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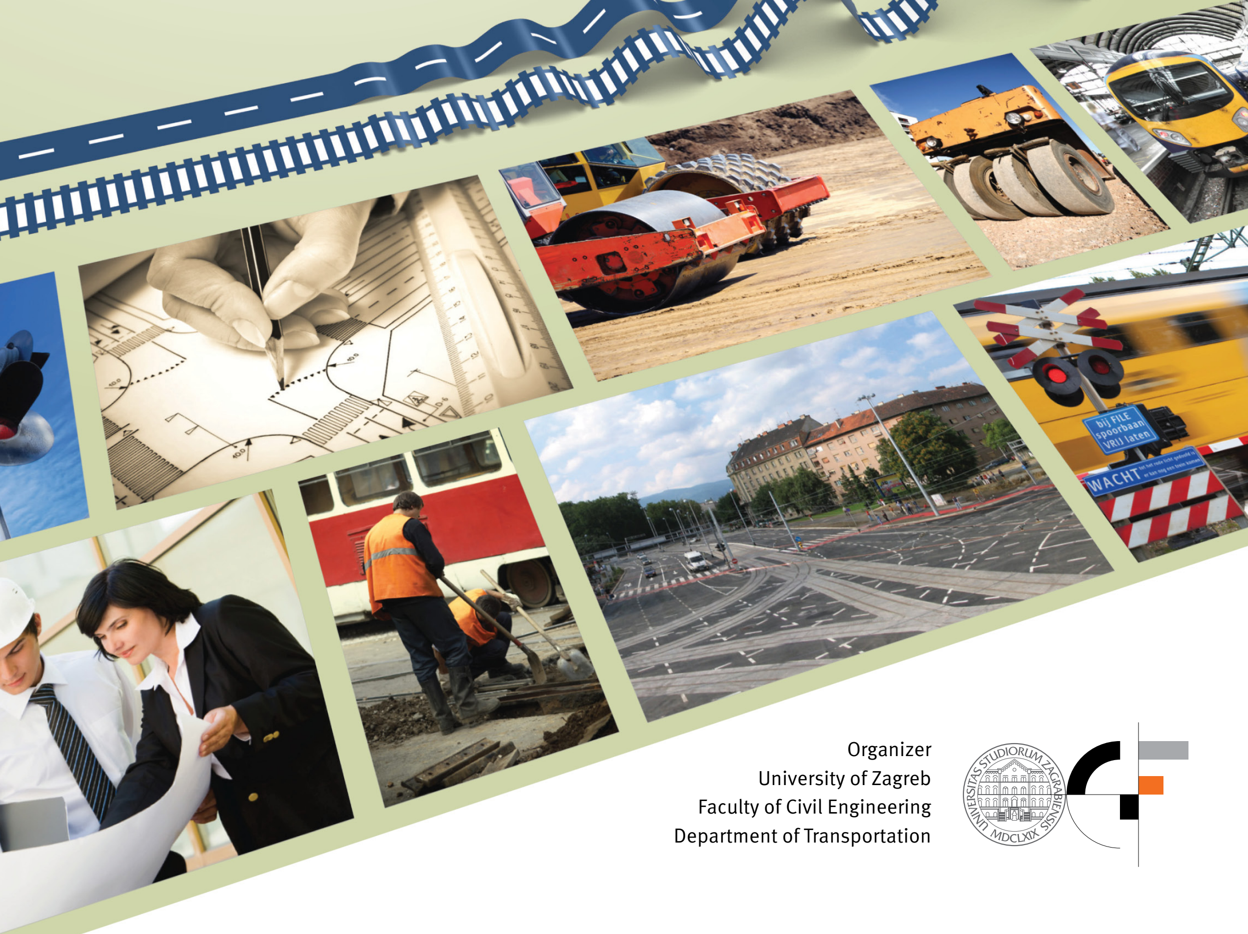
7–9 May 2012, Dubrovnik, Croatia

Road and Rail Infrastructure II

Stjepan Lakušić – EDITOR



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Road and Rail Infrastructure II

