A Review on Strength & Rutting Characteristics of WBM with Partial Replacement of Aggregates by Steel

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Abstract - *Utilizing industrial byproducts is a major task in the current scenario of rapid industrial growth all around the globe. Many industrial wastes/byproducts are suitable for use in various constructions. In highway constructions the most generally used byproduct is flyash from thermal power stations. Rice husk ash is also used along with lime, lime-flyash lime-rice husk ash are different combinations usually adopted. Recycled concrete aggregates, municipal wastes processed with proper techniques, quarry wastes and slurry dust from marble polishing plants are other wastes used in highway construction. Steel production is marked as the backbone of developmental economies in the history of modern nations. It is one of the very few materials which are multi- functional and most-adaptive in its usage. Steel production is also seen as strategic part any country's economy, currently China is the highest producer of steel with 803.8 million metric tons and India occupies 3rd position with 89.4 million tons as per the data released by World Steel Association based in Brussels for the year 2015. Blast furnace slag, Granulated Blast Furnace Slag (GBFS) and Steel slag are three different byproducts from iron and steel industries located in various parts of our country. Feasibility study to utilize them instead of conventional road aggregates was done by CRRI. Air cooled blast furnace slag and weathered steel slag can be used instead of conventional stone aggregates in construction of WBM layers and for mechanical stabilization as per IRC:SP:20-2002. In the present study coarser fraction of steel slag is being used as coarse aggregate and fines of steel are used as screenings.*

***Key Words*: Granulated Blast Furnace Slag, Roller Compactor cum Rut Analyzer, compaction and rutting.**

1. INTRODUCTION

Water Bound Macadam (WBM) is a layer which can be used as a sub-base or base or surface course, it consists of mechanically interlocked aggregates with its voids filled by screenings and binder with aid of water. It was originally introduced by a Scottish engineer John.L.Macadam in 1820 as comprising of only aggregates meeting a specific gradation to form a mechanically interlocked mix compacted with light application of water. It had various defects like frequent loss of aggregates and poor engineer by name Richard Edgeworth modified it by adding fine screenings of the same material as that of aggregates to fill voids in aggregates and a binder with aid of water for proper binding of the mix. This modified WBM had comparatively more durability and good ride quality. In our country WBM is mainly used as a base course for important roads like NH because of its good drainage characteristics, however for low volume roads it is used as a surface course also. IRC:19-2005 deals exclusively with specifications for materials and construction of water bound macadam layer. Similar details about WBM are noticed in IRC:37-2012 for roads with volume more than 1msa and in IRC:SP:20-2002 & IRC:SP:72-2015 for low volume rural roads i.e. less than 1msa. Water Bound Macadam (WBM) consists of coarse aggregates, screenings and binder. Coarse aggregates used should be clean free from dirt and any deleterious matter. Crushed stones, crushed slag, kankar, laterite or over burnt bricks can be used as aggregates. Aggregates should be chemically stable and water absorption should not exceed 10 percent. There are 3 sets of grading requirements for coarse aggregates of different sizes, namely Grade-1, Grade-2 and Grade-3. However only Grade-3 is used for surface course and remaining two namely Grade-1 and Grade-2 are used for sub- base and base course only. The compacted thickness of Grade-1 is 100mm where as that of Grade-2 and Grade-3 is 75mm each. Also the aggregates should have permissible Los Angeles abrasion and aggregate impact value. Screenings which fill the voids should be as far as possible of the same material as that of coarse aggregates. There are two sets of gradations available for screenings viz. Type A and Type B. Type A screenings can be used with Grade-1 and Grade-2 coarse aggregates. Type B screenings can be used with Grade-2 and Grade-3 coarse aggregates. Binding material is used in WBM in order to hold the mix together with aid of water. Binding material is fine grained material having permissible values of plasticity index depending upon the climatic conditions of road. Dust (soil or lime stone dust), kankar nodules or any other locally available fine grained material may used as binder. Unlike various types of bituminous courses quantities of coarse aggregates, screenings and binder are directly obtained by volumes given in IRC code for required compacted thickness of 100mm or 75mm, not by proportioning of constituent materials to obtain a proper blend. For a given function of WBM layer i.e. sub-base or base or surface course corresponding coarse aggregate-screening combination is selected e.g. coarse aggregate Grade-3 & screenings Type B (Grade-3-B) is selected for surface course. Construction of WBM layer begins by ensuring the surface receiving WBM is non- bituminous as it will lead to drainage problems and insufficient bondage, at proper grade and camber and is free from ruts, dirt and dust. Coarse aggregates are evenly spread and rolled by 8-10 tonnes roller. Screenings are then applied followed by rolling along with light application of water. Brooming is regularly carried out for each layer of screenings application, as screenings are applied at a very slow rate in two or three layers. Later the binding material is applied in the same manner as that of screenings with aid of water followed by rolling and slurry resulting is swept by brooms. No traffic is allowed to ply over WBM as it is left overnight for setting and drying. As like any other pavement layer water bound macadam layer is also prone to various distresses/deformations: Surface unevenness, potholes, raveling, corrugations and rutting due to pumping action of pneumatic tyred vehicles along with abrasion and grinding effect of solid iron wheeled bullock carts. Periodical surface blinding, filling up of potholes and rectifying raveling by pick and roll method are some of the maintenance measures usually adopted for WBM. Rutting or permanent deformation is formation of channelized depressions along wheel paths in flexible pavements. For roads with volume beyond 1msa permissible rut depth is 20mm as per IRC:37-2012 page 15 and 50mm for village roads where volume is below 1msa as per IRC:SP:20-2002 page 95. Rutting occurs due to densification i.e. volume change and repetitive shear deformation i.e. plastic flow with no volume change. Rutting is categorized as subgrade rutting in which case subgrade soil under goes rutting which is reflected to all the above layers over it and mix rutting in which subgrade is intact one of the pavement layer/s under goes rutting which gets reflected to subsequent layers. Given the low volume and different composition of traffic on rural roads compared to other important highways, the stress and deformation experienced by pavement also differs in its nature. Rutting of pavement surface is one such deformation which affects the serviceability when it becomes severe. By enforcing stringent compaction specifications and ensuring sufficient strength in pavement structural design rutting of pavement can be limited to certain extent.

