ADVANCING ASPHALT MIXTURES IN SOUTH AFRICA: UNCOVERING SUITABLE NON-CONVENTIONAL MATERIALS AND DESIGN METHODOLOGIES/PROCEDURES

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ABSTRACT

Asphalt mixtures are often regarded as the most popular type of surfacing material used in roadway development. However, in recent years there has been an increase in pavement failures in asphalt roadways. Countries such as South Africa, in particular, are experiencing the severe hindrance of these damaged roadways, which lead to numerous socio-economic issues. The determination of the current state, of the study, of the use of non-conventional materials in asphalt as well as understanding if the industry is ready and willing to consider the use of these modified asphalt mixes. This allows researchers to consider new and innovative ways for further research on this imperative topic, as well as accelerating the process of the civil engineering industry implementing modified asphalt mixtures into the development of several new infrastructures. The study aims to determine if the civil engineering industry will consider using various types of non-conventional materials in asphalt mixtures to improve the roadways' overall performance capabilities. The study uses the quantitative survey method to gather crucial information. The target group selected for the survey consisted of individuals, particularly in the asphalt industry, who either contribute or contain knowledge on non-conventional materials or developing modified or traditional asphalt mixtures. The survey was carried out through a questionnaire developed using Google Forms to reach a considerable number of individuals in the target group. The results highlighted interest from the industry; however, there is still scepticism regarding the viability of incorporating non-conventional material in the asphalt mixtures, illustrating a potential for further development in this research area to be accomplished.

1. INTRODUCTION

1.1 Background

The development of asphalt mixtures has been a popular choice for road construction for several decades, particularly in countries such as South Africa (Venter, 2022). However, it is evident that asphalt pavements often experience numerous issues, either in the mix design, application process or over a period of time, which leads to premature failure such as rutting, cracking and potholes. This results in high maintenance or rehabilitation costs. These issues have prompted engineers to consider the use of other materials to improve the general performance of the asphalt pavements (Mohod & Kadam, 2016).

Research regarding modified asphalt roads has been developed throughout the years to overcome this issue. Engineers have established the research area of considering non-

conventional material in asphalt to allow for imperative solutions to be provided for current issues that are faced in the pavement industry such as the occurrence of various premature pavement failures as well as developing more sustainable and environmentally friendlier asphalt mixtures. (Mishra & Gupta, 2017).

To provide an imperative solution to these pressing issues, extensive research with regards to the incorporation of alternate – more specifically material that would often be referred to as waste – materials in asphalt mixtures to improve the properties of the performance capabilities of the pavement structures (Thom & Dawson, 2019). In order to further the research conducted on this study, the investigation of the current and proposed non-conventional materials used, as well as state of readiness of the industry to implement the modified mixtures, needs to be established, accordingly.

1.2 Objective

The main objective of the survey is to gain an in-depth understanding of the identification of current and proposed non-conventional materials that can be used in asphalt mixtures, within a South African context, through the use of qualitative data. In addition, the determination of the current practices used for developing the modified mixtures is also considered. The target group consists of individuals in the South African civil engineering industry that contribute or contain knowledge with regards to non-conventional materials or practices that are used to develop the modified mixtures.

This information provided, by the predetermined target group, from undertaking the survey, will illustrate the current state and progress of the use of non-conventional materials, by the construction industry, as well as demonstrate an overview of the willingness of the civil engineering industry to accept these new modified mixtures in the development of infrastructures. The results gained from conducting this survey will allow for researchers to continue the study of the use of non-conventional materials in asphalt mixtures from a new perspective, as well as determine innovative ways to accelerate the industry in implementing the modified mixtures in various developments.

2. LITERATURE REVIEW

Asphalt mixtures are one of the most highly desired forms of road pavement across the world. In majority of the European countries, approximately 90% of total the roadways, which amount to an estimate of 5,2 million kilometres, were developed using asphalt. The roadways, globally, serves a vital component to the transportation hub as travel mainly occurs via the various networks (Alkins et al., 2008). This places the integrity and general performance of the road pavements under exuberate scrutiny as the optimal conditions are always required due to the economic significance of the transport industry, as a whole, provides (Dhiman & Arora, 2021).

