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Experimental Study of Partial Replacement of Natural Aggregates and Bitumen with Reclaimed Asphalt Pavement and Waste Plastic in Flexible Pavement – A Review

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Abstract— Accordingly, existing road levels at approaches of these structures are required to be raised making the existing pavement materials redundant. Annually a huge amount of new roads are overlaid on existing road pavement in which a layer of existing bitumen pavement is removed for road development purposes. Utilization of such waste as Reclaimed Asphalt Pavement to replace natural aggregates partially could be helpful both for environmental and economic aspects in the construction industry. Also disposal of waste materials including waste plastic bags has become a serious problem and waste plastics are burnt for apparent disposal which cause environmental pollution. Utilization of waste plastic in bituminous mixes has proved that these enhance the properties of mix in addition to solving disposal problems in various studies. The seasonal change in temperature and loading nature has a significant effect on asphalt behavior because of its viscoelastic nature. Several types of flexible pavement failure/distress occur due to this behavior of asphalt binder, among which rutting and fatigue cracks are very common. The present study is to assess the suitability of using these redundant pavement materials also called Reclaimed Asphalt Pavement (RAP) as potential subbase / base course materials for flexible pavement and perform various laboratory experiments to analyze its strength and durability factors and compare the results with the conventional bituminous mix The purpose of this article is to review global experience with RAP, identify common issues of implementation of this technology and develop methods to ensure a comprehensive approach to the use of RAP.

Keywords— *Waste Plastic, Reclaimed Asphalt Pavement (RAP), Bitumen, Flexible Pavement, Sustainable Construction.*

I. INTRODUCTION

Due to rapid urbanization and population increase, the production of waste is rising significantly in country. Currently, there is no robust recycling program in place; as a result, municipal waste is simply sent to dumpsites, which is affecting human health and the environment. The most promising way to recycle a certain portion of this waste, consisting of HDPE, LDPE, and crumb rubber, is to use it in the construction of roads and other infrastructure. On the other hand, the majority of flexible pavements fail prematurely due to severe temperatures and heavy loading within the Kingdom, as well as due to the use of conventional grade bitumen (PG 64-10) without modifications. Hence this research was carried out to search for possible ways to modify conventional binder from PG 64-10 to higher grades, as well as to recycle this particular type of municipal waste in order to contribute to a cleaner environment. Many studies have been carried out for the re-use of these wastes in different ways. The economic and social development of the nation depends on transportation infrastructure. The growth in any country's economy has a strong relationship with the

development of its transportation sector. Road network has received significant funding for the building of better highways.

Ministry of Transportation in 2013. Worldwide the successful solution of the problems of proper roads maintaining is based on the joint efforts of government, business and scientists. Government is responsible for the up-to-date legal framework for using the best available technologies in the road construction and restoration of asphalt pavement. Business structures are involved in investments and performing the works, and thus contribute to the practical application of new technologies. The scientific community is involved in the improvement of technologies and contribute to the innovative development of the road construction industry. Development of new technologies was always focused on increasing cost-effectiveness, but recently along with the economic effects environmental issues have been considered, such as reducing the negative impact on the environment in the production of materials and execution of works.

The inclusion of waste materials such as reclaimed asphalt pavement (RAP) in pavement mixtures has become increasingly common due to numerous environmental and economic benefits. Practitioners around the world are constantly assessing the advantages of allowing higher percentages of RAP in pavement while also maintaining the highest performance standards to meet the increasing demands and regulations. Many transport authorities and departments have limited the maximum amount of RAP used in surface layers, certain mixtures types and in some cases large or critical projects. The amount of RAP used in surface layers was usually less than 15 percent initially as there was no significant advantage economically for using a larger percentage of RAP.

