invernadero que está sufriendo el planeta.

En vista de lo señalado en párrafos previos, se observa la necesidad de implementar formas de reciclaje de los neumáticos usados. Es, en este sentido, que se puede hacer uso del polvo de llanta que se puede obtener de dos maneras:

Trituración criogénica: este método necesita instalaciones muy complejas, a lo que se suma el hecho de que el mantenimiento de la maquinaria es costos y del proceso es difícil. La baja calidad de los productos obtenidos, la dificultad material y económica para purificar y separar el caucho y el metal entre sí y de los materiales textiles que forman el neumático, provoca que este sistema sea poco recomendable.

Trituración mecánica: los productos resultantes son de alta calidad, limpios de todo tipo de impurezas lo que facilita la utilización de estos materiales en nuevos procesos y aplicaciones. La trituración con sistemas mecánicos es, casi siempre, el paso previo en los diferentes métodos de recuperación y rentabilización de los residuos de neumáticos. Este concepto incluye la fragmentación del neumático en gránulos y separación de componentes (acero y fibras). Los usos más comunes de estos productos son: materiales de relleno, modificadores de asfalto, superficies de atletismo y deportes, y productos moldeados y calandrados. Lo que se pretende es incrementar la calidad y consistencia del polvo de llanta, lo que conducirá a un reciclado del material mucho más extenso.

El resultado de la trituración descrita puede ser utilizado en mezclas asfálticas para la construcción de carreteras, con lo que se podría disminuir la extracción de áridos de las canteras. Se cuenta con estudios realizados en Argentina que han demostrado que en pavimentos rígidos se utilizan entre 1000 y 7000 neumáticos (triturados en forma de polvo de llanta) por kilómetro de una vía de dos carriles, dependiendo del sistema usado en la construcción del pavimento rígido.

Para la obtención del polvo de llanta se seguirá el siguiente proceso:

- Se inicia con la trituración primaria, la cual consiste en llevar al neumático entero a una maquina generalmente de dos rotores con cuchillas que cortan a las llantas en trozos. Los materiales resultantes siguen siendo muy grandes, el objetivo de este primer proceso es solamente trocear al neumático y que no se encuentre en una sola pieza.

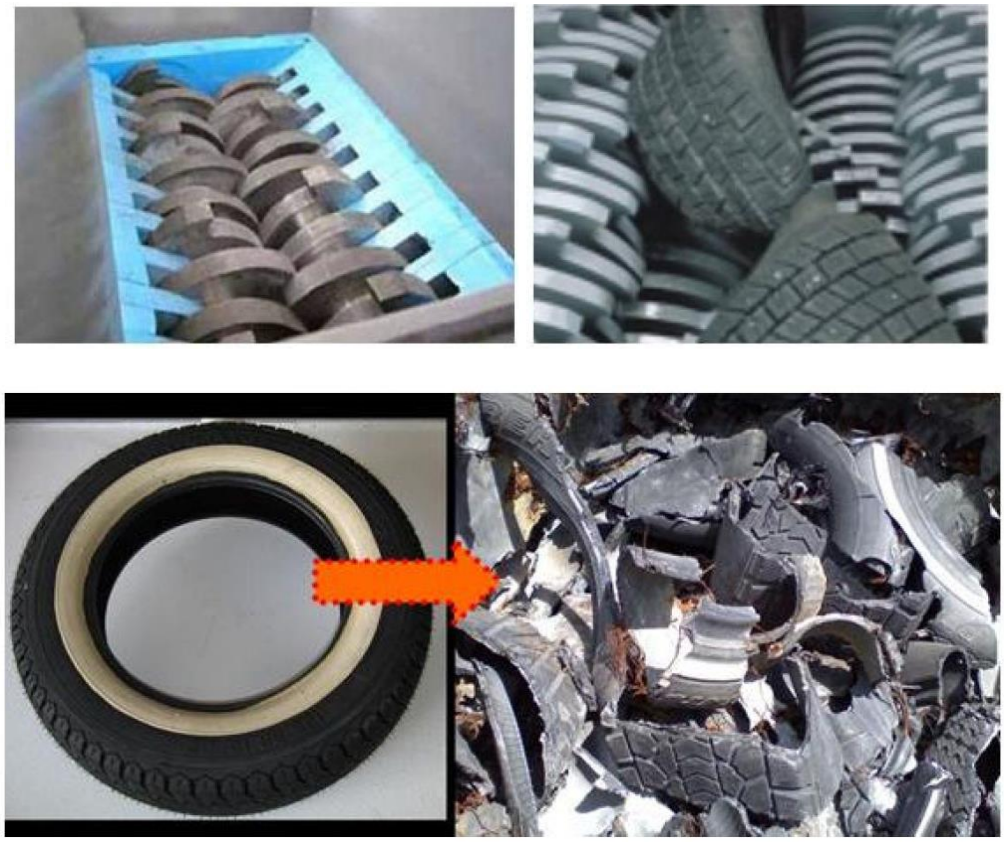


Imagen 4. Proceso de trituración primaria

- Posteriormente se realiza una trituración secundaria en otra máquina trituradora la cual reduce los pedazos de llantas provenientes de la trituración

primaria. Esta máquina cuenta con parrillas metálicas que van tamizando los pedazos de la llanta de acuerdo con el tamaño que se necesita.

Los trituradores que se utilizan para estos procesos son máquinas robustas que generalmente tienen parrillas metálicas que van desde los 20mm hasta los 100mm dependiendo del tamaño estándar del fabricante. Varios fabricantes dan la posibilidad de que las parrillas usadas sean intercambiables con el fin de ofrecer variedad de tamaños.



Imagen 5. Máquina de trituración secundaria

- Luego de la trituración secundaria, se llevan los pedazos de la llanta al granulador primario. El material obtenido de este proceso puede tener hasta 16mm de diámetro.





Imagen 6. Máquinas granuladoras primarias

- El siguiente paso en el proceso hacia el polvo de llanta es la separación del acero armónico de la llanta. Para esto, se utiliza un separador magnético que cuenta con una banda transportadora que se ocupa de conducir el acero hasta un punto de recolección. En este proceso se logra separar has un 99 % del acero armónico de la llanta.



Imagen 7. Separador magnético de acero

- El proceso sigue con el granulado secundario que tiene como objeto reducir aún más el tamaño del material hasta llegar al deseado para el proceso en el que se lo va a utilizar. Estas máquinas pueden dejar material hasta de 0,7 mm.



Imagen 8. Máquina granuladora secundaria



Imagen 9. Producto final del proceso

La instalación de una planta, según datos de empresas recicladoras en Europa (considerando una planta con una capacidad de 2,5 toneladas por hora), requiere una inversión de 2 millones de euros solo para la compra de la maquinaria necesaria. Además, para el funcionamiento de la planta recicladora se necesitan entre 3 y 5 hombres por turno (de 8 horas). El precio de estas líneas de reciclaje puede variar considerablemente dependiendo de las toneladas tratadas por hora además del

tamaño del grano; esto quiere decir, si la línea de fábrica quiere lanzar al mercado una gama de tamaños del grano. Se presentan algunos datos de producción:

1 ton/hr de llantas de carro y camiones produce:	590 kg/hr de granos de goma.
	331 kg/hr de acero armónico.
	167 kg/hr de polvo de llanta.
2,5 ton/hr de llantas de carro y camiones produce:	1475 kg/hr de granos de goma.
	775 kg/hr de acero armónico.
	217 kg/hr de polvo de llanta.
3 ton/hr de llantas de carro y camiones produce:	1770 kg/hr de granos de goma.
	930 kg/hr de acero armónico.
	279 kg/hr de polvo de llanta.
4 ton/hr de llantas de carro y camiones produce:	2360 kg/hr de granos de goma.
	1240 kg/hr de acero armónico.
	365 kg/hr de polvo de llanta.

En adición, en este tipo de procesos se obtienen fibras textiles las cuales se encuentran dentro de la llanta. Estas fibras se obtienen en menor cantidad que el acero armónico y en un porcentaje un poco mayor que el polvo de llanta.



Imagen 10. Granos de diferentes granulometrías (entre 0,5 y 3 mm)



Imagen 11. Polvos de llanta

Otra forma en la cual se puede producir polvo de llanta, como ya se mencionó previamente, es mediante un sistema criogénico en el cual se congelan los neumáticos para que se facilite su trituración y, por ende, la separación de sus componentes. Este sistema se ha utilizado especialmente en la provincia de Nueva Escocia, en Canadá, en donde el 100 % de sus llantas son recicladas mediante este proceso. Los costos son más altos que el de una planta de trituración convencional.

1.3 Pavimentos con polvo de llanta

Los pavimentos modificados con polvo de llanta ya han sido utilizados en países como México, Colombia, España y otros países desarrollados. En estos casos, los resultados han sido favorables en cuanto el desempeño del mismo; no obstante, en cuanto al factor económico, debido a los procesos de fabricación del polvo de llanta, el costo del pavimento se incrementa significativamente (cerca del 35% más caro). Si embargo de lo anterior, el beneficio del reciclaje de la llanta evita problemas ya determinados previamente como los estéticos, de contaminación y problemas de salud en los seres humanos; por lo que el costo adicional es compensado; adicionalmente, según algunos estudios realizados en España, estos pavimentos son mejores en filtrar el agua y producen carreteras más silenciosas.

El primer intento de crear un asfalto con polvo de llanta se dio en Norteamérica en el año 1982 en el estado de California. Este intento confirmó que se podría fabricar asfalto con el polvo de llanta. Sin embargo, es bastante reciente la consideración seria de esta posibilidad. En la actualidad, Gobiernos en todo el mundo han comenzado a implementar estos pavimentos.

En países desarrollados como Estados Unidos se están ya utilizando los llamados “asfaltos modificados con goma” los cuales contienen el polvo de llanta. Como se mencionó, este material tiene un mayor costo pero según estudios realizados posee una vida útil mayor y aumenta su elasticidad ante cambios de temperatura; así es como en el estado de California se impuso como ordenanza la obligatoriedad de usar el 5 % de material proveniente del reciclaje de llantas para la pavimentación de

nuevas vías o repavimentación. Como resultado de esta ordenanza se pavimentaron 25 carreteras con un total de 1,7 millones de neumáticos reciclados en forma de polvo de llanta (CEMPRE, 1998).

En el mercado mexicano se encuentra polvo de llanta a un valor que ronda los 0,25 USD por kilo de producto. La demanda en ese país, en la actualidad, es alta debido a la incorporación de leyes que exigen el reciclado a los fabricantes de llantas o la incorporación de un porcentaje de polvo de llanta en la fabricación de asfalto.

1.4 Propuestas en el Ecuador

En el país, un grupo inversor denominado "Grupo Innovador del Caucho" planea fabricar polvo de llanta, específicamente en Cuenca donde ya está en funcionamiento una planta. Según el grupo mencionado, el costo de la materia prima (en este caso, las llantas) es muy bajo ya que en el Ecuador se considera a los neumáticos simplemente como basura y no se piensa en otro uso. Este grupo plantea expandir la planta de tratamiento para comenzar a utilizar el polvo de hule como material para las carreteras que se están construyendo y repavimentando en el país; siempre con el objetivo adicional de proteger al medio ambiente y la población en general de los problemas derivados de desechar los neumáticos. Esta planta tendrá un área para el almacenamiento de los neumáticos, los respectivos equipos para triturar, los imanes necesarios para la separación de los metales, un silo de almacenamiento y un área para su distribución.

Esta planta, además de fabricar el polvo de llanta en sus distintos tamaños, también planea la fabricación de objetos artesanales elaborados a partir de la materia reciclada. Según el Grupo Innovador del Caucho, las ganancias líquidas de esta planta serán de alrededor de 1500 USD por cada 10 toneladas procesadas (en esta cifra ya se ha tomado en cuenta la amortización de los equipos de la planta). El funcionamiento de esta planta ayudaría a cubrir la demanda que se daría en caso de que una nueva reforma legislativa fuera aprobada en el país tendiente a la construcción de carreteras con mayor vida útil y más silenciosas que las que actualmente existen.

Es de suma importancia que el Ecuador empiece a adoptar ejemplos de otros países que, gracias a normas legislativas innovadoras, se han visto beneficiados con el uso de las nuevas tecnologías que se están usando a favor del medio ambiente. Si esto se aplica en el país, se tomará una nueva conciencia de conservación donde los mayores beneficiarios son los propios seres humanos. En resumen, el reciclaje de llantas ayudará a prevenir problemas estéticos, de contaminación y, lo más importante, problemas de salud en la población que puede ser perjudicada ya sea por el humo que emana de las llantas al quemarse o al ser un foco para la procreación de insectos portantes de diferentes enfermedades.

CAPÍTULO II

ENSAYOS DE AGREGADOS Y EMULSIÓN

Para la realización de la presente tesis se tuvieron que realizar algunos ensayos tanto de agregados, emulsión y, en sí, a las briquetas. Cada uno de los ensayos fue realizado cumpliendo especificaciones técnicas correspondientes a la fabricación de pavimentos.

2.1 Ensayos a los agregados:

Los agregados, tanto finos como gruesos, son provenientes de la mina de Guayllabamba. Esta mina produce material para la elaboración tanto de hormigones como de pavimentos; para esta disertación se realizaron ensayos sobre los materiales para la producción de pavimentos.

2.1.1 Ensayo de Equivalente de Arena:

El objetivo fundamental de este ensayo es determinar la cantidad de polvo fino que afectará a la resistencia de los pavimentos, o definir el porcentaje de arcilla que se tiene en una muestra de agregado fino.

Este ensayo da como resultado la cantidad de arcilla o de polvo fino que se tiene en la muestra; este resultado debe cumplir con valores máximos para esta cantidad de material. En el caso de este estudio, el equivalente de arena dio un valor de 53.28% por lo cual se concluye que se encuentra dentro de los parámetros normales para este ensayo y se puede utilizar el material.

A un volumen determinado de agregado fino se le adiciona una pequeña cantidad de solución floculante, mezclándolos en un cilindro graduado y agitándolos para que las partículas de arena pierdan la cobertura arcillosa. La muestra es entonces irrigada, usando una cantidad adicional de solución floculante, para forzar al material arcilloso a quedar en suspensión sobre la arena. Después de un período de sedimentación, se determinan las alturas de la arcilla floculada y de la arena en el cilindro. El equivalente de arena es la relación entre la altura de arena y la altura de arcilla, expresada en porcentaje.

EA= (A/B)*100

Donde:

A= Lectura de arena

B= Lectura de arcilla

EA= Equivalente de arena



Imagen 12. Equipo para el ensayo de equivalente de arena

2.2 Ensayo de Granulometría

El análisis de tamices es utilizado para determinar la distribución de tamaños o gradación de los agregados disponibles con el fin de conseguir la mejor combinación posible de acuerdo a las especificaciones del *American Society of Testing and Materials* (ASTM). La gradación de los agregados es un factor muy importante tanto para la mezcla de hormigón como para el hormigón asfáltico, ya que de este factor dependen la economía, manejabilidad y la resistencia de la mezcla.

El análisis se lleva a cabo tamizando los agregados a través de una serie de cedazos. Estos tamices están en números ascendentes, esto es: #4, #8, #16, #30, #50, #100, #200 y bandeja para agregados finos y en orden de tamaño descendente 1- ½", 1", ¾", ½", 3/8", #4, #8 y bandeja, para agregado grueso. El número de los tamices indica las aperturas del cedazo por pulgada lineal. Cada filtro tiene un diámetro igual

a la mitad del diámetro del que le precede. Esta numeración varía debido al grueso del alambre utilizado para la malla. El uso de todos los tamices dependerá de la precisión que se requiera o de las especificaciones, ya que en ocasiones solamente se utilizarán algunos de ellos.

Se conoce como agregado fino a todo material que pasa a través del tamiz de 3/8" y el #4 y es retenido casi completamente en el tamiz #200. Agregado grueso es aquel que se retiene en el tamiz #4.

Se han establecido ciertas normas y límites tanto para el tamaño de los agregados como para su granulometría, de esta manera el ingeniero puede seguir una guía o patrón al seleccionar la combinación más adecuada de sus agregados.

Tamiz #	Peso Retenido	Porciento* Retenido	Retenido Acumulado	Porciento Pasando
4	A	$\frac{A}{I}$ x 100 = J	J	100 – J
8	B	$\frac{B}{I}$ x 100 = K	J + K = R	100 - R
16	C	$\frac{C}{I}$ x 100 = L	R + L =S	100 – S
30	D	$\frac{D}{I}$ x 100 = M	S + M = T	100 – T
50	E	$\frac{E}{I}$ x 100 = N	T + N = U	100 – U
100	F	$\frac{F}{I}$ x 100 = O	U + O = V	100 – V
200	G	$\frac{G}{I}$ x 100 = P	V + P = W	100 – W
Bandeja	H	$\frac{H}{I}$ x 100 = Q	W + Q = X	100 – X
	Σ = I	Σ = 100		

Tabla 1. Cálculo de granulometría

La finura relativa de la arena se define como una centésima de la suma de los porcientos retenidos acumulados hasta el tamiz #100 en la prueba de tamices de la arena. Se utilizan seis tamices: el #4, #8, #16, #30, #50 y el #100. Mientras más pequeño sea el número del módulo de finura, más fina será la arena. Una arena que satisfaga las especificaciones del ASTM C 136



Imagen 13. Serie de tamices

2.3 Ensayo de Abrasión

El objetivo de este ensayo es determinar la capacidad del agregado grueso a soportar el desgaste. Este método establece el procedimiento a seguir para determinar el desgaste, por abrasión, del agregado grueso menor de1½" (38 mm), utilizando la denominada "máquina de Los Ángeles".

Granulometría de Ensayo	Número de Esferas	Peso Total de esferas(gr)
A	12	5000 +/- 25
B	11	4585 +/- 25
C	8	3330 +/- 20
D	6	2500 +/- 15

Tabla 2. Peso de esferas para cada granulometría



Imagen 14. Esferas de metal

La muestra consistirá de agregado limpio y debe ser representativa del material que se vaya a ensayar.

Una vez que se alcanza el número requerido de revoluciones del tambor, se tamiza el agregado para determinar el porcentaje que ha sido reducido hasta un tamaño menor al tamiz Nº12.

La máquina de Los Ángeles consiste en un tambor cilíndrico hueco, de acero, cerrado en sus extremos. La carga abrasiva consiste de esferas de acero. Cada una de

ellas debe pesar entre 390 y 445 gramos, esta carga depende de la granulometría de la muestra a ensayarse. Un anaquel que está en el interior del tambor rotatorio recoge la carga de bolas y agregado en cada revolución y la deja caer conforme se aproxima al punto más alto de su recorrido. De este modo, el agregado experimenta cierta acción de frotamiento y vuelcos, así como un impacto considerable, durante las 500 revoluciones que especifica la norma.

Después de efectuar la determinación anteriormente mencionada, se coloca la muestra entera (incluyendo el polvo resultante de la abrasión), para efectuar las 400 revoluciones que aún faltan para terminar el ensayo.

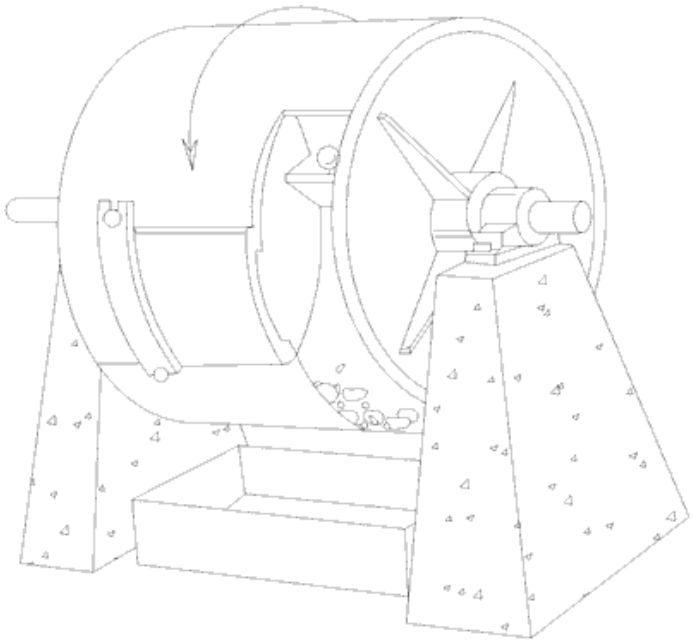


Imagen 15. Máquina de los Ángeles

Se aplica la fórmula:

$$A = \frac{PI - PF}{PI} * 100$$

Donde:

PI= Peso Inicial

PF=Peso Final

A=Abrasión

2.4 Ensayo de Gravedad Específica, Absorción y Peso Unitario:

Los siguientes ensayos determinan las siguientes propiedades que son: gravedad específica, absorción y peso unitario de los agregados finos y gruesos a ser usados en el diseño de mezcla de hormigón o de un pavimento.

La gravedad específica es la relación entre la densidad del material y la densidad del agua. De acuerdo a la condición de humedad del agregado, la gravedad específica se determina en condición seca o saturada con superficie seca (SSD). Esta información permite hacer una relación entre el peso de los agregados y el volumen que ocupa dentro de la mezcla. En los trabajos con hormigón o de pavimentos, el término gravedad específica se refiere a la densidad de la partícula individual y no a la masa de agregado como un entero.

La capacidad de absorción se determina encontrando el peso de un agregado bajo condición saturada (SSD) y en condición seca. La diferencia de pesos expresada como porcentaje del peso seco es la capacidad de absorción. Esta información se

requiere para balancear las necesidades de agua en la mezcla de hormigón y pavimentos.

El peso unitario de un agregado da una medida de los vacíos en un volumen unitario de agregado. Este valor es necesario para determinar la cantidad de agregado grueso que puede ser acomodado en una mezcla de hormigón o de pavimento. Los vacíos en los agregados dependen de varios factores como: tamaño, forma, textura de superficie, granulometría y compactación.

AGREGADO GRUESO

$$\textit{Gravedad Específica de Masa (seca)} = \frac{A}{B-C}$$

Donde:

A = Peso de la muestra secada al horno, expresada en gramos

B = Peso de la muestra SSD, expresada en gramos

C = Peso de la muestra sumergida en agua, expresada en gramos

$$\textit{Gravedad Específica de Masa (SSD)} = \frac{B}{B-C}$$

$$\textit{Absorción} = \frac{B-A}{A} * 100$$

AGREGADO FINO

$$\textit{Gravedad Específica de Masa (seca)} = \frac{A}{B+500-C}$$

Donde:

A = Peso de la muestra secada al horno, expresada en gramos

B = Peso del frasco (picnómetro) con agua, expresada en gramos

C = Peso del frasco + la muestra + el agua, hasta la marca de calibración

500 = Peso de agregado fino saturado usado en gramos

$$Gravedad\ Específica\ de\ Masa\ (SSD) = \frac{500}{B+500-C}$$

$$Absorción = \frac{500+A}{A} * 100$$

2.4.1Gravedad Específica



Imagen 16. Matraces para el cálculo de gravedad específica

2.4.2 Absorción



Imagen 17. Equipo para el ensayo de absorción

2.4.3 Peso Específico



Imagen 18. Cálculo del peso específico

2.5 Ensayo de Resistencia a los Sulfatos:

Este ensayo tiene como objetivo determinar la capacidad de los agregados a soportar el desgaste que se produce al estar expuestos a sustancias químicas. Estos datos

ayudarán a determinar si el material califica para su utilización en hormigones y en pavimentos.

Durante este ensayo, las muestras estarán sumergidas en soluciones de sulfatos; estas tendrán que ser drenadas sin que se produzca pérdida de material durante este proceso. El ensayo toma tiempo pero da una idea más clara de las resistencia de los agregados.

El proceso de este ensayo consiste en una primera etapa en la cual los agregados están sumergidos dentro de la solución; la siguiente fase es el secado de las muestras en la que es importante no perder el volumen de las muestras ya que esto podria producir un resultado no real del ensayo.

Como resultado final, se obtiene que el peso inicial menos el peso final de una muestra representado en porcentaje será la resistencia del marterial a los sulfatos.



Imagen 19. Procedimiento en ensayo de resistencia a los sulfatos

2.5.1 Ensayos a la emulsión:

La emulsión utilizada en esta disertación de tesis es procedente de Chova.

2.6 Ensayo a la Capacidad de Recubrimiento y Resistencia al Agua:

Determina la capacidad de una emulsión asfáltica a: recubrir el agregado completamente, resistir el efecto del mezclado mientras permanece como una película sobre los agregados; y, resistir la acción de lavado del agua una vez finalizada la mezcla. Este ensayo se emplea principalmente para identificar a las emulsiones asfálticas de rotura media adecuada para mezclarse con agregados gruesos calcáreos (la prueba no es aplicable a emulsiones asfálticas de roturas rápida o lenta).

El agregado patrón es recubierto con polvo de carbonato de calcio y luego mezclado con la emulsión asfáltica. Aproximadamente la mitad de la mezcla es colocada sobre un papel absorbente, para un examen visual del área de agregado recubierta por la emulsión asfáltica. El resto de la mezcla es rociado con agua y lavado hasta que el agua corra clara. Este material es colocado sobre un papel absorbente y se examina su recubrimiento. Se repite el ensayo y, en esta oportunidad, el agregado se moja en agua antes de agregar la emulsión; se mezcla y luego se examina visualmente su capacidad de recubrimiento (buena, regular o pobre)

2.7 Ensayo de Tamiz:

El ensayo de tamiz es otra forma de medir la calidad y la estabilidad de la emulsión. La retención de una excesiva cantidad de partículas de asfalto sobre un filtro indica que puede haber problemas en la manipulación y aplicación del material. En este ensayo, una muestra representativa de emulsión asfáltica es vertida a través de un tamiz de 0.850 mm (No 20). En el caso de emulsiones aniónicas, el filtro y el asfalto retenido son lavados primero con una solución débil de oleato de sodio y luego con agua destilada.

Para emulsiones catiónicas, el lavado solo se hace con agua destilada. Luego del lavado, el tamiz y el asfalto se secan en estufa, determinándose el peso del asfalto retenido.

2.8 Ensayo de la Viscosidad de la Emulsión:

La viscosidad es definida como "la propiedad de un fluido que ofrece resistencia al movimiento relativo de sus moléculas" (Mott, 1996). Para emulsiones asfálticas, el ensayo de viscosidad Saybolt Furol es utilizado como una medida de la viscosidad. Los resultados se expresan en Segundos Saybolt Universal. Dependiendo del tipo de emulsión, el ensayo se realiza a una de dos temperaturas, 25ºC (77ºF) o 50ºC (122ºF).

2.9 Ensayo de Residuo de Asfalto y Destilado de Petróleo por Destilación:

Mediante la destilación, se separa el agua del asfalto. Si el material contiene destilado de petróleo, este será separado junto con el agua. Las proporciones relativas de cemento asfáltico, agua y destilado de petróleo en la emulsión pueden medirse una vez que la destilación ha finalizado. Sobre el residuo de cemento asfáltico pueden realizarse ensayos adicionales, con el objeto de determinar las propiedades físicas del asfalto de uso final. En la destilación de emulsiones asfálticas se emplea un alambique de aleación de aluminio y quemadores de anillo. Se realiza la destilación a una temperatura de 260°C, durante 15 minutos. Debido a que la emulsión en la obra rara vez alcanza dicha temperatura, vale señalar que ciertas propiedades del residuo pueden ser alteradas, como por ejemplo las propiedades elásticas aportadas por la modificación del asfalto con polímeros.

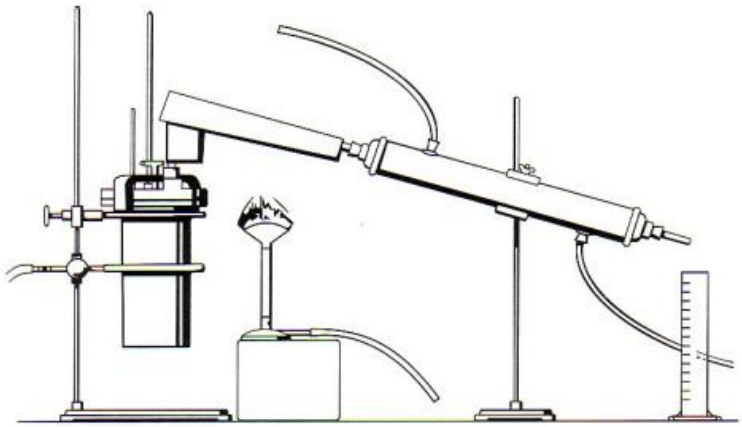


Imagen 20. Sistema de destilación

2.10 Resumen Final de los Resultados

Tras los ensayos de laboratorio, se encontró que cada uno de ellos cumplía con la norma técnica asignada, tal como se presenta en la tabla 3:

NOMBRE DEL ENSAYO	NORMA AASHTO	NORMA ASTM	OBSERVACIONES
Equivalente de Arena	T 176	D 2419	Sí cumple con las Normas
Granulometría	T 27	C 136	Sí cumple con las Normas
Abrasión	T 96	C 131	Sí cumple con las Normas
Gravedad específica, peso unitario y absorción	T 84	C 128	Sí cumple con las Normas
Resistencia a los sulfatos	T 104	C 88	Sí cumple con las Normas
Ensayos a la emulsión	T 59	D 6997	Sí cumple con las Normas

Tabla 3. Resultados finales de los ensayos

CAPÍTULO III

DISEÑO DE LA MEZCLA ASFÁLTICA

El presente capítulo tiene como objetivo el procedimiento a seguir para el diseño de mezclas asfálticas en frío con la incorporación del polvo de llanta con el fin de utilizarlo para el reciclaje de neumáticos.

3.1 Polvo de llanta

El polvo de llanta utilizado en este estudio se obtuvo de la Rencauchadora Ecuador. En la mencionada empresa se compran las llantas y la organización se encarga del proceso de molido, cernido y clasificación por granulometría del polvo. El material tiene un valor de 350 USD más IVA por tonelada. En el estudio se utilizó el polvo de llanta que tiene una granulometría parecida al agregado fino.

Al realizar el análisis granulométrico del polvo de llanta por el ensayo del tamizado se concluyó que el material, en su mayor parte, era retenido en el matiz No. 30, por lo cual al momento de realizar las pruebas, se realizó la sustitución del material de agregado fino que retenía el tamiz No. 30 por el polvo de llanta en las siguientes proporciones: 25%, 50%, 75% y 100% para ensayos individuales con el fin de determinar si se puede utilizar el polvo de llanta como una alternativa de reciclaje en fabricación del mezclas asfálticas en frío.

3.2 Diseño de la mezclas en frío:

En una mezcla asfáltica en frío, el asfalto y el agregado son combinados en proporciones exactas. Las proporciones relativas de estos materiales determinan las propiedades físicas de la mezcla y, eventualmente, el desempeño de la misma como pavimento terminado. A continuación se detalla el método Marshall, diseño comúnmente utilizado para determinar las proporciones apropiadas de emulsión y agregado en una mezcla.

El objetivo de este método es proveer la cantidad adecuada de emulsión que estabilice el material granular con el fin de dar la resistencia o estabilidad requerida para soportar las aplicaciones de carga; por otro lado, permite volver a la mezcla suficientemente estable a los efectos de cambio de humedad.

El procedimiento de diseño comprende las siguientes partes principales:

- Ensayos de calidad del agregado: Para determinar las propiedades del agregado y su conveniencia para el uso en mezclas con emulsiones asfálticas.



Imagen 21. Agregado para mezcla asfáltica

- Ensayos de calidad de las emulsiones asfálticas: Para determinar las propiedades y calidad de la emulsión.
- Tipo y cantidad aproximada de emulsión: Estimar el contenido tentativo de emulsión para un agregado dado. Usando el contenido de asfalto tentativo, se realizan ensayos de recubrimiento para determinar la conveniencia y tipo de emulsión, cantidad de emulsión y agua requerida en la pre-envuelta.
- Humedad de compactación: Calcular el contenido de agua de pre-envuelta, como la cantidad de agua añadida al agregado antes de la emulsión. Se preparan mezclas y se les añade agua con una diferencia del 1%. El agua de premezclado ayuda a que el agregado no absorba el agua contenida en la emulsión.
- Variación del contenido de emulsión: Realizando la mezcla de agregado y agua de premezcla, se preparan mezclas variando el contenido de emulsión. Las mezclas se compactan entonces dentro de moldes Marshall, se les deja curar al aire y se las pone al horno durante tres días a una temperatura de 41°C. Las muestras se ensayan para determinar su densidad Bulk, estabilidad Marshall modificada y flujo.

3.3 Preparación de las briquetas

Las briquetas de ensayo de las mezclas de pavimentación son preparadas haciendo que cada una contenga una ligera cantidad diferente de emulsión. El margen de contenidos de emulsión usado en las briquetas de ensayo está determinado con base a los agregados de la mezcla. La cantidad de agregado en las mezclas está dada por los resultados del análisis granulométrico.

Las muestras son preparadas de la siguiente manera:

1. Al agregado se coloca el porcentaje de agua de pre-envuelta.
2. Al agregado con la humedad de pre-envuelta se le agrega el porcentaje de emulsión y se mezcla completamente hasta que todas las partículas del agregado estén revestidas.
3. Las mezclas se colocan en los moldes Marshall como preparación para la compactación, en donde se usa el martillo Marshall de compactación.
4. Las briquetas son compactadas mediante golpes del martillo Marshall de compactación.

El número de golpes del martillo es de 50 golpes según el ensayo Marshall Modificado para mezclas asfálticas en frío con emulsión.

Después de completar la compactación, se espera 24 horas para desencofrar, y colocar en el horno a 41°C, hasta que la mezcla se encuentre totalmente curada.

3.4 Gravedad Específica

La gravedad específica a emplear en el estudio es la Gravedad Especifica Bulk, la cual se calcula como si se tratara de un agregado. Obteniendo su peso seco, peso sumergido en agua y finalmente su peso saturado. El valor es necesario para determinar el porcentaje de vacíos en la muestra.



Imagen 22. Gravedad específica Bulk

3.5 Valor de estabilidad Marshall



Imagen 23. Valoración de estabilidad Marshall

El valor de estabilidad Marshall es una medida de la carga bajo la cual una probeta cede o falla totalmente. Durante un ensayo, cuando la presión es aplicada lentamente, los cabezales superior e inferior del aparato se acercan y la carga sobre la briqueta aumenta al igual que la lectura en el indicador del cuadrante. La carga máxima indicada por el medidor es el valor de Estabilidad Marshall.

Debido a que la estabilidad Marshall indica la resistencia de una mezcla a la deformación, se puede pensar que si un valor de estabilidad es bueno, entonces un valor más alto será mucho mejor; no obstante, en el caso de las mezclas asfálticas, una estabilidad extremadamente alta se da en detrimento de su durabilidad.

3.6 Valor de fluencia Marshall

La fluencia Marshall, medida en centésimas de pulgada, representa la deformación de la briqueta que está indicada por la disminución en el diámetro vertical de la misma. Las mezclas que tienen valores bajos de fluencia y valores muy altos de estabilidad Marshall son consideradas demasiado frágiles y rígidas para un pavimento en servicio. Por otro lado, aquellas que tienen valores altos de fluencia son consideradas demasiado plásticas y tienen tendencia a deformarse bajo las cargas del tránsito.



Imagen 24. Briqueta de asfalto

CAPÍTULO IV

ENSAYOS DE LABORATORIO

4.1 Gravedad Específica y Absorción del Agregado Fino

Mm: Masa del Matraz

Mmw: Masa del Matraz, agua y muestra

B: Masa de muestra saturada con superficie seca

Ma: Masa de agua añadida al matraz

$$Ma = Mmw - (\mathrm{Mm} + \mathrm{B})$$

		Unidades
Mm	162.12	gr
Mmw	955.8	gr
B	500.78	gr
Ma	292.9	gr

Gravedad Específica Bulk (Ge)

A: Masa de la muestra seca

δH2O: densidad del agua = 0.9975gr/cm3

$$\mathrm{Ge} = \frac{\mathrm{A}}{(\delta \mathrm{H2O} * 500) - \mathrm{Ma}}$$

		Unidades
A	470	gr
Ge	2.283	

Gravedad Específica Saturada con superficie seca (Ges)

$$Ges = \frac{B}{(\delta H2O * 500) - Ma}$$

Ges	2.433

Gravedad Específica Aparente (Gea)

$$Gea = \frac{A}{(\delta H2O * 500) + A + Mm + Mmw}$$

Gea	2.685

Porcentaje de Absorción

$$\%Ab = \frac{B - A}{A} * 100$$

%Ab	6.549

Volúmenes

Volumen Total

$$V\delta H20 = (\delta * 500) - Ma$$

$$V = \frac{V\delta H20}{\delta}$$

VδH2O	205.85	gr

V	206.366	cm3

Volumen del Sólido

$$Vs\delta H20 = (\delta * 500) + A + Mm - Mmw$$

$$Vs = \frac{Vs\delta H20}{\delta}$$

Vsδ H2O	175.07	gr

Vs	175.509	cm3

Volumen de Vacíos

$$Vv = V - Vs$$

Vv	30.857	cm3

Porcentaje de Porosidad

$$n = \frac{Vv}{V} * 100$$

n	14.953	%

Relación de Vacíos

$$e = \frac{Vv}{Vs}$$

e	0.18

4.2 Gravedad Específica y Absorción del Agregado Grueso

A: Masa muestra seca

B: Masa muestra saturada con superficie seca

C: Masa muestra sumergida en el agua

Retiene tamiz 1/2"

A	3150	gr
B	3230	gr
C	1904	gr

Gravedad Específica Bulk (Ge)

$$Ge = \frac{A}{B - C}$$

Ge	2.376

Gravedad Específica Saturada con superficie seca (Ges)

$$Ges = \frac{B}{B - C}$$

Ges	2.436

Gravedad Específica Aparente (Gea)

$$Gea = \frac{A}{A - C}$$

Gea	2.528

Porcentaje de Absorción

$$\%Ab = \frac{B - A}{A} * 100$$

%Ab	2.540	%

Retiene tamiz 4"

A	1720	gr
B	1782	gr
C	1036	gr

Gravedad Específica Bulk (Ge)

Ge	2.306

Gravedad Específica Saturada con superficie seca (Ges)

Ges	2.389

Gravedad Específica Aparente (Gea)

Gea	2.515

Porcentaje de Absorción

%Ab	3.605	%

Promedios

Ge	2.341
Ges	2.412
Gea	2.521
%Ab	3.072

4.3 Equivalente de Arena

Muestra 1

$$EA = \frac{B}{A} * 100$$

Lectura 1 (A)	6.1
Lectura 2 (B)	3.2

EA	52.46

Muestra 2

Lectura 1 (A)	6.1
Lectura 2 (B)	3.3

EA	54.10

Promedio

EA	**53.279**

4.4 Abrasión

A	5045	kg	Masa Inicial de la muestra
B	3945	kg	Masa sostenida en el tamiz N.12
C	1100	kg	Masa de material que pasa tamiz N.12

Porcentaje de desgaste

$$\%D = \frac{C}{A} * 100$$

%D	21.804	%

4.5 Mezcla Asfáltica

MEZCLAS DE AGREGADOS

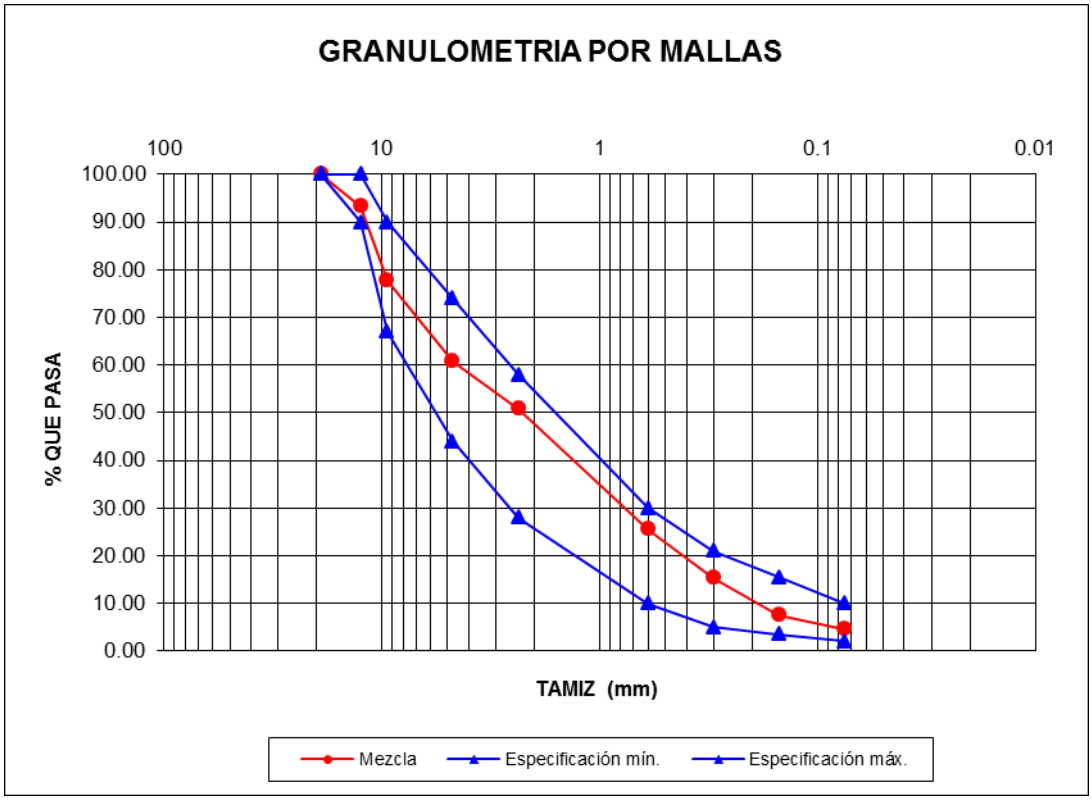
Tamiz	1”	¾”	½"	3/8”	# 4	# 8	# 30	# 50	# 100	# 200	p #200
Tz mm.	25.4	19	12.5	9.5	4.75	2.36	0.6	0.3	0.15	0.075	p 0,075
mat. A	100.00	100.00	83.35	44.41	2.05	0.00	0.00	0.00	0.00	0.00	
mat. B	100.00	100.00	100.00	100.00	99.89	84.82	42.56	25.69	12.57	7.64	
mat. C	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	
mat. D	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	
mezcla	**100.00**	**100.00**	**93.34**	**77.76**	**60.75**	**50.89**	**25.54**	**15.41**	**7.54**	**4.58**	
Ret.Ac.	0.00	0.00	6.66	22.24	39.25	49.11	74.46	84.59	92.46	95.42	4.58
Ret.Parc.	0.00	0.00	6.66	15.58	17.01	9.86	25.36	10.12	7.87	2.96	
% peso	0.00	0.00	73.26	171.34	187.11	108.48	278.92	111.34	86.59	32.54	
% acum.	0.00	0.00	73.26	244.60	431.71	540.19	819.10	930.45	1017.04	1049.58	1100.00
Espec mín	**100**	**100**	**90**	**---**	**44**	**28**	**---**	**5**	**---**	**2**	
Espec máx	**100**	**100**	**100**	**---**	**74**	**58**	**---**	**21**	**---**	**10**	

% DE MEZCLA		
A	0.40	40
B	0.60	60
C	0.00	0
D	0	0

Espec mín	100	100	90	67	44	28	10	5	3.5	2
Espec máx	100	100	100	90	74	58	30	21	15.5	10
Tz mm.	25.4	19	12.5	9.5	4.75	2.36	0.6	0.3	0.15	0.075

Observación:

Material A = Material Grueso
Material B = Material Fino
Especificaciones MOP - 001 - f Tabla 405.5.1 "1/2"



A continuación, se procedió a la incorporación del polvo de llanta a la muestras. Esto se hizo reemplazando un porcentaje de 25%, 50% 75%, y 100% en el material que se retenía en el tamiz #30, ya que este material era el que más aportaba a la muestra de 1100 gr.

