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Development of Workability Measuring Device for Asphalt Mixture Using Electronic Transducer and Temperature Regulator

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ABSTRACT

Continuous increase in the volume of traffic in recent time has resulted to increasing demands for further research relating to the properties of material such as the workability, compatibility and stability of Hot Mixed asphalt. While the literature presents the trend in development and improvement of workability device for asphalt mixture, several authors have call for further research on improving the device. This paper seeks to address this improvement and presents the production of improved device that uses electric transducer and heat regulator for evaluating mixing temperature for workability and compatibility; determine the correlation between workability and compatibility; as a means for developing an index for measuring compatibility and workability at different temperatures; determines the stripping at different mixing and compaction temperatures as well as detecting any variation in the mix design in terms of bitumen content, fraction of combined aggregate before placing the mixed asphalt concrete on the road. This process can be performed either in the laboratory or on the field using the new device.

KEY WORDS: Workability, transducer, mix asphalt design, compatibility, mix performance.

INTRODUCTION

Increasing nature of Traffic volumes, tire pressure, and loading in recent time has place more demand on engineering roads. This development has resulted in the need for improvement in the research relating to properties of material such as the workability, compatibility and stability of Hot Mixed asphalt and more importantly is the development of relevant measuring device. A well designed and constructed road will not only support regional and national development of a country, it was also assist in sustaining the infrastructure for the lifespan it was designed for. In order to achieve this, an adequate design mix of Asphalt and other tests such as workability and stability is required. A number of researchers did evaluate the workability of asphalt mixture either by torque or number of indicators from gyration compactor and porosity [1, 2, 3] measured workability by torque, [4, 5, 6, 7, 8] measured workability by number of indicator from gyration compactor and porosity. Relevant literature has shown that little efforts have been directed the influence of temperature on the compatibility of hot mix asphalt [9]. Recently, Khweir [8] measured workability by number of indicator from gyration compactor and porosity. The authors also called for a study on the effect of mixing temperature on compatibility of asphalt mixture to produce the desirable pavement. We argue that such study can be achieved only by development and use an improved device such as workability device. The organization of this paper is as follow. This next section presents the theory underpinning the production of the device. This is followed by the relevant literatures that suggest the need for the development of an improved workability device. Thereafter, applications of the device are presented followed by verification and calibration of the machine. The procedure involve in operating the device is presented and the last section presents the conclusion made.

1.1 Theoretical Background

While the research can be underpinned by Electrostatic theory, Chemical Bonding theory, Weak Boundary layer theory, Mechanical theory and theory of mixing. For the purpose of this paper, the theory of mixing is considered as the theoretical basis for the proposed device. The reason being that this research aims at producing a prototype device for measuring asphaltic concrete workability, evaluate and investigate the relationship between compatibility and workability, and formulate the categories of compatibility against the torque mixing mixed asphalt.

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2 WORKABILITY DEVICE

2.1 The need for improved workability device

The hot-mix asphalt industry is constantly exploring technological improvements that will enhance the material's performance, increase construction efficiency, conserve resources, and advance environmental stewardship. It is logical that one approach to achieve these goals would involve the production of improved prototype devices and through research and development of improved methods and materials. Previous researches have shown that research in relation to improvement of device for measurement of workability is needed [1, 4, 3, 10]. Some of the empirical studies that support the necessity of this present research are [1], they contributed to the development of device for measuring and comparing the workability of various mixed asphalt, workability and compatibility [2] also contributed to development of new device to measure workability of mixed asphalt. Additionally [3] evaluate a prototype device to measure the workability of mixed asphalt due to changes in mix characteristics. Marvillet and Bougault [1] was the first to develop a workability meter in which the five interchangeable springs were used to determine the torque. The electrical signal was converted to numeric value and subsequently expressed in unit of torque. Using a similar device [3] evaluate a prototype device to measure the workability of hot mix asphalt (HMA) that could identify the influence of mix characteristics on workability. The authors converted the amperage to torque. Recently, Mogawer et al [11] presented a workability measurement device which does not have a temperature control system for maintaining temperature during mixing. The device produced by Mogawer and his colleagues has its own limitations; it can only be used to measure the temperature but not to maintain it. Following Marvillet [1], Gudimettla and Cooley [2, 3] the paddle of the device presented in this paper rotates while the bowl is fixed. In the contrary, the bowl in Mogawer et al [11] device rotates and the paddle fixed. We observe that the authors did not discuss specifically type of torque meter used in their device. Nonetheless, they have make immense contribution to this field of research particularly on Compaction, workability and temperature of Hot mix Asphalts.

