Troxler Electronic Laboratories, Inc. - Troxler International, Ltd.
3008 Cornwallis Road, P.O. Box 12057, Research Triangle Park, NC 27709 - USA
Telephone: 1.919.549.8661 Telefax: 1.919.549.0761 Web: troxlerlabs.com

APPLICATION BRIEF

Model 4140/4141 Gyratory Compactor
Specimen Preparation in Superpave™ Mix Design

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Introduction

From 1987 through 1993, the United States Strategic Highway Research Program (SHRP) developed a new system for analyzing asphalt materials and designing hot mix asphalt. Called Superpave, the program is a system for specifying and testing component materials, designing asphalt mixtures, testing mixes, and predicting pavement performance.

The Troxler Gyratory Compactor is an integral part of the mix design and testing phases of Superpave. The Gyratory Compactor compacts an asphalt specimen by applying a pressure of 600 KPa to the mix while gyrating the mold at an angle of 1.25°. The height of the specimen is continually monitored, providing information on the density of the mix throughout the compaction cycle. This information is recorded and can be sent to a computer, printed, or plotted.

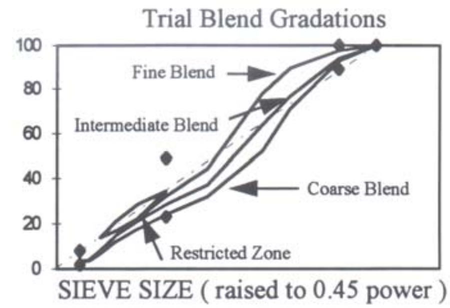
Troxler manufactures two models of Gyratory Compactors. Model 4140, which has an adjustable range of angle from 0.5° to 2.0° and adjustable pressure from 200 KPa to 1000 KPa. Model 4141 has a set angle of 1.25°and set pressure of 600 Kpa. A brief description of Superpave and its use of the Gyratory Compactor will provide a basis for understanding its application in mix design.

Superpave™

Asphalt design using Superpave (which stands for Superior Performing Asphalt Pavements) is performance based. In particular, pavement performance is analyzed with respect to permanent deformation, fatigue cracking, low temperature cracking, and the effects of aging and moisture damage. The performance of both the binder and the asphalt mixture are analyzed in the development. Superpave provides a mix design based on the amount of pavement traffic in ESALs (Equivalent Single Axle Load), the environmental conditions, and the pavement structures.

A mix design using Superpave begins with a selection of materials to be used. Superpave has defined a grading system for asphalt binders, designated PG (for Performance Graded). In the PG grading system, the performance of the binder is defined with a temperature/viscosity profile based on the minimum air temperature and maximum pavement temperature that are encountered at the specific site. Traffic volume and speed may also affect PG - grade selection.

A series of tests are performed on the binder at various temperatures and ages. The Dynamic Shear Rheometer is used to measure the elastic properties of the hot binder, measuring the magnitude and phase response of a thin binder specimen to an oscillatory shear loading. A Bending Beam Rheometer is used to characterize the low temperature stiffness of the binder. A Rotational Viscometer is used to determine the temperature for mixing the asphalt components.



Analysis of various binders is performed at two temperatures to measure changes in properties. Minimum standards for the tests are set, and the minimum and maximum temperatures at which the binder meets these requirements is determined. Hence, the binder is not specified by some property, such as viscosity, but rather by a minimum and maximum temperature. A binder graded PG 64-22 can be expected to have acceptable high temperature qualities at or below 64 °C and adequate low temperature qualities at or above –22 °C. Aggregate gradation is defined using a 0.45 power gradation chart with control points and a restricted zone. This is used to insure a strong stone skeleton with sufficient void space for durability. The design aggregate structure is selected based on the required air voids in the total mix, voids in mineral aggregate (VMA), voids filled with asphalt (VFA), and dust proportions.

Gyratory Compactor and Mix Design

For each aggregate blend, the approximate asphalt content to achieve 4% air voids at N-design is calculated. Using this value for asphalt content, mix is prepared from each blend. At least two specimens are prepared from each blend using the Gyratory Compactor.

The Gyratory Compactor not only provides compacted specimens, it also provides information on the ability of the mix to be compacted. The Gyratory Compactor compacts the asphalt mixture with a fixed pressure while gyrating the mold at a fixed angle.