A (Peso Seco)
B (Peso Sumerg.)
C (Saturado)

	A	B	C	Volumen	Estabilidad	Factor Corrección	Estabilidad corregida	Flujo	
1	894.67	460.5	898.7	438.2	4137	1.32	5460.84	16	
2	893.23	459.64	896.15	436.51	3843	1.32	5072.76	16	
3	912.96	472.07	915.02	442.95	4320	1.32	5702.4	17	
							5412.00	**16**	8% emulsión
4	1015.06	518.89	1018.24	499.35	5321	1.04	5533.84	18	
5	1095.16	547.8	1102.05	554.25	4561	0.89	4059.29	17	
							4796.57	**18**	9% emulsión
6	963.3	501.58	966.64	465.06	5466	1.19	6504.54	17	
7	935.36	482.49	938.98	456.49	4822	1.19	5738.18	12	
8	939.25	487.29	943.26	455.97	4863	1.19	5786.97	15	
							6009.90	**15**	10% emulsión
9	901.62	459.25	904.11	444.86	4067	1.25	5083.75	17	
10	896.54	455.95	898.8	442.85	4058	1.32	5356.56	18	
11	854.25	430.03	856.87	426.84	3102	1.39	4311.78	16	
							4917.36	**17**	11% emulsión
12	800.67	404.82	803.2	398.38	3278	1.56	5113.68	17	
13	830.39	417.78	833.84	416.06	3035	1.47	4461.45	16	
14	658.13	330.93	659.89	328.96	2103	2.27	4773.81	15	
							4782.98	**16**	12% emulsión

25% Polvo de llanta

	A	B	C	Volumen	Estabilidad	Factor Corrección	Estabilidad corregida	Flujo
1	844.02	377.5	850.75	473.25	1921	1.14	2189.94	18
2	947.36	410.95	956.78	545.83	1906	0.93	1772.58	18
3	1016.92	438.76	1026.81	588.05	2085	0.81	1688.85	25
							1883.79	**20**
4	1035.04	452.84	1043.43	590.59	2690	0.81	2178.9	37
5	1023.88	444.75	1029.89	585.14	2215	0.81	1794.15	35
6	1005.17	440.25	1013.5	573.25	228	0.83	189.24	28
							1387.43	**33**
7	1020.01	450.27	1027.05	576.78	2624	0.83	2177.92	26
8	975.52	431.22	982.69	551.47	2631	0.89	2341.59	28
9	1024.83	448.43	1032.45	584.02	2581	0.83	2142.23	25
							2220.58	**26**

50% Polvo de llanta

	A	B	C	Volumen	Estabilidad	Factor Corrección	Estabilidad corregida	Flujo
1	868.16	298.96	883.02	584.06	680	0.83	564.4	21
2	906.37	325.9	918.77	592.87	931	0.81	754.11	18
3	856.63	303.15	869.59	566.44	780	0.86	670.8	19
9% emulsión							**663.10**	**19**
4	836.46	298.2	847.88	549.68	756	0.89	672.84	18
5	892.04	318.75	907.11	588.36	769	0.81	622.89	21
6	909.39	324.56	924.73	600.17	808	0.78	630.24	23
10% emulsión							**641.99**	**21**
7	691.22	254.12	708.56	454.44	504	1.25	630	24
8	874.9	331.88	887.27	555.39	827	0.89	736.03	18
11% emulsión							**683.02**	**21**

75% Polvo de llanta

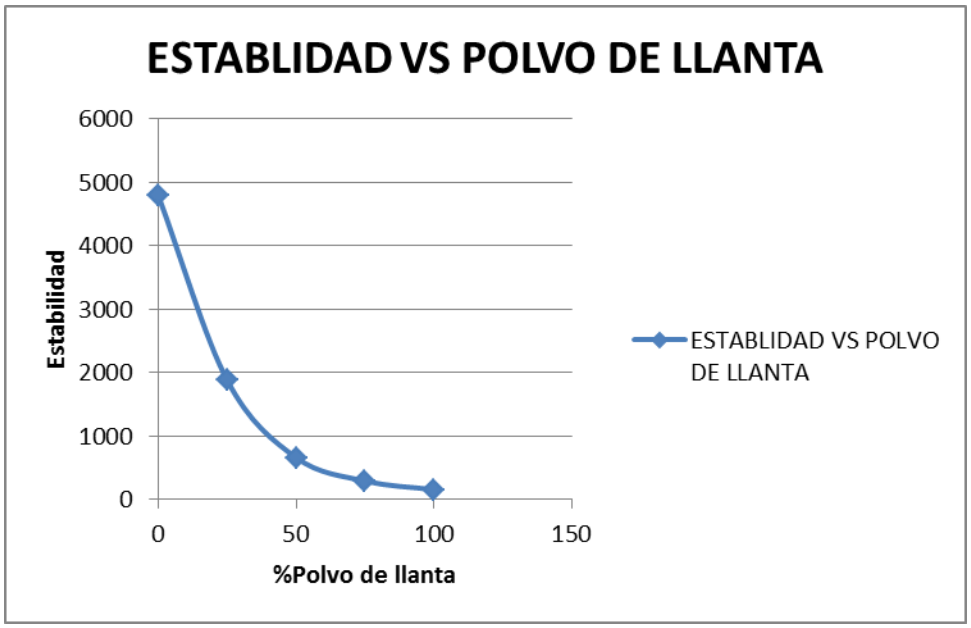
	A	B	C	Volumen	Estabilidad	Factor Corrección	Estabilidad corregida	Flujo
1	786.34	222.91	805.1	582.21	346	0.83	287.18	24
2	859.61	246.05	869.9	623.86	366	0.76	278.16	20
3	828.99	237.93	845.7	607.76	403	0.78	314.34	26
9% emulsión							**293.2**	**23**
4	811.95	236.31	837.3	600.99	296	0.78	230.88	28
5	855.18	243.12	867.3	624.14	402	0.76	305.52	24
6	801.9	226.62	819.1	592.47	350	0.81	283.5	23
10% emulsión							**273.3**	**25**
7	829.17	209.92	841.5	631.62	431	0.76	327.56	31
8	844.79	197.16	861.1	663.94	328	0.89	291.92	30
9	854.07	236.86	868.1	631.24	507	0	0	28
11% emulsión							**206.5**	**30**

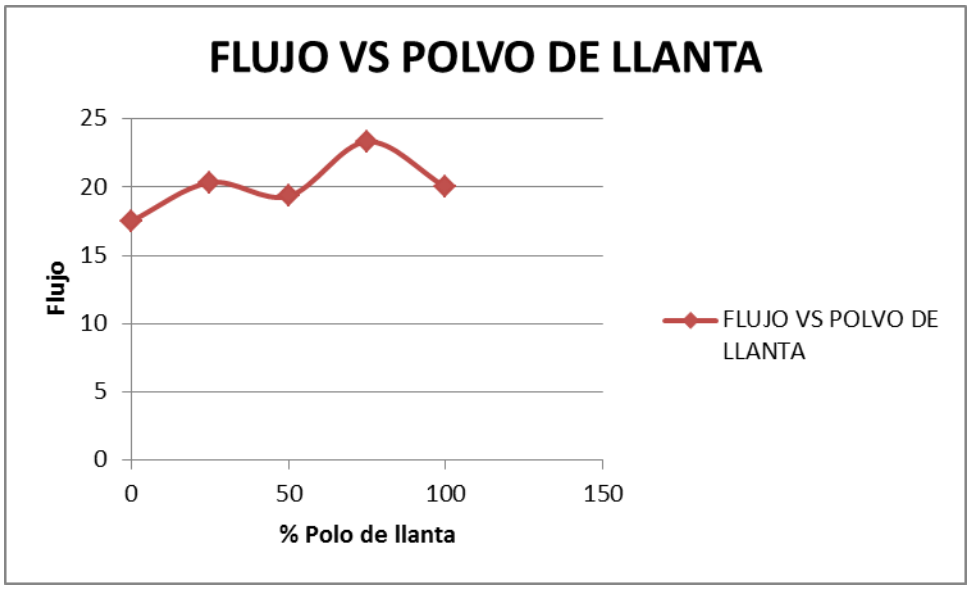
100% Polvo de llanta

	A	B	C	Volumen	Estabilidad	Factor Corrección	Estabilidad corregida	Flujo
1	822.98	184.3	840.16	655.86	233	0.76	177.08	19
2	655.27	136.15	677.79	541.64	149	0.93	138.57	21
9% emulsión							**157.83**	**20**
3	763.2	151.63	781.24	629.61	253	0.76	192.28	24
4	723.35	157.18	743.95	586.77	210	0.81	170.1	22
5	767.16	157.72	781.57	623.85	273	0.76	207.48	28
10% emulsión							**189.95**	**25**
6	758.88	168.61	772.32	603.71	318	0.78	248.04	26
7	745.96	169.24	762.92	593.68	158	0.81	127.98	19
8	742.23	174.15	770.82	596.67	203	0.81	164.43	22
11% emulsión							**180.15**	**22**

9% emulsión

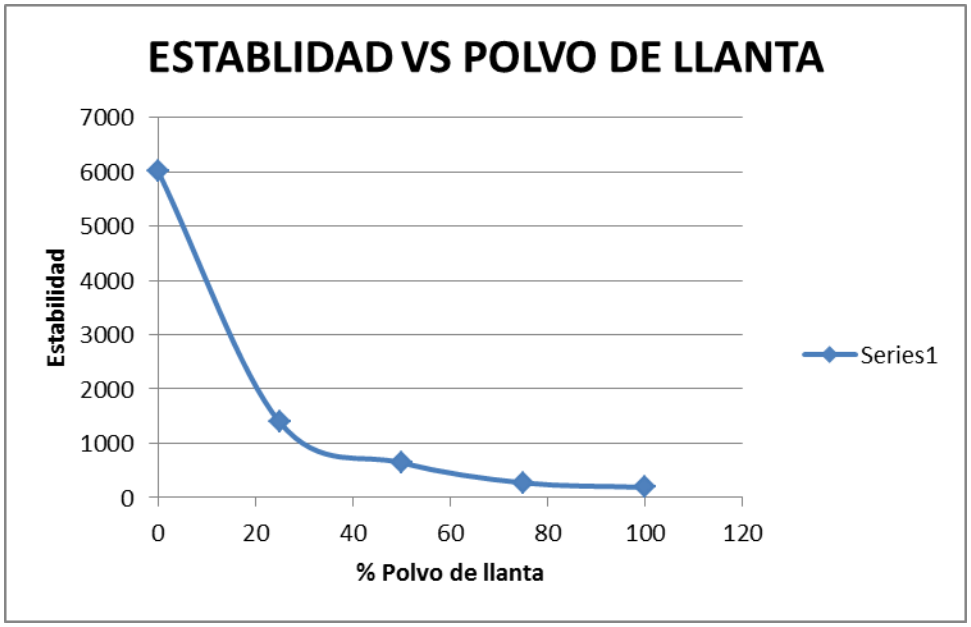
%Polvo Llanta	Estab.	Flujo
0	4796.56	18
25	1883.80	20
50	663.10	19
75	293.20	23
100	157.80	20

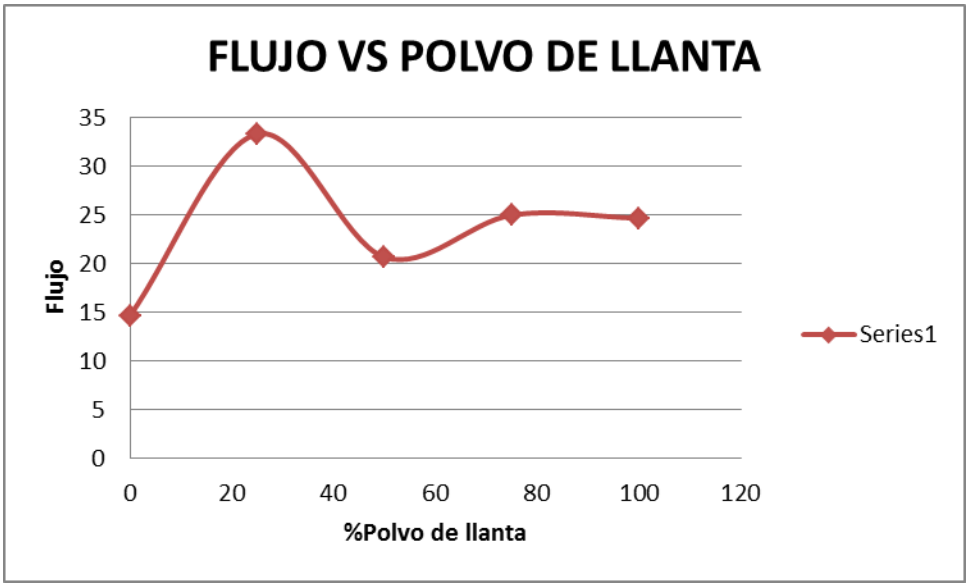




10% emulsión

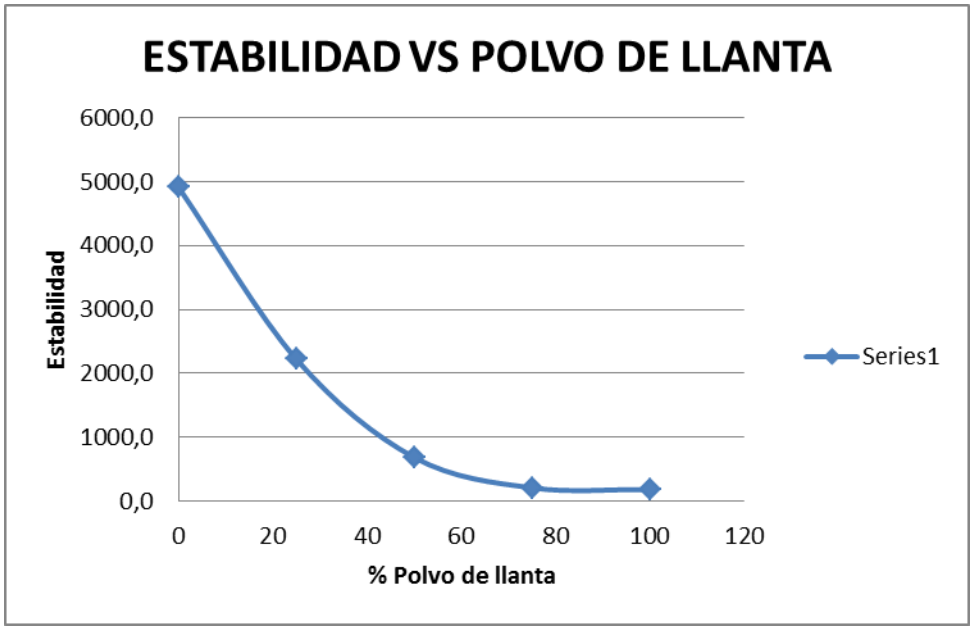
%Polvo Llanta	Estab.	Flujo
0	6009.89	15
25	1387.40	33
50	641.99	21
75	273.30	25
100	190.00	25

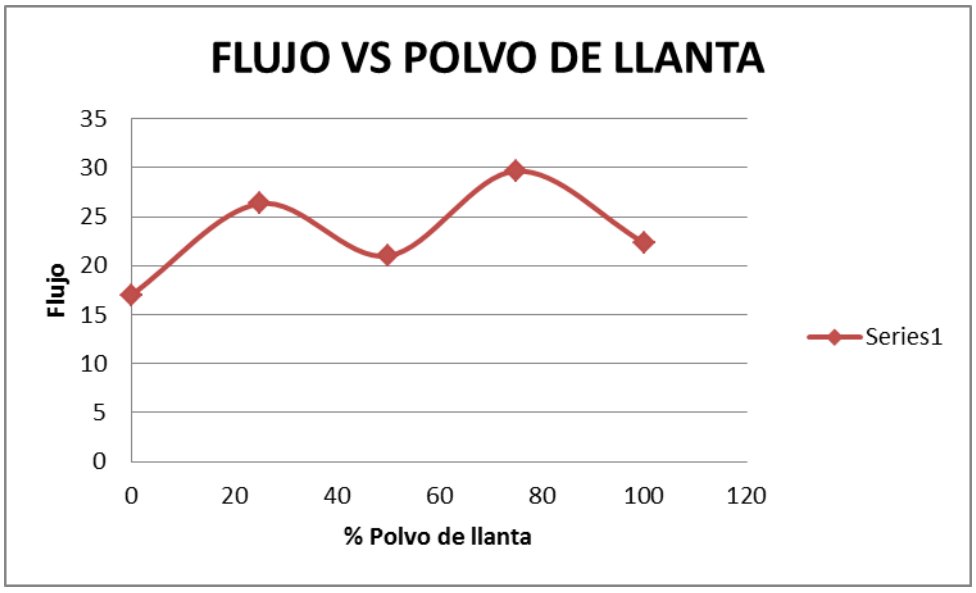




11% emulsión

%Polvo Llanta	Estab.	Flujo
0	4917.40	17
25	2220.60	26
50	683.02	21
75	206.50	30
100	180.15	22





CAPÍTULO V

CONCLUSIONES Y RECOMENDACIONES

5.1 Conclusiones

- Tras la valoración de los ensayos de laboratorio, se concluye que los materiales provenientes de la mina de Guayllabamba, tanto de agregado fino como de agregado grueso, cumplen con las especificaciones ASTM y AASHTO para su uso en pavimentos. El porcentaje al desgaste de abrasión fue de 21,80% y en la norma AASHTO T96 se especifica que el porcentaje debe ser máximo el 40% para ser utilizado en mezclas asfálticas.

- De acuerdo a la norma AASHTO T176, el rango aceptable del equivalente de arena es 0.45 mínimo - 1.0% máximo. El material obtenido en las minas de gauyllabamba cumple con el rango ya que su equivalente de arena es del 0.533%.

- La emulsión fue sometida a sus respectivos ensayos cumpliendo con las normas especificadas:
    - Ensayo de penetración (AASHTO T49)
    - Punto de Inflamación (AASHTO T 48)
    - Punto de Reblandecimiento (AASHTO T 53)

- La mezcla asfáltica a la cual se le incorporó el 25 y 50% del polvo de llanta cumple con la estabilidad que se especifica sea mayor a 500lb. Los valores obtenidos en los ensayos fue de 220.58, y 683.02 respectivamente.

- Una vez sometido a condiciones extremas la mezcla asfáltica ya no cumple con la estabilidad requerida para poder ser utilizada en carreteras.

- Tomando valores menores al 25% del polvo de llanta se podría obtener mezclas asfálticas que cumplan con las normas especificadas para poder ser utilizado en carreteras.

5.2 Recomendaciones

- El reciclaje de llantas es de suma importancia debido a que su incorrecto desecho (generalmente a través del fuego) o almacenamiento tras el uso causan impactos negativos en el ambiente, en el paisaje y, lo más grave, en la salud de las personas.

- En el Ecuador se están desarrollando iniciativas para el tratamiento de los neumáticos de desecho. Estos materiales pueden someterse a dos tipos de trituración: mecánica y criogénica. En el país es más común la trituración mecánica debido a sus menores costos de implementación y mantenimiento.

- Uno de los usos de materiales reciclados de neumáticos usados es en fabricación de asfalto que, en lugares donde se ha utilizado de esta manera, ha presentado resultados favorables tanto por la cantidad usada de material reciclado como por la calidad del producto final, que ha sido un asfalto con mayor vida útil y mejor elasticidad, entre otras características.

- Varios países han impulsado normas legislativas para promover el reciclaje de neumáticos, algunos de los cuales han estipulado el uso del polvo de llantas en la producción de asfalto para la construcción de nuevas carreteras o la reparación de existentes.

- Es recomendable que las autoridades ecuatorianas promuevan, a través de decretos, leyes, ordenanzas y demás herramientas legislativas, el reciclaje de neumáticos usados en favor del paisaje, la naturaleza y la salud del ser humano.

- Por otro lado, al no haber podido utilizar la mezcla asfáltica en calles, se propone realizar los estudios necesarios para la implementación de dicha mezcla en pistas atléticas, esto se debe a que la consistencia del polvo de llanta que es esponjosa, lo que podría reducir el impacto que se produce sobre las rodillas de los atletas. Siempre y cuando no se produzcan micro fisura o fisuras.

- Cuando se realiza la compactación de la briqueta, es importante tener en cuenta que la máquina esté bien lubricada, ya que el número de golpes como la fuerza de los golpes pueden variar y producir daños por rozamiento en la maquinaria. Dando como resultado una mala compactación.

- Para futuras experiencias relacionadas al tema planteado, es recomendable que el material ya tamizado sea diferenciado a través de marcas para que no exista confusión al momento de agregar el material.

- De igual manera, se sugiere a investigadores que realicen ensayos sobre el mismo tema que al momento de desmoldado de las briquetas, la presión que se ejerza en la briqueta sea suave ya que, si se aplica demasiada fuerza la muestra puede romperse e inutilizarse para ensayos.

- En caso de que los materiales no cumplan con las normas técnicas, se deberá buscar otro material de otra mina para determinar que cumpla con las normas técnicas.

- Debido a la dificultad de la mezcla del material con el agua y la emulsión, se recomienda aumentar el tiempo de mezclado y, cuando sea preciso, la cantidad de agua de las mezclas.

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ANEXOS

Standard Method of Test for

Specific Gravity and Absorption of Fine Aggregate

AASHTO Designation: T 84-08[1]
ASTM Designation: C 128-04a

1. SCOPE

1.1. This method covers the determination of bulk and apparent specific gravity, 23/23°C (73.4/73.4°F), and absorption of fine aggregate.

1.2. This method determines (after 15 hours in water) the bulk specific gravity and the apparent specific gravity, the bulk specific gravity on the basis of mass of saturated surface-dry aggregate, and the absorption.

1.3. The values stated in SI units are to be regarded as the standard.

1.4. *This standard may involve hazardous materials, operations, and equipment. This standard does not purport to address all of the safety concerns associated with its use. It is the responsibility of whoever uses this standard to consult and establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*

2. REFERENCED DOCUMENTS

2.1. *AASHTO Standards*:

- M 231, Weighing Devices Used in the Testing of Materials
- T 2, Sampling of Aggregates
- T 19M/T 19, Bulk Density ("Unit Weight") and Voids in Aggregate
- T 85, Specific Gravity and Absorption of Coarse Aggregate
- T 133, Density of Hydraulic Cement
- T 248, Reducing Samples of Aggregate to Testing Size
- T 255, Total Evaporable Moisture Content of Aggregate by Drying

2.2. *ASTM Standards*:

- C 125, Terminology Relating to Concrete and Concrete Aggregates
- C 670, Preparing Precision and Bias Statements for Test Methods for Construction Materials

2.3. *IEEE/ASTM Standard*:

- SI 10, American National Standard for Use of the International System of Units (SI): The Modern Metric System

3. TERMINOLOGY

3.1. *Definitions*:

3.1.1. *absorption*—the increase in the mass of aggregate due to water in the pores of the material, but not including water adhering to the outside surface of the particles, expressed as a percentage of the dry mass. The aggregate is considered "dry" when it has been maintained at a temperature of 110 ± 5°C for sufficient time to remove all uncombined water by reaching a constant mass.

3.1.2. *specific gravity*—the ratio of the mass (or weight in air) of a unit volume of a material to the mass of the same volume of gas-free distilled water at stated temperatures. Values are dimensionless.

3.1.2.1. *apparent specific gravity*—the ratio of the weight in air of a unit volume of the impermeable portion of aggregate at a stated temperature to the weight in air of an equal volume of gas-free distilled water at a stated temperature.

3.1.2.2. *bulk specific gravity*—the ratio of the weight in air of a unit volume of aggregate (including the permeable and impermeable voids in the particles, but not including the voids between particles) at a stated temperature to the weight in air of an equal volume of gas-free distilled water at a stated temperature.

3.1.2.3. *bulk specific gravity (SSD)*—the ratio of the mass in air of a unit volume of aggregate, including the mass of water within the voids filled to the extent achieved by submerging in water for approximately 15 hours (but not including the voids between particles) at a stated temperature, compared to the weight in air of an equal volume of gas-free distilled water at a stated temperature.

4. SIGNIFICANCE AND USE

4.1. Bulk specific gravity is the characteristic generally used for calculation of the volume occupied by the aggregate in various mixtures containing aggregate including portland cement concrete, bituminous concrete, and other mixtures that are proportioned or analyzed on an absolute volume basis. Bulk specific gravity is also used in the computation of voids in aggregate in T 19M/T 19. Bulk specific gravity determined on the saturated surface-dry basis is used if the aggregate is wet, that is, if its absorption has been satisfied. Conversely, the bulk specific gravity determined on the oven-dry basis is used for computations when the aggregate is dry or assumed to be dry.

4.2. Apparent specific gravity pertains to the relative density of the solid material making up the constituent particles not including the pore space within the particles that is accessible to water. This value is not widely used in construction aggregate technology.

4.3. Absorption values are used to calculate the change in the mass of an aggregate due to water absorbed in the pore spaces within the constituent particles, compared to the dry condition, when it is deemed that the aggregate has been in contact with water long enough to satisfy most of the absorption potential. The laboratory standard for absorption is that obtained after submerging dry aggregate for approximately 15 hours in water. Aggregates mined from below the water table may have a higher absorption when used, if not allowed to dry. Conversely, some aggregates when used may contain an amount of absorbed moisture less than the 15 hours soaked condition: For an aggregate that has been in contact with water and that has free moisture on the particle surfaces, the percentage of free moisture can be determined by deducting the absorption from the total moisture content determined by T 255 by drying.

5. APPARATUS

5.1. *Balance,* conforming to the requirements of M 231, Class G 2.

5.2. *Pycnometer*—A flask or other suitable container into which the fine aggregate test sample can be readily introduced and in which the volume content can be reproduced with ±100 mm^3. The volume of the container filled to mark shall be at least 50 percent greater than the space required to accommodate the test sample. A volumetric flask of 500-mL capacity or a fruit jar fitted with a pycnometer top is satisfactory for a 500-g test sample of most fine aggregates. A Le Chatelier flask as described in T 133 is satisfactory for an approximately 55-g test sample.

5.3. *Mold*—A metal mold in the form of a frustum of a cone with dimensions as follows: 40 ± 3 mm inside diameter at the top, 90 ± 3 mm inside diameter at the bottom, and 75 ± 3 mm in height, with the metal having a minimum thickness of 0.8 mm.

5.4. *Tamper*—A metal tamper having a mass of 340 ± 15 g and having a flat circular tamping face 25 ± 3 mm in diameter.

6. SAMPLING

6.1. Sampling shall be accomplished in general accordance with T 2.

7. PREPARATION OF TEST SPECIMEN

7.1. Obtain approximately one kilogram of the fine aggregate from the sample using the applicable procedures described in T 248.

7.1.1. Dry it in a suitable pan or vessel to constant mass at a temperature of 110 ± 5°C (230 ± 9°F). Allow it to cool to comfortable handling temperature, cover with water, either by immersion or by the addition of at least 6 percent moisture to the fine aggregate and permit to stand for 15 to 19 hours.

7.1.2. As an alternative to Section 7.1.1, where the absorption and specific gravity values are to be used in proportioning concrete mixtures with aggregates used in their naturally moist condition, the requirement for initial drying to constant mass may be eliminated and, if the surfaces of the particles have been kept wet, the 15-hour soaking may also be eliminated.

Note 1—Values for absorption and for specific gravity in the saturated surface-dry condition may be significantly higher for aggregate not oven dried before soaking than for the same aggregate treated in accordance with Section 7.1.1.

7.2. Decant excess water with care to avoid loss of fines, spread the sample on a flat nonabsorbent surface exposed to a gently moving current of warm air, and stir frequently to secure homogeneous drying. If desired, mechanical aids such as tumbling or stirring may be employed to assist in achieving the saturated surface-dry condition. As the material begins to dry sufficiently, it may be necessary to work it with the hands in a rubbing motion to break up any conglomerations, lumps, or balls of material that develop. Continue this operation until the test specimen approaches a free-flowing condition. Follow the procedure in Section 7.2.1 to determine whether or not surface moisture is present on the constituent fine aggregate particles. It is intended that the first trial of the cone test will be made with some surface water in the specimen. Continue drying with constant stirring, and if necessary, work the material with a hand-rubbing motion, and test at frequent intervals until the test indicates that the specimen has reached a surface-dry condition.

If the first trial of the surface moisture test indicates that moisture is not present on the surface, it has been dried past the saturated surface-dry condition. In this case, thoroughly mix a few milliliters of water with the fine aggregate and permit the specimen to stand in a covered container for 30 minutes. Then resume the process of drying and testing at frequent intervals for the onset of the surface-dry condition.

7.2.1. *Cone Test for Surface Moisture*—Hold the mold firmly on a smooth nonabsorbent surface with the large diameter down. Place a portion of the partially dried fine aggregate loosely in the mold by filling until overflow occurs and heaping additional material above the top of the mold by holding it with the cupped fingers of the hand holding the mold. Lightly tamp the fine aggregate into the mold with 25 light drops of the tamper. Each drop should start about 5 mm (0.2 in.) above the top surface of the fine aggregate. Permit the tamper to fall freely under gravitational attraction on each drop. Adjust the starting height to the new surface elevation after each drop and distribute the drops over the surface. Remove loose sand from the base and lift the mold vertically. If surface moisture is still present, the fine aggregate will retain the molded shape. When the fine aggregate slumps slightly, it indicates that it has reached a surface-dry condition. Some angular fine aggregate or material with a high proportion of fines may not slump in the cone test upon reaching a surface-dry condition. This may be the case if fines become airborne upon dropping a handful of the sand from the cone test 100 to 150 mm onto a surface. For these materials, the saturated surface-dry condition should be considered as the point that one side of the fine aggregate slumps slightly upon removing the mold.

Note 2—The following criteria have also been used on materials that do not readily slump:

1. *Provisional Cone Test*—Fill the cone mold as described in Section 7.2.1 except only use 10 drops of the tamper. Add more fine aggregate and use 10 drops of the tamper again. Then add material two more times using three and two drops of the tamper, respectively. Level off the material even with the top of the mold; remove loose material from the base; and lift the mold vertically.
2. *Provisional Surface Test*—If airborne fines are noted when the fine aggregate is such that it will not slump when it is at a moisture condition, add more moisture to the sand, and at the onset of the surface-dry condition, with the hand lightly pat approximately 100 g of the material on a flat, dry, clean, dark, or dull nonabsorbent surface such as a sheet of rubber, a worn oxidized, galvanized, or steel surface, or a black-painted metal surface. After one to three seconds, remove the fine aggregate. If noticeable moisture shows on the test surface for more than one to two seconds, then surface moisture is considered to be present on the fine aggregate.
3. Colorimetric procedures described by Kandhal and Lee, *Highway Research Record No. 307*, p. 44.
4. For reaching the saturated surface-dry condition on a single-size material that slumps when wet, hard-finish paper towels can be used to surface dry the material until the point is just reached where the paper towel does not appear to be picking up moisture from the surfaces of the fine aggregate particles.

8. PROCEDURE

8.1. Make and record all mass determinations to 0.1 g.

8.2. Partially fill the pycnometer with water. Immediately introduce into the pycnometer 500 ± 10 g of saturated surface-dry fine aggregate prepared as described in Section 6, and fill with additional water to approximately 90 percent of capacity. Manually roll, invert, and agitate or use a combination of these actions to eliminate all air bubbles in the pycnometer (Note 3). Accomplish mechanical agitation by external vibration of the pycnometer in a manner that will not degrade the sample. A level of agitation adjusted to just set individual particles in motion is sufficient to promote de-airing without degradation. A mechanical agitator shall be considered acceptable for

use if comparison tests for each six-month period of use show variations less than the acceptable range of two results (d2s) indicated in Table 1 from results of manual agitation on the same material. Adjust its temperature to 23.0 ± 1.7°C (73.4 ± 3°F), if necessary by immersion in circulating water, and bring the water level in the pycnometer to its calibrated capacity. Determine total mass of the pycnometer, specimen, and water.

Note 3—It normally takes about 15 to 20 minutes to eliminate air bubbles by manual methods. Dipping the tip of a paper towel into the pycnometer has been found to be useful in dispersing the foam that sometimes builds up when eliminating the air bubbles, or adding a few drops of isopropyl alcohol, after removal of air bubbles and just prior to bringing the water level to its calibrated capacity, has also been found useful in dispersing foam on the water surface. Do not use isopropyl alcohol when using the alternative method described in Section 8.2.1.

Table 1—Precision

	Standard Deviation (1s)[a]	Acceptable Range of Two Results (d2s)[a]
Single-operator precision:		
Bulk specific gravity (dry)	0.011	0.032
Bulk specific gravity (SSD)	0.0095	0.027
Apparent specific gravity	0.0095	0.027
Absorption,[b] percent	0.11	0.31
Multilaboratory precision:		
Bulk specific gravity (dry)	0.023	0.066
Bulk specific gravity (SSD)	0.020	0.056
Apparent specific gravity	0.020	0.056
Absorption,[b] percent	0.23	0.66

[a] These numbers represent, respectively, the (1s) and (d2s) limits as described in ASTM C 670. The precision estimates were obtained from the analysis of combined AASHTO Materials Reference Laboratory reference sample data from laboratories using 15- to 19-hour saturation times and other laboratories using 24 ± 4 hours of saturation time. Testing was performed on aggregates of normal specific gravities, and started with aggregates in the oven-dry condition.

[b] Precision estimates are based on aggregates with absorptions of less than one percent and may differ for manufactured fine aggregates having absorption values greater than one percent.

8.2.1. *Alternative to Determining the Mass in Section 8.2*—The quantity of added water necessary to fill the pycnometer at the required temperature may be determined volumetrically using a buret accurate to 0.15 mL. Compute the total mass of the pycnometer, specimen, and water as follows:

$$C = 0.9975\,V_a + S + W \qquad (1)$$

where:

C = mass of pycnometer with specimen and water to calibration mark, g;
V_a = volume of water added to pycnometer, mL;
S = mass of saturated surface-dry specimen, g; and
W = mass of the pycnometer empty, g.

8.2.2. *Alternative to the Procedure in Section 8.2*—Use a Le Chatelier flask initially filled with water to a point on the stem between the 0 and the 1-mL mark. Record this initial reading with the flask and contents within the temperature range of 23.0 ± 1.7°C (73.4 ± 3°F). Add 55 ± 5 g of fine aggregate in the saturated surface-dry condition (or other mass as necessary to result in raising the water level to some point on the upper series of graduation). After all fine aggregate has been introduced, place the stopper in the flask and roll the flask in an inclined position, or gently whirl it in a horizontal circle so as to dislodge all entrapped air, continuing until no further bubbles rise to the surface (Note 4). Take a final reading with the flask and contents within 1°C (1.8°F) of the original temperature.

Note 4—When using the Le Chatelier flask method, slowly adding a small measured amount (not to exceed 1 mL) of isopropyl alcohol, after removal of air bubbles, has been found useful in dispersing foam appearing on the water surface. The volume of alcohol used must be subtracted from the final reading (R_2).

8.3. Remove the fine aggregate from the pycnometer, dry to constant mass at a temperature of 110 ± 5°C (230 ± 9°F), cool in air at room temperature for 1.0 ± 0.5 hours and determine the mass.

Note 5—In lieu of drying and determining the mass of the sample which has been removed from the pycnometer, a second portion of the saturated surface dry sample may be used to determine the oven dry mass. This sample must be obtained at the same time and be within 0.2 grams of the mass of the sample which is introduced into the pycnometer.

8.3.1. If the Le Chatelier flask method is used, a separate sample portion is needed for the determination of absorption. Weigh a separate 500 ± 10 g portion of the saturated surface-dry fine aggregate, dry to constant mass, and reweigh. This sample must be obtained at the same time as the sample that is introduced into the Le Chatelier flask.

8.4. Determine the mass of the pycnometer filled to its calibration capacity with water at 23.0 ± 1.7°C (73.4 ± 3°F).

8.4.1. *Alternative to Determining the Mass in Section 8.4*—The quantity of water necessary to fill the empty pycnometer at the required temperature may be determined volumetrically using a buret accurate to 0.15 mL. Calculate the mass of the pycnometer filled with water as follows:

$$B = 0.9975\,V + W \qquad (2)$$

where:

B = mass of flask filled with water, g;
V = volume of flask, mL; and
W = mass of the flask empty, g.

9. BULK SPECIFIC GRAVITY

9.1. Calculate the bulk specific gravity, 23/23°C (73.4/73.4°F) as follows:

$$\text{Bulk sp gr} = A/(B + S - C) \qquad (3)$$

where:

A = mass of oven-dry specimen in air, g;
B = mass of pycnometer filled with water, g;
S = mass of saturated surface-dry specimen, g; and
C = mass of pycnometer with specimen and water to calibration mark, g.

9.1.1. If the Le Chatelier flask method was used, calculate the bulk specific gravity, 23/23°C, as follows:

$$\text{Bulk sp gr} = \frac{S_1(A/S)}{0.9975\,(R_2 - R_1)} \qquad (4)$$

where:

S_1 = mass of saturated surface-dry specimen used in Le Chatelier flask, g;
R_2 = final reading of water level in Le Chatelier flask; and
R_1 = initial reading of water level in Le Chatelier flask.

10. BULK SPECIFIC GRAVITY (SATURATED SURFACE-DRY BASIS)

10.1. Calculate the bulk specific gravity, 23/23°C (73.4/73.4°F), on the basis of mass of saturated surface-dry aggregate as follows:

$$\text{Bulk sp gr (saturated surface - dry basis)} = S/(B + S - C) \quad (5)$$

10.1.1. If the Le Chatelier flask method was used, calculate the bulk specific gravity, 23/23°C, on the basis of saturated surface-dry aggregate as follows:

$$\text{Bulk sp gr (saturated surface – dry basis)} = \frac{S_1}{0.9975(R_2 - R_1)} \quad (6)$$

11. APPARENT SPECIFIC GRAVITY

11.1. Calculate the apparent specific gravity, 23/23°C (73.4/73.4°F) as follows:

$$\text{Apparent sp gr} = A/(B + A - C) \quad (7)$$

12. ABSORPTION

12.1. Calculate the percentage of absorption as follows:

$$\text{Absorption, percent} = [(S - A)/A] \times 100 \quad (8)$$

13. REPORT

13.1. Report specific gravity results to the nearest 0.01 and absorption to the nearest 0.1 percent. The Appendix gives mathematical interrelationships among the three types of specific gravities and absorption. These may be useful in checking the consistency of reported data or calculating a value that was not reported by using other reported data.

13.2. If the fine aggregate was tested in a naturally moist condition other than the oven dried and 15-hour soaked condition, report the source of the sample and the procedures used to prevent drying prior to testing.

14. PRECISION AND BIAS

14.1. The estimates of precision of this test method (listed in Table 1) are based on results from the AASHTO Materials Reference Laboratory Reference Sample Program, with testing conducted by this test method and ASTM C 128. The significant difference between the methods is that ASTM C 128 requires a saturation period of 24 ± 4 hours, and T 84 requires a saturation period of 15 to 19 hours. This difference has been found to have an insignificant effect on the precision indices. The data are based on the analyses of more than 100 paired test results from 40 to 100 laboratories.

14.2. Since there is no accepted reference material suitable for determining the bias for the procedure in T 84 for measuring specific gravity and absorption of fine aggregate, no statement on bias is being made.

APPENDIX

(Nonmandatory Information)

X1. INTERRELATIONSHIPS BETWEEN SPECIFIC GRAVITIES AND ABSORPTION AS DEFINED IN METHODS T 84 AND T 85

X1.1. Let:

S_d = bulk specific gravity (dry-basis),
S_s = bulk specific gravity (SSD-basis),
S_a = apparent specific gravity, and
A = absorption in percent.

Then:

$$S_S = (1 + A/100)S_d \qquad (X1.1)$$

$$S_a = \frac{1}{\frac{1}{S_d} - \frac{A}{100}} = \frac{S_d}{1 - \frac{AS_d}{100}} \qquad (X1.2)$$

Or:

$$S_a = \frac{1}{\frac{1 + A/100}{S_s} - \frac{A}{100}} = \frac{S_S}{1 - \frac{A}{100}(S_s - 1)} \qquad (X1.3)$$

$$A = \left(\frac{S_S}{S_d} - 1\right)100 \qquad (X1.4)$$

$$A = \left(\frac{S_a - S_s}{S_a(S_S - 1)}\right)100 \qquad (X1.5)$$

[1] This method is technically equivalent with ASTM C 128-04a.

Standard Method of Test for

Specific Gravity and Absorption of Coarse Aggregate

AASHTO Designation: T 85-08[1]
ASTM Designation: C 127-04

1. SCOPE

1.1. This method covers the determination of specific gravity and absorption of coarse aggregate. The specific gravity may be expressed as bulk specific gravity, bulk specific gravity (saturated-surface-dry (SSD)), or apparent specific gravity. The bulk specific gravity (SSD) and absorption are based on aggregate after 15 hours soaking in water. This method is not intended to be used with lightweight aggregates.

1.2. The values stated in SI units are to be regarded as the standard.

1.3. *This standard may involve hazardous materials, operations, and equipment. This standard does not purport to address all of the safety concerns associated with its use. It is the responsibility of the user of this standard to consult and establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*

2. REFERENCED DOCUMENTS

2.1. *AASHTO Standards*:

- M 43, Sizes of Aggregate for Road and Bridge Construction
- M 92, Wire-Cloth Sieves for Testing Purposes
- M 231, Weighing Devices Used in the Testing of Materials
- T 2, Sampling of Aggregates
- T 19M/T 19, Bulk Density ("Unit Weight") and Voids in Aggregate
- T 27, Sieve Analysis of Fine and Coarse Aggregates
- T 84, Specific Gravity and Absorption of Fine Aggregate
- T 248, Reducing Samples of Aggregate to Testing Size
- T 255, Total Evaporable Moisture Content of Aggregate by Drying

2.2. *ASTM Standard*:

- C 670, Practice of Preparing Precision Statements for Test Methods for Construction Materials

2.3. *IEEE/ASTM Standard*:

- SI 10, American National Standard for Use of the International System of Units (SI): The Modern Metric System

3. TERMINOLOGY

3.1. *Definitions*:

3.1.1. *absorption*—the increase in the mass of aggregate due to water in the pores of the material, but not including water adhering to the outside surface of the particles, expressed as a percentage of the dry mass. The aggregate is considered "dry" when it has been maintained at a temperature of 110 ± 5°C for sufficient time to remove all uncombined water by reaching a constant mass.

3.1.2. *specific gravity*—the ratio of the mass (or weight in air) of a unit volume of a material to the mass of the same volume of gas-free distilled water at stated temperatures. Values are dimensionless.

3.1.2.1. *apparent specific gravity*—the ratio of the weight in air of a unit volume of the impermeable portion of aggregate at a stated temperature to the weight in air of an equal volume of gas-free distilled water at a stated temperature.

3.1.2.2. *bulk specific gravity*—the ratio of the weight in air of a unit volume of aggregate (including the permeable and impermeable voids in the particles, but not including the voids between particles) at a stated temperature to the weight in air of an equal volume of gas-free distilled water at a stated temperature.

3.1.2.3. *bulk specific gravity (SSD)*—the ratio of the mass in air of a unit volume of aggregate, including the mass of water within the voids filled to the extent achieved by submerging in water for approximately 15 hours (but not including the voids between particles) at a stated temperature, compared to the weight in air of an equal volume of gas-free distilled water at a stated temperature.

4. SUMMARY OF METHOD

4.1. A sample of aggregate is immersed in water for approximately 15 hours to essentially fill the pores. It is then removed from the water, the water dried from the surface of the particles, and weighed. Subsequently the sample is weighed while submerged in water. Finally the sample is oven-dried and weighed a third time. Using the mass and weight measurements thus obtained and formulas in the method, it is possible to calculate three types of specific gravity and absorption.

5. SIGNIFICANCE AND USE

5.1. Bulk specific gravity is the characteristic generally used for calculation of the volume occupied by the aggregate in various mixtures containing aggregate, including portland cement concrete, bituminous concrete, and other mixtures that are proportioned or analyzed on an absolute volume basis. Bulk specific gravity is also used in the computation of voids in aggregate in T 19M/T 19. Bulk specific gravity (SSD) is used if the aggregate is wet, that is, if its absorption has been satisfied. Conversely, the bulk specific gravity (oven-dry) is used for computations when the aggregate is dry or assumed to be dry.

5.2. Apparent specific gravity pertains to the relative density of the solid material making up the constituent particles not including the pore space within the particles which is accessible to water.

5.3. Absorption values are used to calculate the change in the mass of an aggregate due to water absorbed in the pore spaces within the constituent particles, compared to the dry condition, when it is deemed that the aggregate has been in contact with water long enough to satisfy most of the

absorption potential. The laboratory standard for absorption is that obtained after submerging dry aggregate for approximately 15 hours in water. Aggregates mined from below the water table may have a higher absorption, when used, if not allowed to dry. Conversely, some aggregates when used may contain an amount of absorbed moisture less than the 15-hour soaked condition. For an aggregate that has been in contact with water and that has free moisture on the particle surfaces, the percentage of free moisture can be determined by deducting the absorption from the total moisture content determined by T 255.

5.4. The general procedures described in this method are suitable for determining the absorption of aggregates that have had conditioning other than the 15-hour soak, such as boiling water or vacuum saturation. The values obtained for absorption by other methods will be different than the values obtained by the prescribed 15-hour soak, as will the bulk specific gravity (SSD).

5.5. The pores in lightweight aggregates may or may not become essentially filled with water after immersion for 15 hours. In fact, many such aggregates can remain immersed in water for several days without satisfying most of the aggregates' absorption potential. Therefore, this method is not intended for use with lightweight aggregate.

6. APPARATUS

6.1. *Balance*, conforming to the requirements of M 231, Class G 5. The balance shall be equipped with suitable apparatus for suspending the sample container in water from the center of the weighing platform or pan of the balance.

6.2. *Sample Container*—A wire basket of 3.35 mm (No. 6) or finer mesh, or a bucket of approximately equal breadth and height, with a capacity of 4 to 7 L for 37.5-mm ($1^1/_2$-in.) nominal maximum size aggregate or smaller, and a larger container as needed for testing larger maximum size aggregate. The container shall be constructed so as to prevent trapping air when the container is submerged.

6.3. *Water Tank*—A watertight tank into which the sample and container are placed for complete immersion while suspended below the balance, equipped with an overflow outlet for maintaining a constant water level.

6.4. *Suspended Apparatus*—Wire suspending the container shall be of the smallest practical size to minimize any possible effects of a variable immersed length.

6.5. *Sieves*—A 4.75-mm (No. 4) sieve or other sizes as needed (Sections 7.2, 7.3, and 7.4), conforming to M 92.

7. SAMPLING

7.1. Sample the aggregate in accordance with T 2.

7.2. Thoroughly mix the sample of aggregate and reduce it to the approximate quantity needed using the applicable procedures in T 248. Reject all material passing a 4.75-mm (No. 4) sieve by dry sieving and thoroughly washing to remove dust or other coatings from the surface. If the coarse aggregate contains a substantial quantity of material finer than the 4.75-mm (No. 4) sieve (such as for Size No. 8 and 9 aggregates in M 43), use the 2.36-mm (No. 8) sieve in place of the 4.75-mm (No. 4) sieve. Alternatively, separate the material finer than the 4.75-mm (No. 4) sieve and test the finer material according to T 84.

7.3. The minimum mass of test sample to be used is given below. In many instances it may be desirable to test a coarse aggregate in several separate size fractions; and if the sample contains more than 15 percent retained on the 37.5-mm ($1^1/_2$-in.) sieve, test the material larger than 37.5 mm in one or more size fractions separately from the smaller size fractions. When an aggregate is tested in separate size fractions, the minimum mass of test sample for each fraction shall be the difference between the masses prescribed for the maximum and minimum sizes of the fraction.

Nominal Maximum Size, mm (in.)	Minimum Mass of Test Sample, kg (lb)
12.5 ($^1/_2$) or less	2 (4.4)
19.0 ($^3/_4$)	3 (6.6)
25.0 (1)	4 (8.8)
37.5 ($1^1/_2$)	5 (11)
50 (2)	8 (18)
63 ($2^1/_2$)	12 (26)
75 (3)	18 (40)
90 ($3^1/_2$)	25 (55)
100 (4)	40 (88)
112 ($4^1/_2$)	50 (110)
125 (5)	75 (165)
150 (6)	125 (276)

7.4. If the sample is tested in two or more size fractions, determine the grading of the sample in accordance with T 27, including the sieves used for separating the size fractions for the determinations in this method. In calculating the percentage of material in each size fraction, ignore the quantity of material finer than the 4.75-mm (No. 4) sieve or 2.36-mm (No. 8) sieve when that sieve is used in accordance with Section 7.2.

8. PROCEDURE

8.1. Dry the test sample to constant mass at a temperature of 110 ± 5°C (230 ± 9°F), cool in air at room temperature for one to three hours for test samples of 37.5 mm ($1^1/_2$-in.) nominal maximum size, or longer for larger sizes until the aggregate has cooled to a temperature that is comfortable to handle (approximately 50°C). Subsequently immerse the aggregate in water at room temperature for a period of 15 to 19 hours.

Note 1—When testing coarse aggregate of large nominal maximum size requiring large test samples, it may be more convenient to perform the test on two or more subsamples, and the values obtained combined for the computation described in Section 9.

8.2. Where the absorption and specific gravity values are to be used in proportioning concrete mixtures in which the aggregates will be in their naturally moist condition, the requirement for initial drying to constant mass may be eliminated, and, if the surfaces of the particles in the sample have been kept continuously wet until test, the 15-hour soaking may also be eliminated.

Note 2—Values for absorption and bulk specific gravity (SSD) may be significantly higher for aggregate not oven dried before soaking than for the same aggregate treated in accordance with Section 8.1. This is especially true of particles larger than 75 mm (3 in.) since the water may not be able to penetrate the pores to the center of the particle in the prescribed soaking period.

8.3. Remove the test sample from the water and roll it in a large absorbent cloth until all visible films of water are removed. Wipe the larger particles individually. A moving stream of air may be used to assist in the drying operation. Take care to avoid evaporation of water from aggregate pores

absorption potential. The laboratory standard for absorption is that obtained after submerging dry aggregate for approximately 15 hours in water. Aggregates mined from below the water table may have a higher absorption, when used, if not allowed to dry. Conversely, some aggregates when used may contain an amount of absorbed moisture less than the 15-hour soaked condition. For an aggregate that has been in contact with water and that has free moisture on the particle surfaces, the percentage of free moisture can be determined by deducting the absorption from the total moisture content determined by T 255.

5.4. The general procedures described in this method are suitable for determining the absorption of aggregates that have had conditioning other than the 15-hour soak, such as boiling water or vacuum saturation. The values obtained for absorption by other methods will be different than the values obtained by the prescribed 15-hour soak, as will the bulk specific gravity (SSD).

5.5. The pores in lightweight aggregates may or may not become essentially filled with water after immersion for 15 hours. In fact, many such aggregates can remain immersed in water for several days without satisfying most of the aggregates' absorption potential. Therefore, this method is not intended for use with lightweight aggregate.

6. APPARATUS

6.1. *Balance*, conforming to the requirements of M 231, Class G 5. The balance shall be equipped with suitable apparatus for suspending the sample container in water from the center of the weighing platform or pan of the balance.

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6.3. *Water Tank*—A watertight tank into which the sample and container are placed for complete immersion while suspended below the balance, equipped with an overflow outlet for maintaining a constant water level.

6.4. *Suspended Apparatus*—Wire suspending the container shall be of the smallest practical size to minimize any possible effects of a variable immersed length.

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7.2. Thoroughly mix the sample of aggregate and reduce it to the approximate quantity needed using the applicable procedures in T 248. Reject all material passing a 4.75-mm (No. 4) sieve by dry sieving and thoroughly washing to remove dust or other coatings from the surface. If the coarse aggregate contains a substantial quantity of material finer than the 4.75-mm (No. 4) sieve (such as for Size No. 8 and 9 aggregates in M 43), use the 2.36-mm (No. 8) sieve in place of the 4.75-mm (No. 4) sieve. Alternatively, separate the material finer than the 4.75-mm (No. 4) sieve and test the finer material according to T 84.

7.3. The minimum mass of test sample to be used is given below. In many instances it may be desirable to test a coarse aggregate in several separate size fractions; and if the sample contains more than 15 percent retained on the 37.5-mm ($1^1/_2$-in.) sieve, test the material larger than 37.5 mm in one or more size fractions separately from the smaller size fractions. When an aggregate is tested in separate size fractions, the minimum mass of test sample for each fraction shall be the difference between the masses prescribed for the maximum and minimum sizes of the fraction.

Nominal Maximum Size, mm (in.)	Minimum Mass of Test Sample, kg (lb)
12.5 ($^1/_2$) or less	2 (4.4)
19.0 ($^3/_4$)	3 (6.6)
25.0 (1)	4 (8.8)
37.5 ($1^1/_2$)	5 (11)
50 (2)	8 (18)
63 ($2^1/_2$)	12 (26)
75 (3)	18 (40)
90 ($3^1/_2$)	25 (55)
100 (4)	40 (88)
112 ($4^1/_2$)	50 (110)
125 (5)	75 (165)
150 (6)	125 (276)

7.4. If the sample is tested in two or more size fractions, determine the grading of the sample in accordance with T 27, including the sieves used for separating the size fractions for the determinations in this method. In calculating the percentage of material in each size fraction, ignore the quantity of material finer than the 4.75-mm (No. 4) sieve or 2.36-mm (No. 8) sieve when that sieve is used in accordance with Section 7.2.

8. PROCEDURE

8.1. Dry the test sample to constant mass at a temperature of 110 ± 5°C (230 ± 9°F), cool in air at room temperature for one to three hours for test samples of 37.5 mm ($1^1/_2$-in.) nominal maximum size, or longer for larger sizes until the aggregate has cooled to a temperature that is comfortable to handle (approximately 50°C). Subsequently immerse the aggregate in water at room temperature for a period of 15 to 19 hours.

Note 1—When testing coarse aggregate of large nominal maximum size requiring large test samples, it may be more convenient to perform the test on two or more subsamples, and the values obtained combined for the computation described in Section 9.

8.2. Where the absorption and specific gravity values are to be used in proportioning concrete mixtures in which the aggregates will be in their naturally moist condition, the requirement for initial drying to constant mass may be eliminated, and, if the surfaces of the particles in the sample have been kept continuously wet until test, the 15-hour soaking may also be eliminated.

Note 2—Values for absorption and bulk specific gravity (SSD) may be significantly higher for aggregate not oven dried before soaking than for the same aggregate treated in accordance with Section 8.1. This is especially true of particles larger than 75 mm (3 in.) since the water may not be able to penetrate the pores to the center of the particle in the prescribed soaking period.

8.3. Remove the test sample from the water and roll it in a large absorbent cloth until all visible films of water are removed. Wipe the larger particles individually. A moving stream of air may be used to assist in the drying operation. Take care to avoid evaporation of water from aggregate pores

during the operation of surface-drying. Determine the mass of the test sample in the saturated surface-dry condition. Record this and all subsequent masses to the nearest 1.0 g or 0.1 percent of the sample mass, whichever is greater.

8.4. After determining the mass, immediately place the saturated-surface-dry test sample in the sample container and determine its mass in water at 23.0 ± 1.7°C (73.4 ± 3°F), having a density of 997 ± 2 kg/m^3. Take care to remove all entrapped air before determining the mass by shaking the container while immersed.

Note 3—The container should be immersed to a depth sufficient to cover it and the test sample during mass determination. Wire suspending the container should be of the smallest practical size to minimize any possible effects of a variable immersed length.

8.5. Dry the test sample to constant mass at a temperature of 110 ± 5°C (230 ± 9°F), cool in air at room temperature one to three hours, or until the aggregate has cooled to a temperature that is comfortable to handle (approximately 50°C), and determine the mass. Use this weight for A in the calculations in Section 9.

9. CALCULATIONS

9.1. *Specific Gravity*:

9.1.1. *Bulk Specific Gravity*—Calculate the bulk specific gravity, 23/23°C (73.4/73.4°F), as follows:

$$\text{Bulk sp gr} = A/(B-C) \qquad (1)$$

where:

A = mass of oven-dry test sample in air, g;
B = mass of saturated-surface-dry test sample in air, g; and
C = mass of saturated test sample in water, g.

9.1.2. *Bulk Specific Gravity (Saturated-Surface-Dry)*—Calculate the bulk specific gravity, 23/23°C (73.4/73.4°F), on the basis of mass of saturated-surface-dry aggregate as follows:

$$\text{Bulk sp gr (saturated - surface - dry)} = B/(B-C) \qquad (2)$$

9.1.3. *Apparent Specific Gravity*—Calculate the apparent specific gravity, 23/23°C (73.4/73.4°F), as follows:

$$\text{Apparent sp gr} = A/(A-C) \qquad (3)$$

9.2. *Average Specific Gravity Values*—When the sample is tested in separate size fractions, the average value for bulk specific gravity, bulk specific gravity (SSD), or apparent specific gravity can be computed as the weighted average of the values as computed in accordance with Section 9.1 using the following equation:

$$G = \frac{1}{\frac{P_1}{100\,G_1} + \frac{P_2}{100\,G_2} + \cdots \frac{P_n}{100\,G_n}} \qquad (4)$$

where:

G = average specific gravity (All forms of expression of specific gravity can be averaged in this manner.);
$P_1, P_2 \ldots P_n$ = mass percentages of each size fraction present in the original sample; and

$G_1, G_2 \ldots G_n$ = appropriate specific gravity values for each size fraction depending on the type of specific gravity being averaged.

Note 4—Some users of this method may wish to express the results in terms of density. Density may be determined by multiplying the bulk specific gravity, bulk specific gravity (SSD), or apparent specific gravity by the density of water (997.5 kg/m^3 or 0.9975 Mg/m^3 or 62.27 lb/ft^3 at 23°C). Some authorities recommend using the density of water at 4°C (1000 kg/m^3 or 1.000 Mg/m^3 or 62.43 lb/ft^3) as being sufficiently accurate. Results should be expressed to three significant figures. The density terminology corresponding to bulk specific gravity, bulk specific gravity (SSD), and apparent specific gravity has not been standardized.

9.3. *Absorption*—Calculate the percentage of absorption, as follows:

$$\text{Absorption, percent} = [(B - A)/A] \times 100 \quad (5)$$

9.4. *Average Absorption Value*—When the sample is tested in separate size fractions, the average absorption value is the average of the values as computed in Section 9.3, weighted in proportion to the mass percentages of the size fractions in the original sample as follows:

$$A = (P_1 A_1/100) + (P_2 A_2/100) + \cdots (P_n A_n/100) \quad (6)$$

where:

A = average absorption, percent;

$P_1, P_2 \ldots P_n$ = mass percentages of each size fraction present in the original sample; and

$A_1, A_2 \ldots A_n$ = absorption percentages for each size fraction.

10. REPORT

10.1. Report specific gravity results to the nearest 0.01, and indicate the type of specific gravity, whether bulk, bulk (saturated-surface-dry), or apparent.

