THE EFFECT OF SPECIMEN PREPARATION ON THE MECHANICAL PROPERTIES OF OPEN GRADED POROUS ASPHALT

AUTHORS

Anika Bushra, Graduate Engineer
Department of Civil and Environmental Engineering, The University of Auckland
E-mail: bushraanika4@gmail.com
Presenter and Primary Author

Erandi N. Seneviratne, Graduate Engineer
Department of Civil and Environmental Engineering, The University of Auckland
E-mail: nilusen12@gmail.com
Presenter and Primary Author

Thomas J. Larkin
Senior Lecturer Department of Civil and Environmental Engineering,
E-mail: t.larkin@auckland.ac.nz
Co-author

Douglas J. Wilson
Senior Lecturer Department of Civil and Environmental Engineering,
E-mail: dj.wilson@auckland.ac.nz
Co-author

Irina Holleran, PhD Candidate, BE (Civil), GIPENZ
Department of Civil and Environmental Engineering, The University of Auckland,
E-mail: imot002@aucklanduni.ac.nz
Co-author

ABSTRACT

The primary purpose of this study is to conduct dynamic modulus testing on OGPA specimens at a range of temperatures and rates of loading (frequency) to understand how OGPA performs under different environmental conditions. Shear Box Compaction (PReSBOX) was used to fabricate OGPA slabs from which 100mm and 50mm diameter specimens were extracted. The first objective was to determine the variability of the dynamic modulus of specimens extracted from different positions within a slab, as well as the variation between two slabs. The second objective, was to determine if a 50mm diameter specimen with a height of 100mm, can be used as an alternative to the standard 100mm diameter specimen when evaluating the dynamic modulus, thereby allowing more specimens to be extracted from a single slab.

Boxplots are used to represent the variability of dynamic modulus values; this shows the range of dynamic modulus values are similar within each slab, indicating little variability within a PReSBOX compacted slab, and between slabs. Subsequently, two master curves were constructed based on the 50mm data and 100mm data respectively, and the curves then superimposed. A direct overlap of the two master curves, indicates that a 50mm OGPA specimen can be used as an alternative to a 100mm diameter specimen.

1. INTRODUCTION

Open Graded Porous Asphalt (OGPA) has been utilized on the NZ road network since the 1970's (MWH, 2006). It is currently the mix of choice and is preferred worldwide over other asphalt mixes as it incorporates various safety and environmental benefits. Some of these benefits include, improved rate of drainage and storm water quality, reduced road surface light reflection and improved skid resistance (Berbee et al. 1999).

The performance properties of OGPA are commonly evaluated by determining its dynamic modulus (Bowers et al. 2015) using equipment such as the Asphalt Standard Tester (AST). Testing in New Zealand is generally carried out in accordance with AASHTO TP 79 (American Association of State Highway Transportation Officials; Standard Method of Test for Determining the Dynamic Modulus and Flow Number for Asphalt Mixtures Using the Asphalt Mixture Performance Tester (AMPT)) (AASHTO, 2009). The standard test specimen used for dynamic modulus is 100mm in diameter and 150mm in height. Previously these test specimens have exclusively been prepared in New Zealand using gyratory compactors. However, this type of compaction method is limited as only one specimen can be extracted per cylinder.

For this research, a more innovative type of compaction equipment called the PReSBOX compactor has been used. The PReSBOX Compactor fabricates a larger sample in the form of a slab, thus allowing several cylindrical test specimen to be extracted from one slab. This not only makes testing more efficient, but also reduces the specimen to specimen variation that may exist in gyratory compacted specimens.

Performing dynamic modulus testing on field source specimen is difficult due to the thinness of the layers in multi-layered OGPA. The standard size specimen used to evaluate the dynamic modulus is 100mm in diameter and 150mm in height, however the total thickness of the surfacing of OGPA is less than 150 mm (Bowers et al. 2015). In this case, a 150mm tall test specimen can be extracted only by coring horizontally and would contain multiple surfacing layers in each core. In contrast, a small scale specimen, which has a target height of 100mm, can be produced by coring vertically. In addition, a small scale specimen, cored horizontally, may also enable extraction of only one surfacing layer per core. This is more useful than obtaining a large scale specimen which not only requires horizontal coring, but also produces a core with multiple surfacing layers, potentially with different properties in each layer.

In New Zealand, OGPA layers are placed in the field at an even lower thickness (up to 35mm per layer with 4 layers staked vertically). This makes it impossible to extract a large scale (100mm diameter x 150 mm height) OGPA core from the field even with a horizontal coring technique. Therefore, a small scale (50mm diameter x 100mm height) specimen may be a more appropriate representation of field placed OGPA layers.

This research comprises two parts; firstly, to use a new method of compaction known as PReSBOX which fabricates a sample in the form of a slab and enables extraction of multiple OGPA specimens for the purpose of dynamic modulus testing. The extent of the variability of dynamic moduli existing within a PReSBOX compacted slab, and between two slabs is also determined. The second part involves comparing the dynamic modulus of a 50mm diameter specimen to a 100mm diameter specimen. The objective of this is to determine if the smaller scale specimen can be used as an alternative to the standard 100mm diameter specimen for the purpose of determining the dynamic modulus. The verification of which will enable dynamic modulus testing to be conducted on OGPA field cores extracted from New Zealand motorways.