The area for future research suggested by the authors is a clear testimony of the need for further research in terms of workability device that can be used to measure workability on road construction site, relationship between workability and compaction, and effect of temperature on workability. Gudimettla et al [3] suggested the need for a refinement of the prototype as it relates to design of paddle and container. Another improvement in the device is to include an additional temperature sensor to provide a better measure of temperature. The authors call for development of device that would yield better results and will be more users friendly. Their work suggested that workability is an important element in obtaining the desired mixed asphalt smoothness and density within a compacted pavement, temperature as well as the constituents in the mix influence workability of Mix Asphalt and that compatibility of mixed asphalt is related to workability.

A major research gap that is worth exploring is the improvement of the workability measurement device, as well as in-depth study on the influence of workability on the compaction of Mix Asphalt research in this area would produce results that may guide experts through the difficulty of compacting a particular mix on the roadway. Literature search has shown that the workability test is currently conducted in the laboratory; hence the need to develop a suitable device for conducting workability test on site and to investigate the relationship between workability and compatibility of Hot mixed Asphalts on site. The purpose of numerous researches conducted on mixed asphalt mixture is to achieve the production of improved layers of road pavement, and stronger and more durable asphalt pavement with better surface structure that can withstand the increasing axle loading of heavy vehicles and traffic [12] along side with changing climatic conditions experienced in many parts of the world. Research into mixed asphalt is crucial because every now and then new roads are being built and the old ones are being reconstructed. The demand for bituminous mixes and the requirements for their quality are also increasing. This paper presents production of an improved device for the measurement of torque using series M420 Rotary torque transducer.

2.2 Applications of workability measuring device

The present improved device was developed for the following uses: mixing, measuring workability and quality control of mixed asphalt. Specifically, the device was developed for the following applications:

1. Measuring workability using transducer
2. Investigating the effect of mixing temperature on compatibility and workability
3. Detecting the tolerance for Asphaltic concrete mixes.
4. Developing a new procedure to achieve workability parameter in mix design

3. DEVELOPING WORKABILITY DEVICE

While the major objective of this paper is to present a newly developed workability measurement device, this paper also discusses the process selecting the best rate of revolution of paddles and types of configurations. It is interesting to note that the transducer in the present device transmits digital data providing the end user with a clean and definite data transmission. The temperature control system on the present device does not only allow temperature of asphalt mixture to be measured, it also enables mixing temperature to be maintained. The issue of changing gradation during mixing and the problem of field compaction mentioned in Transportation Research Board [13, 14]; issue of small change in aggregate gradation that produces poor pavement performance during mixing which Chowdhury *et al* [15] discussed in their work; and the influence of aggregate properties on compatibility discussed in Zoorob [16] can all be addressed using the device presented in this paper. This is achieved because the value of torque is influenced by the nominal maximum aggregate size of the gradation.

3.1 Verification of device

The major materials to be used in conducting the workability related experiments using the device are:
1. Aggregate nominal maximum aggregate size 14 mm of three gradations;
2. Binders with penetration grade 60/70 and 80/100 bitumen; and
3. Mineral Filler –Ordinary Portland cement.