The study involving the use of alternate material into traditional asphalt mixtures, develops a ‘greener’ mixture which provides a feasible solution for issues often encountered by the pavement industry such as cost-efficiency and sustainability. The modified asphalt mixtures, in addition to having environmentally and economic benefits, should also have an improved performance, as compared to traditional mixtures of asphalt (Kowalski et al., 2016).

Traditional asphalt mixtures contain various natural resource such as stone, gravel, sand and so on. The use of these materials places a strain of the development of asphalt

mixtures as there is often a lack of availability of the necessary substances (White & Reid, 2018). To combat this issue, along with the unprecedented expansion of the roadways, globally, the usability of alternate material in the mixes is being investigated and possibly implemented in the industry. This steered the study in the direction of mainly considering other existing material, from the various engineering processes, as substitute aggregates and fillers (Prezzi et al., 2011).

In recent years, one of the most pressing issues faced by the civil engineering industry is the sustainability of structures as well as the most beneficial usage of the excessive amount of several types of waste material, that are made available through various processes, without compromising the integrity of the structures being developed (Xu et al., 2022). Many countries are often faced with the challenge of finding ways to handle these disposed materials, while trying to prevent any harmful impacts on the environment which may result (Pisciotta, 2018).

To overcome this issue, one of the main solutions which is currently being explored, is the recycling of waste material. The phenomenon of recycling became a viable solution to many researchers due to the limitations often faced by engineers with regards to the sourcing of natural resources used for developing structures, particularly those materials used for the development of asphalt mixtures (Yasanthia et al., 2016). This provided an imperative basis for considering the study of alternate material for traditional products, whereby the non-conventional resources would serve as a replacement for the natural aggregates, binders and polymers within the asphalt mixtures developed (Al-Hasan et al., 2020).

3. METHODOLOGY

The following methodological approach served as a vital guide for conducting the survey on the identification of the appropriate non-conventional materials and design methodologies or procedures appropriate for the country. In addition, the appropriate data analysis methods needed to accurately analyse the results obtained from the survey are further highlighted below.

3.1 Target Population

After the development of the type of research the survey will investigate, the appropriate target group must be established in order to obtain relevant results. For this survey, the nature of the study being investigated is based on the civil engineering industry. The targeted population is individuals that are part of the civil engineering field, particularly the asphalt industry. People with knowledge pertaining to the use of non-conventional materials as well as the procedures used for the development of traditional and modified asphalt mixtures were targeted. Individuals of interest for this survey consisted of engineers, researchers, technicians, developers and so on. A specific sample size was not established, as preferably the more responses received the greater the chance for more information on this topic to be provided (Asiamah et al., 2017).

3.2 Qualitative Research Approach

The qualitative research approach is used for the analysis of non-numerical data, and it is method that has been selected for this survey based on the nature of the study. The qualitative research approach allows for the observation of the phenomenon, to be evaluated in a real-life context. Information is provided in the form of views, opinions, facts

and so on. This method was used to determine the necessary information relating to the study (Tenny et al., 2017). The qualitative research method was used to gain knowledge and a further understanding of the aforementioned topic.

3.3 Data Collection

The data collection method selected for this study, is in the form of an online survey. The necessary questions pertaining to the topic, was developed with the survey being presented on Google forms. This was accomplished in order to reach a wider targeted audience as it is more convenient and simpler for individuals to answer and provide the necessary information. The survey was then given to the South African Institution of Civil Engineers, also known as SAICE, to distribute the survey to all members so that the targeted audience may be reached more effectively. The results of the survey were then collected from Google forms.

3.4 Data Analysis Method

The data analysis methods, used in a research, are regarded as an imperative consideration which must be determined to evaluate the relevant data obtained for the specified study. The methods selected, are highly dependent on the type of study and phenomenon that is being investigated (Nassaji, 2015). The following analysis methods were determined as the most appropriate methods that can be used to analyse the nature of the results of the data obtained.