2. Literature review

2.1. Open Graded Porous Asphalt (OGPA)

Open Graded Porous Asphalt (OGPA) is an open graded mixture containing a mix of coarse and fine aggregate, mineral filler, and a bituminous based binder. OGPA is commonly used in New Zealand motorways as a surfacing layer. This surfacing system comprises of up to 4 layers of OGPA, with each layer being 25 – 35mm thick (MWH, 2006). Most of the Auckland motorways now have two to four layers of OGPA. Assessment tools like resilient modulus testing, wheel tracking and fatigue testing, usually performed on structural asphalt, and were used on multiple layer OGPA for the investigation.

Even though OGPA is not a structural layer, dynamic modulus testing can provide very valuable data of fundamental mechanical mix properties. Dynamic modulus testing is a stiffness measurement capable of describing the mechanical properties of any mix or solid. The functionality of the OGPA is determined by its structure. A study by Coleri et al. (2013) has clearly shown that densification of porous asphalt occurs due to traffic and this changes the response to load and thus, affects life.

OGPA has various safety and environmental benefits that makes it more favourable than conventional dense graded mixtures. The higher air void content (approximately 25%) of OGPA, in comparison to a 3-5% air void content of dense graded asphalt, provides better drainage properties and can improve the quality of storm water by reducing the level of pollutants (Berbee et al. 1999). The rapid draining surface layer is beneficial to the safety of motorists, this is especially during heavy rain periods as this significantly reduces the risk of aquaplaning (Fletcher and Theron, 2011). However, the high air void content also has its drawbacks as the continuous channels allow oxygen to readily flow through the pavement, increasing the rate of oxidation. This accelerates the ageing of the binder, making the binder more brittle, resulting in a loss of performance (Putman, 2012).

2.2. Dynamic modulus testing

OGPA is a viscoelastic material and the dynamic modulus, as a function of temperature and loading, is a measure of the stiffness of a material (Bowers et al. 2015). Dynamic modulus testing procedures allow testing to be conducted at different temperatures and loading rates, which provide an understanding of how the environmental conditions and traffic loads effect the performance of OGPA pavements.

Widely used testing equipment includes the Universal Testing Machine (UTM) and the Asphalt Mixture Performance Tester (AMPT). Both devices perform non-destructive performance testing on asphalt specimens namely, dynamic modulus, flow number and flow time (AMPT tester).

Walubita et al. (2014) conducted a study to evaluate the repeatability, comparability and reliability of the UTM and AMPT for testing various performance measures including dynamic modulus testing. The study was limited to testing one dense graded mixture, using a 100mm diameter specimen of 150mm in height. Prior to testing, it was determined that the air void variance between specimens were within an acceptable tolerance, this was key as it ensured the results were unbiased. The results showed that dynamic modulus were fairly comparable at high moduli values, during low temperature testing, corresponding to a greater stiffness. Given the high viscous nature of asphalt, the study confirmed that at high temperatures the moduli values are significantly lower and that a greater variance exists for dynamic modulus results between the UTM and AMPT. A significant difference between the testing machines is the size of the environmental chamber (chamber in which testing is conducted in). The UTM has a significantly larger environmental chamber (up to 10 times larger in volume than the AMPT). Thus, the conditioning process prior to testing for the UTM requires more time than the AMPT to reach target temperature. The research concluded that AMPT was superior to the UTM in terms of temperature operational efficiency.

A recently developed testing device, known as Asphalt Standard Tester (AST) is capable of implementing the most common international performance tests on asphalt specimens. It provides various testing jigs, including facilities for a 50mm diameter specimen and 100mm diameter specimen, which makes this machine very versatile for asphalt mix research. The AST external heating chamber causes a variance in the temperature as the specimen is exposed to room temperature during handling and preparation. Therefore, once set-up for testing is complete, additional conditioning time is required to allow the specimen to reach target testing temperature.

Bowers et al. (2015) conducted a study that involved testing on gyratory compacted asphalt specimens of diameters 38mm, 50mm, and 100mm diameter. The test specimen size commonly used for dynamic modulus testing are of 100mm in diameter and 150mm in height. The aim of this study was to determine if a smaller scale specimen can be used as an alternative to the standard size specimen. The results obtained from the study are as follows:

- At the three lower temperatures, there is very little variability in dynamic modulus results between 38mm, 50mm and 100mm diameter specimens.
- The smaller specimens comprising 50mm and 38mm diameter showed a greater stiffness at higher temperatures (54^0C) of up to 10-20% more when compared to the larger 100mm specimen.

Overall, the study showed that the dynamic modulus of the 50 mm and 38 mm diameter specimen had good correlation with the 100mm diameter specimens. However, further research was recommended to understand the effect of air voids.

The findings are similar to the work carried out by Bowers et al. (2015), however, instead of using gyratory compaction to fabricate specimens, the PReSBOX compactor will be utilised.