10.2. Report the absorption result to the nearest 0.1 percent.

10.3. If the specific gravity and absorption values were determined without first drying the aggregate, as permitted in Section 8.2, it shall be noted in the report.

11. PRECISION AND BIAS

11.1. The estimates of precision of this test method listed in Table 1 are based on results from the AASHTO Materials Reference Laboratory Reference Sample Program, with testing conducted by this test method and ASTM C 127. The significant difference between the methods is that ASTM C 127 requires a saturation period of 24 ± 4 hours, while T 85 requires a saturation period of 15 hours minimum. This difference has been found to have insignificant effect on the precision indices. The data are based on the analyses of more than 100 paired test results from 40 to 100 laboratories.

Table 1—Precision

	Standard Deviation (1s)[a]	Acceptable Range of Two Results (d2s)[a]
Single-operator precision:		
Bulk specific gravity (dry)	0.009	0.025
Bulk specific gravity (SSD)	0.007	0.020
Apparent specific gravity	0.007	0.020
Absorption,[b] percent	0.088	0.25
Multilaboratory precision:		
Bulk specific gravity (dry)	0.013	0.038
Bulk specific gravity (SSD)	0.011	0.032
Apparent specific gravity	0.011	0.032
Absorption,[b] percent	0.145	0.41

[a] These numbers represent, respectively, the (1s) and (d2s) limits as described in ASTM C 670. The precision estimates were obtained from the analysis of combined AASHTO Materials Reference Laboratory reference sample data from laboratories using 15-hour minimum saturation times and other laboratories using 24 ± 4-hour saturation time. Testing was performed on aggregates of normal specific gravities and started with aggregates in the oven-dry condition.

[b] Precision estimates are based on aggregates with absorptions of less than 2 percent.

11.2. *Bias*—Since there is no accepted reference material for determining the bias for the procedure in this test method, no statement on bias is being made.

APPENDIXES

(Nonmandatory Information)

X1. DEVELOPMENT OF EQUATIONS

X1.1. The derivation of the equation is apparent from the following simplified cases using two solids. Solid 1 has a mass W_1 in grams and a volume V_1 in milliliters; its specific gravity (G_1) is therefore W_1/V_1. Solid 2 has a mass W_2 and volume V_2, and $G_2 = W_2/V_2$. If the two solids are considered together, the specific gravity of the combination is the total mass in grams divided by the total volume in milliliters:

$$G = (W_1 + W_2)/(V_1 + V_2) \quad (X1.1)$$

Manipulation of this equation yields the following:

$$G = \frac{1}{\frac{V_1 + V_2}{W_1 + W_2}} = \frac{1}{\frac{V_1}{W_1 + W_2} + \frac{V_2}{W_1 + W_2}} \quad (X1.2)$$

$$G = \frac{1}{\frac{W_1}{W_1 + W_2}\left(\frac{V_1}{W_1}\right) + \frac{W_2}{W_1 + W_2}\left(\frac{V_2}{W_2}\right)} \quad (X1.3)$$

However, the mass fractions of the two solids are:

$$W_1/(W_1 + W_2) = P_1/100 \quad (X1.4)$$

and:

$$W_2/(W_1+W_2)=P_2/100 \qquad (X1.5)$$

and:

$$1/G_1=V_1/W_1 \text{ and } 1/G_2=V_2/W_2 \qquad (X1.6)$$

therefore:

$$G=1/[(P_1/100)(1/G_1)+(P_2/100)(1/G_2)] \qquad (X1.7)$$

An example of the computation is given in Table X1.1.

Table X1.1—Example Calculation of Average Values of Specific Gravity and Absorption for a Coarse Aggregate Tested in Separate Sizes

Size Fraction, mm (in.)	Percent in Original Sample	Bulk Specific Gravity (SSD)[a]	Sample Mass Used in Test, g	Absorption, percent
4.75 to 12.5 (No. 4 to $^1/_2$)	44	2.72	2213.0	0.4
12.5 to 37.5 ($^1/_2$ to $1^1/_2$)	35	2.56	5462.5	2.5
37.5 to 63 ($1^1/_2$ to $2^1/_2$)	21	2.54	12593.0	3.0

[a] Average Specific Gravity (SSD)

$$G_{SSD}=\frac{1}{\frac{0.44}{2.72}+\frac{0.35}{2.56}+\frac{0.21}{2.54}}=2.62 \qquad (X1.8)$$

Average Absorption:

$$A=(0.44)\ (0.4)+(0.35)\ (2.5)+(0.21)\ (3.0)=1.7\% \qquad (X1.9)$$

X2. INTERRELATIONSHIPS BETWEEN SPECIFIC GRAVITIES AND ABSORPTION AS DEFINED IN METHODS T 85 AND T 84

X2.1. *Let*:

S_d = bulk specific gravity (dry basis),
S_s = bulk specific gravity (SSD basis),
S_a = apparent specific gravity, and
A = absorption in percent.

Then:

$$S_s=(1+A/100)\,S_d \qquad (X2.1)$$

$$S_a=\frac{1}{\frac{1}{S_d}-\frac{A}{100}}=\frac{S_d}{1-\frac{AS_d}{100}} \qquad (X2.2)$$

$$S_d=\frac{1}{\frac{1+A/100}{S_s}-\frac{A}{100}} \qquad (X2.3)$$

$$= \frac{S_s}{1-\left[\frac{A}{100}(S_s-1)\right]}$$

$$A = \left(\frac{S_s}{S_d}-1\right)100 \qquad (X2.4)$$

$$A = \left(\frac{S_a - S_s}{S_a(S_s-1)}\right)100 \qquad (X2.5)$$

[1] This method is technically equivalent with ASTM C 127-04.

Standard Method of Test for

Resistance to Plastic Flow of Bituminous Mixtures Using Marshall Apparatus

AASHTO Designation: T 245-97 (2004)

1. SCOPE

1.1. This method covers the measurement of the resistance to plastic flow of cylindrical specimens of bituminous paving mixture loaded on the lateral surface by means of the Marshall apparatus. This method is for use with mixtures containing asphalt cement, asphalt cutback or tar, and aggregate up to 25.4-mm (1-in.) maximum size.

2. APPARATUS

2.1. *Specimen Mold Assembly*—Mold cylinders 101.6 mm (4 in.) in diameter by 76.2 mm (3 in.) in height, base plates, and extension collars shall conform to the details shown in Figure 1. Three mold cylinders are recommended.

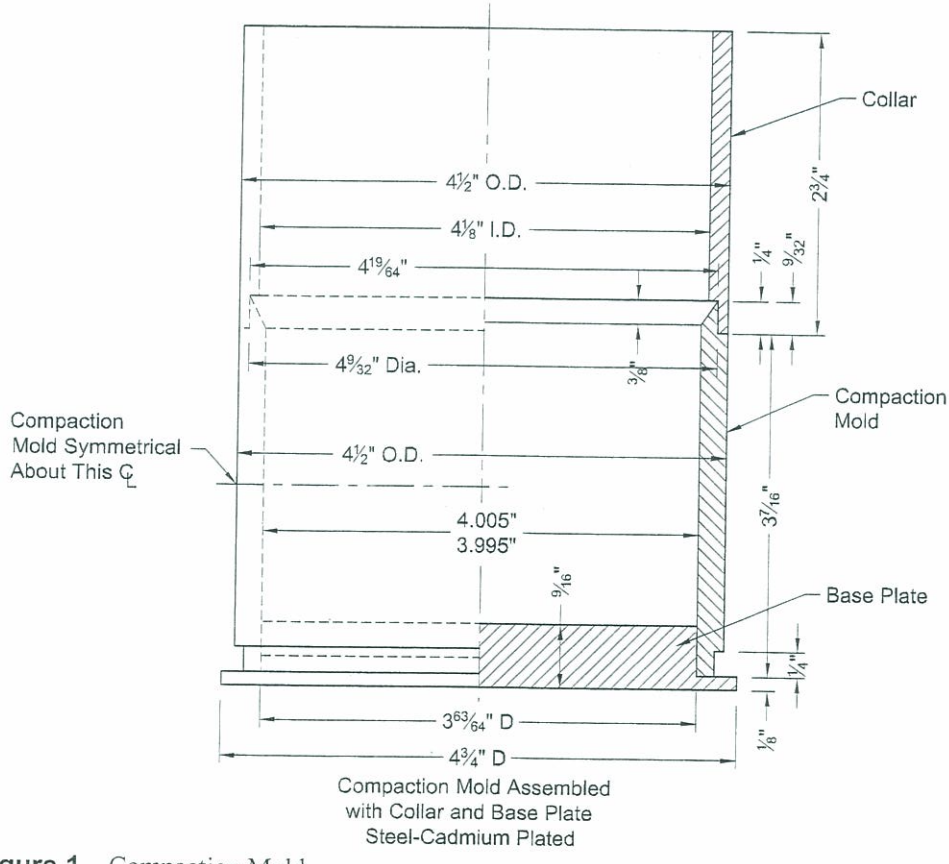


Figure 1—Compaction Mold

Table 1—Table of Equivalents for Figures 1 and 3

Metric Equivalents, mm	U.S. Customary Units, in.	Metric Equivalents, mm	U.S. Customary Units, in.	Metric Equivalents, mm	U.S. Customary Units, in.	Metric Equivalents, mm	U.S. Customary Units, in.
0.11	0.005	17.5	11/16	58.7	2 5/16	104.8	4 1/8
0.8	1/32	19.0	3/4	63.5	2 1/2	108.7	4 9/32
1.6	1/16	22.2	7/8	69.8	2 3/4	109.1	4 19/64
3.2	1/8	23.8	15/16	73.0	2 7/8	114.3	4 1/2
4.8	3/16	25.4	1	76.2	3	117.5	4 5/8
6.4	1/4	28.6	1 1/8	82.6	3 1/4	120.6	4 3/4
7.1	9/32	31.8	1 1/4	87.3	3 7/16	128.6	5 1/16
9.5	3/8	34.9	1 3/8	98.4	3 7/8	130.2	5 1/8
12.6	0.496	38.1	1 1/2	101.2	3 63/64	146.0	5 3/4
12.67	0.499	41.3	1 5/8	101.35	3.990	152.4	6
12.7	1/2	44.4	1 3/4	101.47	3.995	158.8	6 1/4
14.3	9/16	50.8	2	101.6	4	193.7	7 5/8
15.9	5/8	57.2	2 1/4	101.73	4.005	685.8	27

2.2. *Specimen Extractor*, steel, in the form of a disk with a diameter not less than 100 mm (3.95 in.) and 12.7 mm (1/2 in.) thick for extracting the compacted specimen from the specimen mold with the use of the mold collar. A suitable bar is required to transfer the load from the ring dynamometer adapter to the extension collar while extracting the specimen.

2.3. *Compaction Hammer*—The compaction hammer (Figure 2) shall have a flat, circular tamping face and a 4536 ± 9 g (10 ± 0.02 lb) sliding weight (including safety finger guard if so equipped) with a free fall of 457.2 ± 1.524 mm (18 ± 0.06 in.).

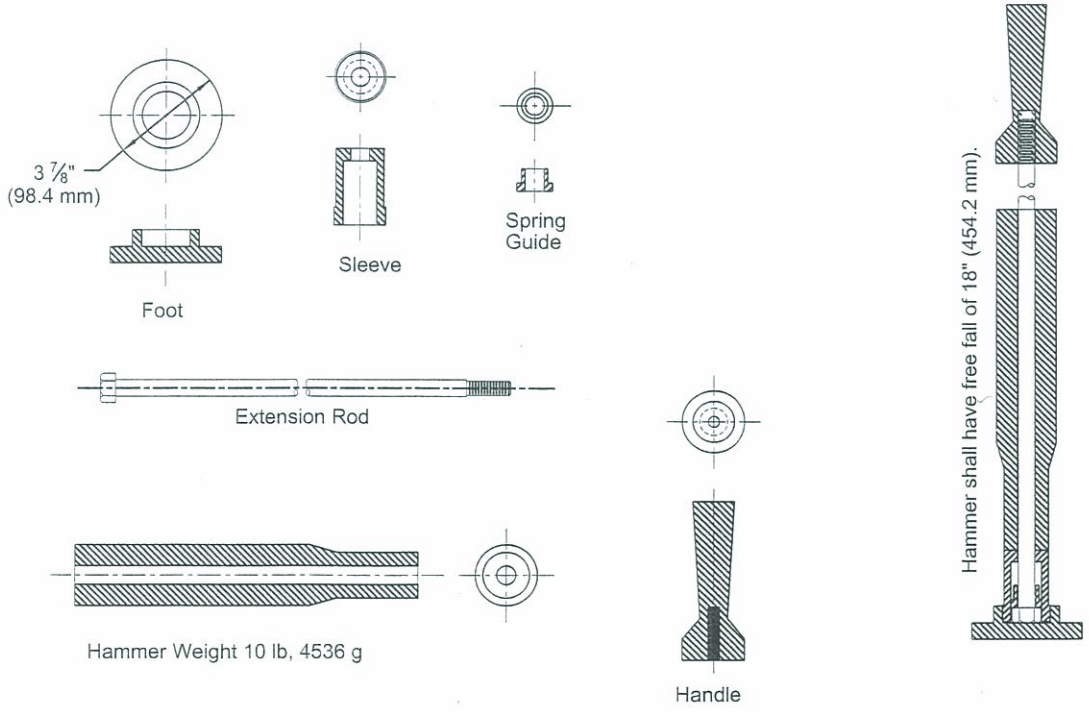


Figure 2—Compaction Hammer

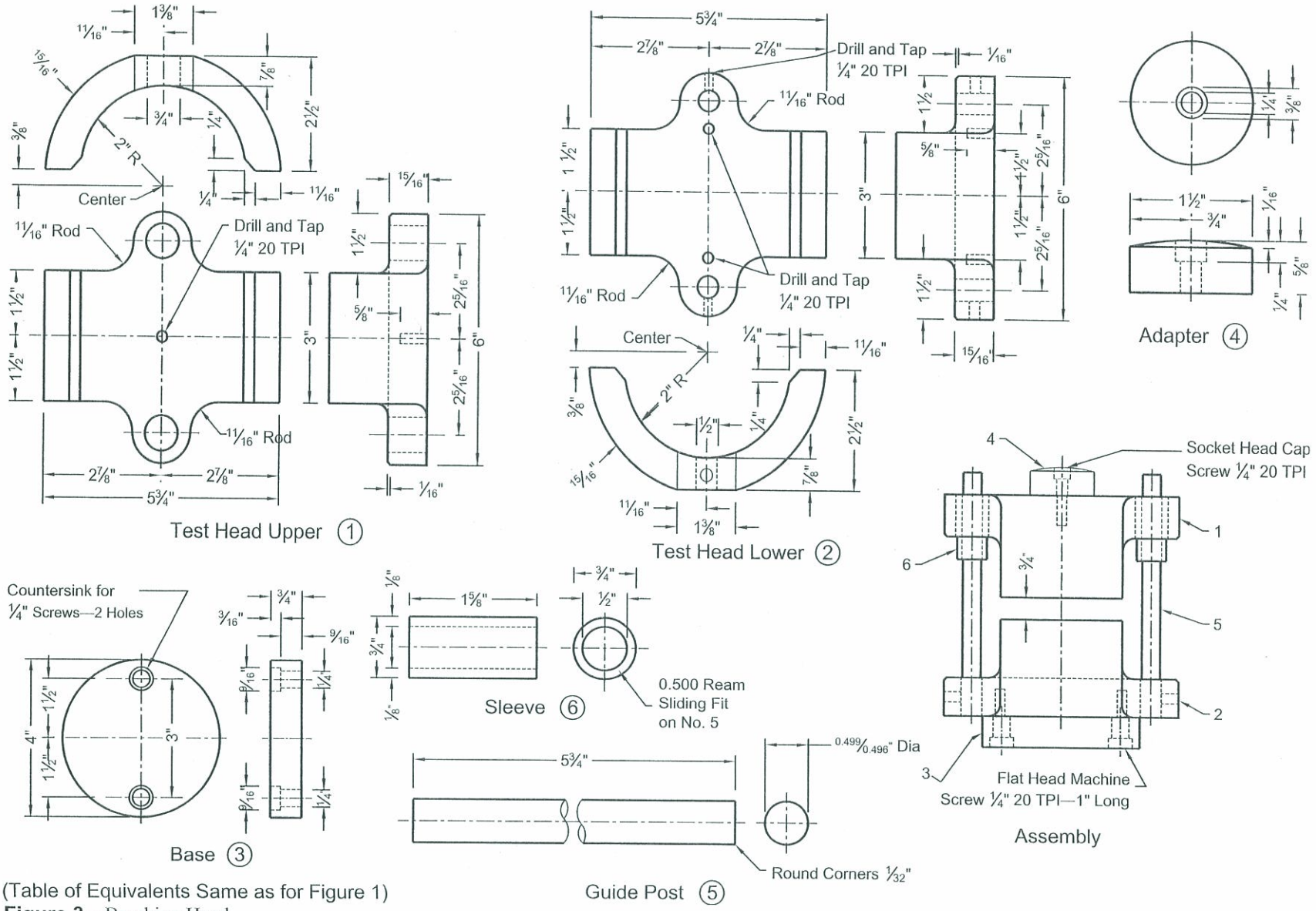
Note 1—The compaction hammer may be equipped with a finger safety guard as shown in Figure 2.

Note 2—Instead of a hand-operated hammer, and associated equipment described in Sections 2.3, 2.4, and 2.5, a mechanically operated hammer may be used provided it has been calibrated to give results comparable with the hand-operated hammer.

2.4. *Compaction Pedestal*—The compaction pedestal shall consist of a 203.2 by 203.2- by 457.2-mm (8- by 8- by 18-in.) wooden post capped with a 304.8- by 304.8- by 25.4-mm (12- by 12- by 1-in.) steel plate. The wooden post shall be oak, pine, or other wood having an average dry weight of 0.67 to 0.77 g/cm^3 (42 to 48 lb/ft^3). The wooden post shall be secured by four angle brackets to a solid concrete slab. The steel cap shall be firmly fastened to the post. The pedestal assembly shall be installed so that the post is plumb and the cap is level.

2.5. *Specimen Mold Holder*—mounted on the compaction pedestal so as to center the compaction mold over the center of the post. It shall hold the compaction mold, collar, and base plate securely in position during compaction of the specimen.

2.6. *Breaking Head*—(Figure 3) shall consist of upper and lower cylindrical segments or test heads having an inside radius of curvature of 50.8 mm (2 in.) accurately machined. The lower segment shall be mounted on a base having two perpendicular guide rods or posts extending upward. Guide sleeves in the upper segment shall be in such a position as to direct the two segments together without appreciable binding or loose motion on the guide rods.



(Table of Equivalents Same as for Figure 1)

Figure 3—Breaking Head

2.7. *Loading Jack*—The loading jack (Figure 4) shall consist of a screw jack mounted in a testing frame and shall produce a uniform vertical movement of 50.8 mm (2 in.)/min. An electric motor may be attached to the jacking mechanism.

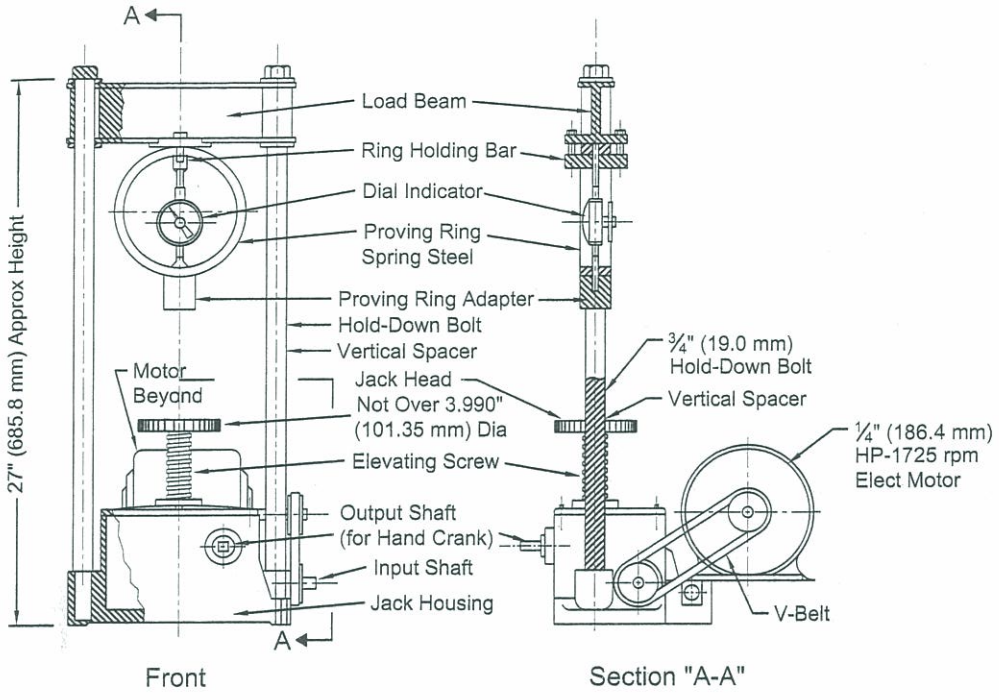


Figure 4—Compression Testing Machine

Note 3—Instead of the loading jack, a mechanical or hydraulic testing machine may be used provided the rate of movement can be maintained at 50.8 mm (2 in.)/min while the load is applied.

2.8. *Ring Dynamometer Assembly*—One-ring dynamometer (Figure 4) of 22.2 kN (5000 lbf) capacity and sensitivity of 44.5 N (10 lbf) up to 4.45 kN (1000 lbf) and 111.2N (25 lbf) between 4.45 and 22.2 kN (1000 and 5000 lbf) shall be equipped with a micrometer dial. The micrometer dial shall be graduated in 0.0025 mm (0.0001 in.). Upper and lower ring dynamometer attachments are required for fastening the ring dynamometer to the testing frame and transmitting the load to the breaking head.

Note 4—Instead of the ring dynamometer assembly, any suitable load-measuring device may be used provided the capacity and sensitivity meet the above requirements.

2.9. *Flowmeter*—The flowmeter shall consist of a guide sleeve and a gauge. The activating pin of the gauge shall slide inside the guide sleeve with a slight amount of frictional resistance. The guide sleeve shall slide freely over the guide rod of the breaking head. The flowmeter gauge shall be adjusted to zero when placed in position on the breaking head when each individual test specimen is inserted between the breaking head segments. Graduations of the flowmeter gauge shall be in 0.25-mm (0.01-in.) divisions.

Note 5—Instead of the flowmeter, a micrometer dial or stress-strain recorder graduated in 0.25 mm (0.01 in.) may be used to measure flow.

2.10. *Ovens or Hot Plates*—Ovens or hot plates shall be provided for heating aggregates, bituminous material, specimen molds, compaction hammers, and other equipment to the required mixing and molding temperatures. It is recommended that the heating units be thermostatically controlled so as to maintain the required temperature within 2.8°C (5°F). Suitable shields, baffle plates, or sand baths shall be used on the surfaces of the hot plates to minimize localized overheating.

2.11. *Heating Device*—A small hot plate with continuously variable heating rate, a sand bath, infrared lamp, or other suitable device shall be available for supplying sufficient heat under the mixing bowl to maintain the aggregate and bituminous material at the desired temperature during mixing. If a hot plate is used, a wire mesh or similar material shall be placed on the hot plate to prevent direct contact between the hot plate and mixing bowl.

2.12. *Mixing Apparatus*—Mechanical mixing is recommended. Any type of mechanical mixer may be used provided it can be maintained at the required mixing temperature and will produce a well-coated, homogeneous mixture of the required amount in the allowable time, and further provided that essentially all of the batch can be recovered. A metal pan or bowl of sufficient capacity and hand mixing may also be used.

2.13. *Water Bath*—The water bath shall be at least 152.4 mm (6 in.) deep and shall be thermostatically controlled so as to maintain the bath at 60 ± 1°C (140 ± 2°F) or 37.8 ± 1°C (100 ± 2°F). The tank shall have a perforated false bottom or be equipped with a shelf for supporting specimens 50.8 mm (2 in.) above the bottom of the bath.

2.14. *Air Bath*—The air bath for asphalt cutback mixtures shall be thermostatically controlled and shall maintain the air temperature at 25 ± 1°C (77° ± 2°F).

2.15. *Miscellaneous Equipment*:

2.15.1. *Containers for Heating Aggregates*— flat-bottom metal pans or other suitable containers.

2.15.2. *Containers for Heating Bituminous Material*—either gill-type tins, beakers, pouring pots, or saucepans may be used.

2.15.3. *Mixing Tool*—either a steel trowel (garden type) or spatula, for spading, and hand mixing.

2.15.4. *Thermometers*—for determining temperatures of aggregates, bitumen, and bituminous mixtures. Armored-glass, dial type, or digital thermometers with metal stems are recommended. A range from 9.9 to 204°C (50 to 400°F), with sensitivity of 2.8°C (5°F) is required.

2.15.5. Thermometers for water and air baths sensitive to 0.2°C (0.4°F) with a range sufficient to determine the specified bath temperature.

2.15.6. *Balance*—2-kg capacity, sensitive to 0.1 g, for weighing molded specimens.

2.15.7. *Balance*—5-kg capacity, sensitive to 1.0 g, for batching mixtures.

2.15.8. *Gloves*—for handling hot equipment.

2.15.9. *Rubber Gloves*—for removing specimens from water bath.

2.15.10. *Marking Crayons*—for identifying specimens.

2.15.11. *Scoop*—flat bottom, for batching aggregates.

2.15.12. *Spoon*—large, for placing the mixture in the specimen molds.

3. TEST SPECIMENS

3.1. *Number of Specimens*—Prepare at least three specimens for each combination of aggregates and bitumen content.

3.2. *Preparation of Aggregates*—Dry aggregates to constant mass at 105 to 110°C (221 to 230°F) and separate the aggregates by dry-sieving into the desired size fractions.[1] The following size fractions are recommended:

- 25.0 to 19.0 mm (1 to $^3/_4$ in.)
- 19.0 to 9.5 mm ($^3/_4$ to $^3/_8$ in.)
- 9.5 mm to 4.75 mm ($^3/_8$ in. to No. 4)
- 4.75 mm to 2.36 mm (No. 4 to No. 8)
- Passing 2.36 mm (No. 8)

3.3. *Determination of Mixing and Compacting Temperatures*:

3.3.1. The temperatures to which the asphalt cement and asphalt cutback must be heated to produce a viscosity of 170 ± 20 cSt shall be the mixing temperature.

3.3.2. The temperature to which asphalt cement must be heated to produce a viscosity of 280 ± 30 cSt shall be the compacting temperature.

3.3.3. From a composition chart for the asphalt cutback used, determine from its viscosity at 60°C (140°F) the percentage of solvent by mass. Also determine from the chart the viscosity at 60°C (140°F) of the asphalt cutback after it has lost 50 percent of its solvent. The temperature determined from the viscosity temperature chart to which the asphalt cutback must be heated to produce a viscosity of 280 ± 30 cSt after a loss of 50 percent of the original solvent content shall be the compacting temperature.

3.3.4. The temperature to which tar must be heated to produce Engler specific viscosities of 25 ± 3 and 40 ± 5 shall be, respectively, the mixing and compacting temperature.

3.4. *Preparation of Mixtures*:

3.4.1. An initial batch shall be mixed for the purpose of "buttering" the mixture bowl and stirrers. This batch shall be emptied after mixing and the sides of the bowl and stirrers shall be cleaned of mixture residue by scraping with a small limber spatula but shall not be wiped with cloth or washed clean with solvent, except when a change is to be made in the binder or at the end of a run.

3.4.2. Weigh into separate pans for each test specimen the amount of each size fraction required to produce a batch that will result in a compacted specimen 63.5 ± 1.27 mm (2.5 ± 0.05 in.) in height (about 1200 g). Mix the aggregate in each pan and place the pans on a hot plate or in the oven and heat to a temperature not exceeding the mixing temperature established in Section 3.3 by more than approximately 28°C (50°F) for asphalt cement and tar mixes at 14°C (25°F) for cutback asphalt mixes. Heat, to the established mixing temperature, just sufficient bituminous material for the batch in a separate container. Charge the mixing bowl with the heated aggregate. Form a crater in the dry-blended aggregate and weigh the preheated required amount of bituminous material into

the mixture. For mixes prepared with cutback asphalt, introduce the mixing blade in the mixing bowl and determine the total mass of the mix components plus bowl and blade before proceeding with mixing. Care must be exercised to prevent loss of the mix during mixing and subsequent handling. At this point, the temperature of the aggregate and bituminous material shall be within the limits of the mixing temperature established in Section 3.3. Mix the aggregate and bituminous material rapidly until thoroughly coated. To maintain proper mixing temperature, one of the methods described in Section 2.11 may be used.

3.4.3. Following mixing, cure asphalt cutback mixtures in a ventilated oven maintained at approximately 11.1°C (20°F) above the compaction temperature. Curing is to be continued in the mixing bowl until the precalculated weight of 50 percent solvent loss or more has been obtained. The mix may be stirred in a mixing bowl during curing to accelerate the solvent loss. However, care should be exercised to prevent loss of the mix. Weigh the mix during curing in successive intervals of 15 minutes initially and less than 10-minute intervals as the weight of the mix at 50 percent solvent loss is approached.

3.5. *Compaction of Specimens*:

3.5.1. Thoroughly clean the specimen mold assembly and the face of the compaction hammer and heat them either in boiling water, on the hot plate, or in an oven, to a temperature between 93.3 and 148.9°C (200 and 300°F). Place a piece of filter paper or paper toweling cut to size in the bottom of the mold before the mixture is introduced. Place the entire batch in the mold, spade the mixture vigorously with a heated spatula or trowel 15 times around the perimeter and 10 times over the interior. Remove the collar and smooth the surface of the mix with a trowel to a slightly rounded shape. Temperatures of the mixtures immediately prior to compaction shall be within the limits of the compacting temperature established in Section 3.3.

3.5.2. Replace the collar, then place a piece of filter paper or paper toweling cut to size on top of the mixture and place the mold assembly on the compaction pedestal in the mold holder, and unless otherwise specified, apply 50 or 75 blows with the compaction hammer with a free fall in 457.2 mm (18 in.). Hold the axis of the compaction hammer perpendicular to the base of the mold assembly during compaction. Remove the base plate and collar, and reverse and reassemble the mold. Apply the same number of compaction blows to the face of the reversed specimen. After compaction, remove the base plate and place the sample extractor on the end of the specimen. Place the assembly with the extension collar up in the testing machine, apply pressure to the collar by means of the load transfer bar, and force the specimen into the extension collar. Lift the collar from the specimen. Carefully transfer the specimen to a smooth, flat surface and allow it to stand overnight at room temperature. Weigh, measure, and test the specimen.

Note 6—In general, specimens shall be cooled as specified in Section 3.5.2. When more rapid cooling is desired, table fans may be used. Mixtures that lack sufficient cohesion to result in the required cylindrical shape on removal from the mold immediately after compaction may be cooled in the mold in air until sufficient cohesion has developed to result in the proper cylindrical shape.

4. PROCEDURE

4.1. Bring the specimens prepared with asphalt cement or tar to the specified temperature by immersing in the water bath 30 to 40 minutes or placing in the oven for two hours. Maintain the bath or oven temperature at 60 ± 1°C (140 ± 1.8°F) for the asphalt cement specimens and 37.8 ± 1°C (100 ± 1.8°F) for tar specimens. Bring the specimens prepared with asphalt cutback to the specified temperature by placing them in the air bath for a minimum of two hours. Maintain the air bath temperature at 25 ± 1°C (77 ± 1.8°F). Thoroughly clean the guide rods and the inside surfaces of the test heads prior to making the test, and lubricate the guide rods so that the upper test head slides freely over them. The testing-head temperature shall be maintained between 21.1 to 37.8°C

(70 to 100°F) using a water bath when required. Remove the specimen from the water bath, oven, or air bath, and place in the lower segment of the breaking head. Place the upper segment of the breaking head on the specimen, and place the complete assembly in position on the testing machine. Place the flowmeter, where used, in position over one of the guide rods and adjust the flowmeter to zero while holding the sleeve firmly against the upper segment of the breaking head. Hold the flowmeter sleeve firmly against the upper segment of the breaking head while the test load is being applied.

4.2. Apply the load to the specimen by means of the constant rate of movement of the loadjack or testing-machine head of 50.8 mm (2 in.) per minute until the maximum load is reached and the load decreases as indicated by the dial. Record the maximum load noted on the testing machine or converted from the maximum micrometer dial reading. Release the flowmeter sleeve or note the micrometer dial reading, where used, the instant the maximum load begins to decrease. Note and record the indicated flow value or equivalent units in twenty-five hundredths of a millimeter (hundredths of an inch) if a micrometer dial is used to measure the flow. The elapsed time for the test from removal of the test specimen from the water bath to the maximum load determination shall not exceed 30 seconds.

Note 7—For core specimens, correct the load when thickness is other than 63.5 mm ($2^1/_2$ in.) by using the proper multiplying factor from Table 2.

5. REPORT

5.1. *The report shall include the following information*:

5.1.1. Type of sample tested (laboratory sample or pavement core specimen);

Note 8—For core specimens, the height of each test specimen in millimeters (or inches) shall be reported.

5.1.2. Average maximum load in pounds-force (or newtons) of at least three specimens, corrected when required;

5.1.3. Average flow value, in hundredths of an inch, twenty-five hundredths of a millimeter, of three specimens; and

5.1.4. Test temperature.

Table 2—Stability Correlation Ratios[a,b]

Volume of Specimen, cm^3	Approximate Thickness of Specimen, in.	mm	Correlation Ratio
200 to 213	1	25.4	5.56
214 to 225	$1^1/_{16}$	27.0	5.00
226 to 237	$1^1/_8$	28.6	4.55
238 to 250	$1^3/_{16}$	30.2	4.17
251 to 264	$1^1/_4$	31.8	3.85
265 to 276	$1^5/_{16}$	33.3	3.57
277 to 289	$1^3/_8$	34.9	3.33
290 to 301	$1^7/_{16}$	36.5	3.03
302 to 316	$1^1/_2$	38.1	2.78
317 to 328	$1^9/_{16}$	39.7	2.50
329 to 340	$1^5/_8$	41.3	2.27
341 to 353	$1^{11}/_{16}$	42.9	2.08
354 to 367	$1^3/_4$	44.4	1.92
368 to 379	$1^{13}/_{16}$	46.0	1.79
380 to 392	$1^7/_8$	47.6	1.67
393 to 405	$1^{15}/_{16}$	49.2	1.56
406 to 420	2	50.8	1.47
421 to 431	$2^1/_{16}$	52.4	1.39
432 to 443	$2^1/_8$	54.0	1.32
444 to 456	$2^3/_{16}$	55.6	1.25
457 to 470	$2^1/_4$	57.2	1.19
471 to 482	$2^5/_{16}$	58.7	1.14
483 to 495	$2^3/_8$	60.3	1.09
496 to 508	$2^7/_{16}$	61.9	1.04
509 to 522	$2^1/_2$	63.5	1.00
523 to 535	$2^9/_{16}$	65.1	0.96
536 to 546	$2^5/_8$	66.7	0.93
547 to 559	$2^{11}/_{16}$	68.3	0.89
560 to 573	$2^3/_4$	69.9	0.86
574 to 585	$2^{13}/_{16}$	71.4	0.83
586 to 598	$2^7/_8$	73.0	0.81
599 to 610	$2^{15}/_{16}$	74.6	0.78
611 to 625	3	76.2	0.76

[a] The measured stability of a specimen multiplied by the ratio for the thickness of the specimen equals the corrected stability for a 63.5 mm ($2^1/_2$-in.) specimen.

[b] Volume-thickness relationship is based on a specimen diameter of 101.6 mm (4 in.).

[1] Detailed requirements for these sieves are given in M 92, Wire-Cloth Sieves for Testing Purposes.

Standard Method of Test for

Resistance to Degradation of Small-Size Coarse Aggregate by Abrasion and Impact in the Los Angeles Machine

AASHTO Designation: T 96-02 (2006)
ASTM Designation: C 131-01

AASHTO T 96-02 (2006) is identical to ASTM C 131-01 except for the following provisions:

1. All references to the ASTM standards contained in ASTM C 131-01, listed in the following table, shall be replaced with the corresponding AASHTO standard.

Referenced Standards	
ASTM	AASHTO
C 136	T 27
C 702	T 248
D 75	T 2
E 11	M 92

2. Add a new Section after Section 3.1 of ASTM C 131-01 as follows:

   3.2 DESCRIPTION OF TERMS

   Constant Mass—Test samples dried at a temperature of 110 ± 5°C (230 ± 9°F) to a condition such that it will not lose more than 0.1 percent moisture after an additional two hours of drying at 110 ± 5°C (230 ± 9°F). Such a condition of dryness can be verified by determining the mass of the sample before and after successive two hours of drying periods. In lieu of such a determination, samples may be considered to have reached constant mass when they have been dried at a temperature of 110 ± 5°C (230 ± 9°F) for an equal or longer period than that previously found adequate for producing the desired constant mass condition under equal or heavier loading conditions of the oven.

3. Add the phrase to the first sentence in Section 6.1 of ASTM C 131-01 as follows:

   ...machine "equipped with a counter and" conforming...

   Also replace the seventh sentence of this section as follows:

   "A removable steel shelf shall extend along the length of the cylinder to within 5 mm (0.2 in.) of the full inside length of the cylinder, project inward 89 ± 2 mm (3.5 ± 0.1 in.) and shall be mounted on the interior cylindrical surface of the cylinder, or on the inside surface of the cover, in such a way that a plane centered between the large faces coincides with an axial plane."

   Also the third from the last sentence of Section 6.1 of ASTM C 131-01 is not included in AASHTO T 96-02 (2006).

4. Changes to Figure 1 of ASTM C 131-01 are as follows:

   a. The phrase "NOT LESS THAN 1270 mm MEASURED ON OUTSIDE OF DRUM" is not included in AASHTO T 96-02 (2006).

b. The steel wall thickness shall be changed from "12.7 mm THICK" to "12.7 ± 3.2 mm ($^1/_2$ ± $^1/_8$″) THICK."

5. Add the following note after Note 2 in ASTM C 131-01:

"NOTE—Due to its mass, the location of the shelf relative to the opening influences the "at rest" position of the opening. The shelf location should be chosen to provide a convenient position of the opening to facilitate the loading of aggregate and spheres and to avoid impact of the charge on the cover."

6. Add the following new section after Section 6.3 of ASTM C 131-01:

"*Oven*—The oven shall be capable of maintaining a uniform temperature of 110 ± 5°C (230 ± 9°F)."

7. Replace Section 6.3 of ASTM C 131-01 with the following:

"*Balance*—The balance shall conform to AASHTO M 231, Class G 5."

Designation: C 131 – 01

Standard Test Method for Resistance to Degradation of Small-Size Coarse Aggregate by Abrasion and Impact in the Los Angeles Machine[1]

This standard is issued under the fixed designation C 131; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

This standard has been approved for use by agencies of the Department of Defense.

1. Scope *

1.1 This test method covers a procedure for testing sizes of coarse aggregate smaller than 37.5 mm (1½ in.) for resistance to degradation using the Los Angeles testing machine (Note 1).

NOTE 1—A procedure for testing coarse aggregate larger than 19.0 mm (¾ in.) is covered in Test Method C 535.

1.2 The values stated in SI units are to be regarded as the standard. The values given in parentheses are for information only.

1.3 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*

2. Referenced Documents

2.1 *ASTM Standards:*

C 125 Terminology Relating to Concrete and Concrete Aggregates[2]

C 136 Test Method for Sieve Analysis of Fine and Coarse Aggregates[2]

C 535 Test Method for Resistance to Degradation of Large-Size Coarse Aggregate by Abrasion and Impact in the Los Angeles Machine[2]

C 670 Practice for Preparing Precision and Bias Statements for Test Methods for Construction Materials[2]

C 702 Practice for Reducing Samples of Aggregate to Testing Size[2]

D 75 Practice for Sampling Aggregates[3]

E 11 Specification for Wire-Cloth and Sieves for Testing Purposes[4]

3. Terminology

3.1 *Definitions*—For definitions of terms used in this test method, refer to Terminology C 125.

4. Summary of Test Method

4.1 This test is a measure of degradation of mineral aggregates of standard gradings resulting from a combination of actions including abrasion or attrition, impact, and grinding in a rotating steel drum containing a specified number of steel spheres, the number depending upon the grading of the test sample. As the drum rotates, a shelf plate picks up the sample and the steel spheres, carrying them around until they are dropped to the opposite side of the drum, creating an impact-crushing effect. The contents then roll within the drum with an abrading and grinding action until the shelf plate picks up the sample and the steel spheres, and the cycle is repeated. After the prescribed number of revolutions, the contents are removed from the drum and the aggregate portion is sieved to measure the degradation as percent loss.

5. Significance and Use

5.1 This test has been widely used as an indicator of the relative quality or competence of various sources of aggregate having similar mineral compositions. The results do not automatically permit valid comparisons to be made between sources distinctly different in origin, composition, or structure. Assign specification limits with extreme care in consideration of available aggregate types and their performance history in specific end uses.

6. Apparatus

6.1 *Los Angeles Machine*—A Los Angeles machine, conforming in all essential characteristics to the design shown in Fig. 1, shall be used. The machine shall consist of a hollow steel cylinder, closed at both ends, conforming to the dimensions shown in Fig. 1, having an inside diameter of 711 ± 5 mm (28 ± 0.2 in.), and an inside length of 508 ± 5 mm (20 ± 0.2 in.). The cylinder shall be mounted on stub shafts attached to the ends of the cylinder but not entering it, and shall be mounted in such a manner that it may be rotated with the axis in a horizontal position within a tolerance in slope of 1 in 100. An opening in the cylinder shall be provided for the introduction of the test sample. A suitable, dust-tight cover shall be provided for the opening with means for bolting the cover in place. The cover shall be so designed as to maintain the cylindrical contour of the interior surface unless the shelf is so located that the charge will not fall on the cover, or come in

[1] This test method is under the jurisdiction of ASTM Committee C09 on Concrete and Concrete Aggregates and is the direct responsibility of Subcommittee C09.20 on Normal Weight Aggregates.

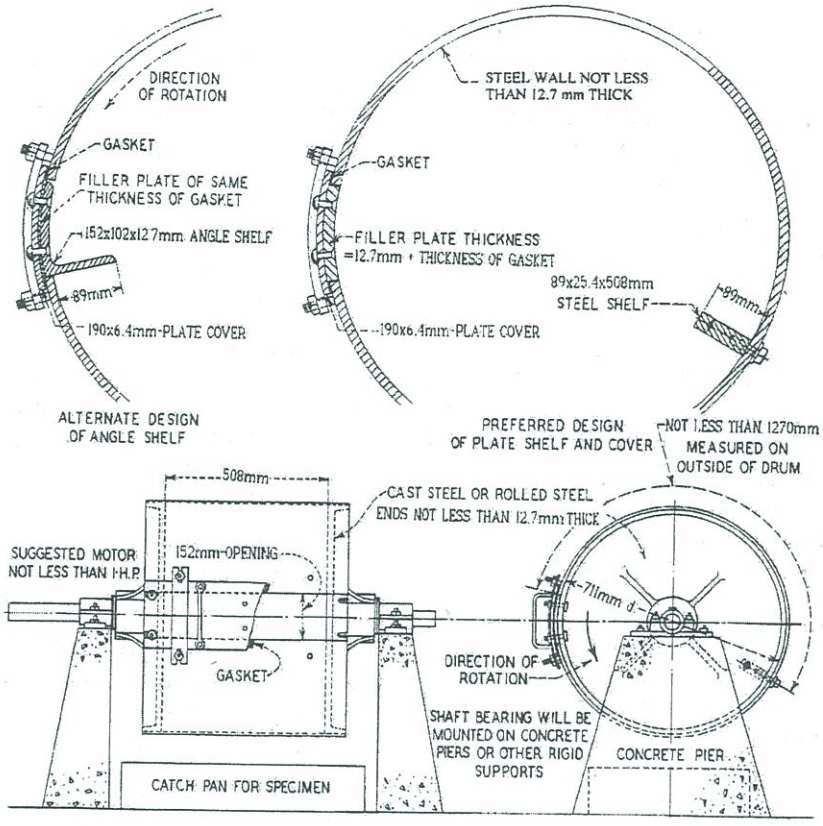
Current edition approved Aug. 10, 2001. Published October 2001. Originally published as C 131 – 37 T. Last previous edition C 131 – 96.

[2] *Annual Book of ASTM Standards*, Vol 04.02.

[3] *Annual Book of ASTM Standards*, Vol 04.03.

[4] *Annual Book of ASTM Standards*, Vol 14.02.

***A Summary of Changes section appears at the end of this standard.**



Inch Equivalents										
mm	6.4	12.7	25.4	89	102	152	190	508	711	1270
in.	¼	½	1	3½	4	6	7½	20	28	50

FIG. 1 Los Angeles Testing Machine

contact with it during the test. A removable steel shelf extending the full length of the cylinder and projecting inward 89 ± 2 mm (3.5 ± 0.1 in.) shall be mounted on the interior cylindrical surface of the cylinder, in such a way that a plane centered between the large faces coincides with an axial plane. The shelf shall be of such thickness and so mounted, by bolts or other suitable means, as to be firm and rigid. The position of the shelf (Note 2) shall be such that the sample and the steel spheres shall not impact on or near the opening and its cover, and that the distance from the shelf to the opening, measured along the outside circumference of the cylinder in the direction of rotation, shall be not less than 1270 mm (50 in.). Inspect the shelf periodically to determine that it is not bent either lengthwise or from its normal radial position with respect to the cylinder. If either condition is found, repair or replace the shelf before further tests are conducted.

NOTE 2—The use of a shelf of wear-resistant steel, rectangular in cross section and mounted independently of the cover, is preferred. However, a shelf consisting of a section of rolled angle, properly mounted on the inside of the cover plate, may be used provided the direction of rotation is such that the charge will be caught on the outside face of the angle.

6.1.1 The machine shall be so driven and so counterbalanced as to maintain a substantially uniform peripheral speed (Note 3). If an angle is used as the shelf, the direction of rotation shall be such that the charge is caught on the outside surface of the angle.

NOTE 3—Back-lash or slip in the driving mechanism is very likely to furnish test results which are not duplicated by other Los Angeles machines producing constant peripheral speed.

6.2 *Sieves*, conforming to Specification E 11.

6.3 *Balance*—A balance or scale accurate within 0.1 % of test load over the range required for this test.

6.4 *Charge*—The charge shall consist of steel spheres averaging approximately 46.8 mm (1 27/32 in.) in diameter and each having a mass of between 390 and 445 g.

6.4.1 The charge, (Note 4) depending upon the grading of the test sample as described in Section 8, shall be as follows:

Grading	Number of Spheres	Mass of Charge, g
A	12	5000 ± 25
B	11	4584 ± 25
C	8	3330 ± 20
D	6	2500 ± 15

NOTE 4—Steel ball bearings 46.0 mm (1 13/16 in.) and 47.6 mm (1⅞ in.) in diameter, having a mass of approximately 400 and 440 g each, respectively, are readily available. Steel spheres 46.8 mm (1 27/32 in.) in diameter having a mass of approximately 420 g may also be obtainable.

TABLE 1 Gradings of Test Samples

Sieve Size (Square Openings)		Mass of Indicated Sizes, g			
		Grading			
Passing	Retained on	A	B	C	D
37.5 mm (1½ in.)	25.0 mm (1 in.)	1 250 ± 25	...	...	...
25.0 mm (1 in.)	19.0 mm (¾ in.)	1 250 ± 25	...	...	...
19.0 mm (¾ in.)	12.5 mm (½ in.)	1 250 ± 10	2 500 ± 10	...	...
12.5 mm (½ in.)	9.5 mm (⅜ in.)	1 250 ± 10	2 500 ± 10	...	...
9.5 mm (⅜ in.)	6.3 mm (¼ in.)	...	...	2 500 ± 10	...
6.3 mm (¼ in.)	4.75-mm (No. 4)	...	...	2 500 ± 10	...
4.75-mm (No. 4)	2.36-mm (No. 8)	...	...	...	5 000 ± 10
Total		5 000 ± 10	5 000 ± 10	5 000 ± 10	5 000 ± 10

The charge may consist of a mixture of these sizes conforming to the mass tolerances of 6.4 and 6.4.1.

7. Sampling

7.1 Obtain the field sample in accordance with Practice D 75, and reduce the field sample to adequate sample size in accordance with Practice C 702.

8. Test Sample Preparation

8.1 Wash and oven dry the reduced sample at 110 ± 5°C (230 ± 9°F) to substantially constant mass (see 9.1.1), separate into individual size fractions, and recombine to the grading of Table 1 most nearly corresponding to the range of sizes in the aggregate as furnished for the work. Record the mass of the sample prior to test to the nearest 1 g.

9. Procedure

9.1 Place the test sample and the charge in the Los Angeles testing machine and rotate the machine at a speed of 30 to 33 r/min for 500 revolutions. (Note 5) After the prescribed number of revolutions, discharge the material from the machine and make a preliminary separation of the sample on a sieve coarser than the 1.70-mm (No. 12). Sieve the finer portion on a 1.70-mm sieve in a manner conforming to Test Method C 136. Wash the material coarser than the 1.70-mm sieve and oven-dry at 110 ± 5°C (230 ± 9°F) to substantially constant mass (see 9.1.1), and determine the mass to the nearest 1 g (Note 6).

9.1.1 If the aggregate is essentially free of adherent coatings and dust, the requirement for washing after test may be waived, but drying before the test is always required. However, in the case of referee testing, the washing procedure shall be performed.

NOTE 5—Valuable information concerning the uniformity of the sample under test may be obtained by determining the loss after 100 revolutions. This loss should be determined without washing the material coarser than the 1.70-mm sieve. The ratio of the loss after 100 revolutions to the loss after 500 revolutions should not greatly exceed 0.20 for material of uniform hardness. When this determination is made, take care to avoid losing any part of the sample; return the entire sample, including the dust of fracture, to the testing machine for the final 400 revolutions required to complete the test.

NOTE 6—Elimination of washing after test will seldom reduce the measured loss by more than about 0.2 % of the original sample mass.

10. Calculation

10.1 Calculate the loss (difference between the original mass and the final mass of the test sample) as a percentage of the original mass of the test sample. Report this value as the percent loss (Note 7).

NOTE 7—The percent loss determined by this test method has no known consistent relationship to the percent loss for the same material when tested by Test Method C 535.

11. Report

11.1 Report the following information:

11.1.1 Identification of the aggregate as to source, type, and nominal maximum size;

11.1.2 Grading designation from Table 1 used for the test; and

11.1.3 Loss by abrasion and impact of the sample expressed to the nearest 1 % by mass.

12. Precision and Bias

12.1 For nominal 19.0-mm (¾-in.) maximum size coarse aggregate with percent losses in the range of 10 to 45 %, the multilaboratory coefficient of variation has been found to be 4.5 %.[5] Therefore, results of two properly conducted tests from two different laboratories on samples of the same coarse aggregates should not differ from each other by more than 12.7 %[5] of their average. The single-operator coefficient of variation has been found to be 2.0 %.[5] Therefore, results of two properly conducted tests by the same operator on the same coarse aggregate should not differ from each other by more than 5.7 % of their average.[5]

12.2 *Bias*—Since there is no accepted reference material suitable for determining the bias for this procedure, no statement on bias is being made.