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THE INFLUENCE OF COMPACTION METHODS ON PROPERTIES OF ASPHALT MIXTURES: IMPACT COMPACTION VS. SLAB COMPACTION

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Abstract

The method of laboratory compaction influences the mechanical properties of asphalt specimens. Hence in selecting a compaction method, factors such as the ease, the cost of specimen production and the ability to represent field compaction are considered. Among the different compaction methods, slab compaction is recognized for its considerable similarity to field compaction. On the other hand, the simplicity of preparing specimens using impact compaction method has led to its widespread use despite its failure to simulate field compaction. The goal of the present study was to compare the properties of specimens prepared by impact and slab compaction. The study specifically aims to determine the shift factors that can be used to relate the properties of impact compacted specimens with specimens prepared by slab compaction. The differently compacted specimens were fabricated with identical geometric and volumetric characteristics using two types of mixtures. Properties investigated included the marshall stability and flow, and the resistance to permanent deformation. The permanent deformation behavior of the specimens was evaluated using uniaxial cyclic compression tests. Results showed that the two compaction methods produced specimens with widely varying mechanical properties. Impact compaction was found to produce specimens that were stable and more resistant to permanent deformation than those produced by slab compaction. Specimens produced by impact compaction were also observed to be less susceptible to flow. The comparison of the specimens' properties revealed the shift factors that can be used to accurately translate the properties of impact compacted specimens to those observed in slab compacted specimens. Shift factors are recommended when using impact compacted specimens in performance related testing of asphalt mixtures. The shift factors may enable the impact compaction method to more closely represent field conditions.

Keywords: asphalt, impact compaction, slab compaction, permanent deformation, compaction shift factor

1 Introduction

The method of compaction is known to influence the mechanical properties of asphalt specimens [1], [2]. Depending on the laboratory compaction method used to simulate the field compaction process, the properties of asphalt specimens have been found to vary [3], [4]. The variation in properties has been largely attributed to the difference in the aggregate matrix produced by the different methods of compaction [5], [6], [7]. Four methods of compaction have commonly been used to produce specimens in the labortory: Impact, vibratory, gyratory and slab compaction. The methods are summarized as follows.
Impact compaction is the most widely used method of laboratory compaction. In this method, a sample of mixture is compacted in a steel mould by repeatedly dropping a standard

hammer. Impact compaction offers the possibility of fabricating specimens with relative ease and at low–cost [8]. The impact nature of the compaction mechanism however, has been noted to poorly represent the kneading effect that exists in field compaction [3], [9].
In vibratory compaction, a rotating vibratory hammer is applied to the specimen face to achieve compaction. The vibratory hammer has the ability to achieve the target bulk density and air voids contents [5]. However, vibratory compaction results in non–uniformity within the compacted specimen owing to the segregation of the aggregates during compaction [10].
Gyratory compaction involves the application of a constant vertical pressure simultaneously with a kneading type of action. Gyratory compaction is known to produce specimens which are representative of materials compacted in situ [1], [4]. On the other hand, gyratory compacted specimens have been associated with problems of non–homogeneity. Variation in the distribution of air voids and segregation of aggregates in gyratory specimens has been documented [7].
Slab (roller or wheel) compaction applies a compactive force using a curved steel foot, which simulates the rolling pattern of a wheel roller. Slab compaction is recognized for its considerable similarity to field compaction process and produces homogeneous specimens with properties comparable to field cores [11]. In addition, slab compaction enables the rapid fabrication of specimens in required numbers and shapes [8].
The compaction methods are further categorized as mould–based or slab compaction [5]. Impact, vibratory and gyratory compactions are classified as mould based methods due to the fact that the specimens are compacted in cylindrical moulds. In slab compaction on the other hand, specimens are cored and cut from a larger compacted mass [6].
In this paper, the properties of impact (mould–based) and slab compacted specimens were examined. The compaction methods selected represent the most widely used methods of specimen preparation in the laboratory testing of asphalt mixtures. The study aimed at quantifying the influence of the selected compaction methods on the permanent deformation response.

