Gyratory compaction: an Italian case study

The use of the gyratory compactor to design and control bituminous mixes is becoming widely used.

In the US the Superpave programme developed by the Strategic Highway Research Program (SHRP), and in Europe through the European Standards prEN 12697-9 and prEN 12697-10, the use of the gyratory compactor is the fundamental instrument for laboratories dedicated to the design and control of bituminous pavements.

The gyratory test defines the mix by its volumetric characteristics. A given sample mass, heated to its optimum temperature in function of the bitumen viscosity required during pavement laying, is held within a cylindrical steel mould and then compacted by two simultaneous actions by the compactor.

A vertical static compression and a gyratory action consists of a rotation with an axial offset of the cylinder mass with respect to the vertical axis of the compactor’s load ram. The normal angles are 1.25° for Superpave and provisionally 1° for European standard projects.

The rotational frequency and vertical pressure is the same for both methods: 30 gyrations per minute and 600 kPa respectively.

The software supplied with the compactor continuously reads decrease of the sample height using an on-board displacement transducer. It displays the sample height, density, percentage voids, percentage voids filled aggregates (VMA), percentage voids filled bitumen (VFB) and percentage of max theoretical density (Gmm) for each gyration and furnishes a compaction curve of percentage max theoretical density versus the number of gyrations which is shown on a log scale on the horizontal axis. Three points corresponding to the three characteristic numbers of gyrations, that is N initial, N design, and N max are plotted on the graph, corresponding to 89%, 96% and 98% of max theoretical density.

The density value at N initial corresponds to the initial densification at start of pavement rolling, while that at N design is the design densification that is to be reached at the completion of rolling.

From this conceptual standpoint a few considerations can be drawn:

- Mixes which give a steep densification curve indicate those with high compactibility. Their structure, consisting of an appropriate dose of bituminous binder and graded aggregates with high angularity, will absorb a high degree of compaction energy or in-situ rolling. Mixes which present a densification curve with a low slope are characterised by poor compactibility.
- Good compactibility corresponds to good resistance to permanent deformation. Indeed, the high compaction
energy can well position the interlocking aggregate pieces in the mix structure. The resulting internal friction guarantees deformation resistance of the mix in situ. With the gyratory compactor the energy is determined by the number of gyrations while the in situ energy is determined by the rolling intensity. From this brief description of the gyratory test, it becomes apparent that the volumetric method is associated to rheological aspects. It can be seen that it is the internal friction that determines the duration of the test; that is the number of gyrations to reach the density at $N_{\text{max}}$. This friction is closely correlated to the shear force that the compactor must overcome during the test. The gyratory movement generates a shear force whose entity depends upon the structure of the mix. The research gyratory compactor, model 77-B0251 from Controls of Italy, differs from the standard model in that it measures the shear force. This is achieved with a special load cell housed in the vertical load ram. With the aid of a PC and the installed software it is possible to read the maximum shear force at each gyration. The test report presents a table with shear force (kN/m²) together with the other parameters normally associated with the gyratory test (sample height, density, voids, VMA, VFB) at the various gyrations. The shear force is expressed in kN/m². The maximum shear forces we have measured in experimentation vary between 300 and 400 kN/m². One may rightly observe that the measured values include the friction induced by the sample on the sides of the cylindrical mould walls during the compaction. While this is true in the determination of the absolute shear value, it becomes negligible if the measurements are used in terms of normalised values (that is the percentage ratio with respect to a given value, for example the maximum recorded value during the test). What is more, in this way it is possible to compare the behaviour of the shear force between various bituminous mixes of the same type.

The machine used in our studies was installed about two years ago at an asphalt plant in San Donato near Milan, Italy. It became evident from the outset that the shear force measurement gave a useful indicator to the operator on the performance of the bituminous mix. Having measurements, comparable between each other, of shear forces during tests, we realised that we had a useful research tool, which allows the investigation of the relationship between this parameter and other parameters.

Thus Controls has been able to study the results of a great number of tests made during this period. Five types of bituminous conglomerates have been considered. A base mix with natural bitumen with penetration 60/70 with 10% recycled. A base mix with bitumen 60/70 modified hard with 10% recycled. A binder with bitumen 60/70 modified hard with 10% recycled. A wearing mix with bitumen 60/70 modified soft with 10% recycled. A drained wearing mix with bitumen 60/70 modified hard. Naturally the data of our study are subject to discontinuity in that they refer to data collected in real working conditions and not ad hoc research mixes.

However, for this very reason, we think we have reached some very interesting correlations which confirm the validity of reading shear forces.

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A fuller version of this report is available from Controls.