The aggregate and binder are combined at an appropriate mixing temperature. The hot mix asphalt (HMA) is aged by placing the loose mix in a pan and allowing it to cure in a forced draft oven at 135 °C for 2 hours. The mix is then brought to compaction temperature by placing in second oven for up to 30 minutes. The molds and mold pucks for the gyratory compactor must be pre-heated in an oven to the designated compaction temperature.

A quantity of HMA sufficient to achieve a 115-mm specimen height is placed between specimen papers in the heated cylindrical mold. Depending on the specific gravity of the aggregates, approximately 4,900 grams is needed for a 115-mm high specimen. The mold has an inner diameter of 150 mm.

The mold is then placed in the Gyratory Compactor, and a ram is moved to apply a fixed pressure of 600 kPa to the mix. The mold is then tilted to 1.25° while the upper and lower pucks remain parallel to each other and perpendicular to the original axis of the cylinder. While maintaining the pressure and preventing the mold from rotating, the mold is gyrated at 1.25° about the original central axis at 30 rpm. As the specimen compacts, its height is measured after each gyration and displayed to the nearest 0.1 mm.

The design number of gyrations (N-design) is based on the design road traffic and average high air temperature. The Gyratory Compactor continues to the designated number of gyrations. The specimen is removed through the top of the mold with an extruder.

Densification Data from Gyratory Compactor

Gmm = 2.562			
# of Gyrations	Specimen 1 % Gmm	Specimen 2 % Gmm	Average % Gmm
5	85.8%	85.5%	85.7%
10	88.2%	87.8%	88.0%
15	89.6%	89.1%	89.4%
20	90.6%	90.1%	90.3%
30	92.1%	91.5%	91.8%
40	93.0%	92.6%	92.8%
50	93.7%	93.3%	93.5%
60	94.4%	94.0%	94.2%
80	95.4%	94.9%	95.1%
100	96.1%	95.6%	95.8%
125	96.8%	96.2%	96.5%
150	97.3%	96.8%	97.0%
174	97.7%	97.2%	97.5%
Gmb (meas)	97.7%	97.2%	

The bulk density of each specimen is measured and, using the height data taken during gyration, the density of the mix at various numbers of gyrations is determined. These densities are converted to a percent of maximum density (%Gmm) and may be plotted on a semi-log graph with the log of the number of gyrations on the x-axis and the percent of maximum density on the y-axis.

Based on the road traffic and temperature requirements of the pavement, an initial, design, and maximum number of gyrations can be determined. The initial value relates to the first roller pass, the design value indicates a mix that has been compacted and has initial traffic loading, while the maximum value relates to the end of design life condition of the pavement. The mix should be less than 89% Gmm at an initial number of gyrations (7 to 10 gyrations). If compaction at the initial number of gyrations is greater than 89% Gmm, the mixture may be too tender allowing the mixture to compact too quickly. At the maximum number of gyrations, the mix should be less than 98% Gmm to prevent low air void contents due to normal traffic compaction throughout the life of the pavement. The target is 96% Gmm (4% air voids) at the design number of gyrations.

Using height data and final bulk specific gravities (Gmb) of two specimens prepared for each aggregate gradation, the values for %Gmm at the initial, design, and maximum number of gyrations for each blend (the average of the two specimens) can be determined as follows:

$$\%Gmm(N) = \frac{h(N)}{h(N_{MAX})} \times \frac{Gmb}{Gmm} \times 100$$

The gyratory height data is also used to calculate the percent air voids, percent voids in mineral aggregate (%VMA), and percent voids filled with aggregate (%VFA) for each blend:

$$\%VMA = 100 - \frac{(\%Gmm \times Gmm \times P_S)}{Gsb}$$

Where: P_S = Percent Of Aggregate
Gsb = Bulk Specific Gravity of the Aggregate

and:

$$\%VFA = 100 \times \frac{(\%VMA - (100 - \%Gmm))}{\%VMA}$$

With this information, an estimated value of asphalt content to achieve 4% air voids at the design number of gyrations can be determined for each blend. Using this estimated value, anticipated results for %VMA and %VFA with the new asphalt content can also be calculated. Finally, the expected values for dust proportion can be approximated.