3.5 Descriptive Analysis

The nature of the survey is based on acquiring qualitative research for the study on the use of non-conventional material in asphalt mixtures. The data obtained, contains information which describe or provide insight into the phenomenon being investigated. The use of descriptive analysis allows for qualitative data to be described, illustrated or summarized in a constructive way to determine crucial information or patterns demonstrated by the attained data.

Descriptive analysis techniques make use of statistical data illustrations such as tables, charts and so on to display the information retrieved from the given set of data (Kemp et al., 2018). To illustrate the information obtained from the qualitative survey, the use of pie charts and bar graphs were generated in order to convey majority of the responses received from the individuals in the sample size. Other responses that could not be placed in a chart or tabulated, from the survey, were described and analysed, accordingly.

3.6 Ethical Considerations

In order to conduct a survey which presents fair and ethical results, it is imperative to adhere to certain considerations when undertaking the task. The following ethical considerations were established for this study. Firstly, the survey being conducted must not contain any personal or compromising information of the individuals answering it. Anonymity of each individual was ensured. The types of questions asked, were strictly based on providing relevant information to the established topic.

Individuals who partook in the survey were also provided with the freedom to answer whichever questions. No incentives were offered for completing the survey. In addition, the types of non-conventional material that was considered for this survey was based on

various types of materials, such as crumb rubber, steel slag, fly ash, plastic and so on, that were used in prior literary research – both internationally and locally – to provide the respondents with viable options that could, possibly, be implemented commercially into the South African asphalt industry.

4. RESULTS

4.1 Question 1

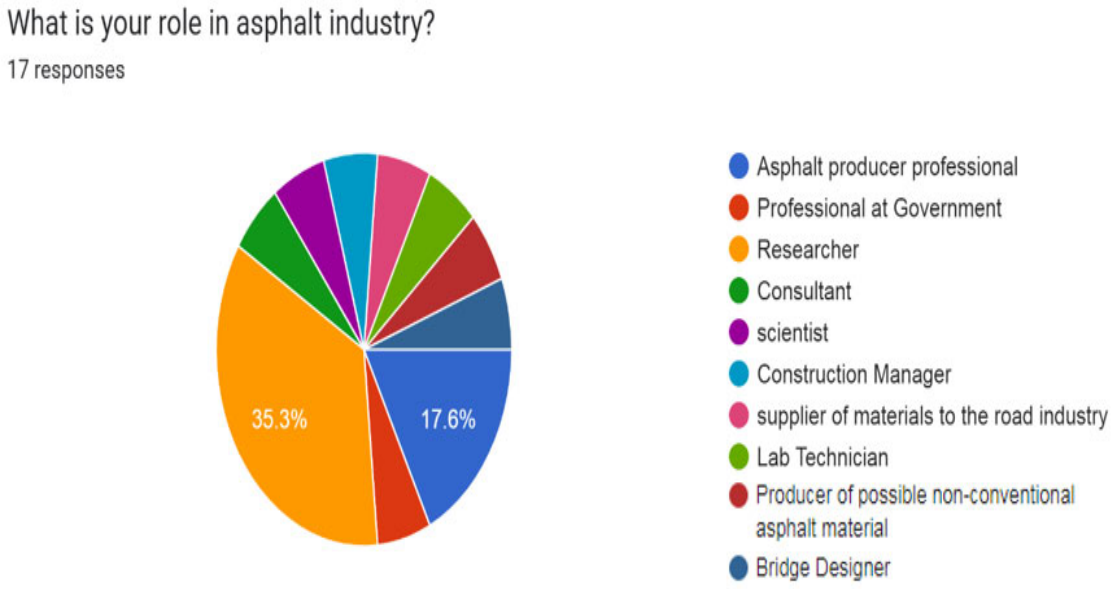

Figure 1: Pie chart depicting the results from Question 1

The first question presented in the survey is determining the role of the respondent in the civil engineering field. This question serves as an indicate, for the area of expertise of the individual. Figure 1 highlights the results obtained from each individual, that answered the question, in form of a pie chart.

