International Journal of Innovative Technology and Exploring Engineering (IJITEE)
ISSN: 2278-3075 (Online), Volume-9 Issue-1, November 2019

Utilizing different wastes in rural roads of Karad, District – Satara, India

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Abstract*: The rural roads in India comprise of village roads (VR) and other district roads (ODR). The traffic intensity is taken as 2 million standard axles (msa) since traffic load has increased on the rural roads. The design guidelines have recommended the utilization of wastes accessible in the nearby vicinity for road construction. Effective disposal of wastes such as plastic, rubber and electronic waste is the main concern in India. The adverse effects of these identified wastes could be put to a beneficial use if utilized in road construction. Due to the increasing trend of heavy traffic on rural roads, a bituminous Macadam layer is generally laid over granular layers of the pavement. As such, the primary objective of the research is to discover the optimum content of using the identified wastes to replace bitumen and aggregates of rural roads. Numbers of laboratory tests have been carried out on modified mixtures to understand the aptness and optimum content of the wastes in construction of rural roads. The strength property of the naturally available soil was studied for the rural roads in Karad. The California bearing ratio test analysis and their outcomes were employed to assess the strength of the subgrade in the study area. Further, based on the suitability of identified wastes in bituminous layer, IITPave software was used to analyze the performance of rural roads of the study area. Using the IITPave software, design charts were created based on utilizing the wastes for rural roads in Karad, District – Satara, India.

Keywords: Marshall Stability, CBR, rural roads, wastes

I. INTRODUCTION

In India, rural roads (RRs) are classified as roads network consisting of village roads (VRs) and other district roads (ODRs) [12]. These rural roads cover up to about 75 % of the whole roads network of the country. In India, Pradhan Mantri Gram SadakYojna (PMGSY) is the designated government body responsible for construction of rural roads all over the country. The design manuals created by PMGSY are based on IRC: SP 72: 2015 [12]. The PMGSY design manuals and IRC: SP 72 code, both have recommended the utilization of waste materials which are accessible in nearby areas in different layers of pavement.

Revised Manuscript Received on November 30, 2019.
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RRs in the study area of Karad, District Satara located in Maharashtra state of India are usually constructed as granular pavements with a thin bituminous layer at the top. The unbound granular layers are usually constructed by borrowing material from other places and thus, the construction costs of pavement increases. Utilization of wastes in road construction proves beneficial for the current burning issue of effective disposal of wastes. Hence, it is a major challenge to construct rural roads in a more sustainable way using locally available waste materials.

To estimate the behavior of rural roads and to analyze the performance of RRs while using different wastes in the component layers of the pavement; the method of employing software can be effectively utilized. As such, the study area was analyzed to understand the traffic rate, soil properties and finding various naturally available wastes which can be incorporated in the road section. In the current study, different wastes have been identified and checked to find the optimum content as well as creating design charts for the same using analytical method.

II. LITERATURE REVIEW

In India, the methods adopted to design flexible rural road pavements are chiefly based on empirical formulae developed based on AASHTO guidelines. The design method followed in the study area is California bearing ratio (CBR) based design method as suggested by IRC: 37: 2012 [11]. Although the design manuals suggest the use of various wastes materials there is a lack of detailed guidelines and hence there is a need to investigate the performance of road incorporated with waste materials. Upon finding optimum content through laboratory testing and using software such as IITPave for analysis; standard design charts can be created based on site specific properties of the subgrade and pavement materials such as Poisson's ratio and modulus of Elasticity. As such, many researchers have worked on finding different waste materials that can be used in pavement section.

Ali Ebrahimi et al. [4] advocate the utilization of materials which are recycled to increase the pavement life by 20% and lessen the base course depth by 30%. K Kranthi Kumar et al. [16] analyzed the reclaimed asphalt pavement (RAP) to find its properties to inculcate in different constituent layers of the pavement section. From the analysis it was found that the optimum content was around 20 % considering various properties such as bottom top cracking, phase angle and resilient modulus of bituminous mixes. The research indicated that RAP can be efficiently employed in base and surface layers of bituminous mixes [3].