Due to these limitations, it is bitumen modifiers such as rejuvenators and antistripping additives to improve their rheological properties and provide a more balanced performance. Many of these commonly used modifiers are polymeric in nature and their incorporation in RAP mixtures are known to enhance their rheological properties (Lyubarskaya et al., 2017). The main objective of this study is to develop polymeric additives by adding waste plastic to the bituminous mix containing RAP and development of Bitumen replaced by Waste Plastic and natural aggregates replaced by Reclaimed asphalt pavement (RAP) for sustainable construction purpose. Various replacement levels of bitumen with Waste Plastic and Natural Aggregates with Reclaimed Asphalt Pavement will be done and Results of test will give guideline for desired properties of materials.

II. LITERATURE REVIEW

Asphalt construction were first introduced to the world in 1870, so apparently, they have been vastly improved since then. However, in our current society, due to environmental and economic concerns, merely creating new asphalt construction is just not good enough. To overcome this problem, many studies are carried out by researchers. In 1992 researcher Khandal stated that, in more recent times, other recycled materials have been incorporated into asphalt mixtures. It includes waste printer toner, crushed glass, incinerator waste, municipal waste and coal mine overburden. Many researches have been conducted for the past two decades. In 2018 the author Zhen Leng, Anand Sreeram, Rabindra Kumar Padhan, Zhifei Tan investigates that the use of reclaimed asphalt pavement (RAP) in road pavement construction has been widely encouraged due to its environmental and economic benefits. This research has shown that the addition of waste plastic materials such as Polyethylene Terephthalate (PET) or their functionalized additives into asphalt pavement may potentially improve the durability of pavement and also help alleviate the environmental problems caused by plastic. In this study, chemically synthesized PET additive was shown to be suitable to be incorporated in asphalt binders containing RAP providing better performance to conventional virgin binder. A limitation of this study was that only binder tests were carried out, therefore upcoming research will be focused on conducting mixture studies to ascertain the viability for field tests. In

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Addition, the RAP used was of moderate ageing level. Future tests should also be conducted using various RAP sources to ascertain and quantify the rejuvenating capability of PET additives.

Dr.R.Vasudevan in stated that the polymer bitumen blend is a better binder compared to plain bitumen. Blend has increased softening point and decreased Penetration value with a suitable ductility. In 2018 researchers Dharamveer Singh, Shashibhushan Girimath discusses about utilization of ground tire rubber (GTR) binder in combination with reclaimed asphalt pavements (RAP) binder can provide added benefits in terms of material, cost and environmental saving, and hence a promising step toward sustainable construction of pavements. The GTR binder was blended with different percentages (15%, 25% and 40% by weight of binder) of RAPs (RAP-A and RAP-S). Thus, a total of seven binders were prepared viz., GTR binder, GTR + 15%RAP-A, GTR + 25%RAP-A, GTR + 40%RAP-A, GTR + 15%RAP-S, GTR + 25%RAP-S, and GTR + 40%RAP-S.

The researcher M.A. Ilin, E.S. Svintsov, presents the article that analyses the problems of lack the system approach to using reclaimed asphalt pavement technologies (RAP) in Russia in 2017. The purpose of this article is to review global experience with RAP, identify common issues of implementation of this technology and develop methods to ensure a comprehensive approach to the use of RAP in Russia. An integrated approach to the use of the technologies of reclaimed asphalt pavement (RAP) includes a number of action sequences on the justification of contractor's decision making performing roadbuilding: the choice of the BAT, assess the implications of selected technologies and the choice of road-building equipment used for production work.

Dulal Chandra Saha, J. N. Mandal from Procedia Engineering, presents research about Laboratory investigations on Reclaimed Asphalt Pavement (RAP) for using it as base course of flexible pavement in 2017. This research states that Reclaimed Asphalt Pavement (RAP) materials are also used for granular subbase and granular base of flexible pavement. Generally for flexible pavement, California Bearing Ratio (CBR) for granular subbase and granular base are 30% and 100% respectively. It has been observed that CBR values of 100% RAP is in the range of 8% - 20%. It is observed from the present study that CBR values of 50% RAP + 50% Crushed Stone Aggregates (CSA) with 2% cement is in excess of 100%. Hence from strength consideration in terms of CBR, RAP mixed with crushed stone aggregates with small quantity of cement can be utilized as subbase / base course of flexible pavement. In the present study, series of CBR tests have been conducted on RAP, RAP-Crushed stone aggregate mix and the same stabilized with various percentages of cement.