2 Experimental Program

2.1 Materials

Two types of asphalt mixtures were used in the study. Mixture 1 consisted of 11–mm aggregates bounded with binder 10/40-65A, while mixture 2 comprised of 11–mm aggregates with binder 25/55-55A. The volumetric and mechanical properties of the mixtures are summarized in Table 1.

Table 1 Mixture properties

Property	Mixture 1	Mixture 2
Air voids [%]	4.6	3.6
Binder content [%]	5.8	6.0
VMA [%]	17.5	17.2
VFA [%]	73.7	79.1
Penetration at 25°C [1/10 mm]	16	23
Softening Point [°C]	68.8	65.7
Elastic Recovery [%]	50	70

2.2 Specimen preparation

A total of sixteen (16) specimens were used for the study. For each mixture, eight specimens were prepared by impact compaction, while another eight specimens were extracted from roller compacted slabs. The methods of specimen preparations are briefly discussed as follows:

2.2.1 Specimen preparation by impact compaction

Impact type compaction was achieved by a mechanical marshall hammer in accordance with DIN EN 12697-30 [12]. In this method, a sample of a mixture was placed in 101.4 mm diameter steel mould, and compacted by 100 hammer–blows. Fifty blows were applied to each face of the specimen.

2.2.2 Specimen preparation by slab compaction

A steel compactor was used to prepare specimens according to DIN EN 12697-33 [13]. The slabs were compacted to dimensions of 320 x 260 x 70 mm as illustrated in Figure 1. The thickness of the slab (70mm) was predetermined so that the cored specimens matched the bulk density achieved by impact compaction. Specimens were cored out to dimensions of 100.0 mm diameter.
All specimens were trimmed to a final length of 60mm. The bulk density of the specimens is shown in Table 2.

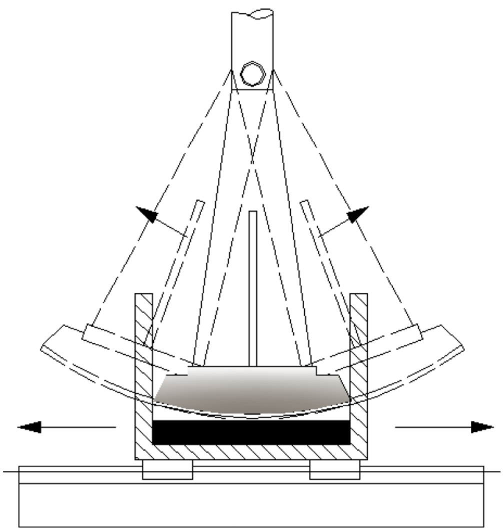

Figure 1 Schematics of slab compaction

Table 2 Bulk specific density of specimens

	Method of compaction	Bulk Density [gm/cm³]	
		Average	Standard Deviation
Mixture 1	Impact compaction	2.320	0.017
	Slab compaction	2.327	0.014
Mixture 2	Impact compaction	2.289	0.006
	Slab compaction	2.295	0.006

2.3 Testing methods

2.3.1 Marshall stability and flow test

The marshall stability and flow values were evaluated according to DIN EN 12697-34 [14]. For each type of compaction, two specimens were tested. The results of the tests were subsequently averaged to obtain the final stability and flow values.

2.3.2 Cyclic compression test

To determine the permanent deformation properties of the mixtures, cyclic compression tests were undertaken. The properties were measured in accordance with the guidelines specified in the German Technical Handbook [15]. The test was carried out with the following test parameters:

- Axial stress: 0.35MPa (maximum) and 0.025MPa (minimum);
- Load duration: 0.2 seconds (stress pulse duration) and 1.5 sec (rest period);
- Temperature: 50°C ;
- Conditioning duration: 2.5 hours;
- Load cycles: upto 10,000 load repetitions or until a turning point in the course of the strain.

Three samples each were tested for the specimens prepared by the two methods. In order to minimize the boundary friction effects, the specimen ends were treated with silicon grease and graphite.

The axial strain was measured using three external displacement transducers. For each test, the strain readings were averaged and plotted as a function of the load cycle (Figure 2). The deformation potential of a given mixture was described using the axial strain and the strain rate at the turning point in the course of the strain (see Figure 2).