Abdhesh Sinha et al. [2] used the finite element analysis to assess the flexible pavement incorporating various types of locally available resources in the sub-base layer. The different materials used in the subbase layer were fly ash, slag of Linz-Donawitz and granulated blast furnace which is classified as industrial wastes.

The study used ANSYS software to analyze the flexible pavement performance using industrial wastes as sub-base material. Jia et al. [15] used recycled C&DW to make use of it in low volume roads construction in China. The common C&DW materials are concrete waste and clay bricks in crushed form. The authors recommend the use of wastes in granular layer based on various tests conducted. The authors also suggest that the mix design procedure should be site specific while using C&DW wastes.

L.R. de Rezende et al. [19] performed extensive laboratorial testing and actual site investigation to find the replacement of natural granular material by non conventional materials. From the study it was found that the mixture of soil and lime and lateritic gravel was a good combination to be used in granular layer of flexible pavement. It was also observed that lateritic gravel could be replaced by quarry waste for use in the mix of lateritic clay and less traffic volume. Kuna et al. [18] suggested a different structural design method namely cumulative design approach for pavements incorporating foamed bitumen.

Kocak et al. [23] explored the possibility of the use of Crumb Rubber Modified Binders as an alternative to the conventional high priced grade binders in mixtures consisting of high percentages of RAP. Appaiah et al. [5] studied the effects of inclusion of thermoplastic modifiers like High density Poly Ethylene and Polypropylene to conventional bitumen. An improvement in the dynamic behavior was noted and modification in the rheological properties. The penetration test result exhibited increase in viscosity. The Polymer modified bitumen with an increment in softening point showed better pavement performance for rutting, fatigue and temperature vulnerability. Anupam et al. [8] probed into the efficacy of using agricultural as well as wastes from industry in subgrade. To improve the bearing capacity of soil, different industrial wastes like fly ash as well as ash of rice husk and bagasse were used while rice straw ash was used as an agricultural waste. Various tests were conducted namely shrinkage limit test, CBR test, Unconfined compressive strength test, triaxial test. Based on the above tests, the authors recommend the use of all the materials identified to be used as soil stabilizer.

Chitraghar and Singh [25] evaluated the asphalt mix containing 30% reclaimed asphalt pavement (RAP) and evaluated it against usual mix without RAP. The method of Marshall mix design was adopted to devise the mixes and the outcomes of indirect tensile strength were evaluated for analysis. The authors concluded that the strength for the mix containing RAP was more than the other mix. Delongui et al. [20] performed a research on using construction and demolition wastes (C&DW) on the basis of resilient modulus using Everstress layered elastic analysis software, shear strength analysis and on the outcomes of permanent deformation based on repeated loading. The results of their study suggested that the shear parameters of C&DW such as effective friction angle and its cohesive intercept are fairly analogous to that of Densely Crushed Graded Basalt (DCGB). The value of Poisson's ratio ($\mu = 0.35$) was also found to be similar to that of granular materials commonly used in pavement design. The authors suggest that due to easy availability and probable decrease in transportation costs, the use of C&DW in the granular layer should be preferred for roads subjected to low volume of traffic.

Sharma et al. [9] assessed the suitability of reclaimed recycled aggregates in flexible pavement section. The optimum content suggested by authors based on laboratory testing and mechanical properties was of 100 % reclaimed aggregates and replacing some portion of viscosity grade (VG) 30 by crumb rubber modified bitumen (CRMB). Gowtham and Ganesh [10] studied the use of steel slag in bituminous mix by utilizing VG 30 and the mix containing crumb rubber. The optimum percentage of steel slag based on Marshall Stability test was suggested as 10 % for both the mixes.