2.3. PReSBOX compactor

The PReSBOX compactor is a piece of equipment that is used to rapidly, repeatedly and cost effectively fabricate asphalt samples in the form of a slab (450mm x 150mm x 185mm) (Qiu et al. 2012). Gabrawy (2000) conducted a study on the performance of PReSBOX compacted asphalt slabs and identified that the method of compaction best replicates the field compaction.

PReSBOX has been used in our study. Typically, the gyratory compactor has been used to compact asphalt samples for the purpose of performance testing. However, the disadvantage with this method is that a single cylindrical specimen is formed from each compaction. Inevitably, there is variation between the specimens using this method (Qiu et al. 2012). To help overcome this variation, a new method of compaction has been developed, known as the Shear Box (PReSBOX) compaction. The PReSBOX allows fabrication of a slab, which can be cored to produce several test specimens from one slab, hence one compaction.

In terms of air voids, Qui et al. (2012) tested the air void variation within and between PReSBOX compacted slabs using dense graded mixtures with different maximum aggregate sizes namely 8mm, 22mm and 32mm. The study observed range of air voids using specimens from a single slab of +/- 0.5% from the average value (air void content of the slab). However, results of air voids from specimens between slabs exhibited a higher range of up to +/- 1% with a single dense graded sample. The study was limited to comparing slabs compacted using only dense graded asphalt mixtures and the PReSBOX. The author concluded that further research is required into using various asphalt mixtures (only four dense graded mixtures were used in the study) and monitoring of the temperature profile should be considered.

2.4. Master curves

The dynamic modulus master curve is a comprehensive test result identifier commonly used as an input parameter for pavement design (Dougan et al. 2003). As stated previously, asphalt mixtures exhibit visco-elastic behaviour, i.e. the mechanical behaviour is dependent on the rate of loading, identified in this work by the use of the term “frequency”, and the properties are temperature dependent (Dougan et al. 2003). The production of a master curve involves transforming the data obtained at one temperature and frequency to an equivalent data related to a different frequency. This is known as the reduced frequency (Hz). The results associated with the reduced frequency incorporates the effects of the frequency and temperature of the testing conditions. The data is shifted onto one curve using a sigmodal function; this allows comparison of the dynamic modulus of different test specimens (including a variety of asphalt mixes and geometries) for a range of frequencies and temperatures (Dougan et al. 2003). These curves can also be used to identify how test samples behave at temperatures and frequencies that may not have been tested for, with due account of uncertainty.

This literature review has identified some gaps in knowledge with respect to testing the performance properties of OGPA both in New Zealand, and internationally. In New Zealand, no work has been carried out preparing test specimens using the PReSBOX compactor. In addition, research on porous asphalt using dynamic modulus testing is also yet to be carried out. International practise is also limited to having only conducted dynamic modulus testing on large scale OGPA specimens (comprising a 100mm diameter and 150mm height specimen) only. Furthermore, OGPA test specimens have not been prepared using the more recently developed PReSBOX compactors. Thus, Dynamic modulus testing on Open Graded Porous Asphalt, using laboratory test specimens prepared using the PReSBOX has not been investigated in NZ or overseas. This research aims to fill some of these gaps in knowledge.

3. Objectives

The PReSBOX compactor is a recent development and there is limited research on samples prepared using this type of compactor. A thorough review of the current literature has identified that, to the author’s knowledge, PReSBOX has not been previously used to prepare OGPA samples for the purpose of dynamic modulus testing. Research on the dynamic modulus itself is limited, as it has been carried out on large scale (100mm diameter x 150mm height) OGPA specimens only. This research aims to fill the gaps in knowledge that exists by satisfying the following objectives:

1) To determine the variability of dynamic modulus specimens taken from PReSBOX compacted OGPA slabs.
2) To determine if, within acceptable engineering limits, a small scale specimen comprising of a cylinder of 50mm diameter and 100mm height can be used as an alternative to the standard 100mm diameter (with a height of 150mm) specimen by comparing dynamic modulus values in a single slab and in companion slabs.

4. Methodology

For the purpose of these experiments, OGPA mix made with greywacke aggregates, comprising a 10mm aggregate size, was used. Slab samples were fabricated using PReSBOX compaction, and a coring and sawing device was used to extract 50mm and 100mm diameter core specimens from each slab. Dynamic modulus testing was conducted on all specimens.

4.1. Weight calculations

The weight of OGPA mix required to fabricate a slab sample using the PReSBOX compactor was calculated using equation (1) below,

$$M = \frac{V * MTSG *(1-AV)}{1000} \qquad (1)$$

Where;

M – Mass of mix required (g)

V – Volume of slab (124857000 mm^3)

MTSG: maximum theoretical specific gravity (2.503)

AV – Air void content (%) (25)

4.2. PReSBOX compaction

Four slab samples were fabricated to extract specimens for testing. Prior to compaction, each bag of OGPA mix was conditioned inside an oven at 130 degrees Celsius for a minimum period of 6 hours. The heated mix was then poured into the PReSBOX steel container; i.e. the mould for the slab sample. A steel rod was spiked into the mixture at the edges of the mould to reduce air void pockets that may form on the outer surface of the slab during the compaction process. All 4 slab samples were fabricated at a target temperature of 130 +/- 5 degrees Celsius using the PReSBOX compactor in accordance with ASTM: D7981-15. (2015). Figure 1 shows the PReSBOX compactor with a PReSBOX fabricated slab sample.