In 2016 the researchers Imran M. Khan, Shahid Kabir, Majed A. Alhussain, Feras F. Almansoor provides their research on use of Crumb-rubber Waste for Sustainable Pavement Construction. This study states that the seasonal change in temperature and loading nature has a significant effect on asphalt behavior because of its viscoelastic nature. Several types of flexible pavement failure/distress occur due to this behavior of asphalt binder, among which rutting and fatigue cracks are very common. In this study, Low Density and High Density Polyethylene and Crumb rubber were used as additions to base bitumen. Dry and clean LDPE, HDPE and Crumb Rubber were used as bitumen modifiers with 2, 4, 8 and 10% by weight of bitumen. Mechanical grinder was used to convert all these waste materials into powder form (between 0.15 mm to 0.75 mm). Based on the results and analysis of this research, it was found that increasing percentages of LDPE, HDPE and CR in general, has a significant effect on the elastic behavior of the modified binder. The addition of 10% LDPE to the binder gives an optimum value for rutting perimeter at all temperatures, which indicates that 10% LDPE-MB offers the best resistance against rutting compared to HDPE and CR.

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Feipeng Xiao, Ningyi Su, Shenglei Yao, Serji Amirkhanian, Jingang Wang provides research on Performance grades, environmental and economic investigations of reclaimed asphalt pavement materials in 2018. This research explored the high and low temperature performance grades as well as energy saving, greenhouse gas (GHG) emission reduction, and cost saving of reclaimed asphalt binders incorporated into the commonly used base binders. Moreover, the results of this study would provide advice and guidance on both economic development policies and environmental protection policies. The experimental designs in this research included three base binders and six RAP sources with respect to the dynamic shear rheometer tests, bending beam rheometer tests and local survey. The results indicated that, at the high temperature, when incorporated 15% and 30% extracted aged binders, one grade (6□) and two grades (12□) of base binders were generally improved respectively. In addition, the increase of 2-3□ and 4-5□ were found at the low temperature when used 15% and 30% aged binders, respectively, regardless of RAP source. Moreover, the reduced energy consumptions, GHG emissions, and costs of the RAP mixtures containing 30% aged binder are generally greater than those with a lower percentage aged binder.

Again in 2017 Farshad Saberi.K, Mansour Fakhri, Ahmad Azami carried research on evaluation of warm mix asphalt mixtures containing reclaimed asphalt pavement and crumb rubber. This study investigates the potential use of crumb rubber and Reclaimed Asphalt Pavement (RAP) in Warm Mix Asphalt (WMA). In fact, the twofold purpose of this research is to improve the performance of asphalt pavement and mitigate the environmental impacts due to waste tires and aged asphalt pavement. In the present paper, seven different asphalt mixtures including 30% and 60% RAP (by the weight of natural aggregate) were modified by 0, 10%, and 20% crumb rubber powder. To this end, natural aggregate was replaced by the different percentages of RAP and crumb rubber in the asphalt mixtures. Also, high percentages of organic additive, Sasobit, including 4% and 5.5% were employed to the mixtures including 30% and 60% RAP, respectively. The findings of this present investigation resulted from Marshall Stability, moisture susceptibility, fatigue cracking, and permanent deformation tests indicate that the high amount of Sasobit can not only reduce the mixing and compacting temperatures, but also provide a sophisticated asphalt mixture modified by crumb rubber, and simultaneously it can be considered as a practical method against global warming and stockpiling waste materials such as RAP and end-of-life tires. Overly, the rubberized asphalt mixtures including high RAP and high Sasobit additive provided a better behavior against moisture susceptibility, fatigue cracking and permanent deformation in comparison with the control mixture, CW.