13. Keywords

13.1 abrasion; aggregate (coarse; small size); degradation; impact; Los Angeles machine

[5] These numbers represent, respectively, the (1S%) and (D2S%) limits as described in Practice C 670.

APPENDIX

(Nonmandatory Information)

X1. MAINTENANCE OF SHELF

X1.1 The shelf of the Los Angeles machine is subject to severe surface wear and impact. With use, the working surface of the shelf is peened by the balls and tends to develop a ridge of metal parallel to and about 32 mm (1¼ in.) from the junction of the shelf and the inner surface of the cylinder. If the shelf is made from a section of rolled angle, not only may this ridge develop but the shelf itself may be bent longitudinally or transversely from its proper position.

X1.2 The shelf should be inspected periodically to determine that it is not bent either lengthwise or from its normal radial position with respect to the cylinder. If either condition is found, the shelf should be repaired or replaced before further tests are made. The influence on the test result of the ridge developed by peening of the working face of the shelf is not known. However, for uniform test conditions, it is recommended that the ridge be ground off if its height exceeds 2 mm (0.1 in.).

SUMMARY OF CHANGES

This section identifies the location of changes to this test method that have been incorporated since the last issue.

(1) References to notes were updated.

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Standard Method of Test for

Emulsified Asphalts

AASHTO Designation: T 59-08

1. SCOPE

1.1 These test methods, given under the headings titled Composition, Consistency, Stability, and Examination of Residue, cover the examination of asphalt emulsions composed principally of a semisolid or liquid asphalt base, water, and an emulsifying agent. The methods cover the following tests:

Test	Section(s)
Composition:	
Water Content	4
Residue and Oil Distillate by Distillation	5
Identification of Oil Distillate by Micro Distillation	6
Residue by Evaporation	7
Particle Charge of Cationic Emulsified Asphalts	8
Consistency:	
Viscosity (Saybolt Furol)	9
Stability:	
Demulsibility	10
Settlement	11
Cement Mixing	12
Sieve Test	13
Coating	14
Miscibility with Water	15
Freezing	16
Coating Ability and Water Resistance	17
Storage Stability of Asphalt Emulsion	18
Examination of Residue	19 to26
Identification Test for Rapid Setting Cationic Emulsified Asphalt	27 to 35
Identification of Cationic Slow Set Emulsions	36 to 42
Field Coating Test on Emulsified Asphalts	43 to 48
Emulsified Asphalt/Job Aggregate Coating Test	49 to 55
Weight per Gallon of Emulsified Asphalt	56 to 62

1.2 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*

2. REFERENCED DOCUMENTS

2.1 *AASHTO Standards*:

- M 85, Portland Cement
- M 92, Wire-Cloth Sieves for Testing Purposes
- M 140, Emulsified Asphalt
- M 208, Cationic Emulsified Asphalt
- M 231, Weighing Devices Used in the Testing of Materials
- M 316, Polymer-Modified Cationic Emulsified Asphalt
- T 40, Sampling Bituminous Materials
- T 44, Solubility of Bituminous Materials
- T 49, Penetration of Bituminous Materials
- T 50, Float Test for Bituminous Materials
- T 51, Ductility of Bituminous Materials
- T 72, Saybolt Viscosity
- T 228, Specific Gravity of Semi-Solid Sections Bituminous Materials

2.2 *ASTM Standards*:

- C 190, Test Method for Tensile Strength of Hydraulic Cement Mortars
- C 778, Specification for Standard Sand
- D 6, Test Method for Loss on Heating of Oil and Asphaltic Compounds
- D 86, Test Method for Distillation of Petroleum Products
- D 128, Test Methods for Analysis of Lubricating Grease
- D 3289, Test Method for Specific Gravity or Density of Semi-Solid and Solid Bituminous Materials (Nickel Crucible Method)
- E 1, Specification for ASTM Liquid-In-Glass Thermometers
- E 145, Specification for Gravity-Convection and Forced-to Ventilation Ovens
- E 1045, Specification for Laboratory Glass Distillation Flasks

3. SAMPLE CONDITIONING FOR TESTING

3.1 All emulsions with viscosity requirements of 50°C (122°F) should be heated to 50 ± 3°C (122 ± 5°F)in the original sample container in a 71°C (160°F) water bath or oven. The container should be vented to relieve pressure. After the sample reaches 50 ± 3°C (122 ± 5°F), stir the sample to achieve homogeneity.

COMPOSITION

4. WATER CONTENT

4.1 *Scope*:

4.1.1 This test method covers the procedure for determining the water content of an emulsified asphalt by reflux distillation using a water trap.

4.2 *Significance and Use*:

4.2.1 This test method measures the amount of water present in the emulsified asphalt, as distinguished from either bitumen or petroleum solvent.

4.3 *Apparatus and Materials*:

4.3.1 *Metal Still*—The metal still (Figure 1(a)) shall be a vertical cylindrical vessel, preferably of copper, having a faced flange at the top to which the head is tightly attached by means of a clamp. The head shall be made of metal, preferably brass or copper, and shall be provided with a tubulation 25.4 mm (1 in.) in inside diameter.

4.3.2 *Glass Still*—The glass still (Figure 1(b)) shall be a short-neck, round-bottom flask, made of well-annealed glass, and having an approximate capacity of 500 mL.

4.3.3 *Heat Source*—The heat source used with the metal still shall be a ring gas burner of 100-mm (4-in.) inside diameter or an electric mantle heater. The heat source for the glass still shall be either an ordinary gas burner or an electric heater.

4.3.4 *Condenser*—The condenser shall be a water-cooled reflux glass-tube type, having a jacket not less than 400 mm (15 $^{3}/_{4}$ in.) in length, with an inner tube 9.5 to 12.7 mm ($^{3}/_{8}$ to $^{1}/_{2}$ in.) in outside diameter. The end of the condenser shall be ground to an angle of 30 ± 5° from the vertical axis of the condenser.

4.3.5 *Trap*—The trap shall be made of annealed glass constructed in accordance with Figure 1(c) and shall be graduated in 0.10-mL divisions from 0 to 2 mL, and in 0.20-mL divisions from 2 to 25 mL.

4.3.6 *Solvent*—Xylol or other petroleum distillate conforming to the following distillation requirements: 98 percent distills between 120 and 250°C (248 and 482°F). This distillation shall be conducted in accordance with ASTM D 86.

4.3.7 *Balance*—Conforming to the requirements of M 231, Class G 2.

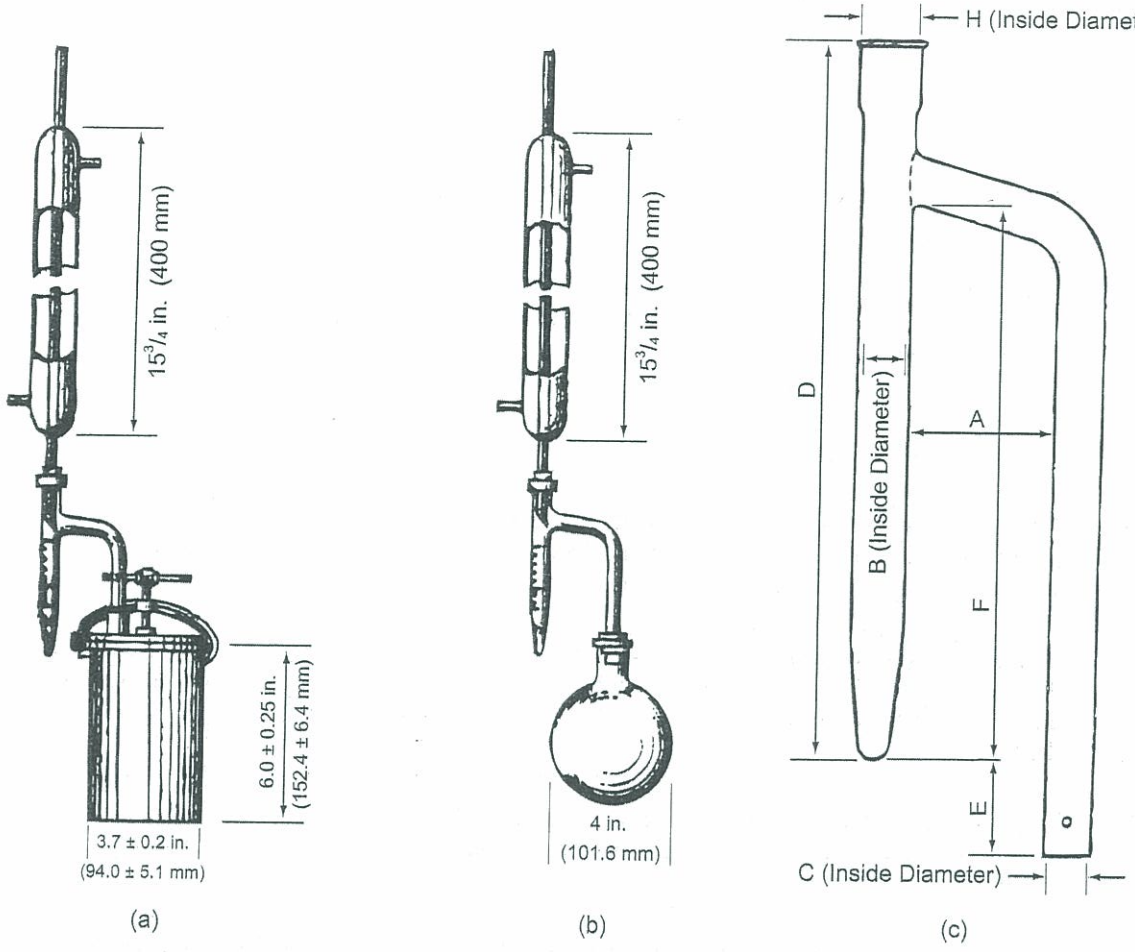
4.4 *Sample*:

4.4.1 Obtain a representative sample of the material for test using standard procedures as specified in T 40.

Note 1—The difficulties in obtaining representative samples for this determination are unusually great, so that the importance of sampling cannot be too strongly emphasized.

4.5 *Procedure*:

4.5.1 When the material to be tested contains less than 25 percent or less water, place 100 ± 0.1 g of the sample in the still. When the material contains more than 25 percent water, use a 50 ± 0.1-g sample. Thoroughly mix the sample to be tested with 200 mL of solvent by swirling, taking proper care to avoid any loss of material.



A = 45 to 55 mm (1.8 to 2.2 in.)
B = 14 to 16 mm (0.55 to 0.62 in.)
C = 12 to 16 mm (0.47 to 0.62 in.)
D = 235 to 255 mm (9.3 to 10.0 in.)
E = 25 to 38 mm (1.0 to 1.5 in.)
F = 186 to 194 mm (7.3 to 7.6 in.)
H = 18 to 19 mm (0.71 to 0.75 in.)

Figure 1—Apparatus for Determining Water Content

4.5.2 Connect the still, trap, and condenser by means of tight-fitting corks as shown in Figure 1(a) or 1(b). Adjust the end of the condenser in the trap to a position which will allow the end to be submerged to a depth of not more than 1 mm (0.04 in.) below the surface of the liquid in the trap after distillation conditions have been established. When using the metal still, insert a heavy paper gasket, moistened with the solvent, between the lid and flange before attaching the clamp. Insert a loose cotton plug in the top of the condenser tube to prevent condensation of atmospheric moisture.

4.5.3 When the ring burner is used with the metal still, place it about 76.2 mm (3 in.) above the bottom of the still at the beginning of the distillation, and gradually lower it as the distillation proceeds. Regulate the heat so that the condensate falls from the end of the condenser at a rate of from 2 to 5 drops per second. Continue the distillation at the specified rate until no water is visible on any part of the apparatus and a constant volume of water is obtained in the trap. Remove any persistent ring of condensed water in the condenser tube by increasing the rate of distillation for a few minutes.

4.6 *Calculation and Report*:

4.6.1 Calculate the water content as follows:

$$\text{Water Content, \%} = (A/B) \times 100 \qquad (1)$$

where:

A = volume of water in trap, mL, and

B = original weight of sample, g.

4.6.2 Report the result as ". . . water weight percent, T 59."

4.7 *Precision and Bias*:

4.7.1 The following criteria should be used for judging the acceptability of results (95 percent probability):

4.7.1.1 Duplicate results by the same operator should not be considered suspect unless they differ by more than the following amount:

Water Content, weight %	Repeatability, weight %
30 to 50	0.8

4.7.1.2 The results submitted by each of two laboratories should not be considered suspect unless they differ by more than the following amount:

Water Content, weight %	Reproducibility, weight %
30 to 50	2.0

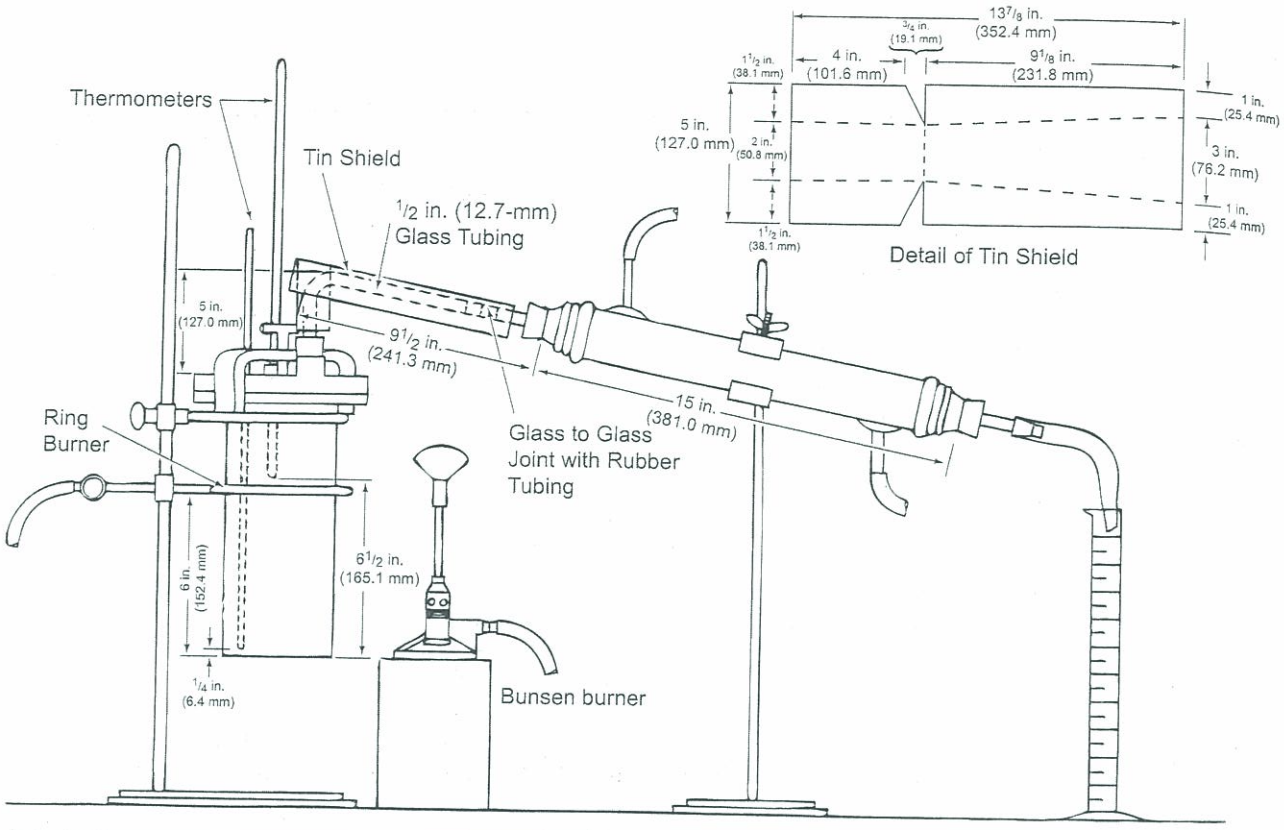
5. RESIDUE AND OIL DISTILLATE BY DISTILLATION

5.1 *Scope*:

5.1.1 This test method covers the quantitative determination of residue and oil distillate in asphalt emulsions composed principally of a semisolid or liquid asphalt base, water, and an emulsifying agent.

5.2 *Significance and Use*:

5.2.1 This test method can be used for quantitative determination of residue and oil distillate in asphalt emulsions for specification acceptance, service evaluation, control, and research. This method can also be used to obtain residue and oil distillate for further testing.



	Metric Equivalents														
in.	1/4	1/2	3/4	1	1 1/2	2	3	4	5	6	6 1/2	9 1/8	9 1/2	13 7/8	15
mm	6.4	12.7	19.1	25.4	38.1	50.8	76.2	101.6	127.0	152.4	165.1	231.8	241.3	352.4	381.0

Figure 4—Apparatus Assembly for Distillation Test of Emulsified Asphalts

5.4 *Procedure*:

5.4.1 Weigh 200 ± 0.1 g of a representative sample of the emulsion in the previously weighed aluminum-alloy still (including lid, clamp, thermometers and gasket, if gasket is used).

5.4.2 Use a gasket of oiled paper between the still and its cover, or grind the joint to a tight fit. Securely clamp the cover on the still.

5.4.3 Insert a thermometer through a cork, in each of the small holes provided in the cover. Adjust these thermometers so that the end of the bulb of one is 6.4 mm (1/4 in.) from the bottom of the still and the bulb of the other is approximately 165 mm (6 1/2 in.) from the bottom of the still.

5.4.4 Place the ring burner around the still about 150 mm (6 in.) from the bottom of the still. Apply heat by lighting this burner and adjusting to low flame. Also apply just enough heat from a bunsen burner to the connecting tube to prevent condensation of water in this tube.

5.4.5 Move the ring burner approximately level with the bottom when the temperature can be read on the lower thermometer, approximately 215°C (420°F). Increase the temperature to 260 ± 5°C (500 ± 10°F), maintaining it at this temperature for 15 min. Complete the total distillation in 60 ± 15 min from the first application of heat.

Note 4—The location of the burner at the start of the test is flexible. It may be raised to decrease chance of foam-over or lowered to middle of still for emulsion containing no solvent. A sudden change in temperature reading of upper thermometer indicates foam on bulb. Remove heat until foaming ceases. (The ring burner may be gradually lowered as the distillation proceeds to ensure that the time requirements of this standard are satisfied.)

5.4.6 Immediately at the expiration of the heating period, again weigh the still and accessories as described in Section 5.4.1. Calculate and report the percentage residue by distillation. Record the volume of oil distillate to the nearest $^1/_2$ mL. Calculate and report the oil distillate as a volume percentage on the total emulsion. Save this oil distillate if identification is desired.

Note 5—The aluminum-alloy still at room temperature (Section 4.6.1) weighs 1.5 g more than at 260°C (500°F). Correct for this error by adding 1.5 g to gross weight obtained in Section 5.4.6 prior to calculating the percentage of residue by distillation.

5.4.7 Remove the cover from the still, stir, and immediately pour suitable portions of the residue into an 236-mL (8-oz) tin or suitable molds and containers for making the required tests. Handle or condition molds and containers for desired examination of the residue as described in Sections 21 to 26, and proceed as required by the appropriate method from the points that follow the pouring stage. If there is foreign matter in the residue, the material shall be poured through a 300-µm (No. 50) sieve prior to pouring into the test molds and containers.

5.5 *Precision and Bias*:

5.5.1 The following criteria should be used for judging the acceptability of results (95 percent probability):

5.5.1.1 Duplicate results by the same operator should not be considered suspect unless they differ by more than the following amount:

Residue by Distillation, weight %	Repeatability, weight %
50 to70	1.0

5.5.1.2 The results submitted by each of two laboratories should not be considered suspect unless they differ by more than the following amount:

Residue by Distillation, weight %	Reproducibility, weight %
50 to70	2.0

5.5.2 The precision for penetration of residue from distillation by this method is the same as that shown in Section 18.7.1.

6. IDENTIFICATION OF OIL DISTILLATE BY MICRO-DISTILLATION

6.1.1 *Scope*:

6.1.1.1 This test method outlines the test procedure for redistillation of oil distillate obtained from previously distilled emulsified asphalt sample (Section 5).

6.1.2 *Significance and Use*:

6.1.2.1 The results of this test method identify and characterize the oil distillate recovered from the emulsified asphalt.

6.1.3 *Apparatus*:

6.1.3.1 Apparatus shall be in accordance with ASTM D 86, with the following exceptions:

6.1.3.1.1 *Flask*—10-mL.

6.1.3.1.2 *Graduated Cylinder*—10-mL, graduation interval $^{1}/_{10}$ mL.

6.1.3.1.3 *Condenser*—borosilicate glass, 100-mm jacket.

6.1.4 *Procedure*:

6.1.4.1 Redistill a 10-mL sample of the oil distillate under prescribed conditions of ASTM D 86, using Group 2 Test Conditions in Table 1 with the following exceptions:

Diameter of hole in flask support, (mm) in.	19 (0.75)
Temperature at start of test:	
Flask and thermometer	not above ambient
Graduate and 10-mL charge	not above ambient

6.1.5 *Calculation and Report*:

6.1.5.1 Calculation and report shall be in accordance with ASTM D 86, where applicable.

Note 6—Better identification of the solvent contained in the emulsion is possible if a larger condenser is used with ice water for the cooling medium during the distillation of the emulsion.

7. RESIDUE BY EVAPORATION

7.1 *Scope*:

7.1.1 This test method covers procedures for a relatively rapid determination of the percentage of emulsion residue.

7.2 *Significance and Use*:

7.2.1 The test may be used to indicate compositional characteristics of emulsified asphalt. Evaporation residue may also be subjected to other characterization tests outlined under the examination of residue sections. However, properties of the residue from evaporation procedure may differ from those of the distillation residue (see Note 8).

7.3 *Apparatus*:

7.3.1 *Beakers*—Low form, 1000-mL capacity, made of glass or metal, or a container of similar capacity.

7.3.2 *Glass Rods*—With flame-polished ends, 6.4 mm ($^{1}/_{4}$ in.) in diameter and 177.8 mm (7 in.) in length.

7.3.3 *Balance*—Capable of weighing 500 g to within ±0.1 g.

7.3.4 *Oven*—Conforming to ASTM E 145, Type lB.

7.3.5 *Sieve*—A 300-μm (No. 50) sieve conforming to M 92.

7.4 *Procedure A*:

7.4.1 Use procedure A when determination of the percentage of residue only is required.

7.4.2 Weigh 50 ± 0.1 g of thoroughly mixed, emulsified asphalt into each of three beakers, each beaker having previously been weighed with a glass rod. Place the beakers containing the rods and sample in the oven, the temperature of which has been adjusted to 163 ± 3°C (325 ± 5°F), for 2 h. At the end of this period remove each beaker and stir the residue thoroughly. Replace in the oven for 1 h, then remove the beakers from the oven, allow to cool to room temperature, and weigh with the rods.

Note 7—Care must be taken to prevent loss of asphalt from the beaker through foaming or spattering, or both. Also, the placing of beakers and emulsion samples in a cold or warm oven and bringing the oven and sample up to a temperature of 163°C (325°F) together is permissible. If preferred, preliminary evaporation of water may be accomplished by careful heating on a hot plate, followed by oven heating at 163°C (325°F) for 1 h.

7.5 *Calculation and Report*:

7.5.1 Calculate the percentage of residue on each beaker as follows:

$$\text{Residue, \%} = 2(A - B) \qquad (2)$$

where:

A = weight of beaker, rod, and residue, g; and

B = tare weight of beaker and rod, g.

7.5.2 Report the percentage of residue by evaporation as the average of the three results.

7.6 *Procedure B*:

7.6.1 Use procedure B when tests on the residue from the emulsion are required.

7.6.2 Proceed in accordance with Section 7.4.2 using four 50 ± 0. l-g samples. After the calculation for percentage of residue, replace the beakers in the oven until the asphalt residue is sufficiently fluid to pass through a 300-μm (No. 50) sieve (usually requiring 15 to 30 min). Pour the residue through the 300-μm (No. 50) sieve into suitable containers and molds for making such tests as desired, as described in Sections 21 to 26.

Note 8—As the method for residue by evaporation described in Section 7 tends to give an asphalt residue lower in penetration and ductility than the distillation method described in Section 5, material may be accepted but shall not be rejected as failing to meet specifications containing requirements for determination of residue by distillation on data obtained by evaporation. If residue from evaporation fails to meet the requirements for properties specified for residue from distillation, tests shall be rerun using the distillation method.

7.7 *Precision and Bias*:

7.7.1 The following criteria should be used for judging the acceptability of results (95 percent probability):

7.7.1.1 Duplicate results by the same operator should not be considered suspect unless they differ by more than the following amount:

Residue by Evaporation, weight %	Repeatability, weight %
50 to 70	0.4

7.7.1.2 The results submitted by each of two laboratories should not be considered suspect unless they differ by more than the following amount:

Residue by Evaporation, weight %	Reproducibility, weight %
50 to 70	0.8

8. PARTICLE CHARGE OF CATIONIC EMULSIFIED ASPHALTS

8.1 *Scope*:

8.1.1 This test method is used to identify cationic emulsions. Positively charged particles are classified as cationic.

8.2 *Significance and Use*:

8.2.1 Cationic emulsions are identified by the migration of the particles to a negatively charged electrode (cathode) by means of a direct current.

8.3 *Apparatus*:

8.3.1 *Current Source*—12-V DC, a milliameter, and a variable resistor (see Figures 5 and 6).

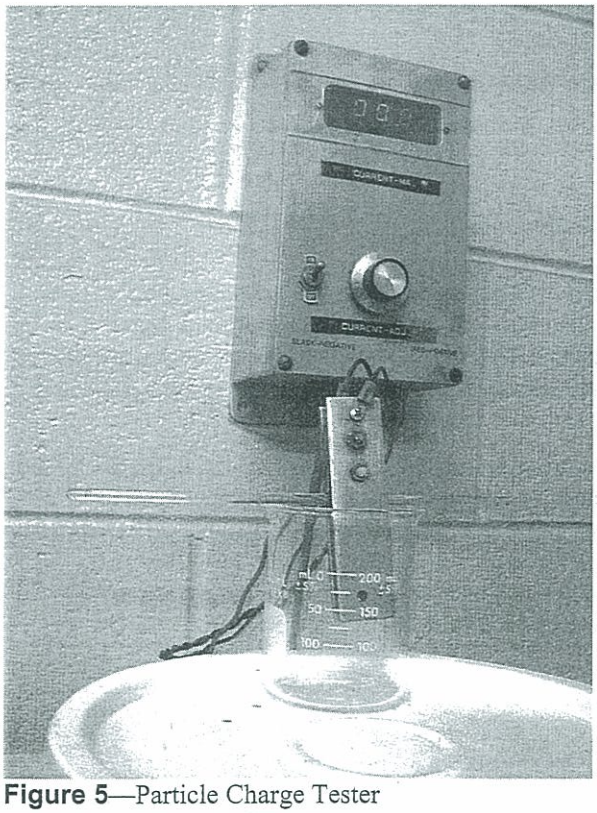
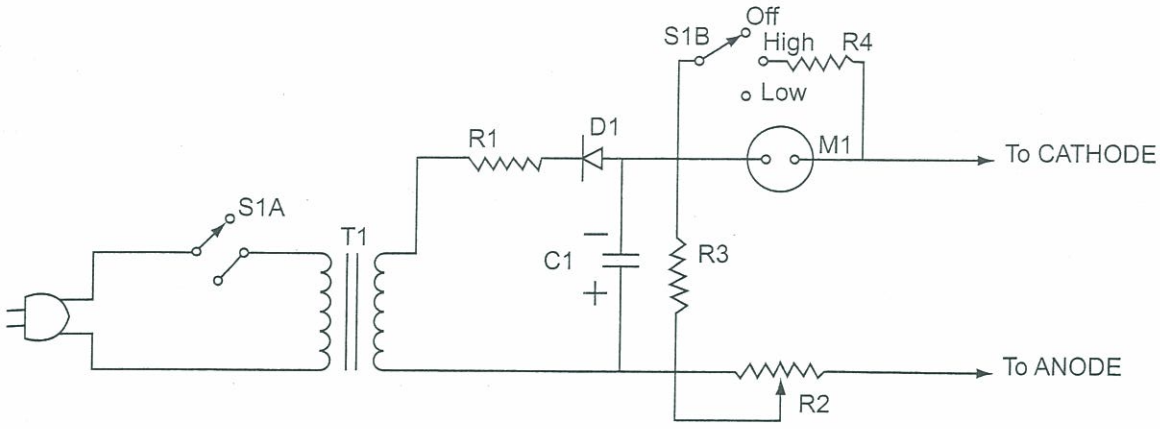


Figure 5—Particle Charge Tester



C1—500-μF 25-V capacitor
D1—silicon diode
M1—0 to 10-mA milliameter
R1—47 Ω, 1-W resistor
R2—5000 Ω potentiometer
R3—6800 Ω 1/4W resistor
R4—meter shunt (determined by type of meter used)
S1—2-pole, 3-position rotary switch
T1—12.6-V filament transformer

Figure 6—Particle Charge Tester Circuit Diagram

8.3.2 *Electrodes*—Two stainless steel plates, 25.4 mm by 101.6 mm (1 in. by 4 in.) insulated from each other and rigidly held parallel 12.7 mm ($^1/_2$ in.) apart (see Figure 7).

8.3.3 *Insulator*—Polytetraflouroethylene resin square rod, virgin electrical grade, 12.7 mm ($^1/_2$ in.) thick (see Figure 7). An insulator made from other suitable material may be used.

8.3.4 *Beaker*—250 mL.

8.3.5 Glass Rod—101.6 mm (4 in.) long and 6.35 mm ($^1/_4$ in.) thick or other suitable material or device that is capable of insulating and suspending the electrode assembly in the emulsion.

8.3.6 *Water Bath*—Capable of maintaining the required testing temperature within the limits specified in this test method.

8.4 *Thermometer*—ASTM No. 19C or 19F conforming to the requirements of ASTM E 1.

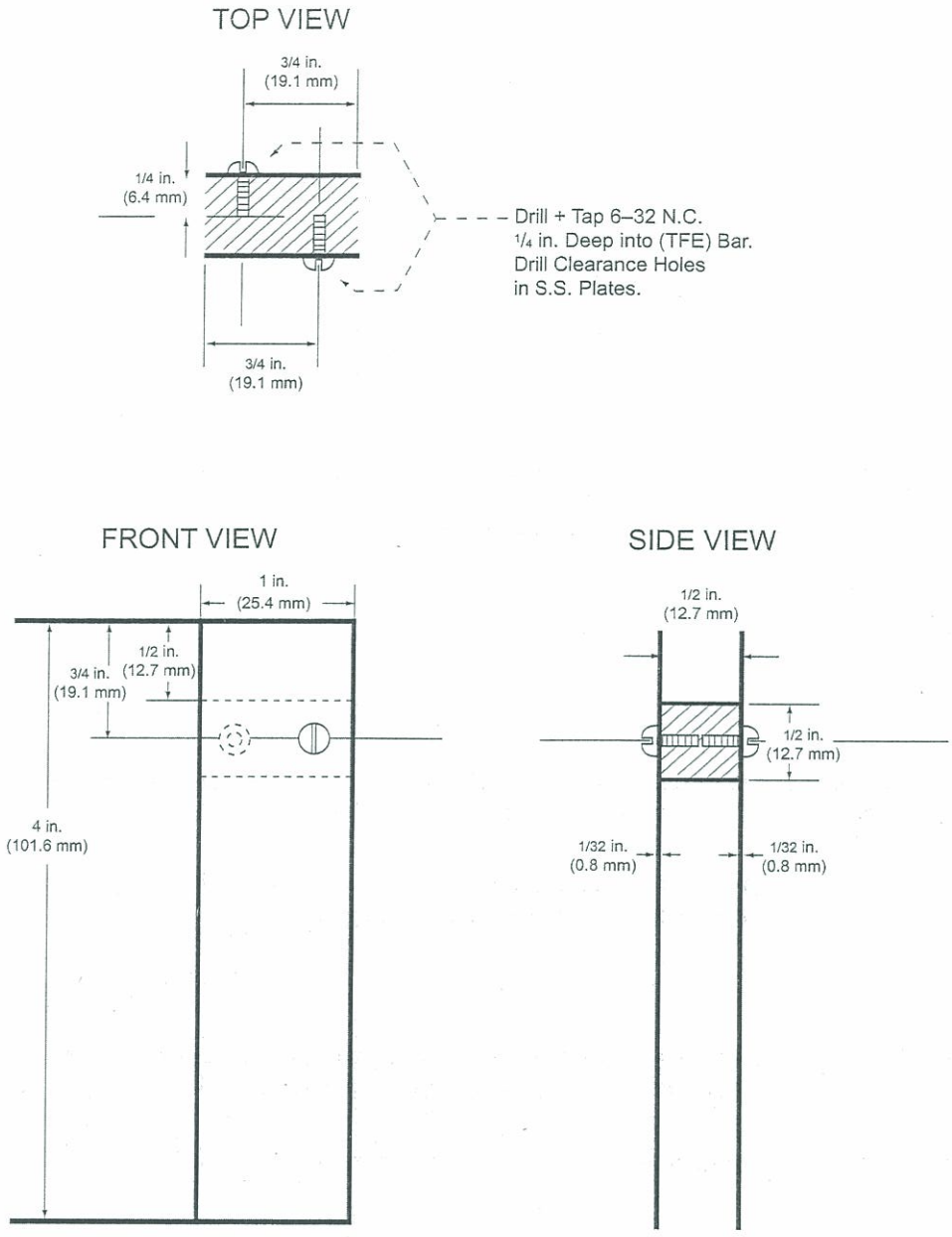


Figure 7—Insulator

8.5 *Procedure*:

8.5.1 Heat the emulsion to be tested to 50 ± 3°C (122 ± 5°F), in a 71 ± 3°C (160 ± 5°F) water bath. Stir the emulsion thoroughly to ensure uniformity of temperature.

8.5.2 Pour the emulsion to be tested into the 250-mL beaker to a height that will allow the electrodes to be suspended 25.4 mm (1 in.) in the emulsion. To facilitate suspension of the electrodes, insert the glass rod or equivalent between the two electrodes under the insulator. Place the ends of the glass rod or equivalent on the two opposite top edges of the beaker. An apparatus capable of manual height adjustment to insulate and suspend electrode assembly in emulsion may be used if desired.

8.5.3 Connect the electrodes, that have been properly cleaned (Note 9), to the DC source.

Note 9—New electrodes and electrodes to be re-used should be cleaned in the following sequence:

1. Wash with distilled water,
2. Wash with a suitable asphalt solvent,
3. Wash with isopropyl or ethyl alcohol, and
4. Wash with distilled water.

8.5.4 Adjust the current to at least 8 mA with the variable resistor and start timing with a suitable timing device. (The 8 mA current is a minimum current value. Higher current levels may be specified. The current used shall be reported.)

8.5.5 When the current drops to 2 mA or at the end of 30 min, whichever occurs first, disconnect the current source and gently wash the electrodes with a smooth, thin stream of distilled water.

8.5.6 Observe the asphalt deposit on the electrodes. A cationic emulsion will deposit a discernible amount of asphalt on the cathode (negative electrode) while the anode (positive electrode) will be relatively clean. Any evidence of a deposit of asphalt on the cathode which is clearly discernible when compared to the anode is to be considered passing.

8.6 *Report*:

8.6.1 Report the following information:

8.6.1.1 Level of current used, and

8.6.1.2 Whether the tested emulsion passes or fails as defined in Section 8.5.6.

8.7 *Precision and Bias*:

8.7.1 This test method, that requires subjective evaluation of test results and reporting of only two possible conditions, does not lend itself readily to a conventional statistical round-robin exercise. At present, there is no precision and bias statement for this test method.

CONSISTENCY

9. VISCOSITY

9.1 *Scope*:

9.1.1 This test method utilizes the Saybolt Furol viscometer to measure the consistency of an asphalt emulsion. It is applicable to all the emulsions specified in M 140, M 208 and M 316.

9.2 *Significance and Use*:

9.2.1 Viscosity has significance in the use of asphalt emulsions because it is a property which affects their utility. When used in application types of construction, the material must be thin enough to be uniformly applied through the spray bar of distributor, yet thick enough so that it will not flow

from the crown or grade of the road. For mixing grade emulsions, the viscosity may affect mixibility and resulting thickness of film on the aggregate. The viscosity of many emulsions is affected by shear. Therefore, strict adherence to test procedure is necessary to achieve precision.

9.3 *Apparatus*:

9.3.1 *Viscometer*—A Saybolt Furol viscometer conforming to the requirements specified in T 72.

9.3.2 *Sieve*—An 850-µm (No. 20) sieve or a 20-mesh strainer of wire cloth, framed or unframed.

9.3.3 *Thermometers*—ASTM No. 17C or 17F for tests at 25°C (77°F) and ASTM No. 19C or 19F for tests at 50°C (122°F), conforming to the requirements of ASTM E 1.

9.3.4 *Water Bath*—capable of maintaining the required testing temperature within the limits specified in Table 2 of T 72.

9.4 *Procedure*:

9.5 *Tests at 25°C (77°F)*—Stir the sample thoroughly without incorporating bubbles and pour it into a 118-mL (4-oz) bottle. Place the bottle in the water bath at 25°C (77°F) for 30 min and mix the sample in the bottle by inverting it several times slowly enough to prevent bubble formation. Pour the sample into the viscometer through the 850-µm (No. 20) sieve or 20-mesh strainer, allowing a small portion to flow through the outlet tube to waste. Place the cork in position, fill the viscometer and, without again stirring the sample, determine the viscosity as prescribed in T 72.

9.5.1 *Tests at 50°C (122°F)*—Clean and dry the viscometer and insert the cork. Heat the emulsion sample to 50 ± 3°C (122 ± 5°F) in a 71 ± 3°C (160 ± 5°F) water bath or oven. Stir the sample thoroughly without incorporating bubbles, and then pour approximately 100 mL into a 400-mL glass beaker. Immerse the bottom of the beaker containing the emulsion approximately 50.8 mm (2 in.) below the level of a 71 ± 3°C (160 ± 5°F) water bath. Hold the beaker upright and stir the emulsion with a wide circular motion at a rate of 60 r/min with the thermometer to obtain uniform temperature distribution. Avoid incorporation of bubbles. Heat the emulsion in the water bath to 51.4 ± 0.3°C (124.5 ± 0.5°F). Immediately pour the emulsion through the 850-µm (No. 20) sieve or 20-mesh strainer into the viscometer until it is above the overflow rim. Stir the emulsion in the viscometer at 60 r/min with the thermometer until the test temperature is attained, avoiding bubble formation. Adjust the bath temperature until the emulsion temperature remains constant for 1 min at 50 ± 0.05°C (122 ± 0.1°F). Withdraw the thermometer. Quickly remove the excess emulsion from the gallery with a suction pipet. Determine the viscosity as described in T 72. Report the results to the nearest 1 s.

Note 10—While the Saybolt Furol viscometer is not used for petroleum products and lubricants when the time of flow is less than 25 s, this instrument is satisfactory for testing emulsified asphalt when the time of flow is not less than 20 s.

9.6 *Precision and Bias*:

9.6.1 The following criteria should be used for judging the acceptability of results (95 percent probability):

9.6.1.1 Duplicate results by the same operator should not be considered suspect unless they differ by more than the following amount:

Test Temperature, °C (F)	Viscosity, s	Repeatability, % of the mean
25 (77)	20 to 100	5
50 (122)	75 to 400	9.6

9.6.1.2 The results submitted by each of two laboratories should not be considered suspect unless they differ by more than the following amount:

Test Temperature, °C (F)	Viscosity, s	Reproducibility, % of the mean
25 (77)	20 to 100	15
50 (122)	75 to 400	21

STABILITY

10. DEMULSIBILITY

10.1 *Scope*:

10.1.1 This test method, applicable to anionic and cationic emulsions of the RS and MS type, measures the chemical breaking of the emulsion.

10.2 *Significance and Use*:

10.2.1 This test method is used to identify or classify an emulsion as an RS or MS by measuring the amount of available asphalt that is broken from the emulsion by utilizing specified amounts and concentrations of calcium chloride solution for anionic emulsions and dioctyl sodium sulfosuccinate for cationic emulsions.

10.3 *Apparatus and Reagents*:

10.3.1 *Wire Cloth*—Three pieces of 1.40-mm (No. 14) wire cloth approximately 127.0 mm (5 in.) square, unframed, having wire diameters and openings that conform to M 92.

10.3.2 *Beakers*—Three metal beakers of 600-mL capacity each.

10.3.3 *Rods*—Three metal rods with rounded ends, approximately 8 mm ($^5/_{16}$ in.) in diameter.

10.3.4 *Buret*—A 50-mL glass buret graduated in 0.1-mL intervals.

10.3.5 *Calcium Chloride Solution (1.11 g/L)*—Dissolve 1.11 g of calcium chloride ($CaCL_2$) in water and dilute to 1 L. The 1.11 g/L calcium chloride solution shall be standardized to be a 0.02 ± 0.001 N solution of calcium chloride in water.

10.3.6 *Calcium Chloride Solution (5.55 g/L)*—Dissolve 5.55 g of CaCl, in water and dilute to 1 L. The 5.55 g/L calcium chloride solution shall be standardized to be a 0.1 N ± 0.001 normal solution of calcium chloride in water.

10.3.7 *Dioctyl Sodium Sulfosuccinate Solution (0.8 percent)*—Dissolve 8.00 g of dioctyl sodium sulfosuccinate in 992 g of water.

10.3.8 *Balance*—Capable of weighing 500 g to within ±0.1 g.

10.4 *Procedure*:

10.4.1 Determine the percentage of residue by distillation as described in Section 5.

10.4.2 Record the weight of each assembly of beaker, rod, and wire cloth.

10.4.3 Weigh 100 ± 0.1 g of the emulsified asphalt into each of three 600-mL beakers in the weighed assemblies. Bring the weighed sample of emulsion and the proper reagent to a temperature of 25 ± 0.5°C (77 ± 1.0°F). Over a period of approximately 2 min, add to each beaker, from a buret, 35 mL of $CaCl_2$ solution (1.11 g/L) (Note 15) for rapid setting emulsions, or 50 mL of $CaCl_2$ solution (5.55 g/L) for mixing-type emulsions. While adding the $CaCl_2$ solution, stir the contents of the beaker continuously and vigorously, kneading any lumps against the sides of the beaker to ensure thorough mixing of the reagent with the emulsion. Continue kneading any lumps for an additional 2 min after the addition of the $CaCl_2$ solution. Preliminary heating at lower temperatures to prevent spattering is permissible.

Note 11—When testing cationic emulsions, use 35 mL of dioctyl sodium sulfosuccinate solution (0.8 percent) instead of 35 mL of CaCl, solution (1.11 g/L).

10.4.4 Decant the mixture of any unbroken emulsion and reagent onto the wire cloth. Rinse the beaker containing the sample and metal rod with distilled water. Knead and break up all lumps, and continue washing the beaker, rod, and wire cloth until the wash water drains clear. Place the wire cloth enclosing the asphalt in the beaker with the metal rod. Place the assembly in a 163°C (325°F) drying oven and dry to constant weight.

10.5 *Calculation*:

10.5.1 Subtract the tare weight of the beaker, rod, and wire cloth from the weight of the dried assembly to obtain the demulsibility residue. Calculate the demulsibility as follows:

$$\text{Demulsibility, \%} = (A/B) \times 100 \qquad (3)$$

where:

A = average weight of demulsibility residue from the three tests of each sample of emulsified asphalt, and

B = weight of residue by distillation in 100 g of the emulsified asphalt.

10.6 *Precision and Bias*:

10.6.1 The following criteria should be used for judging the acceptability of results of tests on RS emulsions (95 percent probability):

Note 12—Precision does not apply when using dioctyl sodium sulfosuccinate solution in the testing of cationic emulsions for demulsibility.

10.6.1.1 Duplicate results by the same operator should not be considered suspect unless they differ by more than the following amount:

Demulsibility, weight %	Repeatability, % of the mean
30 to 100	5

10.6.1.2 The results submitted by each of two laboratories should not be considered suspect unless they differ by more than the following amount:

TS-2a

Demulsibility, weight %	Reproducibility, % of the mean
30 to 100	30

11. SETTLEMENT

11.1 *Scope*:

11.1.1 This test method measures the settlement of an emulsified asphalt that occurs in a cylindrical container.

11.2 *Significance and Use*:

11.2.1 This test method is a measure of the uniformity of an emulsified asphalt dispersion in storage over a period of time.

11.3 *Apparatus*:

11.3.1 *Cylinders*—Two 500-mL glass cylinders, with pressed or molded glass bases and cork or glass stoppers, having an outside diameter of 50 ± 5 mm (2 ± 0.2 in.). The cylinders should have 5-mL graduations. Cylinders with side arms may be used so that samples may be withdrawn without the use of pipettes.

11.3.2 *Glass Pipes*—A 60-mL siphon glass-tube pipet of optional form.

11.3.3 *Balance*—capable of weighing 500 g to within ±0.1 g.

11.3.4 *Beakers*—low form, 1000-mL capacity, made of glass or metal, or a container of similar capacity.

11.4 *Procedure*:

11.4.1 Place a 500-mL representative sample in each of the two glass cylinders. Stopper the cylinders and allow them to stand undisturbed at laboratory air temperature for 5 days. After standing for this period, remove approximately the top 55 mL of emulsion by means of a pipet or siphon without disturbing the balance. Mix each portion thoroughly. Weigh 50 g of each sample into separate weighed 1000-mL low-form glass beakers, and determine the asphalt residue by evaporation in accordance with Section 7.

11.4.2 After removal of the top sample, siphon off approximately the next 390 mL from each of the cylinders. Thoroughly mix the emulsion remaining in the cylinders and weigh 50 g into separate weighed 1000-mL low-form beakers. Determine the asphalt residue of these samples in accordance with Section 7.

Note 13—If the emulsion contains appreciable amounts of oil distillate as determined by distillation (see Section 5.4.6), the settlement value may be calculated from the difference in the percentage of water content between the top and bottom samples as determined by the procedure described in Section 4.5.

Note 14—If cylinders with side arms are used, siphoning is not required. Obtain a 55-mL sample from the upper arm. Drain off 390 mL from the lower arm.

11.5 *Calculation and Report*:

11.5.1 Calculate the settlement for each cylinder as follows:

$$\text{Settlement, \% (5 days)} = B - A \qquad (4)$$

where:

A = the percentage of residue from the top samples, and

B = the percentage of residue from the bottom samples.

Note 15—If the settlement values between the two cylinders differ by more than the stated repeatability, the result is considered suspect and the test shall be repeated. If for individual cylinders the percent residue of both the top and bottom samples is less than the percent residue of the emulsion, the result is considered suspect and the test shall be repeated. If for individual cylinders the percent residue of both the top and bottom samples is greater than the percent residue of the emulsion, the result is considered suspect and the test shall be repeated.

11.5.2 Report the settlement as the average of the two individual cylinder results.

11.6 *Precision and Bias*:

11.6.1 The following criteria should be used for judging the acceptability of results (95 percent probability):

11.6.1.1 Duplicate results by the same operator should not be considered suspect unless they differ by more than the following amount:

Settlement, weight %	Repeatability
0 to 1.0	0.4 weight %
Above 1.0	5 % of the mean

11.6.1.2 The results submitted by each of two laboratories should not be considered suspect unless they differ by more than the following amount:

Settlement, weight %	Reproducibility
0 to 1.0	0.8 weight %
Above 1.0	10 % of the mean

12. CEMENT MIXING

12.1 *Scope*:

12.1.1 This test method is a mixing test used to identify or classify a slow setting, SS or CSS, type of emulsion.

12.2 *Significance and Use*:

12.2.1 The result of this test indicates the ability of a slow setting emulsified asphalt to mix with a finely divided, high surface area material (high early strength, Type III, portland cement) without breaking the emulsion.

12.3 *Apparatus*:

12.3.1 *Sieves*—A 0.180-mm (No. 80) sieve and a 76.2-mm (3-in.) diameter 1.40-mm (No. 14) sieve, made of wire cloth conforming to M 92.

12.3.2 *Dish*—A round-bottom iron dish or a kitchen saucepan of approximately 500-mL capacity.

12.3.3 *Stirring Rod*—A steel rod with rounded ends, approximately 13 mm ($^1/_2$ in.) in diameter.

12.3.4 *Graduate*—A l00-mL graduated cylinder.

12.3.5 *Balance*—Conforming to the requirements of M 231, Class G 2.

12.3.6 *Oven*—As specified in Section 7.3.4.

12.4 *Cement*:

12.4.1 High-early-strength portland cement conforming to the requirements for Type III portland cement in M 85 and having a minimum specific surface area of 1900 cm^2/g (928 ft^2/lb) as measured by the Wagner Turbidimeter.

12.5 *Procedure*:

12.5.1 Dilute the emulsion with distilled water to a residue of 55 percent, as determined by distillation or by evaporation for 3 h at 163°C (325°F).

12.5.2 Sieve a portion of the cement through the 0.18-mm (No. 80) sieve. Weigh 50 ± 0.1 g of the cement passing the 180-μm (No. 80) sieve into the iron dish or saucepan.

12.5.3 Bring the ingredients and apparatus to a temperature of approximately 25°C (77°F) before mixing. Add 100 mL of the diluted emulsion to the cement and stir the mixture at once with the steel rod, using a circular motion at a rate of 60 r/pm. At the end of the 1-mm mixing period, add 150 mL of distilled water, and continue the stirring for 3 min.

12.5.4 Pour the mixture through a weighed 1.40-mm (No. 14) sieve. Use repeated washings to completely remove material from the mixing bowl. Pour these over the sieve, and rinse the sieve using distilled water held at a height of approximately 152.4 mm (6 in.) until the water is clear. Place the sieve in a weighed shallow pan, heat at 163°C (325°F) in an oven, and weigh. Repeat the heating and weighing until successive weights differ by no more than 0.1 g.

12.6 *Report*:

12.6.1 Report the weight, in grams, of the material retained on the sieve and in the pan as the percentage of break in the cement mixing test.

12.7 *Precision and Bias*:

12.7.1 The following criteria should be used for judging the acceptability of results (95 percent probability):

12.7.1.1 Duplicate results by the same operator should not be considered suspect unless they differ by more than the following amount:

Cement Mixing, weight %	Repeatability, weight %
0 to 2	0.2

12.7.1.2 The results submitted by each of two laboratories should not be considered suspect unless they differ by more than the following amount:

Cement Mixing, weight %	Reproducibility, weight %
0 to 2	0.4

13. SIEVE TEST

13.1 *Scope*:

13.1.1 This test method measures the degree to which an emulsified asphalt may contain particles of asphalt or other discreet solids retained on a 0.850 mm (No. 20) mesh sieve.

13.2 *Significance and Use*:

13.2.1 The retention of an excessive amount of particles on the sieve indicates that problems may occur in handling and application of the material. Particles of asphalt retained on the sieve often are caused by agglomeration of the dispersed phase. Storage, pumping, handling, and temperature can all contribute to the formation of particles. Contamination from the tank, transport, or hose are other factors affecting particle formation.

13.3 *Apparatus and Reagents*:

13.3.1 *Sieve*—A sieve having a 76.2-mm (3-in.) frame and an 850-µm (No. 20) wire sieve cloth conforming to M 92.

13.3.2 *Pan*—A tin box cover or shallow metal pan of appropriate size to fit over the bottom of the standard sieve.

13.3.3 *Sodium Oleate Solution (2 percent)*—Dissolve 2 g of pure sodium oleate in distilled water and dilute to 100 mL.

Note 16—Replace sodium oleate solution with distilled water in testing cationic emulsions.