Presti [7] studied various techniques to utilize recycled tyre rubber (RTR) in road asphalt mix. The study focuses on different techniques of wet process such as high viscosity and no agitation to create RTR modified bitumen. The research highlights the benefits and disadvantages of each method. El-Naga and Ragab [14] analyzed the application of waste plastic such as polyethylene terephthalate in bituminous mix. Various tests were conducted including indirect tensile strength, Marshall Stability along with KENPAVE software to obtain an optimum content of 12 %. Kubair et al. [17] evaluated the use of crumb rubber in gap graded bituminous mix. Based on Marshall Stability test, the optimum content of crumb rubber modified bitumen was calculated at 7 %. Pasandin and Perez [1] investigated the use of waste rubber tires along with recycled concrete aggregates (RCA) in bituminous mix. The authors recommend high percentage of RCA to be employed in the mix and calculated the optimal amount of waste rubber as 10 %. Karmakar and Roy [24] utilized waste plastic including high and low density polyethylene combined with waste tires ash. Based on various tests conducted, the authors recommend the content of mixed plastic as 1 % by weight. Yao et al. [27] examined the properties of modified bitumen consisting of combined addition of polyethylene and crumb rubber. A variety of tests were performed to find the characteristics of the modified bitumen. The optimum content for polyethylene was 7 % and for crumb rubber as 15 %. Pakhare and Bhosale [22] used plastic obtained from E-waste to replace aggregates in a dense bituminous mix. The optimum content waste for size of 2.36 mm was up to 8% and for the size of 20 mm it was calculated up to 3%.

III. METHODOLOGY

The rural roads of Karad taluka, located in District – Satara, Maharashtra were considered for this research (Refer fig 1). The rural roads comprise of both VR and ODR. Since, the traffic rate has been on the increasing trend in the study area and is seen to be carrying overloaded vehicles as well, the rate of traffic intensity has been taken as 2 million standard axles (msa).

Based on the soil map obtained from district survey report, the study area is classified primarily into 2 different zones namely, Black cotton soil and Lateritic soil. The road development plan was obtained from the office of Pradhan Mantri Gram SadakYojna (PMGSY), which is the designated government body for the construction of rural roads in India.

Various locations were studied and soil samples collected to find the CBR value of the naturally available soil in the study area. A total of 24 locations were considered and soil samples obtained for the CBR test to find their strength (Refer Table I). Three samples were collected at each location and average value of CBR was calculated. A total of 72 soil samples were tested to find the average CBR of the considered location.

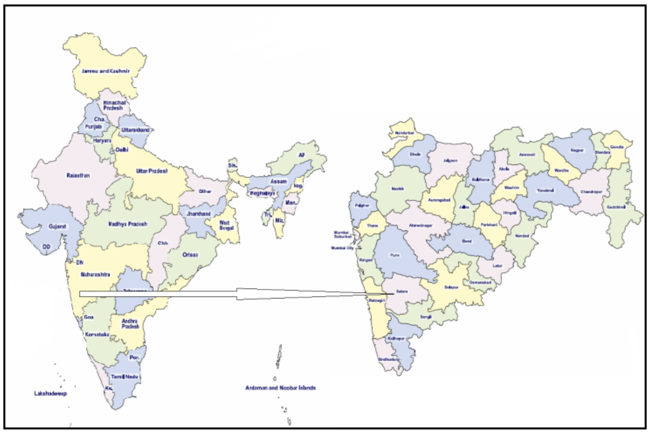

Fig 1. Location map of study area

The modulus of elasticity 'E' for subgrade layer was calculated based on the CBR test results and Poisson's ratio 'μ' assumed based on the type of soil. The equation to determine E was obtained from the design guidelines of IRC 37 [12].

When CBR < 5 then $E = 10 * CBR$ (1)

When CBR > 5 then $E = 17.6 * CBR$ (2)

Table I. Test Results of Soil Samples

Location Name	Type of Soil	Average CBR (%)	E (MPa)
Indoli	Black Cotton	1.03	10.3
Umbraj	Black Cotton	1.54	15.4
Palkarvadi	Black Cotton	1.72	17.2
Goleshwar	Black Cotton	1.79	17.9
Vadgaon Haveli	Black Cotton	1.92	19.2
Shenoli	Black Cotton	1.96	19.6
Belavade	Black Cotton	2.16	21.6
Vahagaon	Black Cotton	2.25	22.5
Shirvad	Black Cotton	2.45	24.5
Jomling	Lateritic	2.77	27.7
Supane	Lateritic	3.04	30.4
Sakurdi	Lateritic	3.50	35.0
Yenape	Lateritic	3.78	37.8
Yelgaon	Lateritic	4.09	40.9
Solshirambe	Lateritic	4.23	42.3
Pachvadeshwar	Black Cotton	4.47	44.7
Atake	Black Cotton	4.63	46.3
Wathar	Black Cotton	4.79	47.9
Malkapur	Black Cotton	5.03	88.52
Jakhinwadi	Black Cotton	5.22	91.87
Nandlapur	Black Cotton	5.48	96.44
Surli ghat	Black Cotton	6.41	112.81
Kamathi	Black Cotton	6.73	118.44
Shamgaon	Black Cotton	6.80	119.68