The purpose of this test is to select the best of rate of revolution of the paddle and type of configuration. The verification process will enables the identification of the torque values for each mix (different binder 60-70,80-100) at temperatures 120 °C, 130 °C, 140 °C, 150 °C, 160 °C, and 170ºC for every three paddles and three revolutions respectively, then, plotted to determine the rate of revolution of paddle and type of configuration designed form attached in index. The processes of verification of the device consist of testing three paddles with different configurations labelled A, B and C. each of these Paddles will be tested on six asphalt mixtures.

Table 1 Matrix for Verification of device

No	Type of paddle	Mix 1	Mix2	Mix 3	Mix 4	Mix 5	Mix 6
1	Paddle A	3	3	3	3	3	3
2	Paddle B	3	3	3	3	3	3
3	Paddle C	3	3	3	3	3	3
	Subtotal	9	9	9	9	9	9
	Total	54 samples					

Note: Each sample was tested at six different temperatures and three rates of revolutions

The mix samples for the verification are labelled 1, 2, 3, 4, 5 and 6 mixes. Paddle A will be fixed to the device and the motor set at 5 RPM, the paddle will be immersed into mix 1 at 120 °C. The torque will be recorded during the paddle revolution. At the same temperature, the RPM will be adjusted to 10 RPM and the torque recorded, this will be repeated for 15 RPM. Using the same paddle A, the temperature will be increased to 130 °C using the heater attached to the device, at RPM 5. The same procedure will be repeated for RPM 10 and 15 RPM while the torque is recorded in each case. The same procedure will be repeated for temperatures 140 °C, 150 °C, 160 °C and 170 °C respectively for mix 1. The entire procedure will be repeated using paddle B and C on mix 1 to complete one set of the test. A graph of torque against temperature will be plotted to obtain the paddle and revolution that produce the widest range of torque. Paddle A, B and C will be repeated on Mix 2, 3, 4, 5 and 6 using the same range of 120 °C-170 °C and revolution of 5, 10 and 15 RPM respectively to produce another three graphs to determine another three sets of wide range of torque. This procedure aims at obtaining the best paddle and rates of revolution suitable for the device.

3.2 Calibration of device

Because the device is locally produced, there is need for its calibration to ensure the required efficiency and performance. The procedure for the calibration of the device is as follows:
A quantity of aggregate will be sieved to pass 5.0 mm sieve. From the aggregate that 3.35 sieve retained, ten (10) samples of 3 kg will be obtained for the calibration process. Each sample of the 3 kg will be mixed in the device bowl using optimum paddle and rate of revolution obtained from verification process described above. The torque and the power will be recorded for each sample of 3 kg aggregate to establish upper and lower limits of torque and power for the device as shown in table 2. This calibration process will be repeated after every ten tests.

Table 2 Matrix for Calibration of device

10 samples to establish upper and lower limits of torque and power will be used as standard	Mix1	Mix2	Mix3	Mix4	Mix5	Mix6
	13	13	13	13	13	13
Subtotal	13	13	13	13	13	13
Total	78 samples					

3.3 Selection of machine components

Table(3) below presents the summary of literature and sources used in the selection of the components for the workability device.

Table 3. Summary of resources for the selection of components of device

S/N	Components	Source/Reference	Remark
1	Paddle	Gudimettla et (2004), French Thermoregulated mixer (federal highway administration), Mogawer et al (2010).	Three different types
2	Motor	Marvillet and Bougault 1979,Gudimettla et (2004)	Rotational speed of 22 RPM , 15 RPM
3	Transducer	Datum Electronics, UK	Company Recommendation
4	Bowl	AASHTO T 245, ASTM D 1559, Kett (1998)	Based on quantity of sample (5 liter)
5	Heater	AASHTO T 245, ASTM D 1559, , Kett (1998), Freddy (2007), Cominsky et al (1994)	Suitable for HMA
	Thermometer	AASHTO T 245, ASTM D 1559, , Kett (1998)	10 °C to 232 °C