13.3.4 *Balances*—Conforming to the requirements of M 231, Class G 5 for weighing the emulsion and M 231, Class G 2 for weighing the sieve and residue.

13.4 *Procedure*:

13.4.1 The temperature at which the sieve test should be performed is related to the emulsion viscosity. For those materials whose viscosity is 100 s or less at 25°C (77°F), perform the test at room temperature. For those materials whose viscosity is more than 100 s at 25°C (77°F) and those whose viscosity is specified at 50°C (122°F), use a test temperature of 50 ± 3°C (122 ± 5°F). If heating is necessary the emulsion, in a closed container, may be placed in an oven or water bath, followed by stirring to achieve homogeneity.

13.4.2 Record the weight of the sieve and pan and wet the wire cloth with the 2 percent sodium oleate solution. Weigh 1000 g of the emulsified asphalt into a suitable container and pour it through the sieve. Wash the container and the residue on the sieve with the sodium oleate solution until the washings run clear. Place the pan under the sieve and heat for 2 h in a 105°C (220°F) drying oven. Cool in a desiccator, and weigh the sieve, pan and residue.

13.5 *Calculation*:

13.5.1 Calculate the percentage of sample retained on the sieve as follows:

$$\text{Sample retained, \%} = (B - A)/10 \qquad (5)$$

where:

A = weight of sieve and pan, g; and

B = weight of sieve, pan, and residue, g.

13.6 *Precision*:

13.6.1 The following criteria should be used for judging the acceptability of results (95 percent probability):

13.6.1.1 Duplicate results by the same operator should not be considered suspect unless they differ by more than the following amount:

Sieve Test, weight %	Repeatability, weight %
0 to 0.1	0.03

13.6.1.2 The results submitted by each of two laboratories should not be considered suspect unless they differ by more than the following amount:

Sieve Test, weight %	Reproducibility, weight %
0 to 0.1	0.01

14. COATING TEST

14.1 *Scope*:

14.1.1 This test method is applicable to those emulsions intended for use by mixing with aggregate. It is not applicable to rapid-setting types or diluted materials used for tack coats, priming, or mulch treatments.

14.2 *Significance and Use*:

14.2.1 The intent of the coating test is to ensure that a given mixing grade emulsion is stable enough as an emulsion and otherwise possesses the ability to mix with a reference stone for the prescribed time and coat it uniformly and thoroughly.

14.3 *Apparatus and Material*:

14.3.1 *Sieves*—Standard 19.0-mm ($^3/_4$-in.) and 6.4-mm ($^1/_4$-in.) sieves conforming to M 92.

14.3.2 *Spatula*—A steel spatula or its equivalent, having a blade approximately 200 mm (8 in.) in length.

14.3.3 *Dish*—A round-bottom iron dish or a kitchen saucepan, of approximately 1-L (1-qt) capacity.

14.3.4 *Stone*—A supply of reference stone (hard limestone, trap rock, or other type) which has been washed with water and dried before using. All stone shall pass through the standard 19.0-mm ($^{1}/_{4}$-in.) screen and not more than 5 percent shall pass through the 6.4-mm ($^{1}/_{4}$-in.) screen.

Note 17—Each laboratory shall select its own reference stone supply, the source of which is not apt to change; this is to obviate rapid changes in the character of reference stone used in any one laboratory.

14.3.5 *Balance*—Conforming to the requirements of M 231, Class G 2.

14.4 *Procedure*:

14.4.1 Weigh 465 ± 0.1 g of stone into the metal pan. Add 35 ± 0.1 g of the emulsion to the stone in the pan, and mix vigorously with the spatula for 3 min.

14.4.2 Record whether or not there is appreciable separation of the asphalt base from the water in the emulsion, and whether or not the stone is uniformly and thoroughly coated with the emulsion.

15. MISCIBILITY WITH WATER

15.1 *Scope*:

15.1.1 This test may be applied to all medium and slow- setting asphalt emulsions. It is not applicable to the rapid- setting types.

15.2 *Significance and Use*:

15.2.1 It is sometimes desirable to dilute an emulsified asphalt in the field with water. This test is designed to ascertain if this may be done safely without breaking the emulsion.

15.3 *Procedure*:

15.3.1 Gradually add 150 mL of distilled water, with constant stirring, to 50 mL of the emulsion in a 400-mL glass beaker. The temperature should be between 21 and 25°C (70 and 77°F). Allow the mixture to stand for 2 h; then examine it for any appreciable coagulation of the asphalt content of the emulsion.

16. FREEZING TEST

16.1 *Scope*:

16.1.1 Emulsified asphalt is normally damaged by freezing temperatures, but specially formulated materials are expected to pass this test.

16.2 *Significance and Use*:

16.2.1 Certain agencies, who desire to use, store or transport emulsified asphalt under less than ideal weather conditions, may require that the product remain homogeneous (unbroken) after being subjected to temperatures of –17.8°C (0°F).

16.2.2 *Apparatus*:

16.2.3 *Container*—Metal container, 500-mL capacity, with a sealable lid.

16.2.4 *Freezer*—Capable of maintaining a temperature of –17.8 ± 0.5°C (0 ± 1°F).

16.3 *Procedure*:

16.3.1 Place approximately 400 g of the emulsion in a clean metal container, such as a 500-mL (1-pt) press-top can.

16.3.2 Expose the emulsion in the closed container to an air temperature of –17.8°C (0°F) for 12 (or more) consecutive hours.

16.3.3 At the expiration of the freezing period, permit the emulsion to thaw by exposure of the container to ambient temperature.

16.3.4 Repeat the freezing and thawing periods until the emulsion will have been subjected to three cycles of freezing and thawing.

16.3.5 After the third cycle, the emulsion may be homogeneous or may have separated into distinct layers which cannot be rendered homogeneous by stirring at laboratory temperature.

16.4 *Report*:

16.4.1 Report the result of this test as either "Homogeneous" or "Broken."

17. COATING ABILITY AND WATER RESISTANCE

17.1 *Scope*:

17.1.1 This test method is intended to aid in the identification of asphalt emulsions suitable for mixing with coarse graded calcareous aggregates. It can be applied to other aggregates. (See Note 18.)

17.2 *Significance and Use*:

17.2.1 This test method covers the determination of the ability of an asphalt emulsion to (1) coat an aggregate thoroughly, (2) withstand a mixing action while remaining as a film on the aggregate, and (3) resist the washing action of water after completion of the mixing.

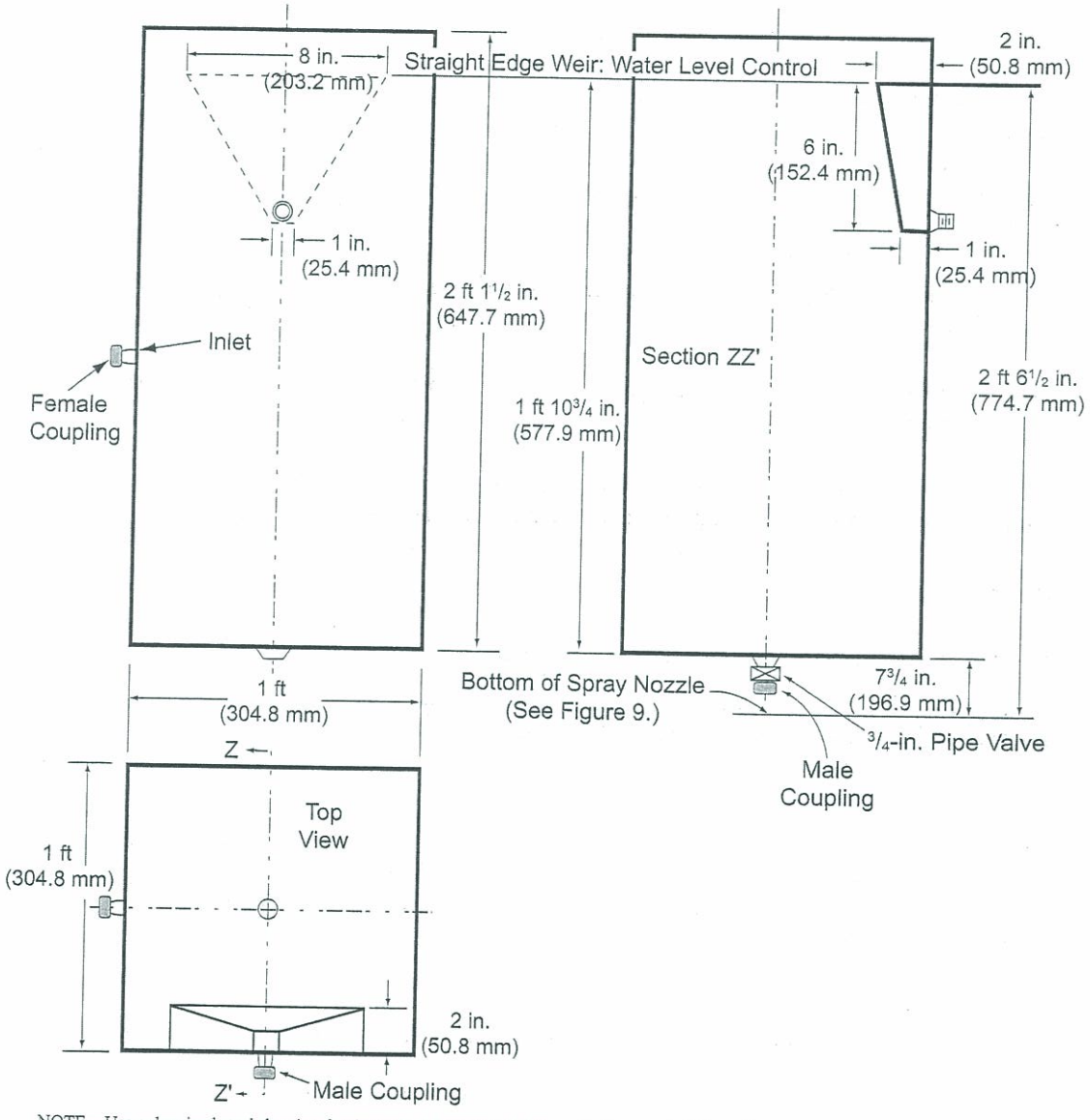
17.3 *Apparatus*:

17.3.1 *Mixing Pan*—A white-enameled kitchen saucepan with handle, of approximately 3-L (3-qt) capacity.

17.3.2 *Spatula*—A steel spatula or its equivalent, having a blade approximately 200 mm (8 in.) in length.

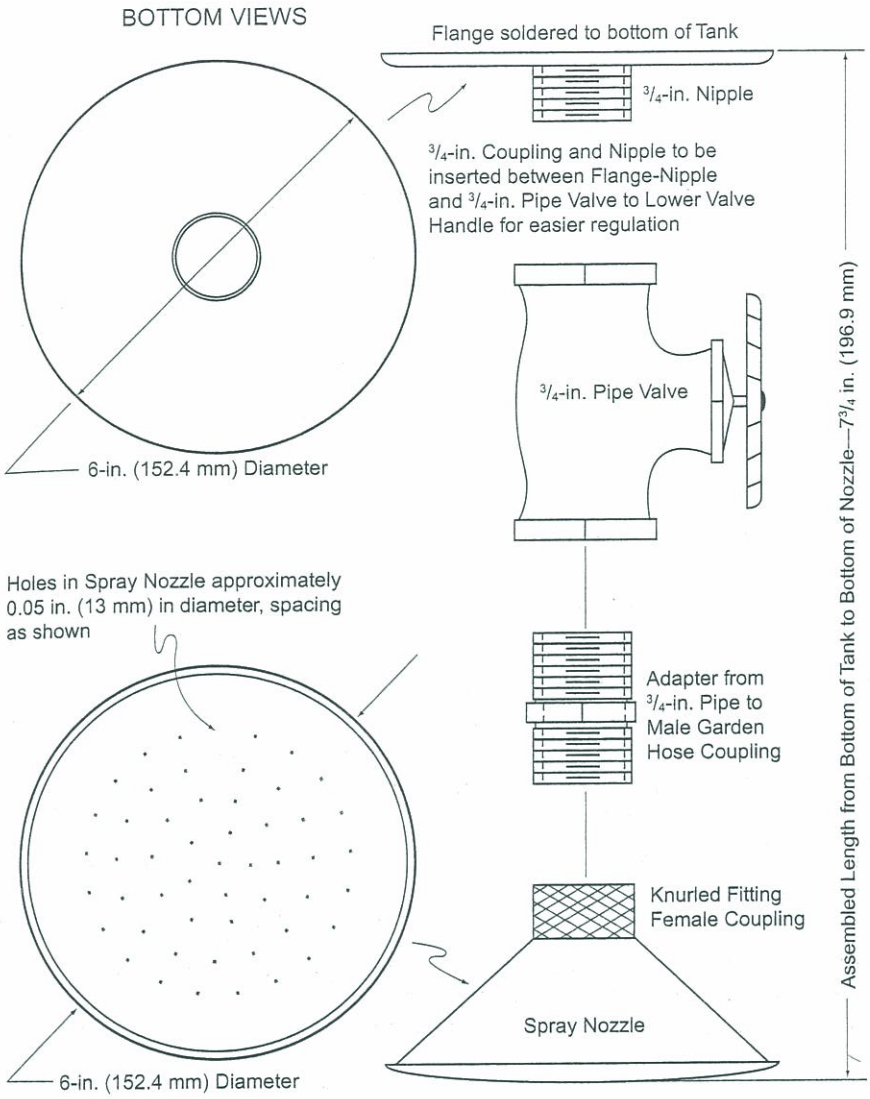
17.3.3 *Sieves*—Standard 19.0 mm ($^3/_4$ in.) and 4.75- mm (No. 4) sieves conforming to M 92.

17.3.4 *Constant-Head Water-Spraying Apparatus*—An apparatus for applying tap water in a spray under a constant head of 774.7 mm (2 ft, $6^1/_2$ in.) (Figures 8 and 9). The water shall issue from the apparatus in a low-velocity spray.



NOTE—Use galvanized steel sheeting for the tank. All joints and fitting attachments shall be soldered and shall be watertight. All couplings shall be standard brass garden hose fittings. The 19.0-mm ($^3/_4$-in.) pipe valve shall be placed as close as possible to the bottom of the tank, allowing space to shut off the valve. The tank shall be placed on a suitable stand, so that the distance from the bottom of the spray head to the top of the test sample is 919.4 ± 25.4 mm (3 ft ± 1 in.).

Figure 8—Constant-Head Flow Tank



NOTE 1—A Speakman, Model 235S, all brass, fixed shower head has been found acceptable.
NOTE 2—Existing 101.6-mm (4-in.) diameter shower heads may continue to be used.

Figure 9—Valve and Nozzle Assembly for Constant-Head Flow Tank

17.3.5 *Thermometer*—An ASTM Low Softening Point Thermometer 15C (or 15F), having a range from –2 to 80°C (or 30 to 180°F) and conforming to the requirements in ASTM E 1.

17.3.6 *Balance*—Conforming to the requirements of M 231, Class G 2.

17.3.7 *Pipet*—10-mL capacity.

17.4 *Materials*:

17.4.1 *Aggregate*—Standard reference aggregate shall be a laboratory-washed and air-dried limestone aggregate graded to pass the 19.0-mm (3/4-in.) sieve and be retained on the 4.75-mm (No. 4) sieve.[3]

Note 18—Aggregates other than limestone may be used provided calcium carbonate is omitted throughout the test method. Laboratory washing and air-drying of such aggregates shall also be omitted.

17.4.2 *Calcium Carbonate*—Chemically pure, precipitated calcium carbonate ($CaCO_3$) shall be used as a dust to be mixed with the standard reference aggregate.

17.4.3 *Water*—Tap water of not over 250 ppm $CaCO_3$ hardness for spraying over the sample.

17.4.4 Absorbent Paper.

17.5 *Sample*:

17.5.1 The sample shall be representative of the asphalt emulsion to be tested.

17.6 *Procedure for Tests with Dry Aggregate*:

17.6.1 Carry out the test at 23.9 ± 5.5°C (75 ± 10°F).

17.6.2 Weigh 461 g of the air-dried, graded reference aggregate in the mixing pan.

17.6.3 Weigh 4.0 g of $CaCO_3$ dust in the mixing pan and mix with the 461 g of aggregate for approximately 1 min by means of a mixing blade to obtain a uniform film of dust on the aggregate particles.

Note 19—The total weight of aggregate and dust shall equal 465 g. If no calcium carbonate is included, the weight of aggregate alone shall be 465 g.

17.6.4 Weigh 35 g of the asphalt emulsion into the aggregate in the pan and mix vigorously with the mixing blade for 5 min using a tossing action created by a back-and-forth motion in an elliptical path of the mixing blade or spoon. At the end of the mixing period, tilt the pan and permit any excess emulsion not on the aggregate to drain from the pan.

17.6.5 Remove approximately one half of the mixture from the pan and place it on absorbent paper and evaluate the coating.

17.6.6 Immediately spray the mixture remaining in the pan with tap water from the constant-head water spraying apparatus to cover the mixture. The distance from the sprayhead to the sample shall be 305 ± 75 mm (12 ± 3 in.). Then carefully pour off the water. Continue spraying and pouring off the water until the overflow water runs clear. Carefully drain off the water in the pan. Scoop the mixture from the mixing pan on to absorbent paper for evaluation of coating retention in the washing test.

17.6.7 Evaluate the mixture immediately by visual estimation as to the total aggregate surface area that is coated with asphalt.

17.6.8 Repeat the evaluation by visual estimation of the coating of aggregate surface area by asphalt after the mixture has been surface air-dried in the laboratory at room temperature. A fan may be used for drying if desired.

17.7 *Procedure for Tests with Wet Aggregate*:

17.7.1 Proceed in accordance with Section 17.6.

17.7.2 Pipet 9.3 mL of water to the aggregate and $CaCO_3$ dust mixture into the mixing pan and mix thoroughly to obtain uniform wetting.

17.7.3 Continue in accordance with Section 17.6.

17.8 *Interpretation of Results*:

17.8.1 Evaluate and report the following information for tests with both dry and wet aggregate:

17.8.1.1 At the end of the mixing period, record the coating of the total aggregate surface area by the asphalt emulsion as good, fair, or poor, where a rating of "good" means fully coated by the asphalt emulsion exclusive of pinholes and sharp edges of the aggregate, a rating of "fair" coating applies to the condition of an excess of coated area over uncoated area, and a rating of "poor" applies to the condition of an excess of uncoated area over coated area.

17.8.1.2 After spraying with water, record the coating of the total aggregate surface area by the asphalt as good, fair, or poor.

17.8.1.3 After air-drying in the laboratory, record the coating of the total aggregate surface area by the asphalt as good, fair, or poor.

17.8.1.4 Comments about the results of the test may be included in the evaluation.

18. STORAGE STABILITY OF ASPHALT EMULSION

18.1 *Scope*:

18.1.1 This test method relates to the ability of an asphalt emulsion to remain as a uniform dispersion during storage. It is applicable to asphalt emulsions composed principally of a semisolid or liquid asphalt base, water, and an emulsifying agent.

18.2 *Summary of Test Method*:

18.2.1 This test method determines the difference in percent residue of samples taken from the top and bottom of material placed in undisturbed simulated storage for 24 h. The result is expressed as the average of the two individual values obtained by determining the difference between the percent residue of the top and bottom samples for each storage cylinder.

18.3 *Significance and Use*:

18.3.1 This test method is useful for determining in a comparatively short time the storage stability of an asphalt emulsion. It is a measure of the permanence of the dispersion as related to time, but it is not to be construed to have significance as a measure of other stability aspects involved in use.

18.4 *Apparatus*:

18.4.1 *Cylinders*—Two 500-mL glass cylinders, with pressed or molded glass bases and cork or glass stoppers, having an outside diameter of 50 ± 5 mm (2 ± 0.2 in.), and having 5-mL graduations.

Note 20—Cylinders with side arms may be used so that samples may be withdrawn without the use of pipettes.

18.4.2 *Glass Pipet*—A 60-mL siphon glass-tube pipet of optional form.

18.4.3 *Balance*—Conforming to the requirements of M 231, Class G 2.

18.4.4 *Beakers*—Low form, 1000-mL capacity, made of glass or metal, or a container of similar capacity.

18.4.5 *Oven*—Conforming to ASTM E 145, Type lB.

18.5 *Procedure*:

18.5.1 Bring the asphalt emulsion to room temperature, 21 to 27°C (70 to 80°F). Place a 500-mL representative sample in each of the two glass cylinders. Stopper the cylinders and allow them to stand undisturbed, at laboratory air temperature 21 to 27°C (70 to 80°F), for 24 h. After standing for this period, remove approximately 55 mL from the top of the emulsion by means of the pipet or siphon without disturbing the balance. Thoroughly mix each portion.

Note 21—If cylinders with side arms are used, siphoning is not required. Obtain a 55-mL sample from the upper arm. Drain off 390 mL from the lower arm.

18.5.2 Weigh 50 ± 0.1 g of each sample into separately weighed 1000-mL glass or aluminum beakers, each beaker having previously been weighed with a 6-mm ($^1/_4$ in.) diameter by 178-mm (7-in.) glass rod. Adjust the temperature of the oven to 163 ± 2.8°C (325 ± 5°F). Then place the beakers containing the rods and sample in the oven for 2 h. At the end of this period remove each beaker and thoroughly stir the residue. Replace in the oven for 1 h, then remove the beakers from the oven, allow to cool to room temperature, and weigh with the rods (see Note 7).

18.5.3 After removal of the top sample, siphon off the next 390 mL (approximate) from each of the cylinders. Thoroughly mix the emulsion remaining in the cylinders and weigh 50 g into separate weighed 1000-mL glass or aluminum beakers. Determine the asphalt residue of these samples in accordance with Section 18.5.2.

18.6 *Calculation and Report*:

18.6.1 Calculate and report the storage stability in accordance with Section 11.5 and observe Note 15.

18.7 *Precision and Bias*:

18.7.1 *Repeatability*—The repeatability standard deviation is 0.2 percent. The average difference between two results, obtained by the same operator with the same equipment, but not concurrently, will be approximately 0.2 percent. Two such values should be considered suspect (95 percent confidence level) if they differ by more than 0.5 percent.

18.7.2 *Reproducibility*—The reproducibility standard deviation is 0.2 percent. The average difference between two results obtained by operators in different laboratories will be approximately 0.3 percent. Two such values should be considered suspect (95 percent confidence level) if they differ by more than 0.6 percent.

Note 22—If this test method is performed using only one cylinder instead of two for each determination as specified in the method, then the following precision criteria should be used:

	Repeatability, %
Standard deviation	0.2
Average difference	0.3
Suspect criterion	0.5

	Reproducibility, %
Standard deviation	0.2
Average difference	0.3
Suspect criterion	0.6

EXAMINATION OF RESIDUE

19. SCOPE

19.1 Test for specific gravity, ash content, solubility in trichloroethylene, penetration, ductility and float test are suggested for examination of the emulsion residue obtained by distillation or evaporation (Section 5 or Section 7).

20. SIGNIFICANCE AND USE

20.1 The suggested procedures are used to characterize and evaluate the properties of emulsion residues.

21. SPECIFIC GRAVITY

21.1 Determine the specific gravity on a representative portion of the residue in accordance with T 228 or ASTM D 3289.

22. ASH CONTENT

22.1 Determine the ash content on a representative portion of the residue in accordance with the rapid routine method of ash determination, as described in Section 7 to 9 of ASTM D 128.

23. SOLUBILITY IN TRICHLOROETHYLENE

23.1 Determine the solubility in trichloroethylene on a representative portion of the residue in accordance with T 44.

24. PENETRATION

24.1 Determine the penetration on a representative portion of the residue in accordance with T 49.

24.2 *Precision*—The following criteria should be used for judging the acceptability of results (95 percent probability):

24.2.1 Duplicate results by the same operator should not be considered suspect unless they differ by more than the following amount:

Penetration of Residue, range	Repeatability, points
80 to 200	15

24.2.2 The results submitted by each of two laboratories should not be considered suspect unless they differ by more than the following amount:

Penetration of Residue, range	Reproducibility, points
80 to 200	30

25. DUCTILITY

25.1 Determine the ductility on a representative portion of the residue in accordance with T 51.

26. FLOAT TEST

26.1 Determine the float test on a representative portion of the residue in accordance with T 50 except revise Section 7.2 of ASTM D 139 as follows:

26.1.1 Pour the residue into the collar at or near 260°C (500°F) preferably, directly from the still. If the residue has been allowed to cool below 260°C (500°F), reheat it to 260°C (500°F) with stirring and pour into the collar.

IDENTIFICATION TEST FOR RAPID-SETTING CATIONIC EMULSIFIED ASPHALT

27. SCOPE

27.1 This test method covers a procedure for identifying rapid-setting cationic emulsified asphalts. Their inability to coat a specific silica sand distinguishes them from medium and slow setting cationic grades.

28. SIGNIFICANCE AND USE

28.1 This test method is based upon the rapid asphalt deposition properties of rapid setting cationic emulsified asphalt as a function of sand surface area and surface charge. The test method differs from the usual coating test because the material passes the requirement when it fails to coat the specified silica sand.

28.2 Impurities in the silica sand often prevent the emulsion from passing the test. Washing the sand to remove impurities prior to test is required. Impurities affecting test results are normally due to the presence of iron (Fe^{+}) and organic dewatering agents that can alter the sand surface charge.

29. APPARATUS

29.1 *Mixing Bowl*—Metal or porcelain saucepan, $2^{1}/_{2}$ to 3 L ($2^{1}/_{2}$ to 3 qt), equipped with a handle.

29.2 *Washing Container*—Beaker made from borosilicate glass, 1000-mL capacity.

29.3 *Stainless Steel Spatula* or *Glass Rod.*

29.4 *Oven*—Convection or forced-draft, capable of maintaining 120 to 150°C (248 to 302°F).

29.5 *Balance*—Conforming to the requirements of M 231, Class G 2.

29.6 *Drying Pan*—Stainless steel or glass, 150 mm (6 in.) by 225 mm (9 in.) or larger.

29.7 *Graduated Cylinder*—Made from borosilicate glass, 500-mL capacity.

29.8 *Thermometer*—ASTM No. 67C or ASTM No. 67F as specified in Table 1 of ASTM E 1.

29.9 *Eye Protection*—Suitable safety glasses or other appropriate eye protection.

29.10 *Hand Protection*—Suitably acid and alcohol resistant.

29.11 Timer.

30. MATERIALS

30.1 *Hydrochloric Acid*—Reagent, 36.5 percent to 38.0 percent.

30.2 *Isopropyl Alcohol*—Reagent, 100 percent.

30.3 Distilled Water.

30.4 Absorbent paper.

30.5 *Silica Sand*—F-95, whole grain.[4]

TYPICAL GRADATION

U.S. Sieve No.	30	40	50	70	100	140	200	270
Millimeters	0.850	0.425	0.300	0.212	0.150	0.106	0.075	0.053
% Passing	100	99	97	89	56	17	2	T

EMULSIFIED ASPHALT (EMULSION) SAMPLE

31.1 Obtain a representative sample of the emulsion for testing in accordance with T 40.

32. SAND PREPARATION

32.1 Prepare 400 mL of 5 percent hydrochloric acid, by volume, in isopropyl alcohol by mixing 20 mL hydrochloric acid into a blend of 80 mL distilled water and 300 mL isopropyl alcohol in a 500-mL graduated cylinder.

32.2 Weigh 500 g of the F-95 silica sand into a 1000-mL beaker. Add 400 mL of the 5 percent hydrochloric acid in isopropyl alcohol/water mixture into the beaker containing the silica sand and stir for five min with a stainless steel spatula or a glass rod.

32.3 Decant the acid/alcohol/water mixture carefully without loss of sand.

32.4 Wash sand with at least 400 mL of hot distilled water, 50 to 70°C (122 to 158°F) and stir for approximately 1 min. Decant water without loss of sand. Repeat water washing the sand two more times.

32.5 Scrape washed sand onto drying pan avoiding as much loss of sand as is possible and spread sand over the surface of the drying pan. Place the pan with the sand in an oven and dry to constant weight at a temperature of 120 to 150°C (248 to 302°F).

32.6 Allow sand to cool and transfer dry sand to a suitable container. Mix sand for approximately 30 s to obtain uniformity.

33. PROCEDURE

33.1 Test at 25 ± 5°C (77 ± 9°F).

33.2 Weigh 465 g of the washed silica sand blend into a 1000-mL beaker. Add 35 g of the emulsion to be tested and mix vigorously with a spatula for approximately two minutes using a combined stirring and kneading action. At the end of the mixing period, tilt the beaker and allow any excess emulsion, which is not on the sand, to drain from the beaker.

33.3 Place the completed mix on absorbent paper. Visually estimate the amount of uncoated and coated area in the mixture. See Note 23.

34. INTERPRETATION OF RESULTS

34.1 From the visual estimation of the amount of uncoated area and coated area in the mixture, record the coating of the total sand surface area by the asphalt emulsion. An excess of uncoated area over the coated area shall be considered as a passing rating for identification of rapid- setting cationic emulsified asphalt.

Note 23—Visual estimation is less accurate at moderate levels of coating than at the two extremes. If results are inconclusive, the washing and mixing procedure should be repeated.

35. PRECISION AND BIAS

35.1 This test method, which requires subjective evaluation of test results and reports only two possible conditions, does not lend itself readily to a statistical round-robin exercise. Development of a procedure to quantitatively determine comparative coating will be considered.

IDENTIFICATION OF CATIONIC SLOW-SET EMULSIONS

36. SCOPE

36.1 This test method is intended to identify a cationic slow-setting grade of emulsified asphalts if the results of the particle charge test are inconclusive.

37. SUMMARY OF TEST METHOD

37.1 A weighed amount of washed and dried silica sand is hand mixed with a weighed amount of emulsified asphalt. Mixing time should extend until aggregate is completely coated. The amount of CSS-grade emulsified asphalt in the mix should yield a total mix asphalt content of about 5.0 percent. The sample is spread out and allowed to air cure for 24 h. The retained coating, after boiling, is then determined.

38. SIGNIFICANCE AND USE

38.1 The conditions of the test are designed to identify the adequacy of a slow-setting grade of emulsified asphalt (CSS-M 208) to properly mix, coat, and adhere to a specified silica sand aggregate.

38.2 This test method is intended to confirm the adhesive properties that exist between a cationic emulsion and silica sand and the ability of the sample to remain coated after being submerged in boiling water.

39. APPARATUS AND MATERIAL

39.1 *Heat Source*—Hot plate or bunsen burner. The use of a bunsen burner will necessitate the placement of an interfacial material between the flame and beaker.

39.2 *Screen*—No. 20 mesh folded into a circular configuration with the edges folded downward, or cut a strip of 0.850 mm (No. 20) mesh screen 25.4 mm (1 in.) by 355.6 mm (14 in.) in length and a circular screen of the circumference of 1000-mL beaker. Bend the strip into a circle and insert it in the bottom of the beaker. Place the circular screen on top of the strip.

39.3 *Beaker*—1000 mL capacity.

39.4 Paper Napkin.

39.5 *20–30 Standard Ottawa Silica Sand*—as described in ASTM C 778 (Silica sand should be washed to remove impurities prior to test).

39.6 *Spatula*—A steel spatula or its equivalent, having a blade of 203.2 mm (8 in.) in length.

39.7 *Mixing Container*—400-mL glass or stainless steel beaker or bowl.

39.8 Beaker Tongs.

39.9 *Eye Protection*—Suitable safety glasses with side shield or any other appropriate eye protection.

39.10 *Hand Protection*—Heat resistant gloves.

39.11 Balance.

39.12 Distilled Water.

40. PROCEDURE

40.1 Weigh 150 g of dry silica sand into the mixing container.

40.2 Add 12 g of the emulsion and immediately begin to mix vigorously for 20 to 60 s or until silica sand is completely coated.

Note 24—Water may be added to facilitate mixing; 1.0 percent is generally sufficient.

40.3 The sample should be spread onto a paper napkin in such a manner as to facilitate curing. Allow to air cure for 24 h. (Remove sample from paper napkin and break into several pieces; observe whether sample is completely cured. If sample is not completely cured, allow additional curing time.)

40.4 Boil about 500 mL of distilled water in a 1000-mL beaker containing 0.850 mm (No. 20) mesh screen shelf. Place the coated silica sand in the boiling water on top of the screen.

40.5 Boil for 10 min and then decant the water.

40.6 Spread the sample on a level surface and observe the coating of the mix.

41. REPORT

41.1 From the visual examination of the amount of coated and uncoated areas in the mixture, record the retained coating, after boiling, of the total sand surface area. If the coating is in excess of 50 percent, the emulsion should be considered as having a passing rating for classification of slow-setting cationic emulsified asphalt.

42. PRECISION AND BIAS

42.1 This test method, which requires subjective evaluation of test results and reports only two possible conditions, does not lend itself readily to a statistical round-robin exercise. At present, there is no precision and bias statement for this test method.

FIELD COATING TEST ON EMULSIFIED ASPHALTS

43. SCOPE

43.1 This is a quick field method to ascertain the compatibility of an asphalt emulsion with the job aggregate.

44. SIGNIFICANCE AND USE

44.1 The test method is proposed for use at the project site to determine (1) the ability of an asphalt emulsion to coat the job aggregate, (2) the ability of the emulsion to withstand mixing, and (3) the water resistance of the emulsion coated aggregate.

45. SUMMARY OF TEST METHOD

45.1 A measured amount of the job aggregate is hand- mixed with a measured amount of the emulsion supplied to the job. The ability of the emulsion to remain as a coating during a 5-mm mixing cycle is observed. The resistance offered by the coating to wash-off is determined by repeated filling with water and emptying a container of the coated aggregate.

46. APPARATUS

46.1 *Metal Containers*—$^1/_2$-L (1-pt) capacity (friction-top pint cans).

46.2 *Metal Porcelain Saucepan*—$2^1/_2$- to 3-L ($2^1/_2$- to 3-qt), equipped with a handle.

46.3 *Dispensing Graduate*—50-mL capacity, preferably plastic.

46.4 *Serving Spoon*—Long-handled.

47. PROCEDURE

47.1 Derim the $^1/_2$-L (1-pt) can.

47.2 Fill the can level with the job aggregate discarding any sizes above 19 mm ($^3/_4$ in.).

47.3 Measure out 50 mL of emulsified asphalt.

47.4 Transfer the aggregate and the emulsion into the porcelain saucepan.

47.5 Hand mix vigorously for 5 min with the long-handled spoon.

47.6 Observe (1) whether the stone is fully coated with the emulsion and rate the coating as good, fair or poor—a rating of good means fully coated by the asphalt emulsion exclusive of pinholes and sharp edges of the aggregate, a rating of fair applies to the condition of an excess of coated area over uncoated area, and a rating of poor applies to the condition of an excess of uncoated area over coated area; and (2) the presence, if any, of free water which denotes breakdown of the emulsion.

47.7 Refill the $^1/_2$-L (1-pt) can with the coated stone.

47.8 Set the can of coated stone upright in the porcelain saucepan.

47.9 Fill the can with water and pour off. Repeat this step five times.

47.10 Transfer the contents of the can onto newspapers. Repeat the observations made in Section 47.6 and record.

48. REPORT

48.1 Report the observations made in Section 47.6 and Section 47.10 as the results from this test.

EMULSIFIED ASPHALT/JOB AGGREGATE COATING TEST

49. SCOPE

49.1 This test method may be used to identify the adequacy of slow setting grade of emulsified asphalt to mix with and coat a dense and fine-graded job aggregate. It is a laboratory test method of screening emulsion candidates for mixing with and coating job aggregates and is not to be construed as a mix design test method.

50. SIGNIFICANCE AND USE

50.1 The conditions of the test arc designed to identify the adequacy of emulsified asphalt, slow-setting grade (CSS-M 208 and SS-M 140) for mixing with and coating dense-graded aggregate and fine-graded aggregate.

51. SUMMARY OF TEST METHOD

51.1 A weighed amount of dry job aggregate is hand- mixed with a weighed amount of water for prewetting the aggregate. The wetted aggregate is then hand-mixed with a weighed amount of emulsified asphalt of known asphalt- cement content until maximum coating of the job aggregate is obtained. (Mix time is usually 15 to 120 s.) The adequacy of emulsified asphalt for mixing with job aggregate is determined by using various amounts of water and emulsified asphalt until a maximum coating of the job aggregate is obtained. This coating is rated as good, fair, or poor.

52. APPARATUS

52.1 *Containers*—A 1000-mL glass beaker, a 1.0-L (l-qt) friction-top metal can, or 1000-mL stainless steel beaker or bowl.

52.2 *Mixing Tool*—A steel spatula or its equivalent, having a blade approximately 203.2 mm (8 in.) in length.

52.3 *Balance*—Capable of weighing 1000 g to within ±0.1 g.

53. PROCEDURE

53.1 Weigh 300 g of dry job aggregate into the container and add water basis dry weight of aggregate. Immediately begin to mix vigorously for 1 min or until all aggregate surfaces subjectively appear to be wetted (as a guide, 2 to 8 percent water for dense-graded aggregate and 4 to 12 percent water for fine-graded aggregate). The natural moisture in a job aggregate may be used in the test if predetermined. Additional water may then be added, if necessary, to obtain the desired level of water to be used for prewetting the aggregate.

53.2 Add the emulsion and immediately begin to mix vigorously, scraping sides and bottom of container, for 15 to 120 s or until maximum coating has been attained (as a guide, basis dry weight of aggregate, 3 to 7 percent Asphalt Cement (A/C) residue for dense aggregate and 4 to 8 percent A/C residue for fine aggregate). Example: 8 percent emulsion at 60 percent solids would be equivalent to 4.8 percent asphalt cement residue in the mix.

53.3 If mix appears to be too dry and insufficiently coated repeat Sections 53.1 and 53.2 using an increased amount of water or emulsified asphalt, or both. If mix appears to be too wet from excessive water or emulsified asphalt, or both, repeat Sections 53.1 and 53.2, using less water or emulsified asphalt, or both.

53.4 For each job aggregate mix observe and record the amount of aggregate prewetting water and asphalt cement residue from the emulsified asphalt and note the one mix that provides the best aggregate coating.

53.5 Rate the best coating as good, fair, or poor using the ratings as defined in Section 17.8.

54. REPORT

54.1 Report the observations made in Sections 53.2 and 53.3 relating to amount of aggregate prewetting water and residual asphalt needed for best obtainable aggregate coating.

54.2 Report the maximum coating achieved as good, fair, or poor in accordance with Section17.8.

55. PRECISION AND BIAS

55.1 The usual methods of analysis for precision cannot be applied to this test method because it is not fully quantitative.

WEIGHT PER GALLON OF EMULSIFIED ASPHALT

56. SCOPE

56.1 This test method is used to determine the weight per gallon of emulsified asphalt used in highway construction. This unit weight is computed by determining the weight of an asphalt emulsion contained in a standard measure of known volume.

Note 25—The calculation of Imperial Gallon Weight may be made by using proper conversion factors.

57. SIGNIFICANCE AND USE

57.1 This test method provides a controlled laboratory test for the determination of quantitative volumes of emulsion asphalt for use in bills of lading, invoicing, and application rates.

58. APPARATUS

58.1 *Weight-per-Gallon Cup*—Stainless steel measure of known standard volume (83.2 mL).

58.2 *Balance*—Conforming to the requirements of M 231, Class G 2.

58.3 *Water Bath*—Constant-temperature maintained at 25 ± 0.5°C (77 ± 1°F).

59. PROCEDURE

59.1 Stir the emulsion sample and place in a constant- temperature water bath maintained at 25 ± 0.5°C (77 ± 1°F) for approximately 1 h.

59.2 Place the measure and its cap on the balance, tare, and zero the balance.

59.3 Remove the emulsion sample from the bath and stir, using care to avoid trapping air in the sample. If necessary, strain through an 850-μm (No. 20) sieve to remove any skin or film that might be present in the emulsion.

59.4 Bring the measure to approximately 25°C (77°F) and pour the emulsion into the measure, filling it completely.

59.5 Start placing the cap onto the measure and remove, with a clean dry rag or paper, the excess emulsion oozing through the orifice in the cap.

59.6 When the cap is placed on tightly, clean the measure carefully, weigh on the tared balance to the nearest 0.01 g, and record.

60. CALCULATION

60.1 Calculate the weight per gallon of emulsion as follows:

$$W = G/10 \qquad (6)$$

where:

W = unit weight of emulsion, lb/gal; and

G = weight of emulsion in measure, g.

61. REPORT

61.1 Report the unit weight of emulsion in pounds per gallon to the nearest 0.01 lb at 25°C (77°F).

62. PRECISION AND BIAS

62.1 The following criteria should be used for judging the acceptability of results (95 percent probability):

62.1.1 Duplicate results by the same operator should not be considered suspect unless they differ by more than the following amount:

Unit Weight	Repeatability
Pounds per gallon at 25°C (77°F)	0.019

62.2 The results submitted by each of two laboratories should not be considered suspect unless they differ by more than the following amount:

Unit weight	Reproducibility
Pounds per gallon at 25°C (77°F)	0.034

Note 26—Weight per gallon at 25°C (77°F) may be translated to weight per gallon at 15.6°C (60°F) by using a multiplier of 1.00475.

63. KEYWORDS

63.1 Asphalt residue; cationic; coating; demulsibility; distillation; emulsified asphalt; evaporation; miscibility; particle charge; rapid-setting; settlement; slow-setting; viscosity; water content.

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[1] Available from Koehler Instrument Company, Inc., 1595 Sycamore Avenue, Bohemia, NY 11716; and Humboldt Manufacturing Co., 3801 North 25th Avenue, Schiller Park, IL 60176.

[2] Available from Humboldt Manufacturing Co., Catalog No. H-1876, 7302 3801 North 25th Avenue, Schiller Park, IL 60176.

[3] Limestone from the Vulcan Materials Midwest Division, 6857 North US Highway 421, Monon, IN 47959, has been found suitable as a reference aggregate.

[4] Fine aggregate is available from U.S. Silica Co., 701 Boyce Memorial Drive, Ottawa, IL. 61350

Standard Method of Test for

Mass [Weight] of Coating on Iron and Steel Articles with Zinc or Zinc-Alloy Coatings

AASHTO Designation: T 65M/T 65-08[1]
ASTM Designation: A 90/A 90M-07

1. SCOPE

1.1. This test method covers procedures for determining the mass [weight] of coating on iron or steel sheet, wire, and other articles in which the coating is zinc or a zinc alloy, such as zinc-5 percent aluminum (including zinc-5 percent aluminum-mischmetal and zinc-5 percent aluminum-0.1 percent magnesium) or 55 percent aluminum-zinc. In the body of this test method, reference to zinc coating shall be interpreted to also include zinc alloy coating except where specifically stated otherwise.

1.2. The final results determined by this test method shall be expressed in SI units or inch–pound units, depending on the units used in the material specification to which the results are to be compared. Certain portions of the procedure involving determination of specimen mass [weight] have traditionally been performed in SI units, and corresponding inch–pound units are not included.

1.3. For sheet products, the final results are expressed as either coating mass [weight] total both sides, or coating mass [weight] separately on each side, depending on the specified requirements.

1.4. *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.* For specific hazards statements, see Section 5.1.

1.5. Current regulation codes and hazard classifications for chemicals used in this test method are listed in R 16.

2. REFERENCED DOCUMENTS

2.1. *AASHTO Standard*:

- R 16, Regulatory Information for Chemicals Used in AASHTO Tests

2.2. *ASTM Standards*:

- A 653/A 653M, Specification for Steel Sheet, Zinc-Coated (Galvanized) or Zinc-Iron Alloy-Coated (Galvannealed) by the Hot-Dip Process
- A 792/A 792M, Specification for Steel Sheet, 55 Percent Aluminum-Zinc Alloy-Coated by the Hot-Dip Process
- A 875/A 875M, Specification for Steel Sheet, Zinc-5 Percent Aluminum Alloy-Coated by the Hot-Dip Process
- D 1193, Specification for Reagent Water
- E 29, Using Significant Digits in Test Data to Determine Conformance with Specifications

Standard Method of Test for

Soundness of Aggregate by Use of Sodium Sulfate or Magnesium Sulfate

AASHTO Designation: T 104-99 (2007)

1. SCOPE

1.1. This method covers the procedure to be followed in testing aggregates to determine their resistance to disintegration by saturated solutions of sodium sulfate or magnesium sulfate. This is accomplished by repeated immersion in saturated solutions of sodium or magnesium sulfate followed by oven drying to partially or completely dehydrate the salt precipitated in permeable pore spaces. The internal expansive force, derived from the rehydration of the salt upon re-immersion, simulates the expansion of water on freezing. This test method furnishes information helpful in judging the soundness of aggregates subject to weathering action, particularly when adequate information is not available from service records of the material exposed to actual weathering conditions. Attention is called to the fact that test results by the use of the two salts differ considerably and care must be exercised in fixing proper limits in any specifications that may include requirements for these tests.

1.2. The values stated in SI units are to be regarded as the standard.

1.3. *This standard may involve hazardous materials, operations, and equipment. This standard does not purport to address all of the safety concerns associated with its use. It is the responsibility of the user of this standard to consult and establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*

2. REFERENCED DOCUMENTS

2.1. *AASHTO Standards*:

- M 92, Wire-Cloth Sieves for Testing Purposes
- M 231, Weighing Devices Used in the Testing of Materials
- R 16, Regulatory Information for Chemicals Used in AASHTO Tests
- T 27, Sieve Analysis of Fine and Coarse Aggregates

2.2. *ASTM Standards*:

- C 670, Practice for Preparing Precision Statements for Test Methods for Construction Materials
- E 100, Specification for ASTM Hydrometers

Note 4—For the solution, 350 g of anhydrous salt or 1230 g of the heptahydrate per liter of water are sufficient for saturation at 23°C (73.4°F). However, since these salts are not completely stable, with the hydrous salt being the more stable of the two, and since it is desirable that an excess of crystals be present, it is recommended that the heptahydrate salt be used and in an amount of not less than 1400 g/L of water.

When preparing the saturated solution of magnesium sulfate, the salt crystals will dissolve more readily if the crystals are added in small amounts and the water temperature is higher than 35°C (95°F) due to the chemical cooling effect during preparation.

Note 5—Distilled water shall be used in referee or comparison testing.

4.2. *Barium Chloride Solution*—A 0.2 molar solution of barium chloride (41.6 g of $BaCl_2$ per liter of solution) to determine the presence of sodium or magnesium sulfate in the wash water.

5. SAMPLES

5.1. *Fine Aggregate*—Fine aggregate for the test shall be passed through a 9.5-mm ($^3/_8$-in.) sieve. The sample shall be of such size that it will yield not less than 100 g of each of the following sizes, expressed in terms of the following sieves:

Passing Sieve	Retained on Sieve
9.5 mm (3/8 in.)	4.75 mm (No. 4)
4.75 mm (No. 4)	2.36 mm (No. 8)
2.36 mm (No. 8)	1.18 mm (No. 16)
1.18 mm (No. 16)	600 µm (No. 30)
600 µm (No. 30)	300 µm (No. 50)

5.1.1. Should the sample contain less than five percent of any of the sizes specified in Section 5.1, that size shall not be tested.

5.2. *Coarse Aggregate*—Coarse aggregate for the test shall consist of material from which the sizes finer than the 4.75-mm (No. 4) sieve have been removed. The sample shall be of such a size that it will yield the amounts indicated in Table 1.

Table 1—Coarse Aggregate Sample

Sieve Size	Mass, g
63 mm to 37.5 mm ($2^1/_2$ in. to $1^1/_2$ in.)	5000 ± 300
Consisting of:	
50-mm to 37.5-mm (2-in. to $1^1/_2$-in.) material	2000 ± 200
63-mm to 50-mm ($2^1/_2$-in. to 2-in.) material	3000 ± 300
37.5 mm to 19.0 mm ($1^1/_2$ in. to $^3/_4$ in.)	1500 ± 50
Consisting of:	
25.0-mm to 19.0-mm (1-in. to $^3/_4$ -in.) material	500 ± 30
37.5-mm to 25.0-mm ($1^1/_2$-in. to 1-in.) material	1000 ± 50
19.0 mm to 9.5 mm ($^3/_4$ in. to $^3/_8$ in.)	1000 ± 10
Consisting of:	
12.5-mm to 9.5-mm ($^1/_2$-in. to $^3/_8$-in.) material	330 ± 5
19.0-mm to 12.5-mm ($^3/_4$-in. to $^1/_2$-in.) material	670 ± 10
9.5 mm to 4.75 mm ($^3/_8$ in. to No. 4)	300 ± 5

5.2.1. Should the sample contain less than five percent of any of the sizes specified in Section 5.2, that size shall not be tested. When a combination of sizes is specified for the test portion and one of the sizes specified is less than five percent of the sample, reduce the test portion by the applicable mass specified in Section 5.2 for the size not available.

5.2.2. When testing large rock (broken stone, ledge rock, cobbles, and boulders for use as riprap, channel lining, etc.), obtain the test portion by crushing, splitting, or sawing the larger sample pieces. Test only those pieces in the 37.5 to 19.0 mm ($1^1/_2$ to $^3/_4$ in.) and 63 to 37.5 mm ($2^1/_2$ to $1^1/_2$ in.) size fractions when size reduction is by crushing or splitting. Test pieces in the 63 to 37.5 mm ($2^1/_2$ to $1^1/_2$ in.) size fraction when size reduction is by sawing.

Note 6—When the rock contains bedding planes, crushing or splitting will usually cause the rock to break on those bedding planes. Sawing will usually leave the bedding planes intact, and thus more likely to split the particles due to growth of the salt crystals in the soundness test.

5.2.3. When testing large rock (to evaluate a potential source) which will be subsequently crushed to produce aggregate, obtain the test portion by crushing the larger sample pieces. Test pieces only in those sizes that will be included in the produced aggregate, but ignoring any material finer than 4.75-mm (No. 4) sieve or coarser than 63-mm ($2^1/_2$-in.) sieve.

5.2.4. When the finished aggregate material will contain particles coarser than 63 mm ($2^1/_2$ in.), such as aggregate for use in mass concrete, crush the material coarser than 63 mm ($2^1/_2$ in.) and distribute the material among that in the range of 63-mm ($2^1/_2$ in.) to 4.75-mm (No. 4) sieves. Discard material finer than 4.75-mm (No. 4) sieve.

5.3. When an aggregate to be tested contains appreciable amounts of both fine and coarse material, having a grading with more than 10 percent coarser than the 9.5-mm ($^3/_8$-in.) sieve and, also, more than 10 percent finer than the 4.75-mm (No. 4) sieve, test separate samples of the minus 4.75 mm (No. 4) fraction and the plus 4.75 mm (No. 4) fraction in accordance with the procedures for fine aggregate and coarse aggregate, respectively. Report the results separately for the fine aggregate fraction and the coarse aggregate fraction, giving the percentages of the coarse and fine size fractions in the initial grading.

6. PREPARATION OF TEST SAMPLE

6.1. *Fine Aggregate*—Thoroughly wash the sample of fine aggregate on a 300-μm (No. 50) sieve, dry to constant mass at 110° ± 5°C (230° ± 9°F), and separate into the different sizes by sieving, as follows: Make a rough separation of the graded sample by means of a nest of the standard sieves specified in Section 5.1. From the fractions obtained in this manner, select samples of sufficient size to yield 100 g after sieving to refusal. (In general, a 110-g sample will be sufficient.) Do not use fine aggregate sticking in the meshes of the sieves in preparing the samples. Weigh samples consisting of 100 ± 0.1 g out of each of the separated fractions after final sieving, record the masses of the test samples, and place in separate containers for the test.