The study area showed CBR ranges from 1.0% to 7.0%, comprising of black cotton soil of soft and medium clay along with medium and shallow lateritic. As such, the range of E varies from 10 MPa to 120 MPa. The Poisson's ratio value (μ) was assumed at 0.35 for the analysis.

Based on the extensive study of the available literature, locally available wastes were identified to incorporate into bituminous mix for the construction of rural roads. Karad is a developing area and due to its close proximity to metropolitan cities, a lot of E-waste is generated. As such, the typical wastes locally available in the study area are Plastic, rubber tyres and E-waste which have been considered for this research study. Various percentage combinations of using wastes in bituminous mix and replacing aggregates were studied. The wastes were varied in different percentages to find their optimum content. The bitumen content was varied from 4.5% to 6.0% with an equal increment of 0.5% for each trial. Based on the findings of Tapase et al. [26], the content of plastic and rubber in bituminous layer was directly assumed to be 7% and 10% respectively. For each of the above trial, waste plastic was used to replace 7% of bitumen, and crumb rubber to replace 10% of the bitumen. Similarly, for each of the above trials, E-waste was varied from 7.5% to 15% with an equal increment of 2.5%. Furthermore, integrated trial combinations of 7% plastic waste with 7.5% E-waste and 10% crumb rubber with 7.5% E-waste were also selected. For the each above said trial combinations, 3 samples were tested to find more accurate results. As such, 108 trial samples were tested based on the above combinations (Refer Table II).

Table II. Trial Combinations

Bitumen Content (%)	4.5	5.0	5.5	6.0
Type of Sample	Control Mix			
	7 percent partial substitution of bitumen by waste plastic			
	10 percent partial substitution of bitumen by crumb rubber			
	7.5 percent partial substitution of aggregates by e-waste			
	10 percent partial substitution of aggregates by e-waste			
	12.5 percent partial substitution of aggregates by e-waste			
	15 percent partial substitution of aggregates by e-waste			
	7 percent partial substitution by plastic waste + 7.5 percent e-waste			
	10 percent partial substitution by rubber + 7.5 percent e-waste			

The aggregates used for the trial mixes were tested for different tests such as crushing strength, abrasion value, water absorption, flakiness index, specific gravity, impact value and elongation index. For the purpose of analysis, VG 30 bitumen grade was employed which is suitable for the annual average temperature of 35°C in the study area.

The experiments performed on the bitumen were ductility, penetration, softening and specific gravity. All the test values for both aggregates and bitumen were within the ranges specified by MoRTH [21].

IV. TESTS, RESULTS & DISCUSSION

The Marshall Stability mix design method has been used to design the trial mixes. The results obtained for various combinations have been drawn in graphs to find the most optimal content of the wastes. The specimen for control mix was designed as per ASTM D 1559 [6]. The samples are prepared by using the dry process and the diameter of the specimens were 100 mm and were loaded circumferentially in the setup. All the test results have been plotted to determine the trend and find the optimum content of waste to replace bitumen.