In 2018, researchers gives performance evaluation of warm mix asphalt involving natural zeolite and reclaimed asphalt pavement (RAP) for sustainable pavement construction. This study present an experimental study to characterize the mechanical behaviour of warm mix asphalt (WMA) mixtures designed with Chilean natural zeolite and different amounts of reclaimed asphalt pavement (RAP) for sustainable pavement construction. Five WMA mixtures were evaluated and compared with one reference hot mix asphalt (HMA). Two WMA mixtures were fabricated with 0.3% and 0.6% w/a natural zeolite; and three WMA mixtures were fabricated with 0.6% w/a natural zeolite and 10%, 20% and 30% RAP content. The binder contents and volumetric properties were obtained according to Chilean standards. The mechanical properties evaluated were stiffness modulus, cracking resistance, moisture sensitivity, resistance to rutting and fatigue behaviour. The results showed that WMA mixtures with natural zeolite can be manufactured at a temperature of 20 C lower than reference HMA, fulfilling the design specifications. Likewise, recycled asphalt mixtures can be fabricated at a lower temperature using natural zeolite, showing good performance properties to be used for sustainable pavement construction.

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III. EXPERIMENTAL MATERIAL

3.1 Plastic

A plastic is a type of synthetic or man-made polymer; similar in many ways to natural resins found in trees and other plants. India's consumption of Plastics will grow 15 million tonnes by 2015 and is set to be the third largest consumer of plastics in the world. Various activities like packing consume almost 50-60% of the total plastics manufactured .Plastic offer advantages lightness, resilience, resistance to corrosion, colour, fastness, transparency, ease of processing etc. The plastic constitutes two major category of plastics based on physical properties; (i) Thermoplastics and (ii) Thermo set plastics. The thermoplastics, constitutes 80% thermo set constitutes approximately 20% of total postconsumer plastics waste generated .In a thermoplastic material the very long chain – like molecules are held together by relatively weak Van der Waals forces. In thermosetting types of plastics the molecular are held together by strong chemical bonds making it quite rigid materials and their mechanical properties are not heat sensitive.

3.2 Bitumen:

The bitumen used for the present work is VG 30 penetration grade and has been widely used for paving application; it is used as binder in present work given in Table. The bitumen is melted in 160-165□.All tests conducted on bitumen were in accordance with procedure laid down in I.S. The basic test properties conducted on bitumen and modified bitumen indicates that the re-placement of bitumen by waste plastic decrease the penetration and ductility value, whereas increase in softening point and specific gravity value, when about 4.5% weight of bitumen.

Table No. 1 : Properties of Bitumen

Properties	Bitumen Grade VG 30
Penetration	50-70
Softening Point	50-70 ^{0}C
Ductility	50-70m

3.3 Reclaimed Asphalt Pavement(RAP):

The physical and chemical properties of various materials use to carry out this experimental study. The materials are Cement, Fine aggregate (F.A), Coarse aggregate (C.A) RAP (Reclaimed asphalt pavement). M-sand was used as fine aggregate in this study, test on the RAP performed after gradation into fine and coarse for both cases, all the test are performed according to Indian standards. Various test results of cement are in the table 1 Sieve analysis results of M-sand and fine RAP are shown in table 2, the sieve analysis results of coarse aggregate and coarse RAP are shown in table3. Specific gravity and water absorption of m-sand, coarse aggregate, fine and coarse RAP are shown table 4 respectively.