Figure 1: PReSBOX compactor

The method of compaction involves a combination of, constant axial load and a shear force that varies harmonically with a constant amplitude. Pneumatic actuators maintain the constant axial force, and the shear cycle is driven by an electric motor driving rams via a gearbox. The maximum shear distortion is chosen by the user and was set at 4 degrees. Figure 2 shows the PReSBOX compaction cycle (comprising of 5 cycles).

A compaction termination parameter controls when the compaction process ends; this includes the no. of cycles, density of air void content of the slab. For the purpose of this study the compaction process was terminated once the slabs reached a target air void content of 25%.

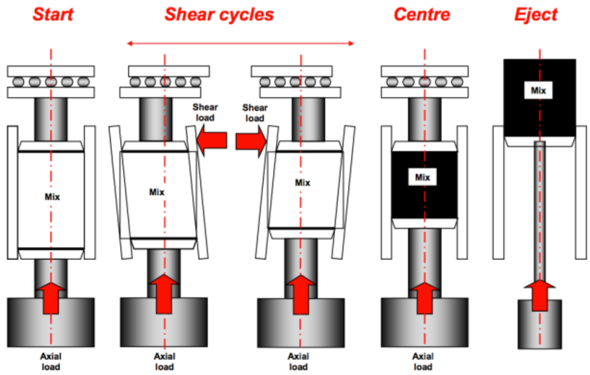

Figure 2: PReSBOX shear cycle (Molenaar et al. 2009)

A layer of epoxy glue was applied to the top and bottom surface of each slab to minimize any breakage that may occur during the coring process. Specimens comprising 50mm and 100mm diameter were extracted, using a coring device, from each slab in the arrangement shown in Figure 3 below.

As can be seen, the specimen were extracted from the edge and centre of the slab. This arrangement was used to determine the range of variability that exists of dynamic modulus at different locations within a slab. Each core was given a unique number that identified it. As shown in Figure 3, for the given slab number (slab 14, 15, 16 or 17), the 100mm core at the edge of the slab was numbered 15.1, the two 50mm cores at the centre were 15.2, 15.3; the two 50mm cores from the edge were 15.5, 15.6; and finally the 100mm core at the centre was numbered 15.4. This numbering arrangement and location of core was the same for all slabs. During the coring process one 50mm specimen (from slab 16) was damaged; this specimen was not used for testing.

Following this, the 50mm and 100mm core specimens were trimmed to a height of 100mm and 150 mm respectively. Due to limitation of equipment the 50mm specimens were manually trimmed, the 100mm specimens were trimmed using an automatic wet saw device with the pre-set height for specimen cutting.

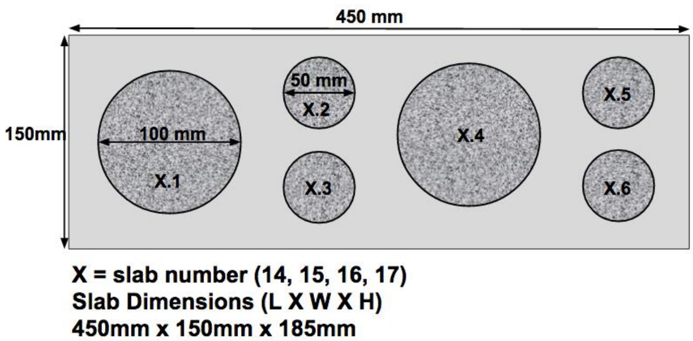

Figure 3: Coring arrangement

Coring and Sawing required constant flow of water through the sample. This left all specimens extracted damp. These specimen needed to be dried prior to dynamic modulus testing. It was intended that a core drying machine would be used, however this was not readily accessible, and therefore an electronic fan and heater was used as an alternative to dry the specimen to a moisture content of less than 0.01%. The water content of each specimen was determined using an iterative process; several measurements were taken of the diameter and height of the specimen to calculate the expected weight. This value was then compared to the measured weight; this process was repeated after further drying until the moisture content was less than 0.01% for each specimen. The surface angularity both longitudinally and horizontally were measured, and compared with the acceptable range, as given in AASHTO TP60-14 (AASHTO, 2011).

Finally, studs were attached for the purpose of dynamic modulus testing. Figure 4 and Figure 5 shows the PReSBOX sample after the specimen were cored and sawed for dynamic modulus testing.

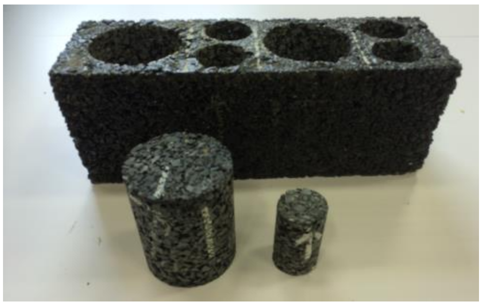

Figure 4: Cored PReSBOX sample with 100mm and 50mm specimens

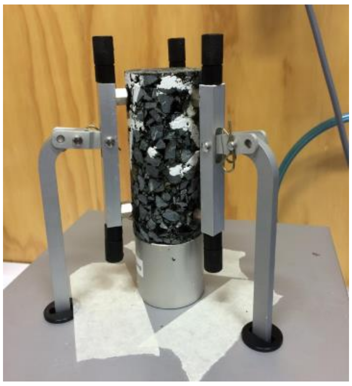

Figure 5: Attaching studs for dynamic modulus testing

4.3. Dynamic modulus testing

Prior to dynamic modulus testing, each specimen was conditioned in an external environmental chamber at the target testing temperature.