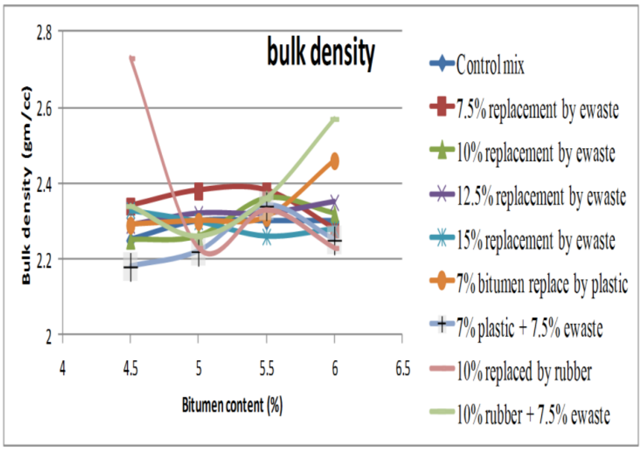

Fig 2. Graph of Bulk Density against Bitumen content

Maximum density of compacted specimen is observed at 5.5% bitumen content for all cases. Bulk density for this content varies in the range of 2.26gm/cc to 2.38 gm/cc.

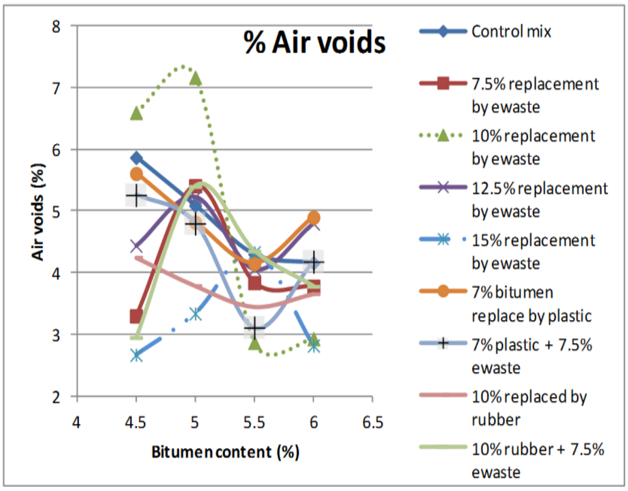

Fig 3. Air Voids in percentage against Bitumen content

Minimum percent air voids are observed in specimen having bitumen content of 5.5%. Percent air voids for the 5.5% content varies in the range of 2.87% to 4.35%. The trend of graph for all cases is similar to each other.

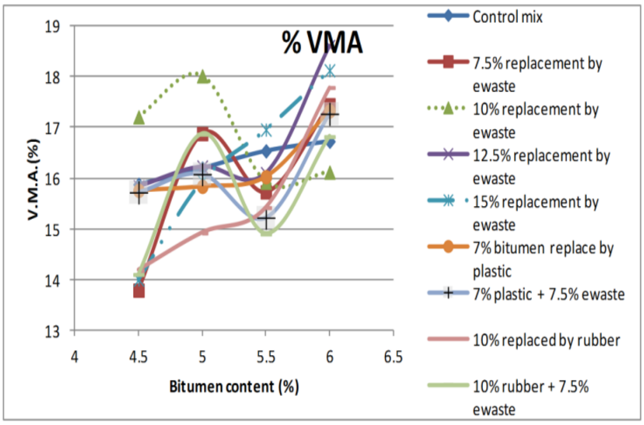

Fig 4. VMA in percentage against Bitumen content

Maximum percent voids in mineral aggregates (VMA) are observed in specimen with 5.5% bitumen content for all cases. Percent V.M.A. for this content varies in the range of 15.12 % to 16.96 %. The trend of graph for all cases is similar to each other.

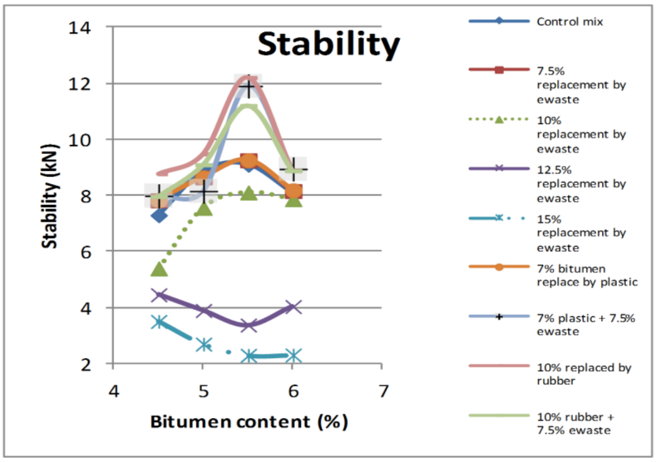

Fig 5. Marshall Stability against Bitumen content

Marshall Stability value was calculated to be maximum for bitumen content of 10% replaced by crumb rubber, followed by bitumen replaced by 7% plastic with 7.5% e-waste and bitumen replaced by 10% rubber with 7.5% e-waste.