6.2. *Coarse Aggregate*—Thoroughly wash and dry the sample of coarse aggregate to constant mass at 110° ± 5°C (230° ± 9°F) and separate it into the different sizes shown in Section 5.2 by sieving to refusal. Weigh out quantities of the different sizes within the tolerances of Section 5.2 and combine them to the designated total mass (Note 7). Record the masses of the test samples and their fractional components. In the case of sizes larger than 19.0 mm ($^3/_4$ in.), record the number of particles in the test samples.

Note 7—The fractional components of each sample may be placed in separate containers if so desired but is not required. If separate containers are used, the two sizes must be combined for the calculations for Section 8.1.2 (Table 2).

Table 2—Suggested Form for Recording Test Data (with Illustrative Test Values)

Sieve Size			Grading of Original Sample, Percent	Mass of Test Fractions Before Test, g	Percentage Passing Designated Sieve After Test	Weighted Percentage Loss
			Soundness Test of Fine Aggregate			
Minus 150 µm			5			
300 µm to 150 µm			12			
600 µm to 300 µm			26	100	4.2	1.1
1.18 mm to 600 µm			25	100	4.8	1.2
2.36 mm to 1.18 mm			17	100	8.0	1.4
4.75 mm to 2.36 mm			11	100	11.2	1.2
9.5 mm to 4.75 mm			4		11.2[a]	0.4
Totals			100			5
			Soundness Test of Coarse Aggregate			
63 mm to 50 mm	2825 g	63 to 37.5 mm	20	4783	4.8	1.0
50 mm to 37.5 mm	1958 g					
37.5 mm to 25.0 mm	1012 g	37.5 to 19.0 mm	45	1525	8.0	3.6
25.0 mm to 19.0 mm	513 g					
19.0 mm to 12.5 mm	675 g	19.0 to 9.5 mm	23	1008	9.6	2.2
12.5 mm to 9.5 mm	333 g					
9.5 mm to 4.75 mm			12	298	11.2	1.3
Totals			100			8

[a] The percentage loss (11.2 percent) of the next smaller size is used as the percentage loss for this size, since this size contains less than five percent of the original sample as received. See Section 10.1.3.4.

7. PROCEDURE

7.1. *Storage of Samples in Solution*—Immerse the samples in the prepared solution of sodium sulfate or magnesium sulfate for not less than 16 hours nor more than 18 hours in such a manner that the solution covers them to a depth of at least 12.5 mm ($^1/_2$ in.) (Note 8). Cover the containers to reduce evaporation and prevent the accidental addition of extraneous substances. Maintain the samples immersed in the solution at a temperature of 20.3 to 21.9°C (68.5 to 71.5°F) for the immersion period.

Note 8—Suitably weighted wire grids placed over the sample in the containers will permit this coverage to be achieved with very light-weight aggregates.

7.2. *Drying Samples After Immersion*—After the immersion period, remove the aggregate sample from the solution, permit it to drain for 15 ± 5 minutes, and place in the drying oven. The temperature of the oven shall have been brought previously to 110° ± 5°C (230° ± 9°F). Dry the samples at the specified temperature until constant mass has been achieved. Establish the time required to attain constant mass as follows: with the oven containing the maximum sample load expected, check the mass losses of test samples by removing and weighing them without cooling, at intervals of two to four hours; make enough checks to establish required drying time for the least favorable oven location (Section 3.6) and sample condition (Note 9). Constant mass will be considered to have been achieved when mass loss is less than 0.1 percent of sample mass in four hours of drying. After constant mass has been achieved, allow the samples to cool to 20 to 25°C (68 to 77°F) (Note 10), when they shall again be immersed in the prepared solution as described in Section 7.1. Cooling may be aided by the use of an air conditioner or fan. Temperature of the material shall be checked by thermometer or other acceptable means before placing the material in the soaking solution.

Note 9—Drying time required to reach constant mass may vary considerably for several reasons. Efficiency of drying will be reduced as cycles accumulate because of salt adhering to particles and, in some cases, because of increase in surface area due to breakdown. The different size

fractions of aggregate will have differing drying rates. The smaller sizes will tend to dry more slowly because of their larger surface area and restricted interparticle voids, but this tendency may be altered by the effects of container size and shape.

Note 10—Experience has shown that sample temperatures significantly different than the solution temperature of 21.1°C (70.0°F) may change the temperature of the solution temporarily, thereby causing a change in salt saturation even though the solution returns to 21.1°C (70.0°F) for most of the soaking period. This may cause erroneous results.

7.3. *Number of Cycles*—Repeat the process of alternate immersion and drying until the required number of cycles is obtained. Preferably, the test shall be performed continuously until the specified number of cycles is obtained. However, if the test must be interrupted, leave the samples in the oven, at 110° ± 5°C (230° ± 9°F) until the testing can be resumed.

7.4. Review the temperature record from the recording unit. Verify solution temperature limits were not exceeded.

8. QUANTITATIVE EXAMINATION

8.1. *Make the quantitative examination as follows*:

8.1.1. After the completion of the final cycle and after the sample has cooled, wash the sample free from the sodium sulfate or magnesium sulfate. Wash by circulating water at 43° ± 6°C (110° ± 10°F) through the samples in their containers by introducing hot water near the bottom and allowing the water to pass through the samples and overflow. The thoroughness of washing shall be checked by obtaining a sample of rinse water after it has passed through the samples and checked with 0.2 molar barium chloride. Further washing is required if sample becomes cloudy upon addition of the barium chloride solution. In areas where the water gives a reaction with barium chloride other analytical means shall be used to assure thoroughness of washing. In the washing operation, the samples shall not be subjected to impact or abrasion that may tend to break up particles.

8.1.2. After the sodium sulfate or magnesium sulfate has been removed, dry each fraction of the sample to constant mass at 110° ± 5°C (230° ± 9°F). Sieve the fine aggregate over the same sieve on which it was retained before the test, and sieve the coarse aggregate over the sieve shown below for the appropriate size of particle. For fine aggregate, the method and duration of sieving shall be the same as were used in preparing the test samples. For coarse aggregate, sieving shall be by hand, with agitation sufficient only to assure that all undersize material passes the designated sieve. No extra manipulation shall be employed to break up particles or cause them to pass the sieves. Determine the mass of the material retained on each sieve and record each amount. The difference between each of these amounts and the initial mass of the fraction of the sample tested is the loss in the test and is to be expressed as a percentage of the initial mass for use in Table 2.

Size of Aggregate	Sieve Used to Determine Loss
63 mm to 37.5 mm ($2^1/_2$ to $1^1/_2$ in.)	31.5 mm ($1^1/_4$ in.)
37.5 mm to 19.0 mm ($1^1/_2$ to $^3/_4$ in.)	16.0 mm ($^5/_8$ in.)
19.0 mm to 9.5 mm ($^3/_4$ to $^3/_8$ in.)	8.0 mm ($^5/_{16}$ in.)
9.5 mm to 4.75 mm ($^3/_8$ in. to No. 4)	4.0 mm (No. 5)

9. QUALITATIVE EXAMINATION

9.1. *Make a qualitative examination of test samples coarser than 19.0 mm (3/4 in.) as follows (Note 11):*

9.1.1. Separate the particles of each test sample into groups according to the action produced by the test (Note 11).

9.1.2. Record the number of particles showing each type of distress.

Note 11—Many types of action may be expected. In general, they may be classified as disintegration, splitting, crumbling, cracking, flaking, etc. While only particles larger than 19.0 mm (3/4 in.) in size are required to be examined qualitatively, it is recommended that examination of the smaller sizes be made in order to determine whether there is any evidence of excessive splitting.

10. REPORT

10.1. *The report shall include the following data (Note 12):*

10.1.1. Mass of each fraction of each sample before test.

10.1.2. Material from each fraction of the sample finer than the sieve designated in Section 8.1.2 for sieving after test, expressed as a percentage of the original mass of the fraction.

10.1.3. Weighted average calculated from the percentage of loss for each fraction, based on the grading of the sample as received for examination determined by using T 27 or, preferably, on the average grading of the material from that portion of the supply of which the sample is representative except that:

10.1.3.1. For fine aggregates with less than 10 percent coarser than the 9.5-mm (3/8-in.) sieve, assume sizes finer than the 300-μm (No. 50) sieve to have zero percent loss and sizes coarser than the 9.5-mm (3/8-in.) sieve to have the same loss as the next smaller size for which test data are available.

10.1.3.2. For coarse aggregate with less than 10 percent finer than the 4.75-mm (No. 4) sieve, assume sizes finer than the 4.75-mm (No. 4) sieve to have the same loss as the next larger size for which test data are available.

10.1.3.3. For an aggregate containing appreciable amounts of both fine and coarse material tested as two separate samples as required in Section 5.3, compute the weighted average losses separately for the minus 4.75-mm (No. 4) and plus 4.75-mm (No. 4) fractions based on recomputed gradings considering the fine fraction as 100 percent and the coarse fraction as 100 percent. Report the results separately giving the percentage of the minus 4.75-mm (No. 4) and plus 4.75-mm (No. 4) material in the initial grading.

10.1.3.4. For the purpose of calculating the weighted average, consider any size in Section 5.1 or 5.2 that contain less than five percent of the sample to have the same loss as the average of the next smaller and the next larger size, or if one of these sizes is absent, to have the same loss as the next larger or next smaller size, whichever is present.

10.1.3.5. For large rock tested according to Section 5.2.2 the weighted average (if more than one size fraction is tested) shall be the arithmetic mean of the loss on the fractions tested.

10.1.3.6. For large rock tested according to Sections 5.2.3 or 5.2.4, the weighted average shall be based on a sample grading conforming to the middle of the specification to which the aggregate will be produced, or the actual grading as produced. If the specification grading includes fractions larger than 63-mm ($2^1/_2$ in.) sieve, assume such sizes have the same percentage loss as the 63 to 37.5 mm ($2^1/_2$ to $1^1/_2$ in.) fraction.

10.1.4. Report the weighted percentage loss to the nearest whole number.

10.1.5. In the case of particles coarser than 19.0 mm ($^3/_4$ in.) before test: (1) the number of particles in each fraction before test, and (2) the number of particles affected, classified as to number disintegrating, splitting, crumbling, cracking, flaking, etc., as shown in Table 3.

Table 3—Suggested Form for Qualitative Examination (with Illustrative Test Values)

Qualitative Examination of Coarse Sizes									
	Particles Exhibiting Distress								Total No. of Particles Before Test
	Splitting		Crumbling		Cracking		Flaking		
Sieve Size	No.	Percent	No.	Percent	No.	Percent	No.	Percent	
63 mm to 37.5 mm	2	7	—	—	2	7	—	—	29
37.5 mm to 19.0 mm	5	—	—	2	—	—	—	—	50

10.1.6. Kind of solution (sodium or magnesium sulfate) and whether the solution was freshly prepared or previously used.

10.1.7. Method of producing particles for test, when reduced from large pieces as described in Sections 5.2.2, 5.2.3, or 5.2.4.

Note 12—Table 2, shown with test values inserted for purpose of illustration, is a suggested form for recording test data. The test values shown might be appropriate for either salt, depending on the quality of the aggregate.

11. PRECISION

11.1. For coarse aggregate with weighted average sulfate soundness losses in the ranges of 6 to 16 percent for sodium and 9 to 20 percent for magnesium, the precision indexes are as indicated, in Table 4 (Note 13).

Table 4—Precision Indexes

	Coefficient of Variation (1s%), percent[a]	Difference Between Two Tests (d2s%), percent of average[a]
Multilaboratory:		
Sodium sulfate	41	116
Magnesium sulfate	25	71
Single-Operator:		
Sodium sulfate	24	68
Magnesium sulfate	11	31

[a] These numbers represent, respectively, the (1s%) and (d2s%) limits as described in ASTM C 670.

Note 13—The values in the precision statement are based on testing according to this method prior to revision in 1991. The revisions in 1991 are believed to improve the precision of the method.

Standard Method of Test for

Bulk Specific Gravity of Compacted Hot Mix Asphalt (HMA) Using Saturated Surface-Dry Specimens

AASHTO Designation: T 166-07

1. SCOPE

1.1. This method of test covers the determination of bulk specific gravity of specimens of compacted hot mix asphalt (HMA).

1.2. This method should not be used with samples that contain open or interconnecting voids or absorb more than 2.0 percent of water by volume, as determined in Sections 7.2 or 10.2 herein.

1.3. The bulk specific gravity of the compacted HMA may be used in calculating the unit mass of the mixture.

1.4. The values stated in SI units are to be regarded as the standard.

1.5. *This standard may involve hazardous materials, operations, and equipment. This standard does not purport to address all the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*

2. REFERENCED DOCUMENTS

2.1. *AASHTO Standards*:

- M 231, Weighing Devices Used in the Testing of Materials
- T 275, Bulk Specific Gravity of Compacted Bituminous Mixtures Using Paraffin-Coated Specimens

3. TERMINOLOGY

3.1. *Definitions:*

3.1.1. *bulk specific gravity (of solids)*—the ratio of the mass in air of a unit volume of a permeable material (including both permeable and impermeable voids normal to the material) at a stated temperature to the mass in air of equal density of an equal volume of gas-free distilled water at a stated temperature. The form of the expression shall be:

Bulk specific gravity at x/y °C *(1)*

where:
x = temperature of the material, and
y = temperature of the water.

3.1.2. *constant mass*—shall be defined as the mass at which further drying does not alter the mass by more than 0.05 percent when weighed at 2-h intervals.

4. TEST SPECIMENS

4.1. Test specimens may be either laboratory-compacted HMA or sampled from HMA pavements.

4.2. *Size of Specimens*—It is recommended that: (1) the diameter of cylindrically compacted or cored specimens, or the length of the sides of sawed specimens, be at least equal to four times the maximum size of the aggregate; and (2) the thickness of specimens be at least one and one-half times the maximum size of the aggregate.

4.3. Specimens shall be taken from pavements with a core drill, diamond or carborundum saw, or by other suitable means.

4.4. Care shall be taken to avoid distortion, bending, or cracking of specimens during and after the removal from the pavement or mold. Specimens shall be stored in a safe, cool place.

4.5. Specimens shall be free from foreign materials such as seal coat, tack coat, foundation material, soil, paper, or foil.

4.6. If desired, specimens may be separated from other pavement layers by sawing or other suitable means. Care should be exercised to ensure sawing does not damage the specimens.

METHOD A

5. APPARATUS

5.1. *Weighing Device*—The weighing device shall have sufficient capacity, be readable to 0.1 percent of the sample mass or better, and conform to the requirements of M 231. The weighing device shall be equipped with a suitable suspension apparatus and holder to permit weighing the specimen while suspended from the center of the scale pan of the weighing device.

5.2. *Suspension Apparatus*—The wire suspending the container shall be the smallest practical size to minimize any possible effects of a variable immersed length. The suspension apparatus shall be constructed to enable the container to be immersed to a depth sufficient to cover it and the test sample during weighing. Care should be exercised to ensure no trapped air bubbles exist under the specimen.

5.3. *Water Bath*—For immersing the specimen in water while suspended under the weighing device, equipped with an overflow outlet for maintaining a constant water level.

6. PROCEDURE

6.1. Dry the specimen to a constant mass at a temperature of 52 ± 3°C (125 ± 5°F). Samples saturated with water shall initially be dried overnight and then weighed at 2-h drying intervals. Recently compacted laboratory samples, which have not been exposed to moisture, do not require drying.

6.2. Cool the specimen to room temperature at 25 ± 5°C (77 ± 9°F), and record the dry mass as *A* (Note 1). Immerse each specimen in water bath at 25 ± 1°C (77 ± 1.8°F) for 4 ± 1 min, and record the immersed mass as *C*. Remove the specimen from the water, damp-dry the specimen by blotting with a damp towel as quickly as possible (not to exceed 5 s), and determine the surface-dry mass as *B*. Any water that seeps from the specimen during the weighing operation is considered part of the saturated specimen. Each specimen shall be immersed and weighed individually.

Note 1—If desired, the sequence of testing operations may be changed to expedite the test results. For example, first the immersed mass *C* can be taken, then the surface-dry mass *B*, and finally the dry mass *A*.

Note 2—Terry cloth has been found to work well for an absorbent cloth. Damp is considered to be when no water can be wrung from the towel.

7. CALCULATION

7.1. Calculate the bulk specific gravity of the specimen as follows:

$$\text{Bulk Specific Gravity} = \frac{A}{B - C} \qquad (2)$$

where:

A = mass of the specimen in air, g;
B = mass of the surface-dry specimen in air, g; and
C = mass of the specimen in water, g.

7.2. Calculate the percent of water absorbed by the specimen (on a volume basis) as follows:

$$\text{Percent of Water Absorbed by Volume} = \frac{B - A}{B - C} \times 100 \qquad (3)$$

7.3. If the percent of water absorbed by the specimen as calculated in Section 6.2 exceeds 2.0 percent, use T 275 to determine the bulk specific gravity.

METHOD B

8. APPARATUS

8.1. *Weighing Device*—The weighing device shall have sufficient capacity, be readable to 0.1 percent of the sample mass or better, and conform to the requirements of M 231.

8.2. *Water Bath*—For immersing the specimen in water.

8.3. *Thermometer*—ASTM 17C (17F), having a range of 19 to 27°C (66 to 80°F), graduated in 0.1°C (0.2°F) subdivisions.

8.4. *Volumeter*[1]—Calibrated to 1200 mL, or an appropriate capacity depending on the size of the test sample. The volumeter shall have a tapered lid with a capillary bore.

9. PROCEDURE

9.1. Dry the specimen to a constant mass at a temperature of 52 ± 3°C (125 ± 5°F). Samples saturated with water shall initially be dried overnight and then weighed at 2-h drying intervals. Recently compacted laboratory samples, which have not been exposed to moisture, do not require drying.

9.2. Cool the specimen to room temperature at 25 ± 5°C (77 ± 9°F), and record the dry mass as *A* (Note 1). Immerse the specimen in the water bath at 25 ± 1°C (77 ± 1.8°F), and let it saturate for at least 10 min. At the end of the 10-min period, fill a calibrated volumeter with distilled water at 25 ± 1°C (77 ± 1.8°F), and weigh the volumeter. Designate this mass as *D*. Remove the saturated specimen from the water bath and damp-dry the specimen by blotting with a damp towel (Note 2) as quickly as possible (not to exceed 5 s). Weigh the specimen, and record the surface-dry mass as *B*. Any water that seeps from the specimen during the weighing operation is considered part of the saturated specimen.

9.3. Place the specimen into the volumeter, and let it stand for at least 60 s. Bring the temperature of the water to 25 ± 1°C (77 ± 1.8°F), and cover the volumeter, making certain that some water escapes through the capillary bore of the tapered lid. Wipe the outside of the volumeter dry with a dry absorbent cloth, and weigh the volumeter and its contents (Note 3). Record this weight as *E*.

Note 3—If desired, the sequence of testing operations can be changed to expedite the test results. For example, first the mass of the saturated, damp-dry specimen *B* can be taken. Then the volumeter containing the saturated specimen and water *E* can be weighed. The dry mass of the specimen *A* can be determined last.

Note 4—Method B is not acceptable for specimens that have more than 6 percent air voids.

10. CALCULATIONS

10.1. Calculate the bulk specific gravity of the specimen as follows:

$$\text{Bulk Specific Gravity} = \frac{A}{B + D - E} \qquad (4)$$

where:

A = mass of the dry specimen, g
B = mass of the surface-dry specimen, g
D = mass of the volumeter filled with water at 25 ± 1°C (77 ± 1.8°F), g; and
E = mass of the volumeter filled with the specimen and water at 25 ± 1°C (77 ± 1.8°F), g.

10.2. Calculate the percent of water absorbed by the specimen (on a volume basis) as follows:

$$\text{Percent of Water Absorbed by Volume} = \frac{B - A}{B + D - E} \times 100 \qquad (5)$$

10.3. If the percent of water absorbed by the specimen as calculated in Section 10.2 exceeds 2.0 percent, use T 275 to determine the bulk specific gravity.

METHOD C (RAPID TEST)

11. PROCEDURE

11.1. This procedure can be used for testing specimens which are not required to be saved and which contain a substantial amount of moisture. Specimens obtained by coring or sawing can be tested the same day by this method.

11.2. The testing procedure shall be the same as given in Sections 6 or 9 except for the sequence of operations. The dry mass *A* of the specimen is determined last as follows.

11.3. Place the specimen in a large, flat-bottom drying pan of known mass. Place the pan and specimen in an oven at 110 ± 5°C (230 ± 9°F). Leave the specimen in the oven until it can be easily separated to the point where the particles of the fine aggregate-asphalt portion are not larger than 6.3 mm ($^1/_4$ in.). Place the separated specimen in an oven at 110 ± 5°C (230 ± 9°F), and dry to a constant mass.

11.4. Cool the pan and specimen to room temperature at 25 ± 5°C (77 ± 9°F). Determine the mass of the pan and specimen; subtract the mass of the pan, and record as the dry mass *A*.

12. CALCULATIONS

12.1. Calculate the bulk specific gravity as given in Sections 7.1 or 10.1.

13. REPORT

13.1. The report shall include the following:

13.1.1. The method used (*A*, *B*, or *C*).

13.1.2. Bulk Specific Gravity reported to the nearest thousandth.

13.1.3. Absorption reported to the nearest hundredth.

14. PRECISION

14.1. Duplicate specific gravity results by the same operator should not be considered suspect unless they differ by more than 0.02.

[1] Suitable aluminum volumeters of different sizes are available from Pine Instrument Co., 101 Industrial Drive, Grove City, PA 16127; and Rainhart Co., 604 Williams St., Austin, TX 78765.

Standard Method of Test for

Theoretical Maximum Specific Gravity and Density of Hot Mix Asphalt (HMA)

AASHTO Designation: T 209-08

1. SCOPE

1.1. This test method covers the determination of the theoretical maximum specific gravity and density of uncompacted hot mix asphalt (HMA) at 25°C (77°F).

Note 1—The precision of the method is best when the procedure is performed on samples that contain aggregates that are completely coated. In order to assure complete coating, it is desirable to perform the method on samples that are close to the optimum asphalt binder content.

1.2. The values stated in SI units are to be regarded as the standard.

1.3. *This standard may involve hazardous materials, operations, and equipment. This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*

2. REFERENCED DOCUMENTS

2.1. *AASHTO Standards*:

- M 231, Weighing Devices Used in the Testing of Materials
- PP 57, Establishing Requirements for and Performing Equipment Calibrations, Standardizations, and Checks
- R 47, Reducing Samples of Hot Mix Asphalt to Testing Size
- T 168, Sampling Bituminous Paving Mixtures

2.2. *ASTM Standards*:

- C 670, Preparing Precision and Bias Statements for Test Methods for Construction Materials
- D 4311, Practice for Determining Asphalt Volume Correction to a Base Temperature

3. TERMINOLOGY

3.1. *Definitions*:

3.1.1. *density, as determined by this test method*—the mass of a cubic meter of the material at 25°C (77°F) in SI units, or the mass of a cubic foot of the material at 25°C (77°F) in inch–pound units.

3.1.2. *residual pressure, as employed by this test method*—the pressure in a vacuum vessel when vacuum is applied.

3.1.3. *specific gravity, as determined by this test method*—the ratio of a given mass of material at 25°C (77°F) to the mass of an equal volume of water at the same temperature.

4. SUMMARY OF TEST METHOD

4.1. A weighed sample of oven-dry HMA in the loose condition is placed in a tared vacuum vessel. Sufficient water at a temperature of 25 ± 0.5°C (77 ± 0.9°F) is added to completely submerge the sample. Vacuum is applied for 15 ± 2 min to gradually reduce the residual pressure in the vacuum vessel to 3.7 ± 0.3 kPa (27.5 ± 2.5 mm Hg). At the end of the vacuum period, the vacuum is gradually released. The volume of the HMA sample is obtained either by immersing the vacuum container with the sample into a water bath and determining the mass (Section 9.5.1) or by filling the vacuum container level full of water and determining the mass in air (Section 9.5.2). At the time of weighing, the temperature is measured as well as the mass. From the mass and volume measurements, the specific gravity or density at 25°C (77°F) is calculated. If the temperature employed is different than 25°C (77°F), an appropriate correction is applied.

5. SIGNIFICANCE AND USE

5.1. The theoretical maximum specific gravities and densities of HMA are intrinsic properties whose values are influenced by the composition of the mixtures in terms of types and amounts of aggregates and asphalt materials.

5.1.1. These properties are used to calculate percent air voids in compacted HMA.

5.1.2. These properties provide target values for the compaction of HMA.

5.1.3. These properties are essential when calculating the amount of asphalt binder absorbed by the internal porosity of the individual aggregate particles in HMA.

6. APPARATUS

6.1. Follow the procedures for performing equipment calibrations, standardizations, and checks found in PP 57.

6.2. *Vacuum Container*:

6.2.1. The vacuum containers described must be capable of withstanding the full vacuum applied, and each must be equipped with the fittings and other accessories required by the test procedure being employed. The opening in the container leading to the vacuum pump shall be covered by a piece of 0.075-mm (No. 200) wire mesh to minimize the loss of fine material.

6.2.2. The capacity of the vacuum container should be between 2000 and 10,000 mL and depends on the minimum sample size requirements given in Section 7.2. Avoid using a small sample in a large container.

6.2.3. *Vacuum Bowl*—Either a metal or plastic bowl with a diameter of approximately 180 to 260 mm (7 to 10 in.) and a bowl height of at least 160 mm (6.3 in.) equipped with a transparent cover fitted with a rubber gasket and a connection for the vacuum line.

6.2.4. *Vacuum Flask for Mass Determination in Air Only (Section 9.5.2)*—A thick-walled volumetric glass flask and a rubber stopper with a connection for the vacuum line.

3.1.3. *specific gravity, as determined by this test method*—the ratio of a given mass of material at 25°C (77°F) to the mass of an equal volume of water at the same temperature.

4. SUMMARY OF TEST METHOD

4.1. A weighed sample of oven-dry HMA in the loose condition is placed in a tared vacuum vessel. Sufficient water at a temperature of 25 ± 0.5°C (77 ± 0.9°F) is added to completely submerge the sample. Vacuum is applied for 15 ± 2 min to gradually reduce the residual pressure in the vacuum vessel to 3.7 ± 0.3 kPa (27.5 ± 2.5 mm Hg). At the end of the vacuum period, the vacuum is gradually released. The volume of the HMA sample is obtained either by immersing the vacuum container with the sample into a water bath and determining the mass (Section 9.5.1) or by filling the vacuum container level full of water and determining the mass in air (Section 9.5.2). At the time of weighing, the temperature is measured as well as the mass. From the mass and volume measurements, the specific gravity or density at 25°C (77°F) is calculated. If the temperature employed is different than 25°C (77°F), an appropriate correction is applied.

5. SIGNIFICANCE AND USE

5.1. The theoretical maximum specific gravities and densities of HMA are intrinsic properties whose values are influenced by the composition of the mixtures in terms of types and amounts of aggregates and asphalt materials.

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6.2.2. The capacity of the vacuum container should be between 2000 and 10,000 mL and depends on the minimum sample size requirements given in Section 7.2. Avoid using a small sample in a large container.

6.2.3. *Vacuum Bowl*—Either a metal or plastic bowl with a diameter of approximately 180 to 260 mm (7 to 10 in.) and a bowl height of at least 160 mm (6.3 in.) equipped with a transparent cover fitted with a rubber gasket and a connection for the vacuum line.

6.2.4. *Vacuum Flask for Mass Determination in Air Only (Section 9.5.2)*—A thick-walled volumetric glass flask and a rubber stopper with a connection for the vacuum line.

6.2.5. *Pycnometer for Mass Determination in Air Only*—A glass, metal, or plastic pycnometer.

6.3. *Balance*—A balance conforming to the requirements of AASHTO M 231, Class G 2. The balance shall be standardized at least every 12 months.

6.3.1. For the mass determination-in-water method (Section 9.5.1), the balance shall be equipped with a suitable apparatus and holder to permit determining the mass of the sample while suspended below the balance. The wire suspending the holder shall be the smallest practical size to minimize any possible effects of a variable immersed length.

6.4. *Vacuum Pump or Water Aspirator*—Capable of evacuating air from the vacuum container to a residual pressure of 4.0 kPa (30 mm Hg).

6.4.1. When a vacuum pump is used, a suitable trap of one or more filter flasks, or equivalent, shall be installed between the vacuum vessel and vacuum source to reduce the amount of water vapor entering the vacuum pump.

6.5. *Vacuum Measurement Device*—Residual pressure manometer[1] or vacuum gauge to be connected directly to the vacuum vessel and capable of measuring residual pressure down to 4.0 kPa (30 mm Hg) or less (preferably to zero). The gauge shall be standardized at least annually and be accurate to 0.1 kPa (1 mm Hg.). It shall be connected at the end of the vacuum line using an appropriate tube and either a "T" connector on the top of the vessel or a separate opening (from the vacuum line) in the top of the vessel to attach the hose. To avoid damage, the manometer shall not be situated on top of the vessel.

Note 2—A residual pressure of 4.0 kPa (30 mm Hg) absolute pressure is approximately equivalent to a 97 kPa (730 mm Hg) reading on a vacuum gauge at sea level.

Note 3—Residual pressure in the vacuum vessel, measured in millimeters of mercury, is the difference in the height of mercury in the Torricellian vacuum leg of the manometer and the height of mercury in the other leg of the manometer that is attached to the vacuum vessel.

6.6. *Manometer or Vacuum Gauge*—Suitable for measuring the vacuum being applied at the source of the vacuum. This device shall be connected directly to the vacuum source or be in the vacuum line close to the source. This device is required to check the reading given by the vacuum measurement device attached directly to the vacuum vessel.

Note 4—The Torricellian vacuum leg of the manometer occasionally acquires one or more bubbles of air that introduce error into the residual pressure reading. By the addition of the secondary manometer or vacuum gauge this error can often be quickly detected by the differences between two vacuum measurements.

Note 5—An example of a correct arrangement of the testing equipment is shown in Figure 1. In the figure, the purpose of the train of small filter flasks is to trap water vapor from the vacuum vessel that otherwise would enter the oil in the vacuum pump and decrease the pump's ability to provide adequate vacuum. Insertion of a valve to isolate the line to each vacuum chamber can reduce wear on the bleeder valve atop each chamber and assist in tracing sealing leaks.

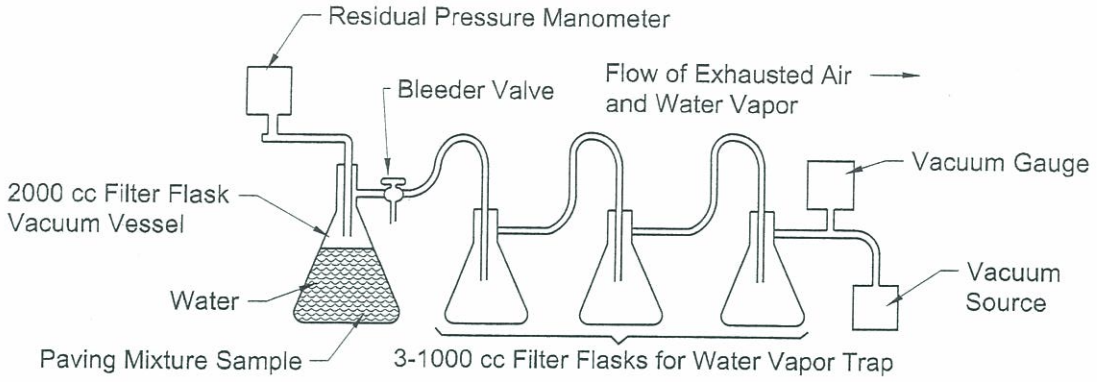


Figure 1—Example of Correct Arrangement of Testing Apparatus

6.7. *Bleeder Valve*—attached to the vacuum train to facilitate adjustment of the vacuum being applied to the vacuum vessel.

6.8. *Thermometric Device (Mass Determination in Air)*—A liquid-in-glass thermometer or other thermometric device, accurate to 0.5°C (1°F), of suitable range with subdivisions of 0.5°C (1°F). The thermometric device shall be standardized at the test temperature at least every 12 months.

6.9. *Water Bath*:

6.9.1. For vacuum bowls, a water bath capable of maintaining a constant temperature between 20 and 30°C (68 and 86°F) is required. (See Appendix X for a method for correcting the theoretical maximum specific gravity to 25°C (77°F) when measurements are made at temperatures other than 25°C (77°F).

6.9.2. *Thermometric Device (Mass Determination in Water)*—A liquid-in-glass thermometer or other thermometric device, accurate to 0.5°C (1°F) shall be used to measure the temperature of the water bath. The thermometric device shall be standardized at least every 12 months.

6.9.3. When using the mass determination-in-water technique (Section 9.5.1), the water bath must be suitable for immersion of the suspended container with its deaerated sample.

6.10. *Drying Oven*—A thermostatically controlled drying oven capable of maintaining a temperature of 135 ± 5°C (275 ± 9°F) or 105 ± 5°C (221 ± 9°F).

6.10.1. *Thermometric Device*—A liquid-in-glass thermometer or other thermometric device accurate to 3°C (5°F) shall be used to measure the temperature of the oven. The thermometric device shall be standardized at least every 12 months.

6.11. *Protective Gloves*—used when handling glass equipment under vacuum.

7. SAMPLING

7.1. Obtain the sample in accordance with T 168.

7.2. The size of the sample shall conform to the following requirements. Samples larger than the capacity of the container may be tested a portion at a time.

Table 1—Minimum Sample Sizes

Size of Largest Particle of Aggregate in Mixture, mm (in.)	Minimum Sample Size, g
50.0 (2)	6000
37.5 (1 1/2)	4000
25.0 (1)	2500
19.0 (3/4)	2000
12.5 (1/2)	1500
9.5 (3/8)	1000
4.75 (No. 4)	500

8. STANDARDIZATION OF FLASKS, BOWLS, AND PYCNOMETERS

8.1. For the mass determination-in-water method (Section 9.5.1), standardize the vacuum bowls for temperature correction by determining the mass of each container when immersed in water over the range of water bath temperatures likely to be encountered in service (Figure 2).

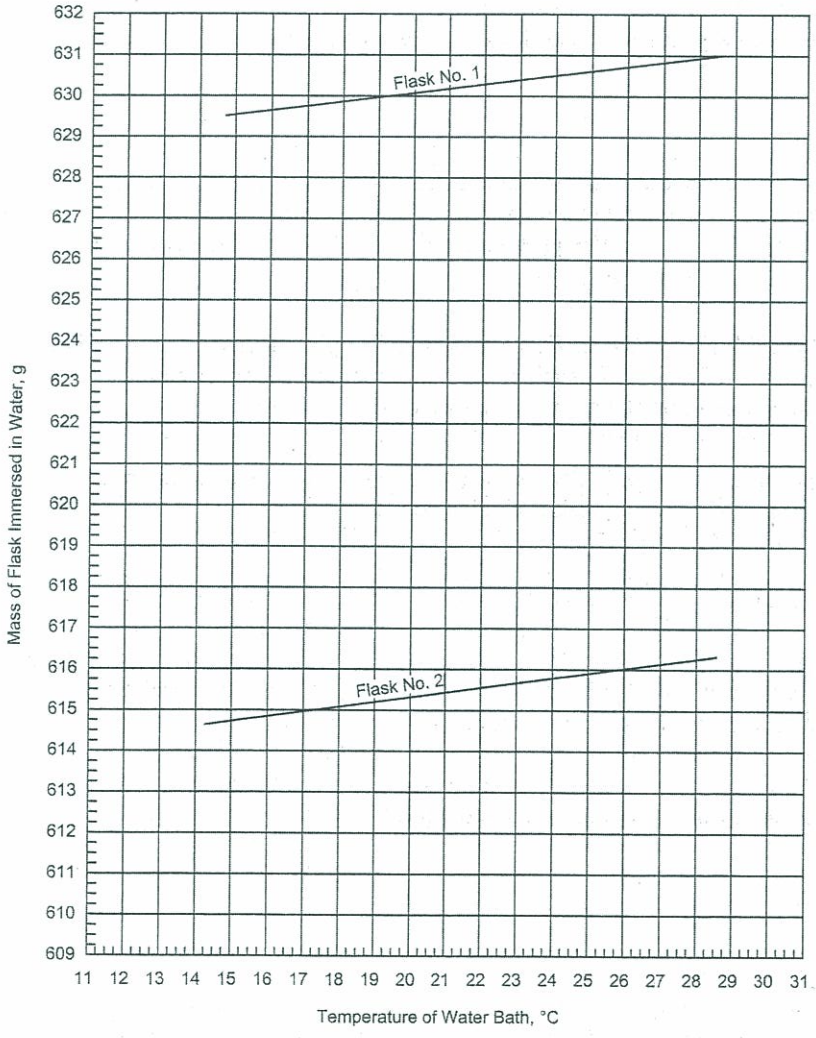


Figure 2—Example Standardization Curve for Volumetric Flask

8.2. For the mass determination-in-air method (Section 9.5.2), standardize the volumetric flasks or pycnometers for temperature correction by determining the mass of the container when filled with water over the range of water bath temperatures likely to be encountered in service (Figure 3). When standardized at 25 ± 0.5°C (77 ± 0.9°F) designate this mass as *D*. Accurate filling may be ensured by the use of a glass cover plate.

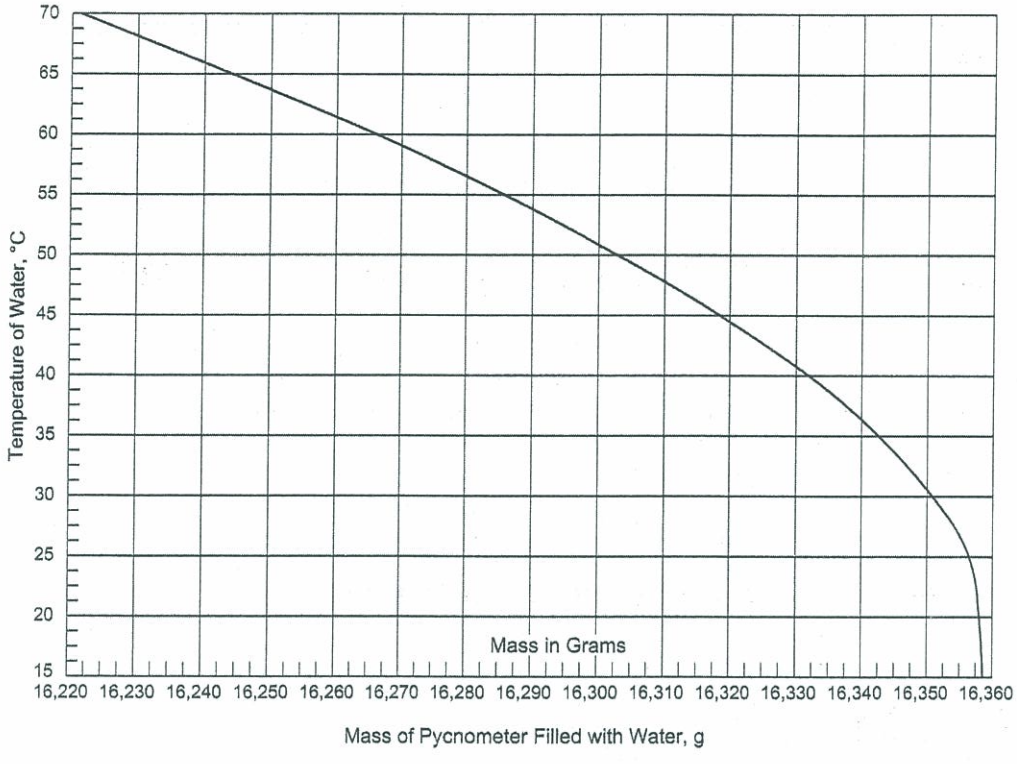


Figure 3—Example Standardization Curve for Pycnometer

8.3. Standardize the large-size plastic pycnometer by accurately determining the mass of water required to fill it over a range of temperature from about 20 to 65°C (70 to 150°F), and construct a standardization curve of mass versus temperature as shown in Figure 3. Care should be taken to follow exactly the same procedure in standardization as in conducting a test.

8.3.1. The following filling procedure may be used for the model with a latched lid and vented stopper. The domed lid is latched in place and the pycnometer nearly filled with water. Leave about 50 mm (2 in.) empty. The release of air bubbles may be facilitated by applying vacuum and by dropping first one side then the other of the pycnometer about 10 mm ($^1/_2$ in.) above a hard, flat surface. This vacuum application and bubble release procedure should take about 10 min so that the temperature equilibrium between the shell and the water approximates that attained when performing a test. The final amount of water is then gently poured in until the level is about halfway up the neck. Any air bubbles caught against the dome that cannot be released by jarring or by swirling the water may be "pricked" or pushed to the surface with a bent wire or other suitable device. Insert the vented stopper using only enough force to just seat the stopper and immediately wipe the excess water off the top.

8.3.2. For the models with a quick-disconnect vacuum line and unlatched lid, the filling procedure is as follows. With the inlet valve closed, apply a vacuum of about 30 kPa (225 mm Hg). Open the inlet valve slowly letting water in until the level reaches 25 mm (1 in.) below the top of the dome and close the valve. Continue applying vacuum and release the bubbles by jarring and rapping the

vessel with a rubber mallet. Slowly open the inlet valve and allow more water in until the water overflows into the aspirator (vacuum) line and then close the valve. This vacuum application and bubble release procedure should take about 10 min so that the temperature equilibrium between the shell and the water approximates that attained when performing a test. Disconnect the vacuum line by pulling it out at the quick-disconnect joint below the gauge.

8.3.3. Wipe the outside of the pycnometer dry, determine the mass of the full pycnometer and measure the water temperature.

Note 6—The shape of the standardization curve is a function of two opposing factors that can be rationally defined. As the temperature is increased, the container itself expands (adding mass—"Pycnometer" line in Figure 4) and the density of the contained water decreases (resulting in loss of mass—"Water" line in Figure 4). These relationships are shown in Figure 4 for a typical large-size pycnometer. The "Water" curve may be constructed by multiplying the volume at 25°C (77°F) by the difference between the density of water at 25°C (77°F), which is 0.9970, and the density of water at the standardization temperature (see Equation 1).

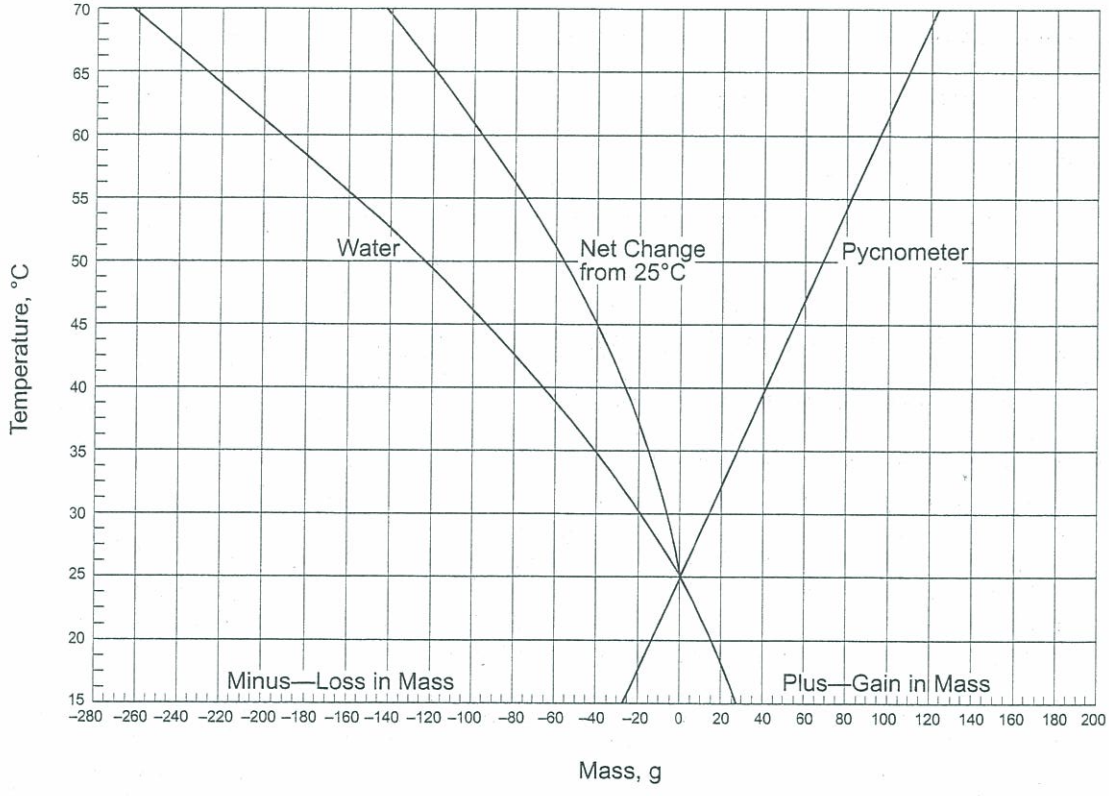


Figure 4—Effect of Change in Density of Water and Volume of Pycnometer with Change in Temperature

$$\text{Difference Due to Water Expansion} = V_{25}(0.9970 - dw)$$

$$\text{Since } V_{25} = W_{25} / 0.9970$$

$$V_{25}(0.9970 - dw) \text{ reduces to } W_{25}\left(1 - \frac{dw}{0.9970}\right) \qquad (1)$$

where:

V_{25} = volume of water to fill a container at 25°C (77°F), cm^3;
W_{25} = mass of water to fill a container at 25°C (77°F), g; and
dw = density of water at the standardization temperature, Mg/m^3.

The rate of change in capacity of the container due to thermal expansion of the pycnometer itself is essentially constant over the temperature range from 20 to 65°C (70 to 150°F). Thus, the "Pycnometer" line in Figure 4 can be drawn through the 0 at 25°C (77°F) point knowing only the slope of the straight line relationship. The slope can be established by averaging at least five standardization mass determinations at some elevated temperature, adding the loss due to water expansion and subtracting the mass at 25°C (77°F), W_{25}, to give the gain in capacity due to expansion of the container. The difference in mass divided by the difference in temperature is the slope of the "Pycnometer" line. For a polycarbonate pycnometer of about 13,500-mL capacity, the slope thus established was 2.75 g/°C (1.53 g/°F). This value is believed to be typical and reasonably constant.

The bending of the standardization curve (Figure 3) due to these offsetting thermal factors thus minimizes experimental error due to temperature effects in the normal working range, 25°C (77°F), for both the volumetric flask and the pycnometer containers. Defining the standardization curve makes it possible to correct for temperature, rather than "bringing the container and sample to temperature" thereby eliminating the cost of a water bath and making it feasible to improve accuracy by testing larger samples and to materially reduce the testing time.

8.4. While standardization of the flask or either pycnometer need to be performed only once, the standardization should be checked occasionally, particularly at 25°C (77°F). The equipment must be kept clean and free from any accumulation that would change the mass if the volume standardization is to remain constant. Care should be taken to use only neutral solvents, especially with plastic containers; glass vessels should not be subjected to high vacuum if they are scratched or damaged.

9. PROCEDURE

9.1. Separate the particles of the HMA sample by hand, taking care to avoid fracturing the aggregate, so that the particles of the fine aggregate portion are not larger than 6.3 mm ($^1/_4$ in.). If an HMA sample is not sufficiently soft to be separated manually, place it in a flat pan, and warm it in an oven until it can be separated as described.

9.2. Samples prepared in a laboratory shall be conditioned and dried in an oven at 135 ± 5°C (275 ± 9°F) for a minimum of 2 h or as appropriate to match the mix design procedure being used. Longer drying time may be necessary for the sample to achieve a constant mass (mass repeats within 0.1 percent). HMA which has not been prepared in a laboratory with oven-dried aggregates shall be dried to a constant mass at a temperature of 105 ± 5°C (221 ± 9°F). This drying and conditioning operation shall be combined with any warming described in Section 9.1.

Note 7—The minimum 2 h time in the oven is specified as the short-term conditioning time for laboratory-prepared specimens. The short-term conditioning at the specified temperature is especially important when absorptive aggregates are used. This short-term conditioning will ensure the computation of realistic values for the amount of asphalt absorbed by the aggregate and void properties of the mix. Plant-produced HMA should not be short-term conditioned since absorption takes place during production.

9.3. Cool the sample to room temperature and place it in a tared and standardized flask, bowl or pycnometer. The sample is to be placed directly into a vacuum container. A container within a container is not to be used. Determine the mass and designate the net mass of the sample as A. Add sufficient water at a temperature of approximately 25°C (77°F) to cover the sample completely.

9.4. Remove air trapped in the sample by applying gradually increased vacuum until the residual pressure manometer reads 3.7 ± 0.3 kPa (27.5 ± 2.5 mm Hg). Maintain this residual pressure for 15 ± 2 min. Agitate the container and contents during the vacuum period either continuously by a

mechanical device, or manually by vigorous shaking at intervals of about 2 min. Glass vessels should be shaken on a resilient surface such as a rubber or plastic mat, and not on a hard surface, so as to avoid excessive impact while under vacuum.

Note 8—The release of entrapped air may be facilitated by the addition of a suitable wetting agent such as Aerosol OT in concentration of 0.001 percent or 0.2 g in 20 L of water. This solution is then diluted by about 20:1 to make a wetting agent of which 5 to 10 mL may be added to the apparatus.

9.5. At the end of the vacuum period, release the vacuum by increasing the pressure at a rate not to exceed 8 kPa (60 mm Hg) per second and proceed with one of the following determinations:

9.5.1. *Mass Determination in Water*—Suspend the container and contents in the water bath and determine the mass after a 10 ± 1 min immersion. Measure the water bath temperature, and if different from 25 ± 1°C (77 ± 2°F), correct the mass to 25°C (77°F) using the standardization temperature adjustment developed in Section 8.1. Designate the mass of the sample in water at 25°C (77°F) as *C*.

Note 9—Instead of using a chart like Figure 2 to establish the mass correction for the temperature of the vacuum vessel submerged by itself in the water bath, this correction can be easily established by rapidly and completely emptying the vacuum container immediately following the final mass determination, and then without delay, determining the mass of the vessel by itself when totally submerged in the water bath.

9.5.2. *Mass Determination in Air*—Fill the flask or any one of the pycnometers with water and adjust the contents to a temperature of 25 ± 1°C (77 ± 2°F). Determine the mass of the container and contents, completely filled, in accordance with Section 8.2 within 10 ± 1 min after completing Section 9.4. Designate this mass as *E*.

Note 10—See Appendix X for correcting the theoretical maximum specific gravity when measurements are made at temperatures other than 25°C (77°F).

10. CALCULATION

10.1. Calculate the theoretical maximum specific gravity of the sample at 25°C (77°F) as follows:

10.1.1. *Mass Determination in Water*:

$$\text{Theoretical Maximum Specific Gravity} = \frac{A}{A - C} \qquad (2)$$

where:

A = mass of the oven-dry sample in air, g; and
C = mass of the water displaced by the sample at 25°C (77°F), g.

10.1.2. *Mass Determination in Air*:

$$\text{Theoretical Maximum Specific Gravity} = \frac{A}{A + D - E} \qquad (3)$$

where:

A = mass of the oven-dry sample in air, g;
D = mass of the container filled with water at 25°C (77°F), g; and
E = mass of the container filled with the sample and water at 25°C (77°F), g.