Unconfined dynamic modulus testing was conducted using the Asphalt Standard Tester (AST). This is a displacement controlled test that uses a harmonic vertical load applied using a hydraulic pump. The AST machine has a 50mm and 100mm testing jig for dynamic modulus testing. The setup involved attaching linear variable differential transducers (LVDT) to the studs on the specimens. The on-specimen LVDT's measure the resultant longitudinal deformation as the cyclic vertical load is applied.

The specimen was firstly centred on the actuator within the testing chamber, and a dummy specimen within the chamber was used to measure the temperature. Testing commenced once the temperature was within +/- 0.5 degrees Celsius of testing temperature. Dynamic modulus testing was conducted in accordance to AASHTO TP79 (AASHTO, 2009). Deviations from the specification included using some test specimens with higher that allowable surface deformation, and lower than allowable air void contents. Data from these specimens were not removed from the data set used.

Testing was conducted at a range of different temperatures and frequencies to assess the effect of different environmental conditions and traffic loads on OGPA pavements.
Temperatures: 4, 20, 30 degrees Celsius
Frequencies: 25, 15, 10, 5, 1, 0.1, 0.01 Hz
Testing was first completed on the 100mm diameter specimens, all with a height of 150mm, from all slabs. Following this, testing was conducted on the 50mm specimens which had a height of 100mm. Figure 6 shows the testing jig for the 50mm specimen.

Figure 6: AST machine and 50mm testing

5. Analysis and Discussion of Results

Dynamic modulus testing was conducted on twenty three 50mm diameter specimens and eight 100mm diameter specimens at 3 different temperatures and 7 different frequencies. A total of 483 dynamic modulus values were obtained from testing.

To analyse the validity of the results, all dynamic modulus values were assessed against AASHTO TP79 – Table 3 (single operator precision for dynamic modulus and phase angle) (AASHTO, 2009). The coefficient of variation for the average dynamic modulus of specimens, at each temperature and frequency, for each slab was calculated. The coefficient of variation for all tests were less than 15%, and all dynamic modulus and phase angle values fell within the AASHTO TP79 acceptable range.

5.1. Slab Variability

Our first objective is to determine the variability in dynamic modulus values between slabs and within each slab. To verify this, a scatter plot of the dynamic modulus results for all specimens, at different temperature and frequencies, were plotted for each slab (refer to Appendix). Figure 7 below shows the scatter plot of dynamic modulus results for slab 14, for the three testing temperatures (4°C, 20°C and 30°C from bottom to top respectively) and seven frequencies (shown along the bottom x axis). Refer to the Appendix for an enlarged version.

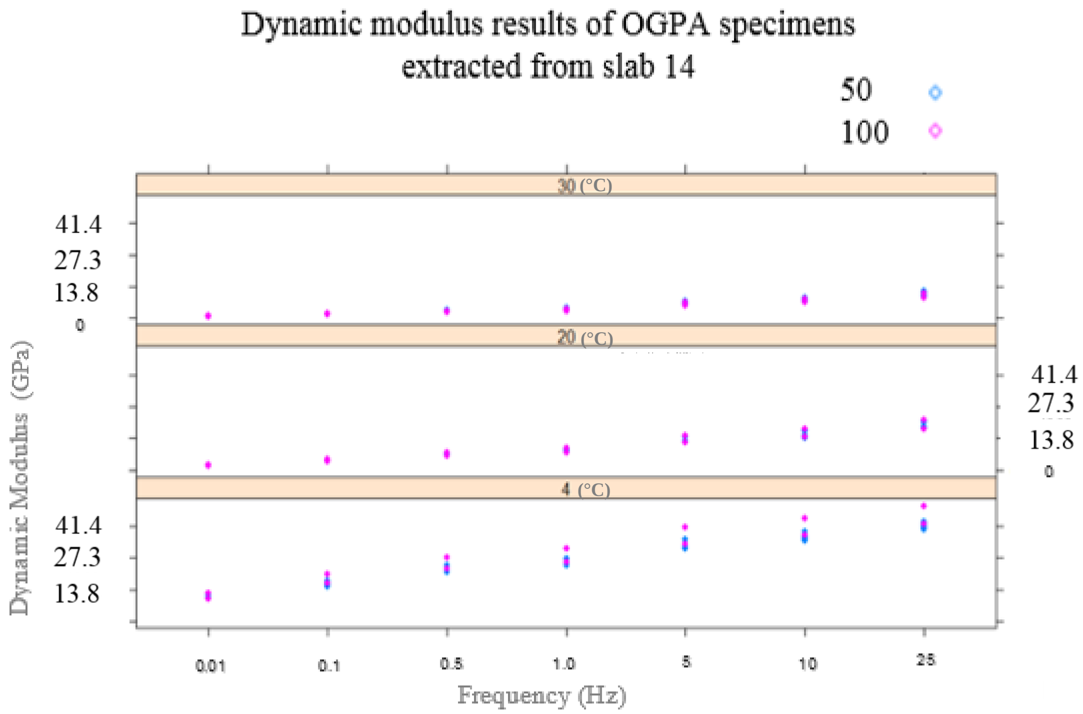

Figure 7: Dynamic modulus results for slab 14

The following trends were observed:

- An increase in the dynamic modulus of OGPA material with increase in frequency (Hz). As the frequency relates to the speed of traffic, this indicates that lower speed vehicles result in more strain on OGPA pavements than high-speed vehicles.
- The higher the temperature, the lower the dynamic modulus of the material, indicating that OGPA pavements are softer during warmer seasons.
- A larger variability, between the 50mm diameter specimens and 100mm specimens could be seen at the lower temperatures (4 degrees Celsius) when compared to values at 20 degrees and 30 degrees

OGPA has a low heat capacity. This indicates that minimal heat is required to raise the temperature of OGPA material. This is likely to have taken effect during dynamic modulus testing conducted at 4 degrees (as the testing temperature is significantly lower than room temperature). Prior to testing, the specimen was handled at room temperature, which may have increased the overall temperature of the specimen (to > 4^0C), and as a result, the temperature of each specimen would have been greater than the target temperature during testing. To reduce this effect, the test specimens were reconditioned in the environmental chamber for an additional period of time. This ensured the environmental chamber of the AST machine was settled at target testing temperature, +/- 0.5 degrees Celsius, before commencing the dynamic modulus testing.

The above trends were observed for all categories of tests. This can be seen in the figure in Appendix which includes the dynamic modulus data for all specimens tested, at different temperatures and frequencies.

Boxplots were used to further assess the variability of dynamic modulus results obtained from testing at 4 degrees Celsius as this temperature showed greatest variability of all temperatures tested (Figure 8 for the full range of frequencies). Each box plot represents the distribution of dynamic modulus values of specimens, extracted from the edge or center of the slab, for each slab, see Figure 9.

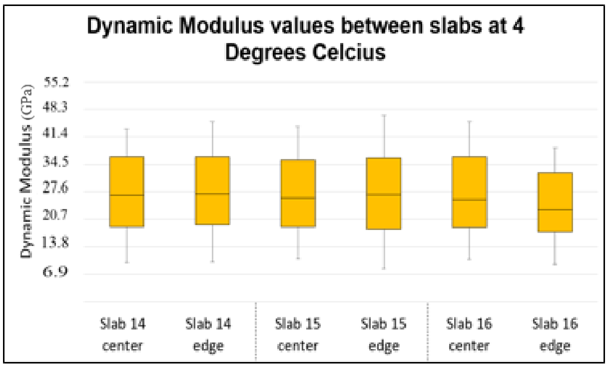

Figure 8: range of dynamic modulus results for each slab at 4 degrees

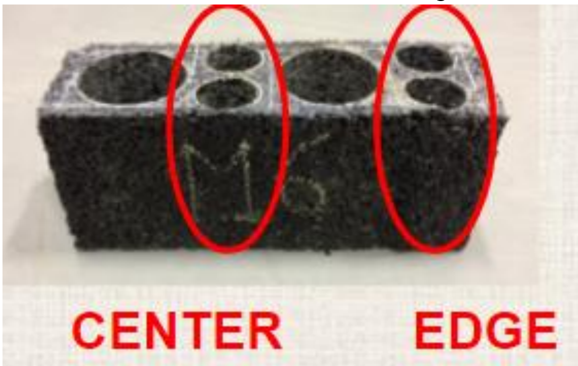

Figure 9: specimen position

Figure 8 above shows, similar dynamic modulus values between slabs. Similar observations can be drawn for specimens extracted from different locations within each slab (14, 15 and 16). However, a closer look at slab 16 – edge shows a lower maximum than the rest. One of the 50mm diameter specimens from slab 16 was damaged during the coring process and was not used for testing. Therefore slab 16 – edge box plot only comprises a range of dynamic modulus values from one specimen, as opposed to the other boxplots, which incorporates data sets from two specimens. This may have contributed to the statistical variance.

Overall visual analysis indicates, there is no evidence to show significant variability of dynamic modulus exists between slabs; therefore, it can be concluded that PReSBOX compaction results in minimal sample-to-sample variation. Furthermore, there is negligible evidence to show the existence of any significant variability between test specimens extracted from the edge and center of the slabs. This indicates that the PReSBOX may be used as a more efficient method of compaction. The equipment can produce multiple test specimens from each compaction process, without the position of extraction significantly contributing to the variance of specimen test results.

5.2. Small scale specimen vs large scale specimen

Our second objective is to determine if a smaller scale specimen of 50mm diameter can be used as an alternative to the standard 100mm diameter.