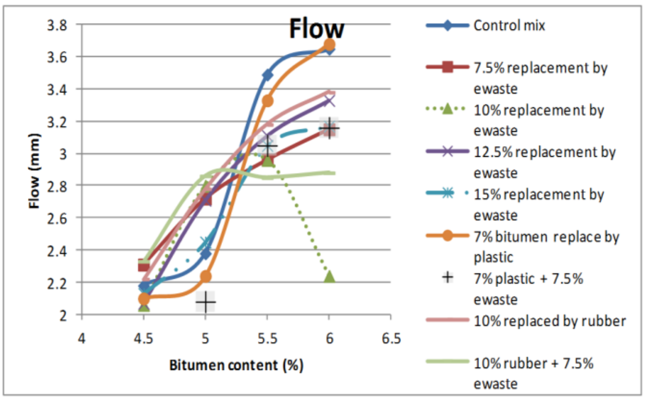

Fig 6. Flow value against Bitumen content

Retrieval Number: A4906119119/2019©BEIESP
DOI: 10.35940/ijitee.A4906.119119
Journal Website: www.ijitee.org

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The flow value is observed maximum at 6.0% bitumen content for all cases. Flow value for this content varies in the order of 3.15 mm to 3.68 mm.

The modified bitumen supplemented with waste plastic of about 7% by weight and crumb rubber of about 10% by weight of bitumen assists in significantly enhancing the Marshall Stability, fatigue life and strength of the bituminous mixture.

V. DESIGN CHARTS

Using the data obtained of the CBR values of the soil available in area, site specific design charts are created while also recommending use of plastic or crumb rubber in bituminous layer. Considering the premature failure of rural roads in the area, the total traffic is assumed up to 2 million standard axles (msa). It is recommended to use bituminous layer of total 75 mm containing bituminous macadam (BM) of 50 mm and open graded premix carpet of 25 mm. The value of Modulus of Elasticity *E* for bituminous layer is assumed constant as 700 MPa and Poisson's ratio μ as 0.3 at an average daily temperature of 35° C [11]. After various trials, the granular layer comprising of base and subbase materials is recommended to be used having the value of *E* as 120 MPa and μ = 0.35. The values of Modulus of Elasticity *E* for subgrade vary from 10 MPa to 120 MPa and the design charts are created for these ranges. As such, the design charts use waste materials and are site specific.

IITPave software has been effectively used to create design charts wherein, the thickness of granular layer has been varied to find the effective depth for the particular values of subgrade. The main failure criterions in flexible pavement are fatigue and rutting. The allowable limits of vertical compressive strain acting on the top of subgrade and horizontal tensile strain acting below the bituminous layer have been calculated based on the equations given in IRC 37: 2012 [11]. The thickness of granular layer has been varied so that the actual strains are well within the allowable limits. The changes in thicknesses have been incremented or decremented by 25 mm. For the purpose of analysis, the standard axle load of 80 KN has been assumed with 0.56 MPa tyre pressure. The centre to centre distance between two wheels is assumed to be 310 mm [26]. It is found that the design thicknesses calculated for this study are in line with the guidelines given by the design manuals but are more optimum, cost saving and site specific which will enhance the performance of the roads in the area.