10.1.3. *Large-Size Plastic Pycnometer Determinations*:

10.1.3.1. If the test temperature is between 22.2 and 26.7°C (72 and 80°F), Equation 3 may be used to calculate specific gravity within a minor amount of error due to thermal effects (0.001 points or less).

10.1.3.2. If the test temperature differs significantly from 25°C (77°F), correct for thermal effects as follows:

$$\text{Specific Gravity} = \frac{A}{(A+F)-(G+H)} \times \frac{dw}{0.9970} \qquad (4)$$

where:

A = mass of the oven-dry sample in air, g;
F = mass of the pycnometer filled with water at the test temperature (Figure 3), g;
G = mass of the pycnometer filled with water and the sample at the test temperature, g;
H = correction for thermal expansion of asphalt (Figure 5), g;
dw = density of water at the test temperature, Curve D in Figure 6, Mg/m^3; and
0.9970 = density of water at 25°C (77°F), Mg/m^3.

The ratio (dw/0.9970) is Curve R in Figure 6.

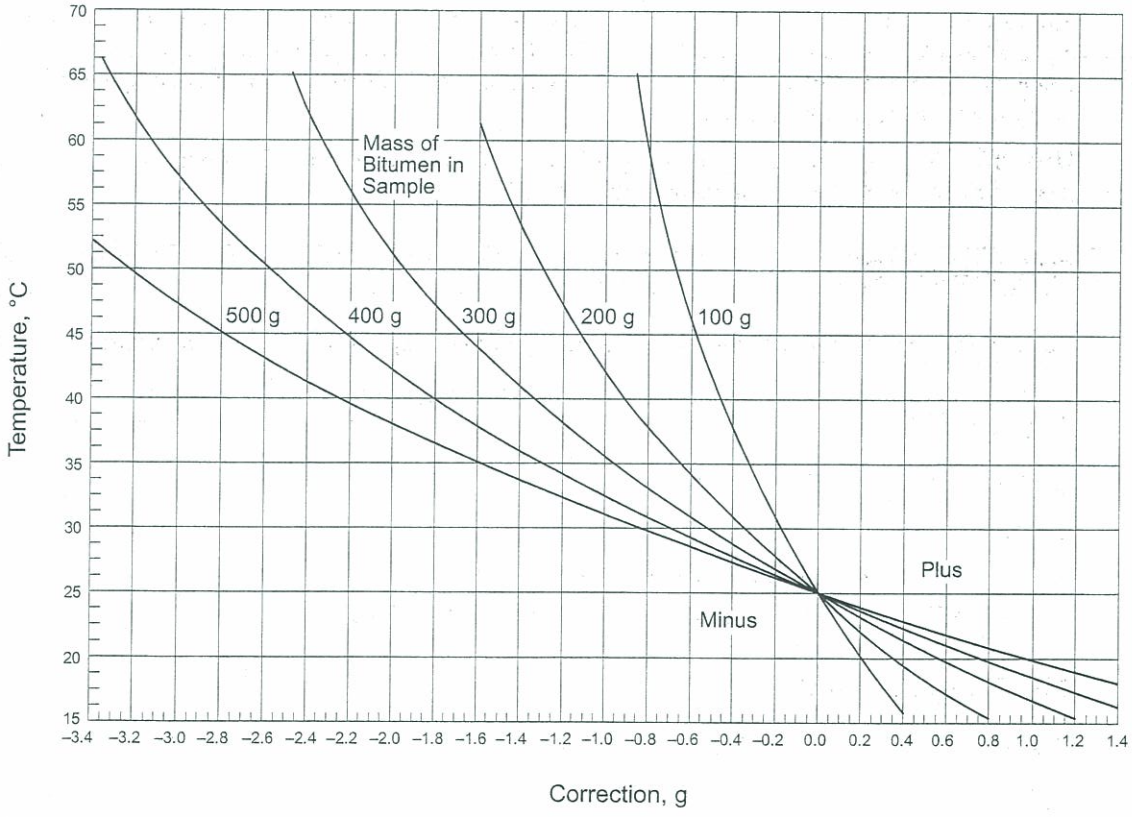


Figure 5—Correction Curves for Expansion of Asphalt, H, in Equation 4

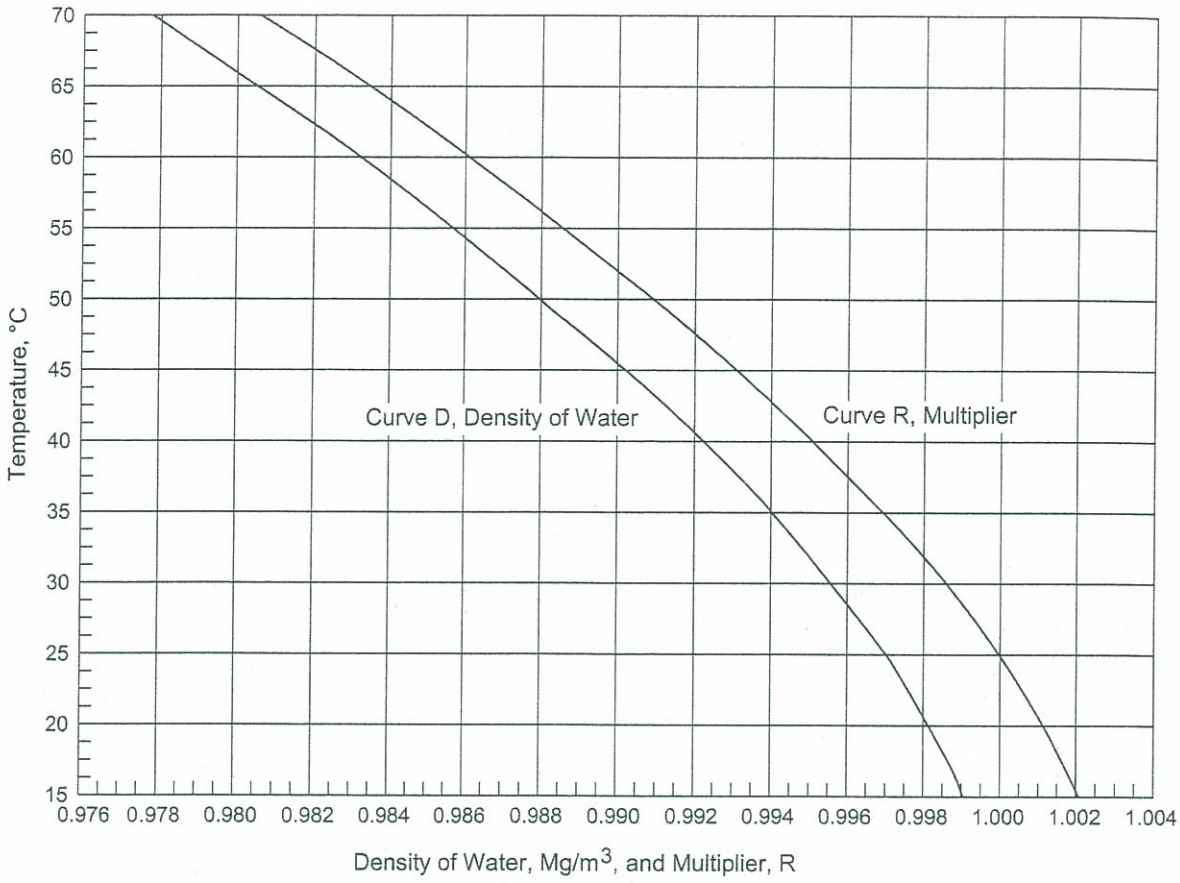


Figure 6—Curves D and R for Equation 4

Note 11—This general procedure for correcting for thermal effects should also be applicable to corresponding measurements made with other suitable containers.

Note 12—When samples are tested a portion at a time, differences between the maximum specific gravities for each portion should be within the precision statements listed in Section 13. If the values are within the precision statements, the specific gravities for each portion shall be averaged. If the values are outside the precision statements, the test shall be performed again.

10.2. *Theoretical maximum density at 25°C (77°F)*:

10.2.1. Calculate the corresponding theoretical maximum density at 25°C (77°F) as follows:

Theoretical maximum density at 25°C (77°F) = theoretical maximum specific gravity × 997.1 kg/m^3 in SI units, or

Theoretical maximum density at 25°C (77°F) = theoretical maximum specific gravity × 62.245 lb/ft^3 in inch–pound units.

where:

The density of water at 25°C (77°F) = 997.1 kg/m^3 in SI units or 62.245 lb/ft^3 in inch–pound units.

11. SUPPLEMENTAL PROCEDURE FOR MIXTURES CONTAINING POROUS AGGREGATE

Note 13—Experiments indicate that this supplemental procedure has an insignificant effect on the test results if the HMA contains individual aggregate with a water absorption below 1.5 percent.

11.1. If the pores of the aggregates are not thoroughly sealed by an asphalt film, they may become saturated with water during the application of vacuum. To determine if this condition has occurred, proceed as follows after completing Section 9.5.1 or 9.5.2. Drain water from the sample. To prevent the loss of fine particles, decant the water through a towel held over the top of the container. Break several large pieces of aggregate and examine the broken surfaces for wetness.

11.2. If the aggregate has absorbed water, spread the sample before an electric fan to remove the surface moisture. Determine the mass at 15 min intervals, and when the loss in mass is less than 0.05 percent for this interval, the sample may be considered to be surface dry. This procedure requires about 2 h and shall be accompanied by intermittent stirring of the sample. Break conglomerations of HMA by hand. Take care to prevent loss of the HMA particles.

11.3. To calculate the specific gravity of the sample, substitute the final surface-dry mass determined in Section 11.2 for A in the denominator of Equation 2 or 3 as appropriate.

12. REPORT

12.1. *Report the following information*:

12.1.1. Specific gravity and density of the HMA to the nearest 0.001 for specific gravity or nearest 1 kg/m^3 (0.1 lb/ft^3) for density as follows: sp gr 25/25°C (77/77°F) or density at 25°C (77°F),

12.1.2. Type of HMA,

12.1.3. Size of the sample,

12.1.4. Number of samples,

12.1.5. Type of container, and

12.1.6. Type of procedure.

13. PRECISION

13.1. Criteria for judging the acceptability of specific gravity test results obtained by this test method are given in the following table:

Table 2—Precision Estimates

Test and Type Index	Standard Deviation (1s)	Acceptable Range of Two Results (d2s)
Test results obtained without use of Section 11[a]		
Single-operator precision	0.0040	0.011
Multilaboratory precision	0.0064	0.019
Test results obtained with use of Section 11 applicable for bowl determination only[b]		
Single-operator precision	0.0064	0.018
Multilaboratory precision	0.0193	0.055

[a] Basis of estimate: 3 replicates, 5 materials, 5 laboratories.

[b] Basis of estimate: 2 replicates, 7 materials, 20 laboratories.

13.2. The figures given in Column 2 are the standard deviations that have been found to be appropriate for the conditions of the test described in Column 1. The figures given in Column 3 are the limits that should not be exceeded by the difference between the results of two properly conducted tests. Multi-laboratory precision has not been verified for 4500-mL or larger pycnometers.

13.3. The values in Column 3 are the acceptable range for two tests. When more than two results are being evaluated, the range given in Column 3 must be increased. Multiply the standard deviation(s) in Column 2 by the multiplier given in Table 1 of ASTM C 670 for the number of actual tests.

Example for three tests: $0.004 \times 3.3 = 0.013$.

Additional guidance and background is given in ASTM C 670.

APPENDIX X

(Nonmandatory Information)

X1. THEORETICAL MAXIMUM SPECIFIC GRAVITY FOR LOOSE HMA

X1.1. *Scope*:

X1.1.1. This appendix has two objectives:

X1.1.1.1. To indicate a method for correcting the theoretical maximum specific gravity to 25°C (77°F) when measurements are made at temperatures other than 25°C (77°F).

X1.1.1.2. To indicate the range of temperature in °C above or below 25°C (77°F) within which no temperature correction is required, because the measured theoretical maximum specific gravity values are shown to be 0.0004 or less away from the value determined at 25°C (77°F).

X1.2. *Indicated Values*:

X1.2.1. The following example values are indicated for the theoretical maximum specific gravity of a loose HMA sample:

X1.2.1.1. Mass of the loose HMA sample = 1251.3 g.

X1.2.1.2. Volume of the loose HMA sample at 25°C (77°F) = 492.77 mL.

X1.2.1.3. Asphalt binder content = 5.0 percent of total mix.

X1.2.1.4. Specific gravity of the asphalt at 25°C (77°F) = 1.029.

X1.2.1.5. Combined bulk specific gravity of the aggregate = 2.714.

X1.2.1.6. Cubical coefficient of expansion of the asphalt binder at 20°C (68°F) = 6.2×10^{-4} mL/mL/°C (ASTM D 4311).

X1.2.1.7. Cubical coefficient of expansion of the aggregate at 20°C (68°F) = 2.2×10^{-5} mL/mL/°C.[2]

X1.3. *Basis of Calculation for One Gram of Loose HMA at 20°C (68°F)*:

X1.3.1. Mass of the asphalt binder = 0.05 g.

X1.3.2. Volume of the asphalt binder = 0.05/1.029 = 0.0486 mL.

X1.3.3. Mass of the aggregate = 0.95 g.

X1.3.4. Volume of the aggregate = 0.95/ 2.714 = 0.3500 mL.

X1.3.5. Volume of the asphalt binder plus aggregate in one gram of loose HMA at 20°C (68°F) = 0.0486 + 0.3500 = 0.3986 mL.

X1.4. *Basis of Calculation for Volume Change of One Gram of Loose HMA for1°C (2°F) from 20°C (68°F):*

X1.4.1. Volume change for the asphalt binder = $6.2 \times 10^{-}4 \times 0.0486 = 0.3013 \times 10^{-4}$ mL = 3.0130×10^{-5} mL.

X1.4.2. Volume change for the aggregate = $2.2 \times 10^{-5} \times 0.3500 = 0.77 \times 10^{-5}$ mL.

X1.4.3. Volume change for of one gram of loose HMA for 1°C (2°F) change in temperature from 20°C (68°F) = $3.0130 \times 10^{-5} + 0.7700 \times 10^{-5} = 3.7830 \times 10^{-5}$ mL.

X1.5. *Volume Correction*:

X1.5.1. For a difference in water temperature of 1°C (2°F) above or below 20°C (68°F), a correction to the volume of water displaced by one gram of loose HMA can be made by the following equation:

$$\text{Correction} = \Delta T \times K_T \times V_T \text{ mL} \qquad (X1.1)$$

where:

ΔT = 1°C (2°F),

K_T = volume change of 1 g of loose HMA for a 1°C (2°F) change in temperature above or below 20°C (68°F) = 3.7830×10^{-5} mL, and

V_T = volume of water for a corresponding 1251.3-g mass of loose HMA at a test temperature of 20°C (68°F) = 492.77 mL.

Substituting these values into the equation gives the following:

Correction = $1 \times 3.7830 \times 10^{-5} \times 492.77 = 0.01864$ mL/g at 20°C (68°F).

X1.6. Table X1.1 illustrates an example of the influence of temperature corrections. For a measured volume and a given mass of HMA tested at specific temperatures, this table relates these influences to the specific gravity of the HMA.

Table X1.1—Influence of Temperature Corrections to a Measured Volume at 20°C of a Given Mass of Loose Paving Mixture, to Provide the Required Theoretical Maximum Specific Gravity at 25°C

Temperature, °C	Volume of HMA at 20°C (68°F), mL	Volume Correction for Temp Change	Corrected Volume of HMA at 20°C (68°F), mL	Mass of HMA, g	Specific Gravity of HMA
1	*2*	*3*	*4 = 2 + 3*	*5*	*6 = 5/4*
31	492.77	0.2046	492.975	1251.3	2.5383
30[a]	492.77	0.1860	492.956	1251.3	2.5384
29[a]	492.77	0.1674	492.937	1251.3	2.5385
28[a]	492.77	0.1488	492.919	1251.3	2.5386
27[a]	492.77	0.1302	492.900	1251.3	2.5386
26[a]	492.77	0.1116	492.882	1251.3	2.5387
25[a]	492.77	0.0930	492.863	1251.3	2.5388
24[a]	492.77	0.0744	492.844	1251.3	2.5389
23[a]	492.77	0.0558	492.826	1251.3	2.5390
22[a]	492.77	0.0372	492.807	1251.3	2.5391
21[a]	492.77	0.0186	492.789	1251.3	2.5392
20	492.77	0.0000	492.772	1251.3	2.5393
19	492.77	–0.0186	492.751	1251.3	2.5394

[a] Range less than 0.0005.

Notes: Strictly speaking, the above table shows that the specific gravity for this particular mix, as measured at 20°C (68°F), just fails to meet the corrected theoretical maximum specific gravity at 25°C (77°F), 2.5388 versus 2.5393, that is, by 0.0005, and that a temperature correction would be required. If the measurement for volume had been made at 21°C (70°F), the table indicates that no temperature correction would have been necessary, because the measurement at 21°C (70°F) would have satisfied the theoretical maximum specific gravity at 25°C (77°F), 2.5388 versus 2.5392, a difference of less than 0.0005.

[1] Sargent Welch, 39745 Gauge-Vacuum, Mercury Prefilled (or equivalent).
[2] Krebs and Walker, *Highway Materials*, McGraw-Hill, Inc., 1971, *p.* 274.

Designation: C127 – 07

Standard Test Method for Density, Relative Density (Specific Gravity), and Absorption of Coarse Aggregate[1]

This standard is issued under the fixed designation C127; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

This standard has been approved for use by agencies of the Department of Defense.

Scope*

1.1 This test method covers the determination of the average nsity of a quantity of coarse aggregate particles (not includ- g the volume of voids between the particles), the relative nsity (specific gravity), and the absorption of the coarse gregate. Depending on the procedure used, the density g/m^3(lb/ft^3)) is expressed as oven-dry (OD), saturated- rface-dry (SSD), or as apparent density. Likewise, relative nsity (specific gravity), a dimensionless quantity, is ex- essed as OD, SSD, or as apparent relative density (apparent ecific gravity). The OD density and OD relative density are termined after drying the aggregate. The SSD density, SSD ative density, and absorption are determined after soaking e aggregate in water for a prescribed duration.

1.2 This test method is used to determine the density of the sentially solid portion of a large number of aggregate rticles and provides an average value representing the mple. Distinction is made between the density of aggregate rticles as determined by this test method, and the bulk nsity of aggregates as determined by Test Method C29/ 9M, which includes the volume of voids between the rticles of aggregates.

1.3 This test method is not intended to be used with htweight aggregates.

1.4 The values stated in SI units are to be regarded as the ndard for conducting the tests. The test results for density ll be reported in either SI units or inch-pound units, as propriate for the use to be made of the results.

1.5 The text of this test method references notes and otnotes which provide explanatory material. These notes and otnotes (excluding those in tables and figures) shall not be nsidered as requirements of this test method.

1.6 *This standard does not purport to address all of the fety concerns, if any, associated with its use. It is the sponsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*

2. Referenced Documents

2.1 *ASTM Standards:*[2]

C29/C29M Test Method for Bulk Density ("Unit Weight") and Voids in Aggregate

C125 Terminology Relating to Concrete and Concrete Aggregates

C128 Test Method for Density, Relative Density (Specific Gravity), and Absorption of Fine Aggregate

C136 Test Method for Sieve Analysis of Fine and Coarse Aggregates

C566 Test Method for Total Evaporable Moisture Content of Aggregate by Drying

C670 Practice for Preparing Precision and Bias Statements for Test Methods for Construction Materials

C702 Practice for Reducing Samples of Aggregate to Testing Size

D75 Practice for Sampling Aggregates

D448 Classification for Sizes of Aggregate for Road and Bridge Construction

E11 Specification for Woven Wire Test Sieve Cloth and Test Sieves

2.2 *AASHTO Standard:*

AASHTO No. T 85 Specific Gravity and Absorption of Coarse Aggregate[3]

3. Terminology

3.1 *Definitions:*

3.1.1 *absorption, n*—the increase in mass of aggregate due to water penetration into the pores of the particles during a prescribed period of time, but not including water adhering to the outside surface of the particles, expressed as a percentage of the dry mass.

This test method is under the jurisdiction of ASTM Committee C09 on crete and Concrete Aggregates and is the direct responsibility of Subcommittee .20 on Normal Weight Aggregates.

Current edition approved Aug. 1, 2007. Published September 2007. Originally roved in 1936. Last previous edition approved in 2004 as C127 – 04. DOI: 520/C0127-07.

[2] For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

[3] Available from American Association of State Highway and Transportation Officials (AASHTO), 444 N. Capitol St., NW, Suite 249, Washington, DC 20001, http://www.transportation.org.

***A Summary of Changes section appears at the end of this standard.**

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3.1.2 *oven-dry (OD), adj—related to aggregate particles,* the condition in which the aggregates have been dried by heating in an oven at 110 ± 5 °C for sufficient time to reach a constant mass.

3.1.3 *saturated-surface-dry (SSD), adj—related to aggregate particles,* the condition in which the permeable pores of aggregate particle are filled with water to the extent achieved by submerging in water for the prescribed period of time, but without free water on the surface of the particles.

3.1.4 *density, n*—the mass per unit volume of a material, expressed as kilograms per cubic metre (pounds per cubic foot).

3.1.4.1 *density (OD), n*—the mass of oven dry aggregate per unit volume of aggregate particles, including the volume of permeable and impermeable pores within the particles, but not including the voids between the particles.

3.1.4.2 *density (SSD), n*—the mass of saturated-surface-dry aggregate per unit volume of the aggregate particles, including the volume of impermeable pores and permeable, water-filled pores within the particles, but not including the voids between the particles.

3.1.4.3 *apparent density, n*—the mass per unit volume of the impermeable portion of the aggregate particles.

3.1.5 *relative density (specific gravity), n*—the ratio of the density of a material to the density of distilled water at a stated temperature; the values are dimensionless.

3.1.5.1 *relative density (specific gravity) (OD), n*—the ratio of the density (OD) of the aggregate to the density of distilled water at a stated temperature.

3.1.5.2 *relative density (specific gravity) (SSD), n*—the ratio of the density (SSD) of the aggregate to the density of distilled water at a stated temperature.

3.1.5.3 *apparent relative density (apparent specific gravity), n*—the ratio of the apparent density of aggregate to the density of distilled water at a stated temperature.

3.1.6 For definitions of other terms related to aggregates, see Terminology C125.

4. Summary of Test Method

4.1 A sample of aggregate is immersed in water for 24 ± 4 h to essentially fill the pores. It is then removed from the water, the water dried from the surface of the particles, and the mass determined. Subsequently, the volume of the sample is determined by the displacement of water method. Finally, the sample is oven-dried and the mass determined. Using the mass values thus obtained and formulas in this test method, it is possible to calculate density, relative density (specific gravity), and absorption.

5. Significance and Use

5.1 Relative density (specific gravity) is the characteristic generally used for calculation of the volume occupied by the aggregate in various mixtures containing aggregate, including portland cement concrete, bituminous concrete, and other mixtures that are proportioned or analyzed on an absolute volume basis. Relative density (specific gravity) is also used in the computation of voids in aggregate in Test Method C29/C29M. Relative density (specific gravity) (SSD) is used if the aggregate is wet, that is, if its absorption has been satisfied. Conversely, the relative density (specific gravity) (OD) is used for computations when the aggregate is dry or assumed to be dry.

5.2 Apparent density and apparent relative density (apparent specific gravity) pertain to the solid material making up the constituent particles not including the pore space within the particles which is accessible to water.

5.3 Absorption values are used to calculate the change in the mass of an aggregate due to water absorbed in the pore spaces within the constituent particles, compared to the dry condition, when it is deemed that the aggregate has been in contact with water long enough to satisfy most of the absorption potential. The laboratory standard for absorption is that obtained after submerging dry aggregate for a prescribed period of time. Aggregates mined from below the water table commonly have a moisture content greater than the absorption determined by this test method, if used without opportunity to dry prior to use. Conversely, some aggregates which have not been continuously maintained in a moist condition until used are likely to contain an amount of absorbed moisture less than the 24-h soaked condition. For an aggregate that has been in contact with water and that has free moisture on the particle surfaces, the percentage of free moisture is determined by deducting the absorption from the total moisture content determined by Test Method C566.

5.4 The general procedures described in this test method are suitable for determining the absorption of aggregates that have had conditioning other than the 24-h soak, such as boiling water or vacuum saturation. The values obtained for absorption by other test methods will be different than the values obtained by the prescribed soaking, as will the relative density (specific gravity) (SSD).

5.5 The pores in lightweight aggregates are not necessarily filled with water after immersion for 24 h. In fact, the absorption potential for many such aggregates is not satisfied after several days' immersion in water. Therefore, this test method is not intended for use with lightweight aggregate.

6. Apparatus

6.1 *Balance*—A device for determining mass that is sensitive, readable, and accurate to 0.05 % of the sample mass at any point within the range used for this test, or 0.5 g, whichever is greater. The balance shall be equipped with suitable apparatus for suspending the sample container in water from the center of the platform or pan of the balance.

6.2 *Sample Container*—A wire basket of 3.35 mm (No. 6) or finer mesh, or a bucket of approximately equal breadth and height, with a capacity of 4 to 7 L for 37.5-mm (1½-in.) nominal maximum size aggregate or smaller, and a larger container as needed for testing larger maximum size aggregate. The container shall be constructed so as to prevent trapping air when the container is submerged.

6.3 *Water Tank*—A watertight tank into which the sample container is placed while suspended below the balance.

6.4 *Sieves*—A 4.75-mm (No. 4) sieve or other sizes as needed (see 7.2-7.4), conforming to Specification E11.

6.5 *Oven*—An oven of sufficient size, capable of maintaining a uniform temperature of 110 ± 5 °C (230 ± 9 °F).

7. Sampling

7.1 Sample the aggregate in accordance with Practice D75.

7.2 Thoroughly mix the sample of aggregate and reduce it to the approximate quantity needed using the applicable procedures in Practice C702. Reject all material passing a 4.75-mm (No. 4) sieve by dry sieving and thoroughly washing to remove dust or other coatings from the surface. If the coarse aggregate contains a substantial quantity of material finer than the 4.75-mm sieve (such as for Size No. 8 and 9 aggregates in Classification D448), use the 2.36-mm (No. 8) sieve in place of the 4.75-mm sieve. Alternatively, separate the material finer than the 4.75-mm sieve and test the finer material according to Test Method C128.

NOTE 1—If aggregates smaller than 4.75 mm (No. 4) are used in the sample, check to ensure that the size of the openings in the sample container is smaller than the minimum size aggregate.

7.3 The minimum mass of test sample to be used is given as follows. Testing the coarse aggregate in several size fractions is permitted. If the sample contains more than 15 % retained on the 37.5-mm (1½-in.) sieve, test the material larger than 37.5 mm in one or more size fractions separately from the smaller size fractions. When an aggregate is tested in separate size fractions, the minimum mass of test sample for each fraction shall be the difference between the masses prescribed for the maximum and minimum sizes of the fraction.

Nominal Maximum Size, mm (in.)	Minimum Mass of Test Sample, kg (lb)
12.5 (½) or less	2 (4.4)
19.0 (¾)	3 (6.6)
25.0 (1)	4 (8.8)
37.5 (1½)	5 (11)
50 (2)	8 (18)
63 (2½)	12 (26)
75 (3)	18 (40)
90 (3½)	25 (55)
100 (4)	40 (88)
125 (5)	75 (165)

7.4 If the sample is tested in two or more size fractions, determine the grading of the sample in accordance with Test Method C136, including the sieves used for separating the size fractions for the determinations in this method. In calculating the percentage of material in each size fraction, ignore the quantity of material finer than the 4.75-mm (No. 4) sieve (or 2.36-mm (No. 8) sieve when that sieve is used in accordance with 7.2).

NOTE 2—When testing coarse aggregate of large nominal maximum size requiring large test samples, it may be more convenient to perform the test on two or more subsamples, and the values obtained combined for the computations described in Section 9.

8. Procedure

8.1 Dry the test sample in the oven to constant mass at a temperature of 110 ± 5 °C, cool in air at room temperature for 1 to 3 h for test samples of 37.5-mm (1½-in.) nominal maximum size, or longer for larger sizes until the aggregate has cooled to a temperature that is comfortable to handle (approximately 50 °C). Subsequently immerse the aggregate in water at room temperature for a period of 24 ± 4 h.

8.2 Where the absorption and relative density (specific gravity) values are to be used in proportioning concrete mixtures in which the aggregates will be in their naturally moist condition, the requirement in 8.1 for initial drying is optional, and, if the surfaces of the particles in the sample have been kept continuously wet until tested, the requirement in 8.1 for 24 ± 4 h soaking is also optional.

NOTE 3—Values for absorption and relative density (specific gravity) (SSD) may be significantly higher for aggregate not oven dried before soaking than for the same aggregate treated in accordance with 8.1. This is especially true of particles larger than 75 mm since the water may not be able to penetrate the pores to the center of the particle in the prescribed soaking period.

8.3 Remove the test sample from the water and roll it in a large absorbent cloth until all visible films of water are removed. Wipe the larger particles individually. A moving stream of air is permitted to assist in the drying operation. Take care to avoid evaporation of water from aggregate pores during the surface-drying operation. Determine the mass of the test sample in the saturated surface-dry condition. Record this and all subsequent masses to the nearest 0.5 g or 0.05 % of the sample mass, whichever is greater.

8.4 After determining the mass in air, immediately place the saturated-surface-dry test sample in the sample container and determine its apparent mass in water at 23 ± 2.0 °C. Take care to remove all entrapped air before determining its mass by shaking the container while immersed.

NOTE 4—The difference between the mass in air and the mass when the sample is submerged in water equals the mass of water displaced by the sample.

NOTE 5—The container should be immersed to a depth sufficient to cover it and the test sample while determining the apparent mass in water. Wire suspending the container should be of the smallest practical size to minimize any possible effects of a variable immersed length.

8.5 Dry the test sample in the oven to constant mass at a temperature of 110 ± 5 °C, cool in air at room temperature 1 to 3 h, or until the aggregate has cooled to a temperature that is comfortable to handle (approximately 50 °C), and determine the mass.

9. Calculations

9.1 *Relative Density (Specific Gravity)*:

9.1.1 *Relative Density (Specific Gravity) (OD)*—Calculate the relative density (specific gravity) on the basis of oven-dry aggregate as follows:

$$\text{Relative density (specific gravity) (OD)} = A/(B - C) \quad (1)$$

where:

A = mass of oven-dry test sample in air, g,
B = mass of saturated-surface-dry test sample in air, g, and
C = apparent mass of saturated test sample in water, g.

9.1.2 *Relative Density (Specific Gravity) (SSD)*—Calculate the relative density (specific gravity) on the basis of saturated-surface-dry aggregate as follows:

$$\text{Relative density (specific gravity) (SSD)} = B/(B - C) \quad (2)$$

9.1.3 *Apparent Relative Density (Apparent Specific Gravity)*—Calculate the apparent relative density (apparent specific gravity) as follows:

$$\text{Apparent relative density (apparent specific gravity)} = A/(A - C)$$

9.2 *Density:*

9.2.1 *Density (OD)*—Calculate the density on the basis of oven-dry aggregate as follows:

$$\text{Density (OD), kg/m}^3, = 997.5\ A/(B - C) \quad (4)$$

$$\text{Density (OD), lb/ft}^3, = 62.27\ A/(B - C) \quad (5)$$

NOTE 6—The constant values used in the calculations in 9.2.1-9.2.3 (997.5 kg/m^3 and 62.27 lb/ft^3) are the density of water at 23 °C.

9.2.2 *Density (SSD)*—Calculate the density on the basis of saturated-surface-dry aggregate as follows:

$$\text{Density (SSD), kg/m}^3, = 997.5\ B/(B - C) \quad (6)$$

$$\text{Density (SSD), lb/ft}^3, = 62.27\ B/(B - C) \quad (7)$$

9.2.3 *Apparent Density*—Calculate the apparent density as follows:

$$\text{Apparent density, kg/m}^3 = 997.5\ A/(A - C) \quad (8)$$

$$\text{Apparent density, lb/ft}^3 = 62.27\ A/(A - C) \quad (9)$$

9.3 *Average Density and Relative Density (Specific Gravity) Values*—When the sample is tested in separate size fractions, compute the average values for density or relative density (specific gravity) of the size fraction computed in accordance with 9.1 or 9.2 using the following equation:

$$G = \frac{1}{\frac{P_1}{100\,G_1} + \frac{P_2}{100\,G_2} + \cdots \frac{P_n}{100\,G_n}} \text{ (see AppendixX1)} \quad (10)$$

where:

G = average density or relative density (specific gravity). All forms of expression of density or relative density (specific gravity) can be averaged in this manner,

$G_1, G_2 \ldots G_n$ = appropriate average density or relative density (specific gravity) values for each size fraction depending on the type of density or relative density (specific gravity) being averaged, and

$P_1, P_2, \ldots P_n$ = mass percentages of each size fraction present in the original sample (not including finer material—see 7.4).

9.4 *Absorption*—Calculate the percentage of absorption, as follows:

$$\text{Absorption, \%} = [(B - A)/A] \times 100 \quad (11)$$

NOTE 7—Some authorities recommend using the density of water at 4 °C (1000 kg/m^3 or 1.000 Mg/m^3 or 62.43 lb/ft ^{3}) as being sufficiently accurate.

9.5 *Average Absorption Value*—When the sample is tested in separate size fractions, the average absorption value is the average of the values as computed in 9.4, weighted in proportion to the mass percentages of each size fraction present in the original sample (not including finer material—see 7.4) as follows:

$$A = (P_1A_1/100) + (P_2A_2/100) + \ldots (P_nA_n/100) \quad (12)$$

where:

A = average absorption, %,

$A_1, A_2 \ldots A_n$ = absorption percentages for each size fraction, and

$P_1, P_2, \ldots P_n$ = mass percentages of each size fraction present in the original sample.

10. Report

10.1 Report density results to the nearest 10 kg/m^3, or 0.5 lb/ft^3, relative density (specific gravity) results to the nearest 0.01, and indicate the basis for density or relative density (specific gravity), as either (OD), (SSD), or apparent.

10.2 Report the absorption result to the nearest 0.1 %.

10.3 If the density, relative density (specific gravity) and absorption values were determined without first drying the aggregate, as permitted in 8.2, note that fact in the report.

11. Precision and Bias

11.1 The estimates of precision of this test method listed in Table 1 are based on results from the AASHTO Materials Reference Laboratory Proficiency Sample Program, with testing conducted by this test method and AASHTO Method T 85. The significant difference between the methods is that Test Method C127 requires a saturation period of 24 ± 4 h, while AASHTO Method T 85 requires a saturation period of 15 h minimum. This difference has been found to have an insignificant effect on the precision indices. The data are based on the analyses of more than 100 paired test results from 40 to 100 laboratories. The precision estimates for density were calculated from values determined for relative density (specific gravity), using the density of water at 23 °C for the conversion.

11.2 *Bias*—Since there is no accepted reference material for determining the bias for the procedure in this test method, no statement on bias is being made.

TABLE 1 Precision

	Standard Deviation (1s)[A]	Acceptable Range of Two Results (d2s)[A]
Single-Operator Precision:		
Density (OD), kg/m^3	9	25
Density (SSD), kg/m^3	7	20
Apparent density, kg/m^3	7	20
Relative density (specific gravity) (OD)	0.009	0.025
Relative density (specific gravity) (SSD)	0.007	0.020
Apparent relative density (apparent specific gravity)	0.007	0.020
Multilaboratory Precision:		
Density (OD), kg/m^3	13	38
Density (SSD), kg/m^3	11	32
Apparent density, kg/m^3	11	32
Relative density (specific gravity) (OD)	0.013	0.038
Relative density (specific gravity) (SSD)	0.011	0.032
Apparent relative density (apparent specific gravity)	0.011	0.032

[A] These numbers represent, respectively, the (1s) and (d2s) limits as described in Practice C670. The precision estimates were obtained from the analysis of combined AASHTO Materials Reference Laboratory proficiency sample data from laboratories using 15 h minimum saturation times and other laboratories using 24 ± 4 h saturation times. Testing was performed on normal-weight aggregates, and started with aggregates in the oven-dry condition.

12. Keywords

12.1 absorption; aggregate; apparent density; apparent relative density; coarse aggregate; density; relative density; specific gravity

APPENDIXES

(Nonmandatory Information)

X1. DEVELOPMENT OF EQUATIONS

X1.1 The derivation of the equation is from the following simplified cases using two solids. Solid 1 has a mass M_1 in grams and a volume V_1 in millilitres; its relative density (specific gravity) (G_1) is therefore M_1/V_1. Solid 2 has a mass M_2 and volume V_2, and $G_2 = M_2/V_2$. If the two solids are considered together, the relative density (specific gravity) of the combination is the total mass in grams divided by the total volume in millilitres:

$$G = (M_1 + M_2) / (V_1 + V_2) \quad \text{(X1.1)}$$

Manipulation of this equation yields the following:

$$G = \frac{1}{\frac{V_1 + V_2}{M_1 + M_2}} = \frac{1}{\frac{V_1}{M_1 + M_2} + \frac{V_2}{M_1 + M_2}} \quad \text{(X1.2)}$$

$$G = \frac{1}{\frac{M_1}{M_1 + M_2}\left(\frac{V_1}{M_1}\right) + \frac{M_2}{M_1 + M_2}\left(\frac{V_2}{M_2}\right)} \quad \text{(X1.3)}$$

However, the mass fractions of the two solids are:

$$M_1/(M_1 + M_2) = P_1/100 \text{ and } M_2/(M_1 + M_2) = P_2/100 \quad \text{(X1.4)}$$

and,

$$1/G_1 = V_1/M_1 \text{ and } 1/G_2 = V_2/M_2 \quad \text{(X1.5)}$$

Therefore,

$$G = \frac{1}{\frac{P_1}{100}\frac{1}{G_1} + \frac{P_2}{100}\frac{1}{G_2}} \quad \text{(X1.6)}$$

An example of the computation is given in Table X1.1.

TABLE X1.1 Example of Calculation of Weighted Values of Relative Density (Specific Gravity) and Absorption for a Coarse Aggregate Tested in Separate Sizes

Size Fraction, mm (in.)	% in Original Sample	Sample Mass Used in Test, g	Relative Density (Specific Gravity) (SSD)	Absorption, %
4.75 to 12.5 (No. 4 to ½)	44	2213.0	2.72	0.4
12.5 to 37.5 (½ to 1½)	35	5462.5	2.56	2.5
37.5 to 63 (1½ to 2½)	21	12593.0	2.54	3.0

Average Relative Density (Specific Gravity) (SSD)

$$G_{SSD} = \frac{1}{\frac{0.44}{2.72} + \frac{0.35}{2.56} + \frac{0.21}{2.54}} = 2.62$$

Average Absorption

$$A = (0.44)\,(0.4) + (0.35)\,(2.5) + (0.21)\,(3.0) = 1.7\ \%$$

X2. INTERRELATIONSHIPS BETWEEN RELATIVE DENSITIES (SPECIFIC GRAVITIES) AND ABSORPTION AS DEFINED IN TEST METHODS C127 AND C128

X2.1 Where:

S_d = relative density (specific gravity) (OD),
S_s = relative density (specific gravity) (SSD),
S_a = apparent relative density (apparent specific gravity), and
A = absorption in %.

X2.2 Calculate the values of each as follows:

$$S_s = (1 + A/100)S_d \quad \text{(X2.1)}$$

$$S_a = \frac{1}{\frac{1}{S_d} - \frac{A}{100}} = \frac{S_d}{1 - \frac{AS_d}{100}} \quad \text{(X2.2)}$$

$$S_a = \frac{1}{\frac{1 + A/100}{S_s} - \frac{A}{100}} = \frac{S_s}{1 - \left[\frac{A}{100}(S_s - 1)\right]} \quad \text{(X2.3)}$$

$$A = \left(\frac{S_s}{S_d} - 1\right) 100 \quad \text{(X2.4)}$$

$$A = \left(\frac{S_a - S_s}{S_a (S_s - 1)}\right) 100 \quad \text{(X2.5)}$$

SUMMARY OF CHANGES

Committee C09 has identified the location of selected changes to this test method since the last issue, C127 – 04, that may impact the use of this test method. (Approved August 1, 2007)

(*1*) Revised 3.1.4.2.

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Designation: C128 – 07a

Standard Test Method for Density, Relative Density (Specific Gravity), and Absorption of Fine Aggregate[1]

This standard is issued under the fixed designation C128; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

This standard has been approved for use by agencies of the Department of Defense.

1. Scope*

1.1 This test method covers the determination of the average density of a quantity of fine aggregate particles (not including the volume of voids between the particles), the relative density (specific gravity), and the absorption of the fine aggregate. Depending on the procedure used, the density, in kg/m^3(lb/ft^3) is expressed as oven-dry (OD), saturated-surface-dry (SSD), or as apparent density. Likewise, relative density (specific gravity), a dimensionless quality, is expressed as OD, SSD, or as apparent relative density (apparent specific gravity). The OD density and OD relative density are determined after drying the aggregate. The SSD density, SSD relative density, and absorption are determined after soaking the aggregate in water for a prescribed duration.

1.2 This test method is used to determine the density of the essentially solid portion of a large number of aggregate particles and provides an average value representing the sample. Distinction is made between the density of aggregate particles as determined by this test method, and the bulk density of aggregates as determined by Test Method C29/C29M, which includes the volume of voids between the particles of aggregates.

1.3 This test method is not intended to be used for lightweight aggregates.

1.4 The values stated in SI units are to be regarded as the standard for conducting the tests. The test results for density shall be reported in either SI units or inch-pound units, as appropriate for the use to be made of the results.

1.5 The text of this test method references notes and footnotes which provide explanatory material. These notes and footnotes (excluding those in tables and figures) shall not be considered as requirements of this test method.

1.6 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*

2. Referenced Documents

2.1 *ASTM Standards:*[2]

C29/C29M Test Method for Bulk Density ("Unit Weight") and Voids in Aggregate

C70 Test Method for Surface Moisture in Fine Aggregate

C117 Test Method for Materials Finer than 75-μm (No. 200) Sieve in Mineral Aggregates by Washing

C125 Terminology Relating to Concrete and Concrete Aggregates

C127 Test Method for Density, Relative Density (Specific Gravity), and Absorption of Coarse Aggregate

C188 Test Method for Density of Hydraulic Cement

C566 Test Method for Total Evaporable Moisture Content of Aggregate by Drying

C670 Practice for Preparing Precision and Bias Statements for Test Methods for Construction Materials

C702 Practice for Reducing Samples of Aggregate to Testing Size

D75 Practice for Sampling Aggregates

D854 Test Methods for Specific Gravity of Soil Solids by Water Pycnometer

2.2 *AASHTO Standard:*

AASHTO No. T 84 Specific Gravity and Absorption of Fine Aggregates[3]

3. Terminology

3.1 *Definitions:*

3.1.1 *absorption, n*—the increase in mass of aggregate due to water penetrating into the pores of the particles, during a prescribed period of time but not including water adhering to the outside surface of the particles, expressed as percentage of the dry mass.

[1] This test method is under the jurisdiction of ASTM Committee C09 on Concrete and Concrete Aggregates and is the direct responsibility of Subcommittee C09.20 on Normal Weight Aggregates.

Current edition approved Aug. 1, 2007. Published September 2007. Originally approved in 1936. Last previous edition approved in 2007 as C128–07. DOI: 10.1520/C0128-07A.

[2] For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

[3] Available from American Association of State Highway and Transportation Officials (AASHTO), 444 N. Capitol St., NW, Suite 249, Washington, DC 20001, http://www.transportation.org.

***A Summary of Changes section appears at the end of this standard.**

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3.1.2 *density, n*—the mass per unit volume of a material, expressed as kilograms per cubic metre (pounds per cubic foot).

3.1.2.1 *density (OD), n*—the mass of oven-dry aggregate particles per unit volume of aggregate particles, including the volume of permeable and impermeable pores within particles, but not including the voids between the particles.

3.1.2.2 *density (SSD), n*—the mass of saturated-surface-dry aggregate per unit volume of the aggregate particles, including the volume of impermeable pores and permeable, water-filled pores within the particles, but not including the voids between the particles.

3.1.2.3 *apparent density, n*—the mass per unit volume of the impermeable portion of the aggregate particles.

3.1.3 *oven-dry (OD), adj—related to aggregate particles,* the condition in which the aggregates have been dried by heating in an oven at 110 ± 5 °C for sufficient time to reach a constant mass.

3.1.4 *relative density (specific gravity), n*—the ratio of the density of a material to the density of water at a stated temperature; the values are dimensionless.

3.1.4.1 *relative density (specific gravity), (OD), n*—the ratio of the density (OD) of the aggregate to the density of water at a stated temperature.

3.1.4.2 *relative density (specific gravity), (SSD), n*—The ratio of the density (SSD) of the aggregate to the density of water at a stated temperature.

3.1.4.3 *apparent relative density (apparent specific gravity), n*—the ratio of the apparent density of aggregate to the density of water at a stated temperature.

3.1.5 *saturated-surface-dry (SSD), adj—related to aggregate particles,* the condition in which the permeable pores of aggregate particles are filled with water to the extent achieved by submerging in water for the prescribed period of time, but without free water on the surface of the particles.

3.1.6 For definitions of other terms related to aggregates see Terminology C125.

4. Summary of Test Method

4.1 A sample of aggregate is immersed in water for 24 ± 4 h to essentially fill the pores. It is then removed from the water, the water is dried from the surface of the particles, and the mass determined. Subsequently, the sample (or a portion of it) is placed in a graduated container and the volume of the sample is determined by the gravimetric or volumetric method. Finally, the sample is oven-dried and the mass determined again. Using the mass values thus obtained and formulas in this test method, it is possible to calculate density, relative density (specific gravity), and absorption.

5. Significance and Use

5.1 Relative density (specific gravity) is the characteristic generally used for calculation of the volume occupied by the aggregate in various mixtures containing aggregate including portland cement concrete, bituminous concrete, and other mixtures that are proportioned or analyzed on an absolute volume basis. Relative density (specific gravity) is also used in the computation of voids in aggregate in Test Method C29/C29M. Relative density (specific gravity) (SSD) is used in the determination of surface moisture on fine aggregate by displacement of water in Test Method C70. Relative density (specific gravity) (SSD) is used if the aggregate is wet, that is, if its absorption has been satisfied. Conversely, the density or relative density (specific gravity) (OD) is used for computations when the aggregate is dry or assumed to be dry.

5.2 Apparent density and apparent relative density (apparent specific gravity) pertain to the solid material making up the constituent particles not including the pore space within the particles that is accessible to water. This value is not widely used in construction aggregate technology.

5.3 Absorption values are used to calculate the change in the mass of an aggregate material due to water absorbed in the pore spaces within the constituent particles, compared to the dry condition, when it is deemed that the aggregate has been in contact with water long enough to satisfy most of the absorption potential. The laboratory standard for absorption is that obtained after submerging dry aggregate for a prescribed period of time. Aggregates mined from below the water table commonly have a moisture content greater than the absorption determined by this test method, if used without opportunity to dry prior to use. Conversely, some aggregates which have not been continuously maintained in a moist condition until used are likely to contain an amount of absorbed moisture less than the 24-h soaked condition. For an aggregate that has been in contact with water and that has free moisture on the particle surfaces, the percentage of free moisture is determined by deducting the absorption from the total moisture content determined by Test Method C566 by drying.

5.4 The general procedures described in this test method are suitable for determining the absorption of aggregates that have had conditioning other than the 24-h soak, such as boiling water or vacuum saturation. The values obtained for absorption by other test methods will be different than the values obtained by the prescribed 24-h soak, as will the density (SSD) or relative density (specific gravity (SSD).

5.5 The pores in lightweight aggregates are not necessarily filled with water after immersion for 24 h. In fact, the absorption potential for many such aggregates is not satisfied after several days immersion in water. Therefore, this test method is not intended for use with lightweight aggregate.

6. Apparatus

6.1 *Balance*—A balance or scale having a capacity of 1 kg or more, sensitive to 0.1 g or less, and accurate within 0.1 % of the test load at any point within the range of use for this test method. Within any 100-g range of test load, a difference between readings shall be accurate within 0.1 g.

6.2 *Pycnometer (for Use with Gravimetric Procedure)*—A flask or other suitable container into which the fine aggregate test sample can be readily introduced and in which the volume content can be reproduced within ± 0.1 cm^3. The volume of the container filled to mark shall be at least 50 % greater than the space required to accommodate the test sample. A volumetric flask of 500-cm^3 capacity or a fruit jar fitted with a pycnometer top is satisfactory for a 500-g test sample of most fine aggregates.

6.3 *Flask (for Use with Volumetric Procedure)*—A Le Chatelier flask as described in Test Method C188 is satisfactory for an approximately 55-g test sample.

6.4 *Mold and Tamper for Surface Moisture Test*—The metal mold shall be in the form of a frustum of a cone with dimensions as follows: 40 ± 3-mm inside diameter at the top, 90± 3-mm inside diameter at the bottom, and 75 ± 3 mm in height, with the metal having a minimum thickness of 0.8 mm. The metal tamper shall have a mass of 340 ± 15 g and a flat circular tamping face 25 ± 3 mm in diameter.

6.5 *Oven*—An oven of sufficient size, capable of maintaining a uniform temperature of 110 ± 5 °C (230 ± 9 °F).

7. Sampling

7.1 Sample the aggregate in accordance with Practice D75. Thoroughly mix the sample and reduce it to obtain a test specimen of approximately 1 kg using the applicable procedures described in Practice C702.

8. Preparation of Test Specimen

8.1 Place the test specimen in a suitable pan or vessel and dry in the oven to constant mass at a temperature of 110 ± 5 °C (230 ± 9 °F). Allow it to cool to comfortable handling temperature (approximately 50 °C), cover with water, either by immersion or by the addition of at least 6 % moisture to the fine aggregate, and permit to stand for 24 ± 4 h.

8.1.1 Where the absorption and relative density (specific gravity) values are to be used in proportioning concrete mixtures in which the aggregates will be in their naturally moist condition, the requirement in 8.1 for initial drying is optional, and, if the surfaces of the particles in the sample have been kept continuously wet until tested, the requirement in 8.1 for 24 ± 4 h soaking is also optional.

NOTE 1—Values for absorption and for relative density (specific gravity) (SSD) may be significantly higher for aggregate not oven dried before soaking than for the same aggregate treated in accordance with 8.1.

8.2 Decant excess water with care to avoid loss of fines (see also Appendix X1), spread the sample on a flat nonabsorbent surface exposed to a gently moving current of warm air, and stir frequently to secure homogeneous drying. Employ mechanical aids such as tumbling or stirring to assist in achieving the saturated surface-dry condition, if desired. Continue this operation until the test specimen approaches a free-flowing condition. Follow the procedure in 8.3 to determine if surface moisture is still present on the constituent fine aggregate particles. Make the first trial for surface moisture when there is still some surface water in the test specimen. Continue drying with constant stirring and test at frequent intervals until the test indicates that the specimen has reached a surface-dry condition. If the first trial of the surface moisture test indicates that moisture is not present on the surface, it has been dried past the saturated surface-dry condition. In this case, thoroughly mix a few millilitres of water with the fine aggregate and permit the specimen to stand in a covered container for 30 min. Then resume the process of drying and testing at frequent intervals for the onset of the surface-dry condition.