Based on these estimated values, each blend can be evaluated using volumetric design criteria based on the traffic and maximum aggregate size. Using this information, an optimal blend of aggregate is selected. Typical design criteria are as follows:

%Gmm (N-Initial)	< 89%	(All Mixes)
%Gmm (N-Design)	= 96%	(Design Target)
%Gmm (N-Maximum)	< 98%	(All Mixes)
%VMA	13.0% Minimum	(19 mm Nominal)
%VFA	65% to 75%	(10–30 x $l0^7$ ESALS)

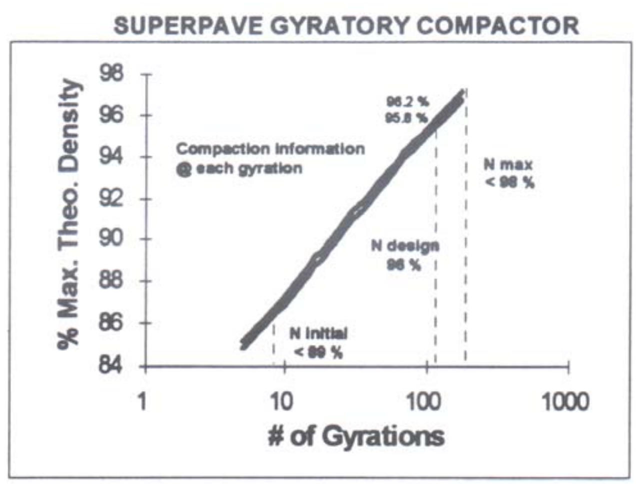
Once the aggregate blend is selected, the optimal asphalt content must be determined. Two specimens are prepared in the gyratory compactor using the desired aggregate blend and asphalt content values at the estimated value and the estimated value –0.5%, +0.5%, and +1.0%.

The bulk specific gravity (GMB) from the gyratory compacted specimen is used to calculate %Gmm at initial, design, and maximum number of gyrations. This information is also used to calculate %VMA, %VFA, and dust proportion for each mix. Again, this information is evaluated using the design criteria to select an optimal asphalt content.

For the moisture sensitivity test performed in accordance with AASHTO T 283, the Troxler Gyratory Compactor can be used to prepare specimens with 7% air voids using the Gyrate-To-Height feature. This allows the operator to select a mass to height relationship that will yield the target air void content.

The Gyratory Compactor is instrumental in field quality control of mix designs. The Gyratory Compactor can compact specimens using HMA directly from the truck or plant to determine that nothing has changed in the mix to affect initial, design, or final asphalt densities.

The Marshall Hammer cannot be used in lieu of a Gyratory Compactor for Superpave mix design or field verification. This is due to the variability of hammer-based specimens. In addition, specimens prepared with a Marshall Hammer can only be tested for bulk specific gravity (and % Compaction) of the finished samples; whereas, the gyratory compacted specimen is monitored throughout the compaction effort, resulting in % Compaction at every gyration.



Advantages of the Gyratory Compactor

The Troxler Gyratory Compactor offers numerous advantages over previous gyratory compactors. Troxler uses an innovative method of angle induction called “base-offset angle induction.” Previous compactors induced the angle by using three sets of cam-followers to hold a heavy ring that was part of the mold. By offsetting the cam-followers and then rotating all the cam followers about the mold, the angle was induced and gyration accomplished.

Troxler induces the angle by holding the top of the mold in a fixed position while displacing the base about an offset bearing. By continuing to rotate the offset bearing, the induced angle is gyrated about the central axis. The angle can then be removed by reversing the direction of rotation. This method of angle induction is not only inherently more efficient, but also eliminates the wear associated with the high pressures seen in the pinching cam-follower systems. Also, with no horizontal surfaces involved in angle inducement, the Troxler method is less prone to angle error due to asphalt or trash build-up.

With the more efficient angle induction method, the Troxler Gyratory Compactor is completely electric with a stepping motor supplying compaction pressure and a dc motor driving the gyration and angle induction. No hydraulics are needed. The maximum power required for the Troxler unit is 120 V ac (1200 W, 10 A at 120 V ac).

Greater efficiency, combined with direct drive between the stepping motor and a ball screw jack to drive the ram reduces the wear and required maintenance on the Troxler machine. Parts that could see high wear, such as the mold and the pucks, are hardened and are easy to inspect or replace if needed.

Verification of the Troxler Gyratory Compactor calibration is simple and largely automatic. Height verification is performed by placing a single standard in the sample chamber and entering the actual standard height (stamped on the standard). For pressure verification, a load cell is placed in the sample chamber and its output is connected to the Gyratory Compactor through the serial port. The system then automatically performs a six-point pressure verification and displays the results. Rotational speed verification is performed automatically using dual hall-effect sensors.