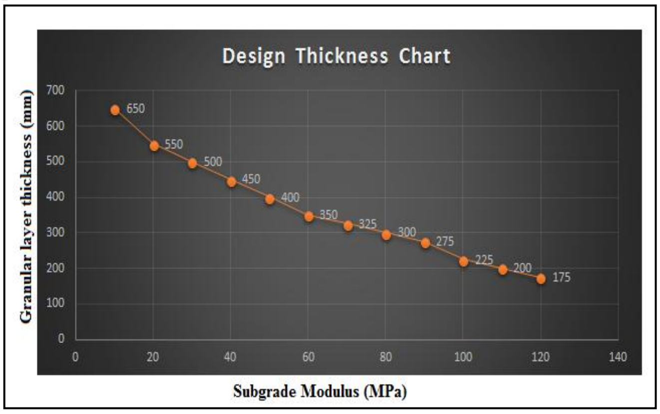

Fig 7. Design thickness chart (granular layer thickness v/s Subgrade Modulus)

VI. CONCLUSIONS

1) Partial substitution of aggregates by e-waste and partial substitution of bitumen by crumb rubber or plastic is technically feasible.
2) As per IS:SP:98 [13], with the dry process, plastic waste can be used to partially replace bitumen by 7% and 10% by waste rubber to form a modified bitumen in bituminous layer having 5.5% optimum bitumen content.
3) From the analysis, it can be suggested that the partial replacement of aggregates using e-waste alone is 7.5%.
4) From the obtained test results, it can be stated that e-waste combined with plastic or crumb rubber can be effectively utilized in the pavement section having high stability value.
5) From the analysis, partial replacement of bitumen by 7% plastic with 7.5% e-waste and by 10% rubber with 7.5% e-waste is possible and gives optimum results.
6) The design charts need to be site specific to avoid premature failure of roads and not solely rely on the general guidelines provided by the design manuals.
7) It is suggested that the maximum depth/thickness should be 150 mm for base course while any extra depth/thickness be constructed as sub-base.
8) The study can further be extended to create design charts by changing the depth/thickness and material properties of constituent layers.

REFERENCES

1. A.R. Pasandin & I. Perez,"Fatigue performance of bituminous mixtures made with recycled concrete aggregates and waste tire rubber" Construction & Building Materials, Elsevier, 2017, pp 26-33.
2. Abdhesh K.Sinha, Satish Chandra and Praveen Kumar,"Finite element analysis of flexible pavement with different subbase materials" Indian Highways, 2014, New Delhi, 42(2), 53-63.
3. Adriana Vargas-Nordcbeck & David H. Timm,"Rutting characterization of warm mix asphalt and high RAP mixtures" Road Materials and Pavement Design, 2012, 13:sup1, 1-20, doi: 10.1080/14680629.2012.657042.
4. Ali Ebrahimi , Brian R. Kootstra , Tuncer B. Edil& Craig H. Benson,"Practical approach for designing flexible pavements using recycled roadway materials as base course" Road Materials and Pavement Design, 2012, 13:4, 731-748, doi.org/10.1080/14680629.2012.695234.
5. Appiah Johnson Kwabena, Berko-Boateng Victor Nana, Tagbor Trinity Ama,"Use of waste plastic materials for road construction in Ghana" Case Studies in Construction Materials, 2017, http://dx.doi.org/10.1016/j.cscm.2016.11.001
6. ASTM Standard D 1559 "Standard Test Method for Resistance to Plastic Flow of Bituminous Mixtures Using Marshall Apparatus 4-inch Intended for Mixes Containing Aggregate up to 1-inch", USA, 1992.
7. Davide Lo Presti,"Recycled Tyre Rubber Modified Bitumen for road asphalt mixtures: A literature review" Construction & Building Materials, Elsevier, Vol. 49, 2013, pp 863-881, http://dx.doi.org/10.1016/j.conbuildmat.2013.09.007
8. Dr. Aditya Kumar Anupam, Dr. Praveen Kumar and Dr. G. D. Ransinchung R. N.,"Laboratory study on performance of various agricultural and industrial waste materials in road construction" Indian Highways, volume 45, No. 5, 2017, pp 13-28.
9. Dr. Umesh Shama, Harish Kumar Giri and Ankita Khatri,"Use of recycled asphalt material for sustainable road construction" Indian Highways, Vol. 46, No. 9, 2018, pp 29-38.
10. Gowtham C & K Ganesh,"Evaluation of rutting performance in plain and modified bituminous concrete mix using steel slag as partial filler replacement" Indian Highways, Vol. 46, No. 12, 2018, pp 33-41.