In order to investigate this, the dynamic modulus values measured over a range of temperatures and frequencies of loading are transformed into a master curve for analysis of the performance of the asphalt mixtures. Individual curves at different temperatures and frequencies are first produced and then transformed into a single master curve using mathematical equations (AASHTO, 2013).

Two master curves were constructed; one based on the 50mm data, and one based on the 100mm data; as shown in Figure 10 and 11

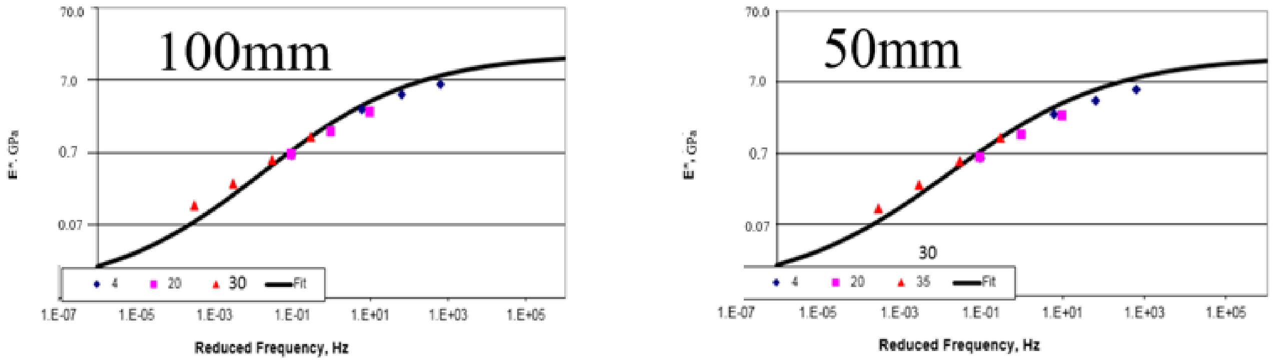

Figure 10: Master curves for 100mm and 50mm specimens respectively

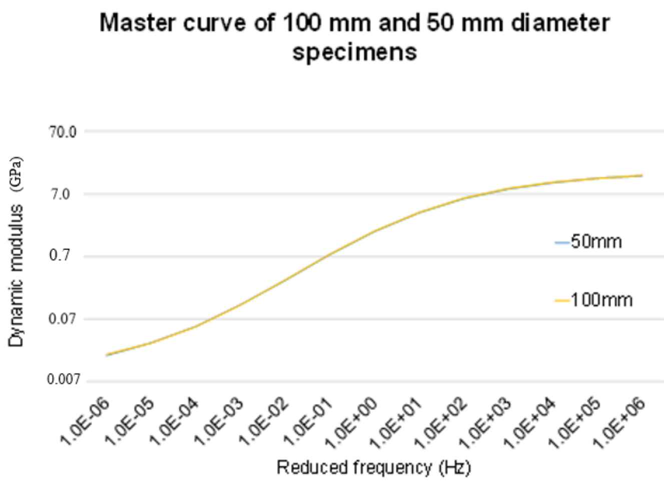

Figure 11: Overlap of 50mm and 100mm master curves

It can be seen that the data points follow the curve very closely and no apparent outliers are visible. As noted, the master curves were developed by transforming the dynamic modulus data points obtained at one temperature and frequency to the equivalent data related to a different frequency; this is known as the reduced frequency (Hz). The individual data points (shown in Appendix A) comprised some variability, the master curves do not overlap completely.

The results associated with the reduced frequency incorporates the effects of the frequency and temperature of the testing conditions. When superimposed, these 50mm and 100mm diameter master curves were found to be very similar. This is shown in **Error! Reference source not found.**2 below where the two curves have overlapped. This indicates that, under laboratory conditions, both 50mm and 100mm test specimens produce very similar performance properties in terms of dynamic modulus, despite having different geometries. This suggests that a small scale specimen (50mm diameter) may be used, within engineering accuracy, as an alternative to the standard large scale (100mm diameter) specimen for the purpose of determining the dynamic modulus.

This outcome suggests that a small scale field specimen, with a 50mm diameter and height of 100 mm (single layer) can usefully be extracted from New Zealand motorways for the purpose of dynamic modulus testing. This will provide more knowledge of the performance of OGPA surfacing pavements in New Zealand, and a better understanding of the effect of different environmental conditions and traffic speeds on OGPA pavements.

5.3. Statistical analysis

A one way analysis of variance (ANOVA) test was conducted to determine whether any statistical difference exists in the values of dynamic modulus between the different PReSBOX slabs and the specimens of different geometry.

The null hypothesis assumes that no variability exists, however, the small p value (<0.05) obtained from the tests, results in rejection of this hypothesis. This suggests that variability does exist between and within the slabs.

Overall the data is too limited (limited number of statistical samples) to undertake any meaningful statistical analysis that would provide a strong statistical argument in terms of evaluating the variability in dynamic modulus values between the four slabs.

6. Conclusions

A literature review and laboratory study was conducted to help fill the current knowledge gaps concerning OGPA and its use on New Zealand motorways. The performance properties of OGPA specimens, prepared using the PReSBOX compactor, was evaluated in terms of dynamic modulus as a function of temperature and rate of loading.