Angle verification is quick and easy using the electronic angle excursion indicator. The indicator is used to identify the induced angle as the compactor gyrates at the constant pressure with HMA in the mold. Measuring the angle under load provides improved reliability. Adjustment of the angle on 4140 can be performed by loosening two screws and resetting a sliding block. The resulting angle is then determined by measuring the base excursion and entering that number into the compactor controller unit. The system then calculates the mold angle based on a factory calibration. The entire process takes less than twenty minutes to complete. The Troxler TMA (True Mold Angle) device can be used to dynamically measure the true mold angle during the compaction.

The Troxler Gyratory Compactor complies with all specifications issued by the Federal Highway Administration in their requirements for Superpave. The Troxler angle is adjustable from 0.5° to 2.0° with an accuracy of ± 0.02°. Pressure is calibrated and adjustable from 200 KPa to 1000 KPa. Specimen height can be as low as 50 mm.

The Troxler Gyratory Compactor is shipped from the factory calibrated to the SHRP Superpave specifications. The angle is calibrated and set at 1.25°, the pressure is set at 600 KPa, and the rotational speed is set at 30 RPM. The compactor is designed to produce 150-mm specimens. An optional package is available for preparing 100-mm specimens.

Operation of the Troxler Gyratory Compactor requires only a single keypress. This will lower the ram, induce the angle, perform a compaction while recording height data, remove the angle, raise the ram, and download the height data to a computer or printer. The system is microcontroller-based, storing all calibration constants in non-volatile RAM. Last 6 data sets in the model 4140 and last 12 sets in the model 4141 are stored with time/date stamping.

Another feature of the Troxler Gyratory Compactor is the ability to compact to a target specimen height. Instead of compacting for a set number of gyrations, the user may enter a desired specimen height and compact until this height is achieved or until the maximum number of gyrations is reached. This is useful in generating specimens with a target percent air voids.

The Gyratory Compactor offers many advantages over hammer-based methods of specimen preparation. The major advantage of the Gyratory Compactor is the ability not only to produce a finished specimen, but also to provide density data per gyration during compaction. This allows the user to design for the target compaction when the road is placed, prevents tender mixes and demonstrates long-term compaction effects.

Further, the gyratory method of compaction is more similar to actual traffic loads on roads compared to compaction done using a Marshall Hammer. The compaction effort with the Gyratory Compactor utilizes direct, continuous vertical pressure combined with rotational shear forces, rather than peak impulse pressures.

Finally, the Gyratory Compactor provides repeatable results. Since the parameters of the work going into the mix are highly controlled, the output from various compactors should be essentially the same.

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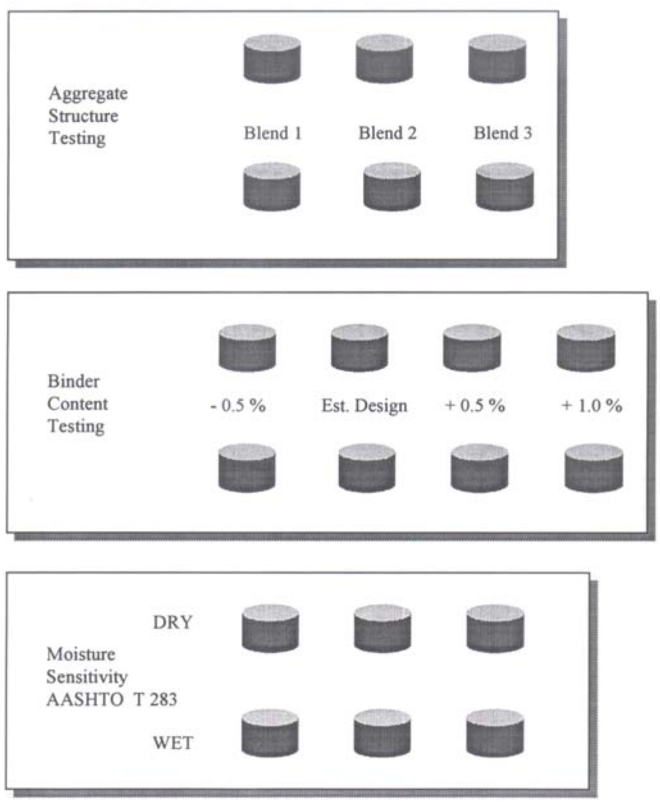

Total Specimen s=20