11. IRC: 37-2012. "Guidelines for the design of flexible pavements." Indian Roads Congress, New Delhi.
12. IRC: SP: 72-2015 (First Revision). "Guidelines for the design of flexible pavements for Low Volume Rural Roads." New Delhi: Indian Roads Congress.
13. IRC: SP: 98-2013 "Guidelines for the use of waste plastic in hot bituminous mixes(dry process) in wearing courses" Indian Roads Congress, New Delhi.
14. Islam Abo El-Naga and Mohamed Ragab "Benefits of utilization the recycle polyethylene terephthalate waste plastic materials as a modifier to asphalt mixtures" Construction & Building Materials, Elsevier, 2019, pp 81-90, https://doi.org/10.1016/j.conbuildmat.2019.05.172
15. Jia Xiaoyang, Ye Fen & Huang Baoshan,"Utilization of construction and demolition wastes in low volume roads for rural areas in China" Transportation Research Record: Journal of the Transportation Research Board, 2015, pp. 39–47, DOI: 10.3141/2474-05
16. K. Kranthi Kumar, R. Rajasekhar, M. Amarnatha Reddy and B. B. Pandey,"Reclaimed asphalt pavements in bituminous mixes" Indian Highways, 2014, pp 12-18.
17. K. Sai Kubair, Shreyans R. Surana, M. Venkata Sai Krishna, Sridhar Raju and V. Vinayaka Ram,"Rutting potential of gap graded warm mix asphalt with higher percentage of crumb rubber" Urbanization Challenges in Emerging Economies, ASCE, pp 539-548.
18. Kranthi Kuna, Gordon Airey, Nick Thom,"Structural design of pavements incorporating foamed bitumen mixtures" Proceedings of the Institution of Civil Engineers, 2016, doi: 10.1680/jcoma.16.00039
19. L.R. de Rezende, M.O. Marques & N.L. da Cunha,"The use of nonconventional materials in asphalt pavements base" Road Materials and Pavement Design, 2015, 16:4, 799-814, doi: 10.1080/14680629.2015.1055334.
20. Lucas Delongui, Matheus Matuella, Washington Peres Nunez, William Fedrigo, Luiz Carlos Pinto & Jorge Augusto Pereira,"Construction& demolition waste parameters for rational pavement design" Construction & Building Materials, 2018, pp 105-112,doi:10.1016/j.conbuildmat.2018.02.086
21. Ministry of Road Transport and Highways (2010). Basic road statistics of India 2004–2008, Report by Transportation Research Wing, Government of India, New Delhi.
22. Pakhare Jagjit Laxman and Bhosale Sukhanand Sopan,"Effect of Ewaste plastic as aggregate replacement on Marshall mix design of dense bituminous macadam" Indian Highways, Vol. 45, No. 4, 2017, pp 51-60.
23. Salih Kocak& M. Emin Kutay,"Use of crumb rubber in lieu of binder grade bumping for mixtures with percentage of reclaimed asphalt pavement" Road Materials & Pavement Design , doi: 10.1080/14680629.2016.1142466
24. Sandip Karmakar& Tapas Kumar Roy,"Effect of waste plastic and waste tires ash on mechanical behavior of bitumen" Journal of Materials in Civil Engineering, ASCE, 2016, DOI: 10.1061/(ASCE)MT.1943-5533.0001484.
25. Srinivas F. Chitraghar & DharamveerSingh,"Laboratory performance of asphalt mixes containing recycled asphalt pavement" Indian Highways, Vol. 45, No. 12, 2017, pp 17-22.
26. Tapase A. B. & Kadam D. B. "Performance evaluation of polymer modified bitumen in flexible pavement" Journal of Environmental Research and Development, (2014), Vol. 8, No. 3.
27. Zhanyong Yao, Jizhe Zhang, Faliang Gao, Shengjie Liu & Tenghai Yu,"Integrated utilization of recycled crumb rubber and polyethylene for enhancing the performance of modified bitumen" Construction & Building Materials, Elsevier, 2018, pp 217-224.

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