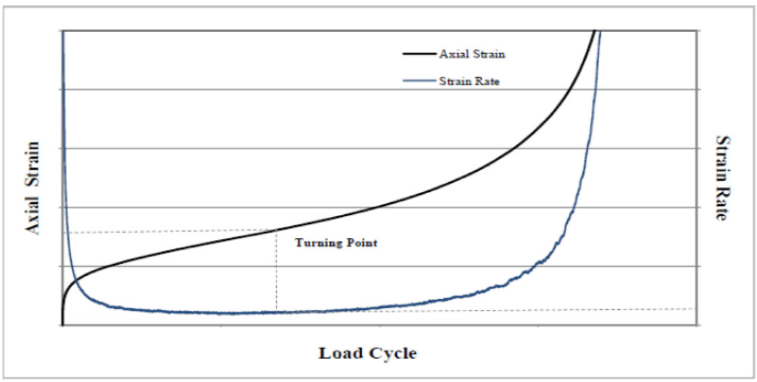

Figure 2 Typical plot of axial strain versus load cycle

3 Results

The results of the stability and flow tests are presented in Figure 3 and Figure 4. Figure 5 and Figure 6 summarize the results from the cyclic compression tests.

3.1 Influence of compaction methods on stability and flow

The comparison of the marshall stability values in Figure 3 shows that impact compaction gave specimens of slightly higher stability. However, the difference in the stability values between the differently compacted specimens appears to be less marked. Given that the specimens have comparable bulk density, it is reasonable to presume that the influence of

compaction method on stability is insignificant when specimens are compacted to a target bulk density.
Figure 4 on the other hand indicated that the effect of compaction method was more pronounced on the marshall flow of specimens. The flow values of the specimens produced by slab compaction were found to be higher (approximately by a factor of two). Since the volumetric compositions of the specimens are similar, the variations in the flow values might have occurred due to differences in the aggregate structure. The mould confinement in mould based specimens has been noted to induce a greater degree of circumferential aggregate orientation [5]. Accordingly, it is possible that the confining effect that exists in mould based compactions might have created an aggregate structure that is stiffer and less susceptible to flow.
Note: IC= Impact Compaction, SC= Slab Compaction

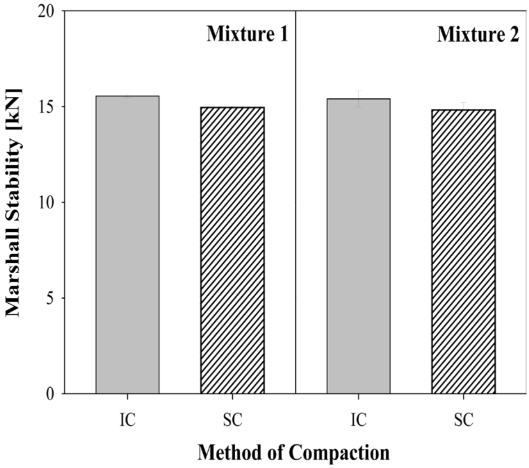

Figure 3 Influence of compaction method on marshall stability

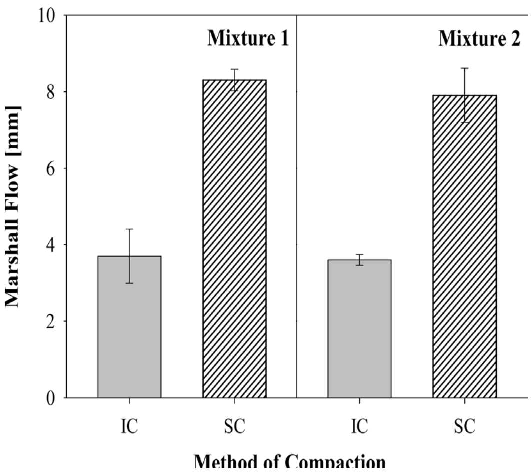

Figure 4 Influence of compaction method on marshall flow

3.2 Influence of compaction methods on permanent deformation response

The effect of the compaction method on the resistance to permanent deformation was described using the axial strain (Figure 5) and the strain rate (Figure 6). Note: IC= Impact Compaction, SC= Slab Compaction

From the figures, the following observation was made.