As illustrated, in Figure 1, the most prominent role of the individual that answered the survey is a researcher within the civil engineering industry, which accounts for 35.3% of respondents. The second largest faction, consisting of 17.6%, is individuals that are Asphalt Producers. Other types of roles that were presented consists of Professional at Government level, construction manager, material supplier and so on. Each respondent, for this survey, has a vital role in the civil industry which is able to contribute imperative information pertaining to this study area.

4.2 Question 2

Question 2 from the survey, asks the respondents if their department, specifies the use of non-conventional materials in asphalt mixes (e.g. recycled asphalt pavement). This question is imperative as it determines whether the respondent is aware of the phenomenon of using of non-conventional materials in the development of asphalt mixtures. Figure 2, as illustrated, provides an overview of the answers received in the form of a pie chart.

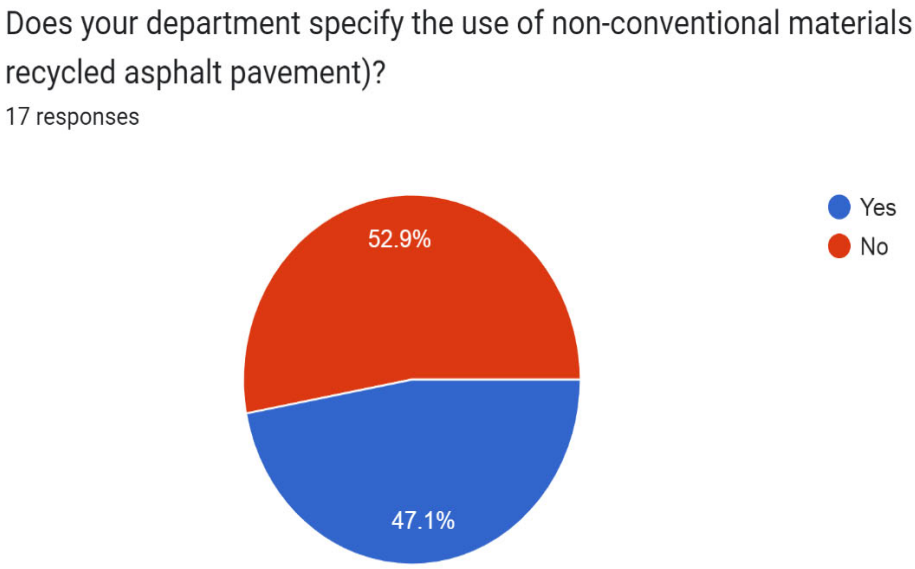

Figure 2: Pie chart illustrating the results received from Question 2

As shown in Figure 2, the majority of respondents, with 52.9%, stating that their respective departments have not specified the use of the non-conventional material in asphalt mixes. However, 47.1% of individuals answered that their department has considered and provided information on the use of non-conventional materials in asphalt mixtures. This illustrates that the knowledge and, more specifically, the practice of using alternate, non-conventional material is still a relatively new practice in the South African civil engineering industry.

4.3 Question 3

The third question asks individuals that have answered ‘yes’ in the previous question, to list the types of materials that they have been introduced or have been working with for the development of asphalt mixtures. The following types of materials were stated by the respondents: fly ash, recycled plastic, recycled asphalt pavements, crumb rubber, steel slag, plastic, waste oil, recycled glass, chrome slag and recycled aggregates.

From the list of non-conventional materials presented prior, majority of the materials stated are recycled. Majority of the individuals also stated that they are introduced to several types of non-conventional material, which illustrates that there is a significant interest in using these alternate types of materials in the development of asphalt mixtures, from the industry in general. The most common answer received is the use of fly ash. Other popular responses were crumb rubber, recycled aggregates, glass, plastic and recycled asphalt pavement.

4.4 Question 4

Question 4 of the survey asks respondents, the amount of non-conventional asphalt mixtures that they have produced or used over a 5-year period. Answers ranged from 0 to a maximum of 5 million tonnes. This range illustrates that there has been some significant development of the use of the non-conventional mixes. The respondent who stated that they have produced 5 million tonnes, most likely means that the amount of modified asphalt has been used in the construction of a new roadway development.