Note: The reference numbers of the citation in the table 3 above are 2, 21, 11, 1, 22, 17, 18, 19 and 20

Photograph of workability device

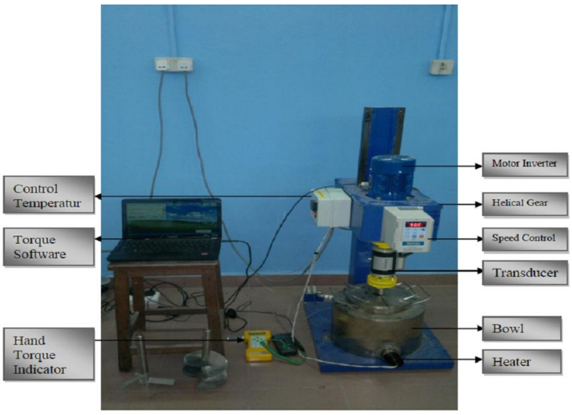

Figure 1. Photograph of workability device connected to computer installed with software

Photograph of device paddle

Figure 2 Photograph of three types of paddle used in verification of device

3.4 How to operate the device

The device consists of six components: motor, transducer and bowl with heater, temperature regulator, paddle and computer installed with torque software. After the preparing the aggregate and binder the mix design, then the mix design is determined. The aggregate and the binder are heated separately in the oven according to the mix design. The device is switch on earlier to allow the bowl heated to the mix temperature. The heated aggregate is fed in to the bowl of the device followed by the binder. The bowl contains silicon oil which helps in heating and maintaining the temperature of both aggregate and binder. The device is also equipped with temperature regulator which controls the temperature of materials in the bowl. When the device is switched on, and the materials fed into the bowl, the paddle rotates and remixes the binder and aggregate. The remix continues until it is observed that all the aggregate are coated with the binder. The transducer attached to the device is set to read all the data logged at every thirty second (30 sec) and output is read on the computer installed with torque software.

The output on the screen: torque of the asphalt, the speed of the paddle, power of mixing, and the energy produced can all be correlated with performance test of the mix design used: resilient modulus, moisture sustainability and volumetric properties.

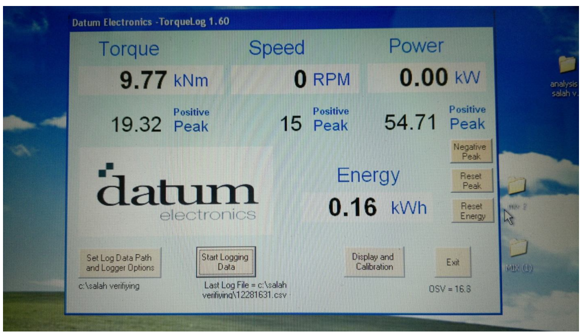

Figure 3: Torque software output Digital Data from which output can be recorded. The figure above will be displayed on the computer screen connected to the device.

4. CONCLUSION

Continuous increasing in Traffic volumes and loading in our cities has culminated to need for improvement in the research relating to properties of material such as the workability, compactibility and stability of mixed asphalt and more importantly, the development of relevant measuring device. The aim of the present study is to respond to the call by scholars and professionals in this field of research that suggest the need for improvement of workability devices. Underpinned by theory of mixing, the paper put forwards the development of an improved device based on the trends identified in the literature. The proposed device will reduce time spent in measuring torque, power and speed using transducer. The workability testing of mixed asphalt can be used as a tool to select desired mixed asphalt and improve the quality control and assurance.

Finally, It is interesting to note that one unique qualities of the newly developed workability device are: mobility, equip with heater and temperature regulator, it is portable, t is computerized, and data can be logged, at a selectable interval from the transducer data rate (normally approximately 100 per second) to once every 30 minutes. Future research should focus correlating the output from the workability device with performance test and volumetric properties of mixed asphalt.

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