Specimens prepared by impact compaction exhibited lower axial strain in comparison to those prepared by slab compaction. Impact compaction method produced specimens that are approximately three times resistant to permanent deformation than the slab compacted specimens.The low strain observed in impact compacted specimens indicated that mould based specimens were more resistant to permanent deformation.

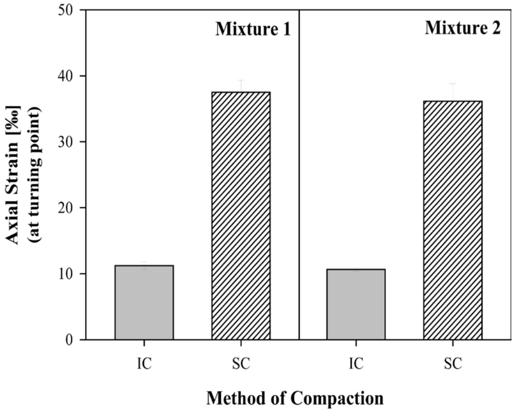

Figure 5 Influence of compaction method on axial strain

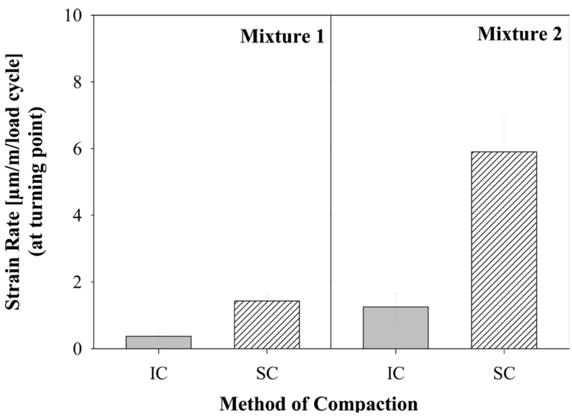

Figure 6 Influence of compaction method on axial strain rate

When using the strain rate as a measure of the deformation performance, it was found that impact compacted specimens displayed a lower rate of deformation. The low deformation rate similarly established that the impact compacted specimens were more resistant to permanent deformation than the specimens produced by slab compaction.

The different performance of the specimens could again be related to the difference in the aggregate matrix. According to Hartman et al. [2], the kneading action generated by slab compaction produced a uniformly distributed aggregate structure that is able to accommodate the reorientation of the aggregates. Consequently, it can be argued that further compaction of the aggregate particles (in slab compacted specimens) would be expected during the compressive load tests. This is evidently reflected by the excessive deformation observed in slab compacted specimens.

3.3 Compaction shift factors

Although it is agreed that slab compaction closely resembles the pavement compaction, the method requires more material to prepare the test specimens. Moreover, the method is labor intensive as specimens have to be cored out from a larger compacted mass. Impact compaction alternatively offers a method for producing specimens with relative ease.

Impact compacted specimens may be used for testing the performance related properties of asphalt mixtures provided that the influences of compaction are factored in. By introducing shift factors, the results of tests using either impact or slab compacted specimens may be used interchangeably. The shift factors account for the variations in the aggregate structure that is unique to the compaction method used.

For the test conditions used in this study, the compaction shift factors for translating the properties of impact compacted specimens with the performance expected in slab compacted specimens are shown in Table 3.

Table 3 Compaction shift factors

Property	Compaction Shift Factor
Marshall flow [mm]	2.0
Axial strain [‰]	3.3 – 3.4
Axial strain rate [µm/m/load cycle]	3.9 – 4.0

4 Summary

The study demonstrated that the method of compaction affects the mechanical properties of compacted mixtures. The mould based impact compaction method was found to produce specimens that are stiffer and more resistant to permanent deformation than those produced by slab compaction.

Given that impact compaction offers a simplified method for producing specimens, the study recommends shift factors when using impact compacted specimens in performance related testing of asphalt mixtures. The shift factors may enable the impact compaction method to more closely represent field conditions. The shift factors account for the variations in the aggregate structure that is unique to the compaction method used.

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