4.5 Question 5

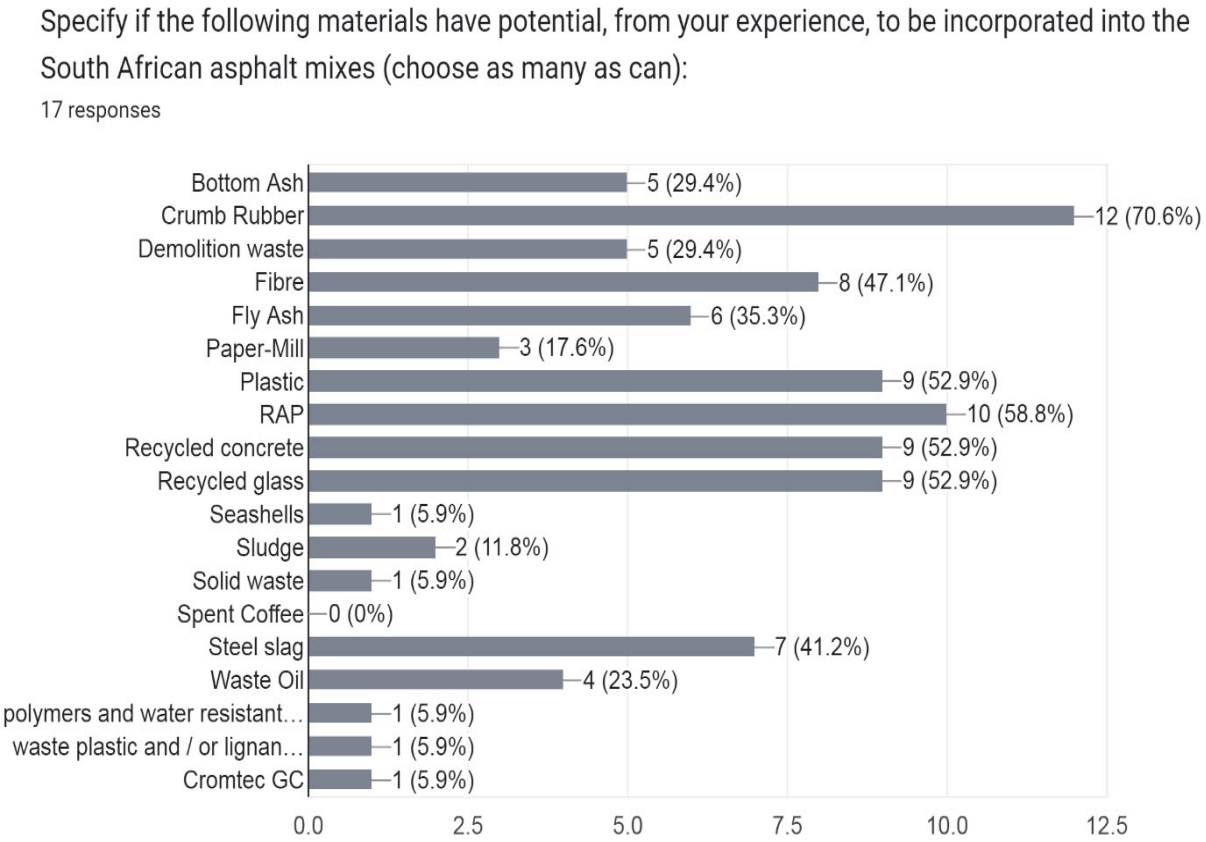

Figure 3: Bar graph presenting results obtained from Question 5

The fifth question involved asking individuals if they see possible potential of various non-conventional material, from a specified list, being implemented in South African asphalt mixes. Figure 3, as presented, illustrates a bar graph of the responses received. Individuals were allowed to select more than one type of material from the list provided.