8.3 *Test for Surface Moisture*—Hold the mold firmly on a smooth nonabsorbent surface with the large diameter down. Place a portion of the partially dried fine aggregate loosely in the mold by filling it to overflowing and heaping additional material above the top of the mold by holding it with the cupped fingers of the hand holding the mold. Lightly tamp the fine aggregate into the mold with 25 light drops of the tamper. Start each drop approximately 5 mm above the top surface of the fine aggregate. Permit the tamper to fall freely under gravitational attraction on each drop. Adjust the starting height to the new surface elevation after each drop and distribute the drops over the surface. Remove loose sand from the base and lift the mold vertically. If surface moisture is still present, the fine aggregate will retain the molded shape. Slight slumping of the molded fine aggregate indicates that it has reached a surface-dry condition.

8.3.1 Some fine aggregate with predominately angular-shaped particles or with a high proportion of fines does not slump in the cone test upon reaching the surface-dry condition. Test by dropping a handful of the fine aggregate from the cone test onto a surface from a height of 100 to 150 mm, and observe for fines becoming airborne; presence of airborne fines indicates this problem. For these materials, consider the saturated surface-dry condition as the point that one side of the fine aggregate slumps slightly upon removing the mold.

NOTE 2—The following criteria have also been used on materials that do not readily slump:

(1) Provisional Cone Test—Fill the cone mold as described in 8.3 except only use 10 drops of the tamper. Add more fine aggregate and use 10 drops of the tamper again. Then add material two more times using 3 and 2 drops of the tamper, respectively. Level off the material even with the top of the mold, remove loose material from the base; and lift the mold vertically.

(2) Provisional Surface Test—If airborne fines are noted when the fine aggregate is such that it will not slump when it is at a moisture condition, add more moisture to the sand, and at the onset of the surface-dry condition, with the hand lightly pat approximately 100 g of the material on a flat, dry, clean, dark or dull nonabsorbent surface such as a sheet of rubber, a worn oxidized, galvanized, or steel surface, or a black-painted metal surface. After 1 to 3 s, remove the fine aggregate. If noticeable moisture shows on the test surface for more than 1 to 2 s then surface moisture is considered to be present on the fine aggregate.

(3) Colorimetric procedures described by Kandhal and Lee, Highway Research Record No. 307, p. 44.

(4) For reaching the saturated surface-dry condition on a single size material that slumps when wet, hard-finish paper towels can be used to surface dry the material until the point is just reached where the paper towel does not appear to be picking up moisture from the surfaces of the fine aggregate particles.

9. Procedure

9.1 Test by either the gravimetric procedure in 9.2 or the volumetric procedure in 9.3. Make all determinations of mass to 0.1 g.

9.2 *Gravimetric (Pycnometer) Procedure*:

9.2.1 Partially fill the pycnometer with water. Introduce into the pycnometer 500 ± 10 g of saturated surface-dry fine aggregate prepared as described in Section 8, and fill with additional water to approximately 90 % of capacity. Agitate the pycnometer as described in 9.2.1.1 (manually) or 9.2.1.2 (mechanically).

9.2.1.1 Manually roll, invert, or agitate the pycnometer (or use a combination of these actions) to eliminate visible air bubbles.

NOTE 3—About 15 to 20 min are normally required to eliminate the air bubbles by manual methods. Dipping the tip of a paper towel into the pycnometer has been found to be useful in dispersing the foam that sometimes builds up when eliminating the air bubbles. Optionally, a small amount of isopropyl alcohol may be used to disperse the foam.

9.2.1.2 Mechanically agitate the pycnometer by external vibration in a manner that will not degrade the sample. A level of agitation adjusted to just set individual particles in motion is sufficient to promote de-airing without degradation. A mechanical agitator shall be considered acceptable for use if comparison tests for each six-month period of use show variations less that the acceptable range of two results (d2s) indicated in Table 1 from the results of manual agitation on the same material.

9.2.2 After eliminating all air bubbles, adjust the temperature of the pycnometer and its contents to 23.0 ± 2.0 °C if necessary by partial immersion in circulating water, and bring the water level in the pycnometer to its calibrated capacity. Determine the total mass of the pycnometer, specimen, and water.

TABLE 1 Precision

	Standard Deviation (1s)[A]	Acceptable Range of Two Results (d2s)[A]
Single-Operator Precision:		
Density (OD), kg/m³	11	13
Density (SSD), kg/m³ [B†]	9.5	27
Apparent density, kg/m³	9.5	27
Relative density (specific gravity) (OD)	0.011	0.032
Relative density (specific gravity) (SSD)	0.0095	0.027
Apparent relative density (apparent specific gravity)	0.0095	0.027
Absorption[C], %	0.11	0.31
Multilaboratory Precision:		
Density (OD), kg/m³	23	64
Density (SSD), kg/m³	20	56
Apparent density, kg/m³	20	56
Relative density (specific gravity) (OD)	0.023	0.066
Relative density (specific gravity) (SSD)	0.020	0.056
Apparent relative density (apparent specific gravity)	0.020	0.056
Absorption[C], %	0.23	0.66

[A] These numbers represent, respectively, the (1s) and (d2s) limits as described in Practice C670. The precision estimates were obtained from the analysis of combined AASHTO Materials Reference Laboratory proficiency sample data from laboratories using 15 to 19-h saturation times and other laboratories using 24 ± 4-h saturation time. Testing was performed on normal weight aggregates, and started with aggregates in the oven-dry condition.

[B†] Revised editorially to correct a typographical error in August 2003.

[C] Precision estimates are based on aggregates with absorptions of less than 1 % and may differ for manufactured fine aggregates and the aggregates having absorption values greater than 1 %.

9.2.3 Remove the fine aggregate from the pycnometer, dry in the oven to constant mass at a temperature of 110 ± 5 °C (230 ± 9 °F), cool in air at room temperature for 1 ± ½ h, and determine the mass.

9.2.4 Determine the mass of the pycnometer filled to its calibrated capacity with water at 23.0 ± 2.0 °C.

9.3 *Volumetric (Le Chatelier Flask) Procedure*:

9.3.1 Fill the flask initially with water to a point on the stem between the 0 and the 1-mL mark. Record this initial reading with flask and contents within the temperature range of 23.0 ± 2.0 °C. Add 55 ± 5 g of fine aggregate in the saturated surface-dry condition (or other measured quantity as necessary). After all fine aggregate has been introduced, place the stopper in the flask and roll the flask in an inclined position, or gently whirl it in a horizontal circle so as to dislodge all entrapped air, continuing until no further bubbles rise to the surface (Note 4). Take a final reading with the flask and contents within 1 °C of the original temperature.

NOTE 4—A small measured amount (not to exceed 1 mL) of isopropyl alcohol may be used to eliminate foam appearing on the water surface. The volume of alcohol used must be subtracted from the final reading (R_2).

9.3.2 For determination of the absorption, use a separate 500 ± 10-g portion of the saturated surface-dry fine aggregate, dry to constant mass, and determine the dry mass.

10. Calculations

10.1 *Symbols*:

A = mass of oven dry specimen, g

B = mass of pycnometer filled with water, to calibration mark, g

C = mass of pycnometer filled with specimen and water to calibration mark, g

R_1= initial reading of water level in Le Chatelier flask, mL

R_2= final reading of water in Le Chatelier flask, mL

S = mass of saturated surface-dry specimen (used in the gravimetric procedure for density and relative density (specific gravity), or for absorption with both procedures), g

S_1= mass of saturated surface-dry specimen (used in the volumetric procedure for density and relative density (specific gravity)), g

10.2 *Relative Density (Specific Gravity)*:

10.2.1 *Relative Density (Specific Gravity) (Oven dry)*—Calculate the relative density (specific gravity) on the basis of oven-dry aggregate as follows:

10.2.1.1 *Gravimetric Procedure*:

$$\text{Relative density (specific gravity) (OD)} = A/(B + S - C) \quad (1)$$

10.2.1.2 *Volumetric Procedure*:

$$\text{Relative density (specific gravity) (OD)} = [S_1\,(A/S)]/[0.9975\,(R_2 - R_1)] \quad (2)$$

10.2.2 *Relative Density (Specific Gravity) Saturated Surface-dry)*—Calculate the relative density (specific gravity) on the basis of saturated surface-dry aggregate as follows:

10.2.2.1 *Gravimetric Procedure*:

$$\text{Relative density (specific gravity) (SSD)} = S/(B + S - C) \quad (3)$$

10.2.2.2 *Volumetric Procedure*:

$$\text{Relative density (specific gravity) (SSD)} = S_1/[0.9975\,(R_2 - R_1)] \quad (4)$$

10.2.3 *Apparent Relative Density (Apparent Specific Gravity)*—Calculate the apparent relative density (apparent specific gravity) as follows:

10.2.3.1 *Gravimetric Procedure*:

$$\text{Apparent relative density (apparent specific gravity)} = A/(B + A - C) \quad (5)$$

10.2.3.2 *Volumetric Procedure*:

$$\text{Apparent relative density (apparent specific gravity)} = \frac{S_1\,(A/S)}{0.9975\,(R_2 - R_1) - [(S_1/S)(S - A)]} \quad (6)$$

10.3 *Density*:

10.3.1 *Density (Oven-dry)*—Calculate the density on the basis of oven-dry aggregates as follows:

10.3.1.1 *Gravimetric Procedure*:

$$\text{Density (OD), kg/m}^3 = 997.5\,A/(B + S - C) \quad (7)$$

$$\text{Density (OD), lb/ft}^3 = 62.27\,A/(B + S - C) \quad (8)$$

10.3.1.2 *Volumetric Procedure*:

$$\text{Density (OD), kg/m}^3 = 997.5\,S_1\,(A/S)/[0.9975\,(R_2 - R_1)] \quad (9)$$

$$\text{Density (OD), lb/ft}^3 = 62.27\,S_1\,(A/S)/[0.9975\,(R_2 - R_1)] \quad (10)$$

NOTE 5—The constant values used in the calculations in 10.3.1-10.3.3 (997.5 kg/m^3 and 62.27 lb/ft^3) are the density of water at 23 °C. Some authorities recommend using the density of water at 4 °C (1000 kg/m^3 or 1.00 Mg/m^3 or 62.43 lb/ft^3) as being sufficiently accurate.

10.3.2 *Density (Saturated surface-dry)*—Calculate the density on the basis of saturated surface-dry aggregate as follows:

10.3.2.1 *Gravimetric Procedure*:

$$\text{Density (SSD), kg/m}^3 = 997.5\,S/(B + S - C) \quad (11)$$

$$\text{Density (SSD), lb/ft}^3 = 62.27\,S/(B + S - C) \quad (12)$$

10.3.2.2 *Volumetric Procedure*:

$$\text{Density (SSD), kg/m}^3 = 997.5\,S_1/[0.9975\,(R_2 - R_1)] \quad (13)$$

$$\text{Density (SSD), lb/ft}^3 = 62.27\,S_1/[0.9975\,(R_2 - R_1)] \quad (14)$$

10.3.3 *Apparent Density*—Calculate the apparent density as follows:

10.3.3.1 *Gravimetric Procedure*:

$$\text{Apparent density (SSD), kg/m}^3 = 997.5\,A/(B + A - C) \quad (15)$$

$$\text{Apparent density (SSD), lb/ft}^3 = 62.27\,A/(B + A - C) \quad (16)$$

10.3.3.2 *Volumetric Procedure*:

$$\text{Apparent density (SSD), kg/m}^3, = \frac{997.5\,S_1\,(A/S)}{0.9975\,(R_2 - R_1) - [(S_1/S)(S - A)]} \quad (17)$$

$$\text{Apparent density (SSD), lb/ft}^3, = \frac{62.27\,S_1\,(A/S)}{0.9975\,(R_2 - R_1) - [(S_1/S)(S - A)]} \quad (18)$$

10.4 *Absorption*—Calculate the percentage of absorption as follows:

$$\text{Absorption, \%} = 100\,[(S - A)/A] \quad (19)$$

11. Report

11.1 Report density results to the nearest 10 kg/m^3, or 0.5 lb/ft^3, relative density (specific gravity) results to the nearest 0.01, and indicate the basis for density or relative density (specific gravity), as either oven-dry (OD), saturated-surface-dry (SSD), or apparent.

11.2 Report the absorption result to the nearest 0.1 %.

11.3 If the density and relative density (specific gravity) values were determined without first drying the aggregate, as permitted in 8.2, note that fact in the report.

12. Precision and Bias

12.1 *Precision*—The estimates of precision of this test method (listed in Table 1) are based on results from the AASHTO Materials Reference Laboratory Proficiency Sample Program, with testing conducted by this test method and AASHTO Method T 84. The significant difference between the methods is that Test Method C128 requires a saturation period of 24 ± 4 h, and AASHTO Test Method T 84 requires a saturation period of 15 to 19 h. This difference has been found to have an insignificant effect on the precision indices. The data are based on the analyses of more than 100 paired test results from 40 to 100 laboratories. The precision estimates for density were calculated from values determined for relative density (specific gravity), using the density of water at 23 °C for the conversion.

12.2 *Bias*—Since there is no accepted reference material suitable for determining the bias for this test method, no statement on bias is being made.

13. Keywords

13.1 absorption; aggregate; apparent density; apparent relative density; density; fine aggregate; relative density; specific gravity

APPENDIXES

(Nonmandatory Information)

X1. POTENTIAL DIFFERENCES IN BULK RELATIVE DENSITY AND ABSORPTION DUE TO PRESENCE OF MATERIAL FINER THAN 75 μm

X1.1 It has been found that there may be significant differences in bulk relative density and absorption between fine aggregate samples tested with the material finer than 75 μm (No. 200) present and not present in the samples. Samples from which the material finer than 75 μm is not removed usually give a higher absorption and a lower bulk relative density compared with testing the same fine aggregate from which the material finer than 75 μm is removed following the procedures of Test Method C117. Samples with material finer than 75 μm may build up a coating around the coarser fine aggregate particles during the surface drying process. The resultant relative density and absorption that is subsequently measured is that of the agglomerated and coated particles and not that of the parent material. The difference in absorption and relative density determined between samples from which the material finer than 75 μm have not been removed and samples from which the material finer than 75 μm have been removed depends on both the amount of the material finer than 75 μm present and the nature of the material. When the material finer than 75 μm is less than about 4 % by mass, the difference in relative density between washed and unwashed samples is less than 0.03. When the material finer than 75 μm is greater than about 8 % by mass, the difference in relative density obtained between washed and unwashed samples may be as great as 0.13. It has been found that the relative density determined on fine aggregate from which the material finer than 75 μm has been removed prior to testing more accurately reflects the relative density of the material.

X1.2 The material finer than 75 μm, which is removed, can be assumed to have the same relative density as the fine aggregate. Alternatively, the relative density (specific gravity) of the material finer than 75 μm may be further evaluated using Test Method D854, however, this test determines the apparent relative density and not the bulk relative density.

X2. INTERRELATIONSHIPS BETWEEN RELATIVE DENSITIES (SPECIFIC GRAVITIES) AND ABSORPTION AS DEFINED IN TEST METHODS C127 AND C128

X2.1 This appendix gives mathematical interrelationships among the three types of relative densities (specific gravities) and absorption. These may be useful in checking the consistency of reported data or calculating a value that was not reported by using other reported data.

X2.2 Where:

S_d = relative density (specific gravity) (OD),
S_s = relative density (specific gravity) (SSD),
S_a = apparent relative density (apparent specific gravity), and
A = absorption, in %.

Calculate the values of each as follows:

$$S_s = (1 + A/100)S_d \quad \text{(X2.1)}$$

$$S_s = \frac{1}{\frac{1}{S_d} - \frac{A}{100}} = \frac{S_d}{1 - \frac{AS_d}{100}} \quad \text{(X2.2)}$$

$$\text{or } S_a = \frac{1}{\frac{1 + A/100}{S_s} - \frac{A}{100}} \quad \text{(X2.3)}$$

$$= \frac{S_s}{1 = \frac{A}{100}(S_s - 1)}$$

$$A = \left(\frac{S_s}{S_d} - 1\right) 100 \quad \text{(X2.4)}$$

$$A = \left(\frac{S_a - S_s}{S_a(S_s - 1)}\right) 100 \quad \text{(X2.5)}$$

SUMMARY OF CHANGES

Committee C09 has identified the location of selected changes to this test method since the last issue, C128 – 07, that may impact the use of this test method. (Approved August 1, 2007)

(*1*) Revised 3.1.2.2.

(*2*) Revised 9.2.1.1.

Committee C09 has identified the location of selected changes to this test method since the last issue, C128 – 04a, that may impact the use of this test method. (Approved February 1, 2007)

(*1*) Revised 9.2.1.1.

(*2*) Added new Appendix X1 and renumbered subsequent sections.

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Designation: C131 – 06

Standard Test Method for Resistance to Degradation of Small-Size Coarse Aggregate by Abrasion and Impact in the Los Angeles Machine[1]

This standard is issued under the fixed designation C131; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

This standard has been approved for use by agencies of the Department of Defense.

1. Scope*

1.1 This test method covers a procedure for testing sizes of coarse aggregate smaller than 37.5 mm (1½ in.) for resistance to degradation using the Los Angeles testing machine (Note 1).

NOTE 1—A procedure for testing coarse aggregate larger than 19.0 mm (¾ in.) is covered in Test Method C535.

1.2 The values stated in SI units are to be regarded as the standard. The inch-pound values given in parentheses are for information only.

1.3 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*

2. Referenced Documents

2.1 *ASTM Standards:*[2]

A6/A6M Specification for General Requirements for Rolled Structural Steel Bars, Plates, Shapes, and Sheet Piling

C125 Terminology Relating to Concrete and Concrete Aggregates

C136 Test Method for Sieve Analysis of Fine and Coarse Aggregates

C535 Test Method for Resistance to Degradation of Large-Size Coarse Aggregate by Abrasion and Impact in the Los Angeles Machine

C670 Practice for Preparing Precision and Bias Statements for Test Methods for Construction Materials

C702 Practice for Reducing Samples of Aggregate to Testing Size

D75 Practice for Sampling Aggregates

E11 Specification for Woven Wire Test Sieve Cloth and Test Sieves

3. Terminology

3.1 *Definitions*—For definitions of terms used in this test method, refer to Terminology C125.

4. Summary of Test Method

4.1 This test is a measure of degradation of mineral aggregates of standard gradings resulting from a combination of actions including abrasion or attrition, impact, and grinding in a rotating steel drum containing a specified number of steel spheres, the number depending upon the grading of the test sample. As the drum rotates, a shelf plate picks up the sample and the steel spheres, carrying them around until they are dropped to the opposite side of the drum, creating an impact-crushing effect. The contents then roll within the drum with an abrading and grinding action until the shelf plate picks up the sample and the steel spheres, and the cycle is repeated. After the prescribed number of revolutions, the contents are removed from the drum and the aggregate portion is sieved to measure the degradation as percent loss.

5. Significance and Use

5.1 This test has been widely used as an indicator of the relative quality or competence of various sources of aggregate having similar mineral compositions. The results do not automatically permit valid comparisons to be made between sources distinctly different in origin, composition, or structure. Assign specification limits with extreme care in consideration of available aggregate types and their performance history in specific end uses.

6. Apparatus

6.1 *Los Angeles Machine*—A Los Angeles machine, conforming in all essential characteristics to the design shown in Fig. 1, shall be used. The machine shall consist of a hollow steel cylinder, with a wall thickness of not less than 12.4 mm (Note 2) closed at both ends, conforming to the dimensions shown in Fig. 1, having an inside diameter of 711 ± 5 mm (28

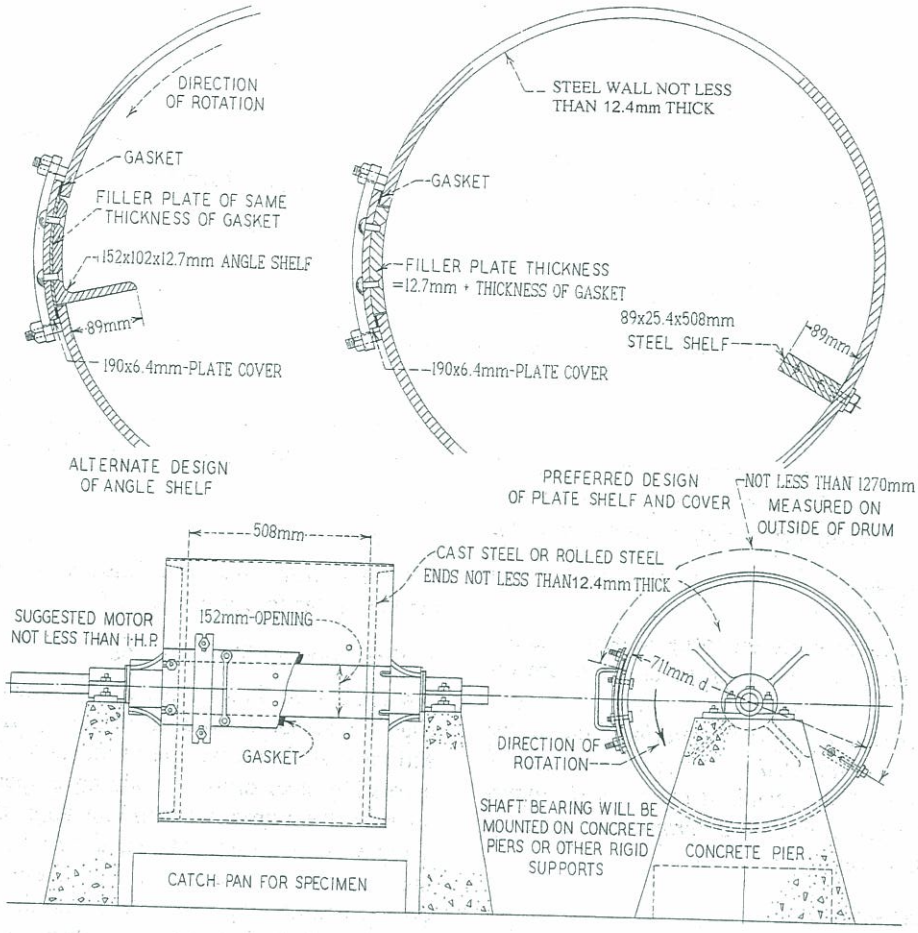
[1] This test method is under the jurisdiction of ASTM Committee C09 on Concrete and Concrete Aggregates and is the direct responsibility of Subcommittee C09.20 on Normal Weight Aggregates.

Current edition approved August 1, 2006. Published August 2006. Originally approved in 1937. Last previous edition approved in 2003 as C131-03. DOI: 10.1520/C0131-06.

[2] For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

***A Summary of Changes section appears at the end of this standard.**

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Inch Equivalents

m	6.4	12.7	25.4	89	102	152	190	508	711	1270
	¼	½	1	3½	4	6	7½	20	28	50

FIG. 1 Los Angeles Testing Machine

0.2 in.), and an inside length of 508 ± 5 mm (20 ± 0.2 in.). e interior surface of the cylinder shall be free from protru- ns disrupting the path of the sample and steel spheres except the shelf described below. The cylinder shall be mounted on b shafts attached to the ends of the cylinder but not entering and shall be mounted in such a manner that it rotates with axis in a horizontal position within a tolerance in slope of 1 100. An opening in the cylinder shall be provided for the oduction of the test sample. A suitable, dust-tight cover ll be provided for the opening with means for bolting the er in place. The cover shall be so designed as to maintain cylindrical contour of the interior surface unless the shelf is ocated that the charge will not fall on the cover, or come in tact with it during the test. A removable steel shelf nding the full length of the cylinder and projecting inward ± 2 mm (3.5 ± 0.1 in.) shall be mounted on the interior ndrical surface of the cylinder, in such a way that a plane ered between the large faces coincides with an axial plane. shelf shall be of such thickness and so mounted, by bolts ther suitable means, as to be firm and rigid. The position of shelf (Note 3) shall be such that the sample and the steel res shall not impact on or near the opening and its cover, and that the distance from the shelf to the opening, measured along the outside circumference of the cylinder in the direction of rotation, shall be not less than 1270 mm (50 in.). Inspect the shelf periodically to determine that it is not bent either lengthwise or from its normal radial position with respect to the cylinder. If either condition is found, repair or replace the shelf before further tests are conducted.

NOTE 2—This is the minimum tolerance permitted on 12.7 mm (½ in.) rolled steel plate as described in Specification A6/A6M.

NOTE 3—The use of a shelf of wear-resistant steel, rectangular in cross section and mounted independently of the cover, is preferred. However, a shelf consisting of a section of rolled angle, properly mounted on the inside of the cover plate, may be used provided the direction of rotation is such that the charge will be caught on the outside face of the angle.

6.1.1 The machine shall be so driven and so counterbalanced as to maintain a substantially uniform peripheral speed (Note 4). If an angle is used as the shelf, the direction of rotation shall be such that the charge is caught on the outside surface of the angle.

NOTE 4—Back-lash or slip in the driving mechanism is very likely to furnish test results which are not duplicated by other Los Angeles machines producing constant peripheral speed.

TABLE 1 Gradings of Test Samples

Sieve Size (Square Openings)		Mass of Indicated Sizes, g			
		Grading			
Passing	Retained on	A	B	C	D
37.5 mm (1½ in.)	25.0 mm (1 in.)	1 250 ± 25	...	...	...
25.0 mm (1 in.)	19.0 mm (¾ in.)	1 250 ± 25	...	...	...
19.0 mm (¾ in.)	12.5 mm (½ in.)	1 250 ± 10	2 500 ± 10	...	...
12.5 mm (½ in.)	9.5 mm (⅜ in.)	1 250 ± 10	2 500 ± 10	...	...
9.5 mm (⅜ in.)	6.3 mm (¼ in.)	...	...	2 500 ± 10	...
6.3 mm (¼ in.)	4.75-mm (No. 4)	...	...	2 500 ± 10	...
4.75-mm (No. 4)	2.36-mm (No. 8)	...	...	...	5 000 ± 10
Total		5 000 ± 10	5 000 ± 10	5 000 ± 10	5 000 ± 10

6.2 *Sieves*, conforming to Specification E11.

6.3 *Balance*—A balance or scale accurate within 0.1 % of test load over the range required for this test.

6.4 *Charge*—The charge shall consist of steel spheres averaging approximately 46.8 mm (1 27/32 in.) in diameter and each having a mass of between 390 and 445 g.

6.4.1 The charge, (Note 5) depending upon the grading of the test sample as described in Section 8, shall be as follows:

Grading	Number of Spheres	Mass of Charge, g
A	12	5000 ± 25
B	11	4584 ± 25
C	8	3330 ± 20
D	6	2500 ± 15

NOTE 5—Steel ball bearings 46.0 mm (1 13/16 in.) and 47.6 mm (1⅞ in.) in diameter, having a mass of approximately 400 and 440 g each, respectively, are readily available. Steel spheres 46.8 mm (1 27/32 in.) in diameter having a mass of approximately 420 g may also be obtainable. The charge may consist of a mixture of these sizes conforming to the mass tolerances of 6.4 and 6.4.1.

7. Sampling

7.1 Obtain the field sample in accordance with Practice D75, and reduce the field sample to adequate sample size in accordance with Practice C702.

8. Test Sample Preparation

8.1 Wash the reduced sample and oven dry at 110 ± 5 °C (230 ± 9 °F) to substantially constant mass (see 9.1.1), separate into individual size fractions, and recombine to the grading of Table 1 most nearly corresponding to the range of sizes in the aggregate as furnished for the work. Record the mass of the sample prior to test to the nearest 1 g.

9. Procedure

9.1 Place the test sample and the charge in the Los Angeles testing machine and rotate the machine at a speed of 30 to 33 r/min for 500 revolutions (Note 6). After the prescribed number of revolutions, discharge the material from the machine and make a preliminary separation of the sample on a sieve coarser than the 1.70-mm (No. 12) sieve. Sieve the finer portion on a 1.70-mm sieve in a manner conforming to Test Method C136. Wash the material coarser than the 1.70-mm (No. 12) sieve and oven-dry at 110 ± 5 °C (230 ± 9 °F) to substantially constant mass (see 9.1.1), and determine the mass to the nearest 1 g (Note 7).

9.1.1 If the aggregate is essentially free of adherent coatings and dust, the requirement for washing after the test is optional. However, in the case of referee testing, the washing procedure shall be performed.

NOTE 6—Valuable information concerning the uniformity of the sample under test may be obtained by determining the loss after 100 revolutions. The loss should be determined by dry sieving the material on the 1.70-mm sieve without washing. The ratio of the loss after 100 revolutions to the loss after 500 revolutions should not greatly exceed 0.20 for material of uniform hardness. When this determination is made, take care to avoid losing any part of the sample; return the entire sample, including the dust of fracture, to the testing machine for the final 400 revolutions required to complete the test.

NOTE 7—Elimination of washing after test will seldom reduce the measured loss by more than about 0.2 % of the original sample mass.

10. Calculation

10.1 Calculate the loss (difference between the original mass and the final mass of the test sample) as a percentage of the original mass of the test sample. Report this value as the percent loss (Note 8).

NOTE 8—The percent loss determined by this test method has no known consistent relationship to the percent loss for the same material when tested by Test Method C535.

11. Report

11.1 Report the following information:

11.1.1 Identification of the aggregate as to source, type, and nominal maximum size;

11.1.2 Grading designation from Table 1 used for the test; and

11.1.3 Loss by abrasion and impact of the sample expressed to the nearest 1 % by mass.

12. Precision and Bias

12.1 For nominal 19.0-mm (¾-in.) maximum size coarse aggregate with percent losses in the range of 10 to 45 %, the multilaboratory coefficient of variation has been found to be 4.5 %.[3] Therefore, results of two properly conducted tests from two different laboratories on samples of the same coarse aggregates are not expected to differ from each other by more

[3] These numbers represent, respectively, the (1s%) and (d2s%) limits as described in Practice C670.

than 12.7 %[3] (95 % probability) of their average. The single-operator coefficient of variation has been found to be 2.0 %.[3] Therefore, results of two properly conducted tests by the same operator on the same coarse aggregate are not expected to differ from each other by more than 5.7 % (95 % probability) of their average.[3]

12.2 *Bias*—Since there is no accepted reference material suitable for determining the bias for this procedure, no statement on bias is being made.

13. Keywords

13.1 abrasion; aggregate (coarse; small size); degradation; impact; Los Angeles machine

APPENDIX

(Nonmandatory Information)

X1. MAINTENANCE OF SHELF

X1.1 The shelf of the Los Angeles machine is subject to severe surface wear and impact. With use, the working surface of the shelf is peened by the balls and tends to develop a ridge of metal parallel to and about 32 mm (1¼ in.) from the junction of the shelf and the inner surface of the cylinder. If the shelf is made from a section of rolled angle, not only may this ridge develop but the shelf itself may be bent longitudinally or transversely from its proper position.

X1.2 The shelf should be inspected periodically to determine that it is not bent either lengthwise or from its normal radial position with respect to the cylinder. If either condition is found, the shelf should be repaired or replaced before further tests are made. The influence on the test result of the ridge developed by peening of the working face of the shelf is not known. However, for uniform test conditions, it is recommended that the ridge be ground off if its height exceeds 2 mm (0.1 in.).

SUMMARY OF CHANGES

Committee C09 has identified the location of selected changes to this test method since the last issue, C131 – 03, that may impact the use of this test method. (Approved August 1, 2006)

(*1*) Revised 6.1.

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Designation: C136 – 06

Standard Test Method for Sieve Analysis of Fine and Coarse Aggregates[1]

This standard is issued under the fixed designation C136; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

This standard has been approved for use by agencies of the Department of Defense.

1. Scope*

1.1 This test method covers the determination of the particle size distribution of fine and coarse aggregates by sieving.

1.2 Some specifications for aggregates which reference this test method contain grading requirements including both coarse and fine fractions. Instructions are included for sieve analysis of such aggregates.

1.3 The values stated in SI units are to be regarded as the standard. The values in parentheses are provided for information purposes only. Specification E11 designates the size of sieve frames with inch units as standard, but in this test method the frame size is designated in SI units exactly equivalent to the inch units.

1.4 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*

2. Referenced Documents

2.1 *ASTM Standards:*[2]

C117 Test Method for Materials Finer than 75-μm (No. 200) Sieve in Mineral Aggregates by Washing

C125 Terminology Relating to Concrete and Concrete Aggregates

C637 Specification for Aggregates for Radiation-Shielding Concrete

C670 Practice for Preparing Precision and Bias Statements for Test Methods for Construction Materials

C702 Practice for Reducing Samples of Aggregate to Testing Size

D75 Practice for Sampling Aggregates

E11 Specification for Woven Wire Test Sieve Cloth and Test Sieves

2.2 *AASHTO Standard:*

AASHTO No. T 27 Sieve Analysis of Fine and Coarse Aggregates[3]

3. Terminology

3.1 *Definitions*—For definitions of terms used in this standard, refer to Terminology C125.

4. Summary of Test Method

4.1 A sample of dry aggregate of known mass is separated through a series of sieves of progressively smaller openings for determination of particle size distribution.

5. Significance and Use

5.1 This test method is used primarily to determine the grading of materials proposed for use as aggregates or being used as aggregates. The results are used to determine compliance of the particle size distribution with applicable specification requirements and to provide necessary data for control of the production of various aggregate products and mixtures containing aggregates. The data may also be useful in developing relationships concerning porosity and packing.

5.2 Accurate determination of material finer than the 75-μm (No. 200) sieve cannot be achieved by use of this test method alone. Test Method C117 for material finer than 75-μm sieve by washing should be employed.

5.3 Refer to methods of sampling and testing in Specification C637 for heavyweight aggregates.

6. Apparatus

6.1 *Balances*—Balances or scales used in testing fine and coarse aggregate shall have readability and accuracy as follows:

6.1.1 For fine aggregate, readable to 0.1 g and accurate to 0.1 g or 0.1 % of the test load, whichever is greater, at any point within the range of use.

[1] This test method is under the jurisdiction of ASTM Committee C09 on Concrete and Concrete Aggregates and is the direct responsibility of Subcommittee C09.20 on Normal Weight Aggregates.

Current edition approved Feb. 15, 2006. Published March 2006. Originally approved in 1938. Last previous edition approved in 2005 as C136 – 05. DOI: 10.1520/C0136-06.

[2] For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

[3] Available from American Association of State Highway and Transportation Officials, 444 North Capitol St. N.W., Suite 225, Washington, DC 20001.

***A Summary of Changes section appears at the end of this standard.**

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6.1.2 For coarse aggregate, or mixtures of fine and coarse aggregate, readable and accurate to 0.5 g or 0.1 % of the test load, whichever is greater, at any point within the range of use.

6.2 *Sieves*—The sieve cloth shall be mounted on substantial frames constructed in a manner that will prevent loss of material during sieving. The sieve cloth and standard sieve frames shall conform to the requirements of Specification E11. Nonstandard sieve frames shall conform to the requirements of Specification E11 as applicable.

NOTE 1—It is recommended that sieves mounted in frames larger than standard 203.2-mm (8 in.) diameter be used for testing coarse aggregate to reduce the possibility of overloading the sieves. See 8.3.

6.3 *Mechanical Sieve Shaker*—A mechanical sieving device, if used, shall create motion of the sieves to cause the particles to bounce, tumble, or otherwise turn so as to present different orientations to the sieving surface. The sieving action shall be such that the criterion for adequacy of sieving described in 8.4 is met in a reasonable time period.

NOTE 2—Use of a mechanical sieve shaker is recommended when the size of the sample is 20 kg or greater, and may be used for smaller samples, including fine aggregate. Excessive time (more than approximately 10 min) to achieve adequate sieving may result in degradation of the sample. The same mechanical sieve shaker may not be practical for all sizes of samples, since the large sieving area needed for practical sieving of a large nominal size coarse aggregate very likely could result in loss of a portion of the sample if used for a small sample of coarse aggregate or fine aggregate.

6.4 *Oven*—An oven of appropriate size capable of maintaining a uniform temperature of 110 ± 5 °C (230 ± 9 °F).

7. Sampling

7.1 Sample the aggregate in accordance with Practice D75. The size of the field sample shall be the quantity shown in Practice D75 or four times the quantity required in 7.4 and 7.5 (except as modified in 7.6), whichever is greater.

7.2 Thoroughly mix the sample and reduce it to an amount suitable for testing using the applicable procedures described in Practice C702. The sample for test shall be approximately the quantity desired when dry and shall be the end result of the reduction. Reduction to an exact predetermined quantity shall not be permitted.

NOTE 3—Where sieve analysis, including determination of material finer than the 75-μm sieve, is the only testing proposed, the size of the sample may be reduced in the field to avoid shipping excessive quantities of extra material to the laboratory.

7.3 *Fine Aggregate*—The size of the test sample, after drying, shall be 300 g minimum.

7.4 *Coarse Aggregate*—The size of the test sample of coarse aggregate shall conform with the following:

Nominal Maximum Size, Square Openings, mm (in.)	Test Sample Size, min, kg (lb)
9.5 (⅜)	1 (2)
12.5 (½)	2 (4)
19.0 (¾)	5 (11)
25.0 (1)	10 (22)
37.5 (1½)	15 (33)
50 (2)	20 (44)
63 (2½)	35 (77)
75 (3)	60 (130)
90 (3½)	100 (220)
100 (4)	150 (330)
125 (5)	300 (660)

7.5 *Coarse and Fine Aggregate Mixtures*—The size of the test sample of coarse and fine aggregate mixtures shall be the same as for coarse aggregate in 7.4.

7.6 *Samples of Large Size Coarse Aggregate*—The size of sample required for aggregate with 50-mm nominal maximum size or larger is such as to preclude convenient sample reduction and testing as a unit except with large mechanical splitters and sieve shakers. As an option when such equipment is not available, instead of combining and mixing sample increments and then reducing the field sample to testing size, conduct the sieve analysis on a number of approximately equal sample increments such that the total mass tested conforms to the requirement of 7.4.

7.7 In the event that the amount of material finer than the 75-μm (No. 200) sieve is to be determined by Test Method C117, proceed as follows:

7.7.1 For aggregates with a nominal maximum size of 12.5 mm (1/2 in.) or less, use the same test sample for testing by Test Method C117 and this test method. First test the sample in accordance with Test Method C117 through the final drying operation, then dry sieve the sample as stipulated in 8.2-8.7 of this test method.

7.7.2 For aggregates with a nominal maximum size greater than 12.5 mm (½ in.), use a single test sample as described in 7.7.1, or optionally use separate test samples for Test Method C117 and this test method.

7.7.3 Where the specifications require determination of the total amount of material finer than the 75-μm sieve by washing and dry sieving, use the procedure described in 7.7.1.

8. Procedure

8.1 Dry the sample to constant mass at a temperature of 110 ± 5 °C (230 ± 9 °F).

NOTE 4—For control purposes, particularly where rapid results are desired, it is generally not necessary to dry coarse aggregate for the sieve analysis test. The results are little affected by the moisture content unless: (*1*) the nominal maximum size is smaller than about 12.5 mm (½ in.); (*2*) the coarse aggregate contains appreciable material finer than 4.75 mm (No. 4); or (*3*) the coarse aggregate is highly absorptive (a lightweight aggregate, for example). Also, samples may be dried at the higher temperatures associated with the use of hot plates without affecting results, provided steam escapes without generating pressures sufficient to fracture the particles, and temperatures are not so great as to cause chemical breakdown of the aggregate.

8.2 Select sieves with suitable openings to furnish the information required by the specifications covering the material to be tested. Use additional sieves as desired or necessary to provide other information, such as fineness modulus, or to regulate the amount of material on a sieve. Nest the sieves in order of decreasing size of opening from top to bottom and place the sample on the top sieve. Agitate the sieves by hand or by mechanical apparatus for a sufficient period, established by trial or checked by measurement on the actual test sample, to meet the criterion for adequacy or sieving described in 8.4.

8.3 Limit the quantity of material on a given sieve so that all particles have opportunity to reach sieve openings a number of times during the sieving operation. For sieves with openings

smaller than 4.75-mm (No. 4), the quantity retained on any sieve at the completion of the sieving operation shall not exceed 7 kg/m^2 of sieving surface area (Note 5). For sieves with openings 4.75 mm (No. 4) and larger, the quantity retained in kg shall not exceed the product of 2.5 × (sieve opening, mm × (effective sieving area, m^2)). This quantity is shown in Table 1 for five sieve-frame dimensions in common use. In no case shall the quantity retained be so great as to cause permanent deformation of the sieve cloth.

8.3.1 Prevent an overload of material on an individual sieve by one of the following methods:

8.3.1.1 Insert an additional sieve with opening size intermediate between the sieve that may be overloaded and the sieve immediately above that sieve in the original set of sieves.

8.3.1.2 Split the sample into two or more portions, sieving each portion individually. Combine the masses of the several portions retained on a specific sieve before calculating the percentage of the sample on the sieve.

8.3.1.3 Use sieves having a larger frame size and providing greater sieving area.

NOTE 5—The 7 kg/m^2 amounts to 200 g for the usual 203.2-mm (8-in.) diameter sieve (with effective sieving surface diameter of 190.5 mm (7.5 in.)).

8.4 Continue sieving for a sufficient period and in such manner that, after completion, not more than 1 % by mass of the material retained on any individual sieve will pass that sieve during 1 min of continuous hand sieving performed as follows: Hold the individual sieve, provided with a snug-fitting pan and cover, in a slightly inclined position in one hand. Strike the side of the sieve sharply and with an upward motion against the heel of the other hand at the rate of about 150 times per minute, turn the sieve about one sixth of a revolution at intervals of about 25 strokes. In determining sufficiency of sieving for sizes larger than the 4.75-mm (No. 4) sieve, limit the material on the sieve to a single layer of particles. If the size of the mounted testing sieves makes the described sieving motion impractical, use 203-mm (8 in.) diameter sieves to verify the sufficiency of sieving.

TABLE 1 Maximum Allowable Quantity of Material Retained on a Sieve, kg

Sieve Opening Size, mm	Nominal Dimensions of Sieve[A]				
	203.2-mm dia[B]	254-mm dia[B]	304.8-mm dia[B]	350 by 350 mm	372 by 580 mm
	Sieving Area, m^2				
	0.0285	0.0457	0.0670	0.1225	0.2158
125	C	C	C	C	67.4
100	C	C	C	30.6	53.9
90	C	C	15.1	27.6	48.5
75	C	8.6	12.6	23.0	40.5
63	C	7.2	10.6	19.3	34.0
50	3.6	5.7	8.4	15.3	27.0
37.5	2.7	4.3	6.3	11.5	20.2
25.0	1.8	2.9	4.2	7.7	13.5
19.0	1.4	2.2	3.2	5.8	10.2
12.5	0.89	1.4	2.1	3.8	6.7
9.5	0.67	1.1	1.6	2.9	5.1
4.75	0.33	0.54	0.80	1.5	2.6

[A] Sieve frame dimensions in inch units: 8.0-in. diameter; 10.0-in. diameter, 12.0-in. diameter; 13.8 by 13.8 in. (14 by 14 in. nominal); 14.6 by 22.8 in. (16 by 24 in. nominal).

[B] The sieve area for round sieve frames is based on an effective diameter 12.7 mm (½ in.) less than the nominal frame diameter, because Specification E11 permits the sealer between the sieve cloth and the frame to extend 6.35 mm (¼ in.) over the sieve cloth. Thus the effective sieving diameter for a 203.2-mm (8.0-in.) diameter sieve frame is 190.5 mm (7.5 in.). Sieves produced by some manufacturers do not infringe on the sieve cloth by the full 6.35 mm (¼ in.).

[C] Sieves indicated have less than five full openings and should not be used for sieve testing except as provided in 8.6.

8.5 In the case of coarse and fine aggregate mixtures, refer to 8.3.1 to prevent overloading of individual sieves.

8.5.1 Optionally, reduce the portion finer than the 4.75-mm (No. 4) sieve using a mechanical splitter according to Practice C702. If this procedure is followed, compute the mass of each size increment of the original sample as follows:

$$A = \frac{W_1}{W_2} \times B \quad (1)$$

where:

A = mass of size increment on total sample basis,
W_1 = mass of fraction finer than 4.75-mm (No. 4) sieve in total sample,
W_2 = mass of reduced portion of material finer than 4.75-mm (No. 4) sieve actually sieved, and
B = mass of size increment in reduced portion sieved.

8.6 Unless a mechanical sieve shaker is used, hand sieve particles larger than 75 mm (3 in.) by determining the smallest sieve opening through which each particle will pass. Start the test on the smallest sieve to be used. Rotate the particles, if necessary, in order to determine whether they will pass through a particular opening; however, do not force particles to pass through an opening.

8.7 Determine the mass of each size increment on a scale or balance conforming to the requirements specified in 5.1 to the nearest 0.1 % of the total original dry sample mass. The total mass of the material after sieving should check closely with original mass of sample placed on the sieves. If the amounts differ by more than 0.3 %, based on the original dry sample mass, the results should not be used for acceptance purposes.

8.8 If the sample has previously been tested by Test Method C117, add the mass finer than the 75-μm (No. 200) sieve determined by that test method to the mass passing the 75-μm (No. 200) sieve by dry sieving of the same sample in this test method.

9. Calculation

9.1 Calculate percentages passing, total percentages retained, or percentages in various size fractions to the nearest 0.1 % on the basis of the total mass of the initial dry sample. If the same test sample was first tested by Test Method C117, include the mass of material finer than the 75-μm (No. 200) size by washing in the sieve analysis calculation; and use the total dry sample mass prior to washing in Test Method C117 as the basis for calculating all the percentages.

9.1.1 When sample increments are tested as provided in 7.6, total the masses of the portion of the increments retained on each sieve, and use these masses to calculate the percentages as in 9.1.

9.2 Calculate the fineness modulus, when required, by adding the total percentages of material in the sample that is coarser than each of the following sieves (cumulative percentages retained), and dividing the sum by 100: 150-μm (No.

100), 300-μm (No. 50), 600-μm (No. 30), 1.18-mm (No. 16), 2.36-mm (No. 8), 4.75-mm (No. 4), 9.5-mm (3/8-in.), 19.0-mm (3/4-in.), 37.5-mm (1½-in.), and larger, increasing in the ratio of 2 to 1.

10. Report

10.1 Depending upon the form of the specifications for use of the material under test, the report shall include the following:

10.1.1 Total percentage of material passing each sieve, or

10.1.2 Total percentage of material retained on each sieve, or

10.1.3 Percentage of material retained between consecutive sieves.

10.2 Report percentages to the nearest whole number, except if the percentage passing the 75-μm (No. 200) sieve is less than 10 %, it shall be reported to the nearest 0.1 %.

10.3 Report the fineness modulus, when required, to the nearest 0.01.

11. Precision and Bias

11.1 *Precision*—The estimates of precision for this test method are listed in Table 2. The estimates are based on the results from the AASHTO Materials Reference Laboratory Proficiency Sample Program, with testing conducted by Test Method C136 and AASHTO No. T 27. The data are based on the analyses of the test results from 65 to 233 laboratories that tested 18 pairs of coarse aggregate proficiency test samples and test results from 74 to 222 laboratories that tested 17 pairs of fine aggregate proficiency test samples (Samples No. 21 through 90). The values in the table are given for different ranges of total percentage of aggregate passing a sieve.

11.1.1 The precision values for fine aggregate in Table 2 are based on nominal 500-g test samples. Revision of this test method in 1994 permits the fine aggregate test sample size to be 300 g minimum. Analysis of results of testing of 300-g and 500-g test samples from Aggregate Proficiency Test Samples 99 and 100 (Samples 99 and 100 were essentially identical) produced the precision values in Table 3, which indicate only minor differences due to test sample size.

NOTE 6—The values for fine aggregate in Table 2 will be revised to reflect the 300-g test sample size when a sufficient number of Aggregate Proficiency Tests have been conducted using that sample size to provide reliable data.

TABLE 2 Precision

	Total Percentage of Material Passing		Standard Deviation (1s), %[A]	Acceptable Range of Two Results (d2s), %[A]
Coarse Aggregate:[B]				
Single-operator precision	<100	≥95	0.32	0.9
	<95	≥85	0.81	2.3
	<85	≥80	1.34	3.8
	<80	≥60	2.25	6.4
	<60	≥20	1.32	3.7
	<20	≥15	0.96	2.7
	<15	≥10	1.00	2.8
	<10	≥5	0.75	2.1
	<5	≥2	0.53	1.5
	<2	>0	0.27	0.8
Multilaboratory precision	<100	≥95	0.35	1.0
	<95	≥85	1.37	3.9
	<85	≥80	1.92	5.4
	<80	≥60	2.82	8.0
	<60	≥20	1.97	5.6
	<20	≥15	1.60	4.5
	<15	≥10	1.48	4.2
	<10	≥5	1.22	3.4
	<5	≥2	1.04	3.0
	<2	>0	0.45	1.3
Fine Aggregate:				
Single-operator precision	<100	≥95	0.26	0.7
	<95	≥60	0.55	1.6
	<60	≥20	0.83	2.4
	<20	≥15	0.54	1.5
	<15	≥10	0.36	1.0
	<10	≥2	0.37	1.1
	<2	>0	0.14	0.4
Multilaboratory precision	<100	≥95	0.23	0.6
	<95	≥60	0.77	2.2
	<60	≥20	1.41	4.0
	<20	≥15	1.10	3.1
	<15	≥10	0.73	2.1
	<10	≥2	0.65	1.8
	<2	>0	0.31	0.9

[A] These numbers represent, respectively, the (1s) and (d2s) limits described in Practice C670.

[B] The precision estimates are based on aggregates with nominal maximum size of 19.0 mm (3/4 in.).

11.2 *Bias*—Since there is no accepted reference material suitable for determining the bias in this test method, no statement on bias is made.

12. Keywords

12.1 aggregate; coarse aggregate; fine aggregate; gradation; grading; sieve analysis; size analysis

TABLE 3 Precision Data for 300-g and 500-g Test Samples

Fine Aggregate Proficiency Sample				Within Laboratory		Between Laboratory	
Test Result	Sample Size	Number Labs	Average	1s	d2s	1s	d2s
Test Method C136/AASHTO No. T 27							
Total material passing the No. 4 sieve (%)	500 g	285	99.992	0.027	0.066	0.037	0.104
	300 g	276	99.990	0.021	0.060	0.042	0.117
Total material passing the No. 8 sieve (%)	500 g	281	84.10	0.43	1.21	0.63	1.76
	300 g	274	84.32	0.39	1.09	0.69	1.92
Total material passing the No. 16 sieve (%)	500 g	286	70.11	0.53	1.49	0.75	2.10
	300 g	272	70.00	0.62	1.74	0.76	2.12
Total material passing the No. 30 sieve (%)	500 g	287	48.54	0.75	2.10	1.33	3.73
	300 g	276	48.44	0.87	2.44	1.36	3.79
Total material passing the No. 50 sieve (%)	500 g	286	13.52	0.42	1.17	0.98	2.73
	300 g	275	13.51	0.45	1.25	0.99	2.76
Total material passing the No. 100 sieve (%)	500 g	287	2.55	0.15	0.42	0.37	1.03
	300 g	270	2.52	0.18	0.52	0.32	0.89
Total Material passing the No. 200 sieve (%)	500 g	278	1.32	0.11	0.32	0.31	0.85
	300 g	266	1.30	0.14	0.39	0.31	0.85

SUMMARY OF CHANGES

Committee C09 has identified the location of selected changes to this test method since the last issue, C136 – 05, that may impact the use of this test method. (Approved February 15, 2006)

(1) Revised 8.5.1.
(2) Revised 7.7.2.
(3) Revised 8.5.

Committee C09 has identified the location of selected changes to this test method since the last issue, C136 – 04, that may impact the use of this test method. (Approved February 1, 2005)

(1) Added 5.3.
(2) Revised 8.5.

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