Table No. 2 : Properties of RAP

Sr no	Proporties	Value
1	Specific gravity	3.15 g/cc
2	Initial setting time	56 min
3	Final setting time	363 min
4	Standard consistency	27%
5	Fineness modulus	9%

Compressive strength decreased for 100% recycled asphalt pavement aggregate as coarse aggregate. Abrasion process improved the compressive strength to a little higher .Abrasion process

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also improved the compressive and flexural strengths than the fully replaced recycled asphalt pavement aggregate concrete and 30% replaced recycled asphalt pavement aggregate concrete. A higher water absorption is shown by recycled asphalt pavement aggregate treated by abrasion at 28th day. Acid attack causes loss in weight of specimen with age. The highest resistance was shown by fully recycled asphalt pavement aggregate concrete than the normal concrete. Recycled asphalt pavement aggregate after abrasion had higher resistance to acid attack than that without abrasion at 30%.

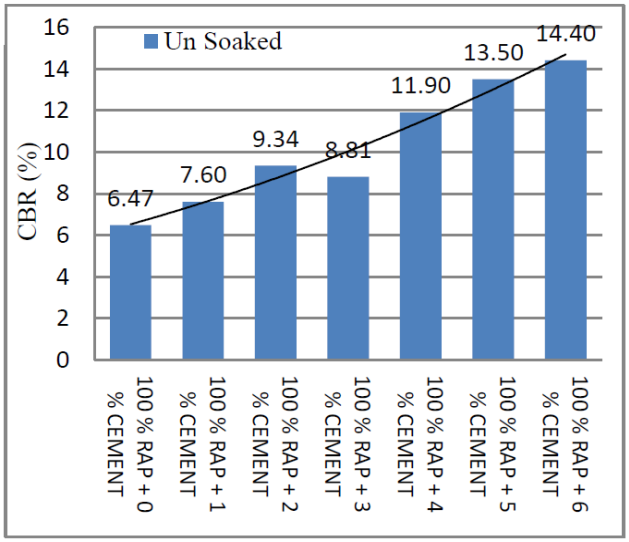

Fig. No. 1 - Unsoaked CBR value of RAP with varying % of cement

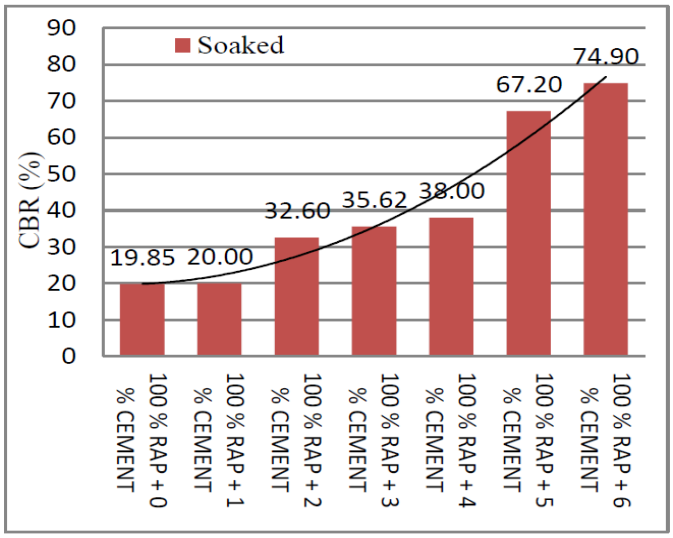

Fig. No. 2 - Soaked CBR value of RAP with varying % of cement

It is observed that, Unsoaked CBR value of 100% RAP varies from 6.5% to 14.5% with cement varying from 0 – 6%. Similarly soaked CBR value varies from 20% to 75% for 100% RAP with cement varying from 0 – 6%.

IV. CONCLUSION

As a result, it can be concluded that the addition of plastic wastes, such as Low Density Polyethylene (LDPE) and High Density Polyethylene (HDPE), to neat binder can play a significant role in improving the elastic behavior of binder in order to extend the service life of pavements in terms of reduced susceptibility to rutting and cracking. In addition, the use of these recycled wastes will play a significant role in reducing the use of non-renewable resources, in constructing sustainable pavements, and in reducing the environmental impacts of waste disposal at dumpsite.

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