From the results demonstrated from Figure 3, the most prominent non-conventional material, with a significant 70.6%, that is believed by respondents to be a viable option for asphalt mixtures, is crumb rubber. This material was then followed by recycled asphalt pavement, with 58.8%. Materials such as plastic recycled concrete and recycled glass are the third most popular choice with an equal weighting of 52.9%. The other materials listed, also illustrate a considerable percentage as believed so by individuals.

4.6 Question 6

Question 6 asked the respondents for any type of website links, procedures or guidelines that they have developed or are aware of, for the use of non-conventional materials in asphalt mixtures. Some individuals offered their contact information or website, to provide more information on the use of non-conventional material in asphalt mixtures. Other respondents stated that they do not have any links or procedures to provide.

4.7 Question 7

The final question asked individuals to provide any other, further information that they believe would be useful to share. From the answers received, one individual recommended that proper research should be conducted on the types of non-conventional

materials, that were suggested in Question 5, as majority of materials may lead to leaching and contamination issues as well as there may be failure in binding of the traditional materials with the non-conventional ones which will result in eroding. Another individual stated that there are current significant developments being conducted on using non-conventional materials in asphalt, and will be able to share the imperative information, once received.

4.8 Summary

The results received from the survey, based on the identification of the appropriate non-conventional materials and design methodologies or procedures appropriate for the country, can be regarded as an overall successful as vital information was provided by individuals in significant roles, within the South African asphalt industry. The majority of individuals stated that they were aware of the use of non-conventional material in asphalt mixtures with few respondents also stating that they have been involved in the development of the modified mixes within the last five years, with significant amounts of the mixes being produced. The consensus, that can be derived, is that although significant interest has been shown by the industry, there is still further research which needs to be undertaken, on this study, as scepticism is vastly present.

5. CONCLUSION AND RECOMMENDATIONS

5.1 Conclusion

The target group that was determined for this survey consisted of individuals from the civil engineering industry, particularly those who are from the asphalt industry, that contain knowledge on non-conventional materials, or the processes used with regards to conventional or modified asphalt mixes. The survey was developed using Google Forms for the easy distribution and collection of information. The survey was sent to the South African Institution of Civil Engineers, also known as SAICE, to distribute to their members as they would be able to assist with reaching the target audience.

The overall feedback, from the responses received, from various individuals in the asphalt industry, illustrated that there has been an interest in the use of non-conventional materials in asphalt mixtures, by the South African civil engineering field. Although, from the 17 individuals that partook in the survey, more than 50% of respondents stated that they were unaware, of the use of non-conventional materials in asphalt, which illustrates that there is further investment, within this research area, that needs to be accomplished. Individuals also provided feedback on the types of materials they were familiar with, with majority stating that fly ash, crumb rubber and waste plastics were most prominent.

A few of the individuals stated that they have also developed mixes containing various types of non-conventional materials over a 5-year period, depicting promise for this specified study. This interest presented by the industry, for this area of research, allows for further development to be continued. Although, there has been positive feedback received from this survey, the responses indicate that there are still significant research and industry gaps with regards to the use of non-conventional material in asphalt mixtures.

Further research needs to be investigated on the most appropriate types of non-conventional materials that can be used in asphalt mixtures as majority of the materials that have been suggested prior, such as PET plastic, can lead to leaching and inadequate binding in the mixes – causing unfavourable results. In addition, the long-term effects, of

the non-conventional material in the asphalt, need to be studied in order to determine the viability of these modified mixtures been implemented in our industry, within the foreseeable future.

5.2 Recommendations

The following recommendations are suggested for improving the results of the survey which was based on the identification of the appropriate non-conventional materials and design methodologies or procedures appropriate for the country. These suggestions may be implemented if the survey were to be repeated.

- Try to obtain a larger sample size of individuals in the specified target group, as only 17 individuals responded to the survey.
- Include more questions based on the types of procedures used for non-conventional materials in asphalt mixtures.
- More enquiries should be made from individuals that have used the modified asphalt mixtures in real-life applications, to determine if the mixes illustrated favourable results.
- Consider offering incentives to individuals to partake in the survey, as it may aid in acquiring a greater response.

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