The first objective of this research was to determine existence of significant variability, in practical engineering terms, of the dynamic modulus of specimens extracted from PReSBOX compacted slabs. The results obtained from this study show that there is negligible evidence to indicate that significant variability exists within a PReSBOX compacted slab. Furthermore, results showed minimal variability between slabs. This suggests that the PReSBOX compactor can be used as a more effective alternative to conventional compactors, such as gyratory compaction.

The second objective was to determine if a small-scale specimen, with a diameter of 50mm and a height of 100mm, may be used as an alternative to the standard 100mm diameter specimen for evaluating the dynamic modulus of OGPA. The results of this study, shown by way of the overlap of the two master curves, for the 50mm and 100mm data, provides a clear indication that very similar dynamic modulus values, clearly within an acceptable engineering tolerance, can be obtained when using a 50mm diameter specimen to represent the “standard” specimen of 100mm diameter. This suggests that a 50mm diameter specimen could be a suitable alternative to the conventional 100 mm diameter specimen for dynamic modulus testing.

To further investigate relationships, statistical analysis of variance was carried out. According to the p values obtained, slab samples and test specimens of different geometry are statistically different. No specific trends could be drawn from this analysis, as the research was limited by the small number of samples used. Overall, for engineering purposes, all dynamic modulus values have been compared against the standard acceptable range given by AASHTO (AASHTO, 2013). All values obtained fell within the standard acceptable range. Furthermore, visual interpretation of all 483 dynamic moduli showed negligible variability when displayed on master curves and data plots.

To conclude, PReSBOX can be used as a more effective alternative to conventional compactors.
It has also been established that different specimen geometries (50mm and 100mm diameter) does not contribute to a significant difference in dynamic modulus, in engineering terms. A 50mm test specimen can therefore be used as a suitable alternative to the standard 100mm test specimen for

evaluating the dynamic modulus of OGPA. This in turn means that dynamic modulus testing on field samples may now be successfully carried out in New Zealand, which may not have been considered to be the case previously.

7. Limitations and Recommendations

The results of this study have been shown to successfully investigate relationships which have not been previously considered, however, limitations exist. Due to time constraints, this research was limited to only one asphalt mix), one coring arrangement and testing of only two specimen geometries (50mm and 100mm diameter). This lead to a small number of samples being prepared, thus hindering the ability to evaluate statistical relationships accurately. It is therefore recommended that future research be conducted on the following:

- varying asphalt mixes
- alternative coring arrangements within slabs
- dynamic modulus testing on 38mm diameter test specimen, in conjunction with 50mm and 100mm diameter specimens

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Appendix

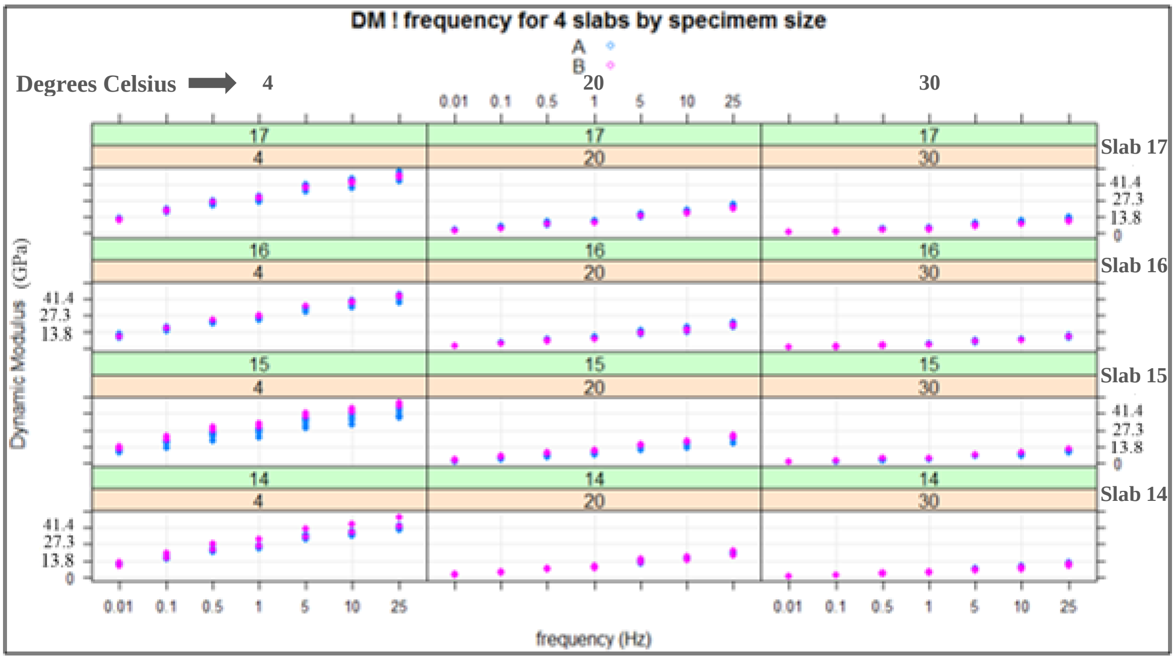

Figure: Dynamic modulus values at different temperatures and frequencies