1.1 Literature reviews

This chapter deals with previous studies about rutting on unpaved roads, use of industrial by-products in highway construction and rutting using Roller Compactor cum Rut Analyzer (RCRA). RCRA is capable of performing both compaction and rutting test simulating field conditions as nearly as possible in the laboratory. Various studies about utilization of steel industry by-product are also focused.

G.Madhavi Latha, et al., (2010)[1] carried out rutting studies on unpaved roads. They constructed a 2m long and 1m wide unpaved road over a subgrade prepared by in situ natural soil in the IISc campus. Grid points were placed across the road with equal spacing of 10cm, 11 such grid points were in place at each section and a total of 3 such sections were made along the road to monitor the rut depth when a scooter weighing 106kg moved on it at an average speed of 20kmph. Unreinforced and reinforced roads rut depths and traffic benefit ratios were compared to evaluate reinforcing materials. Unreinforced road was simply prepared by laying a 100mm thick properly blended aggregate layer over well compacted subgrade. Over this in- situ dry soil was placed and compacted with appropriate quantity of water to provide a good riding surface which was 50mm thick. Different reinforcements used in the study were geotextiles, biaxial geogrid, uniaxial geogrid, geocell layer and tyre shreds. Reinforced sections were prepared by placing the respective reinforcements at the interface of aggregate layer and subgrade. Unreinforced section performed very poorly in rutting test whereas all reinforced sections performance was considerably good. Among reinforced sections, geocell layer outperformed tyre shreds, which performed better than geotextiles. The ratio of number of passes required to cause a certain permanent deformation i.e. rut depth in a reinforced layer of given thickness to the number of passes required to cause same rut depth in an unreinforced section of same thickness is Traffic Benefit Ratio (TRB). Even in terms of TRB geocell layer performed better than other reinforcements, followed by tyre shreds and geotextiles.

B.V.Kiran Kumar, et al., (2012)[2] indigenously built an equipment called Roller Compactor cum Rut Analyzer (RCRA) which is capable of performing both compaction and rutting on a layer. Its outstanding feature is that, it simulates field conditions of compaction and rutting in laboratory. Unlike other equipments in laboratory which compact by use of rammers which is not a practice in field, RCRA compacts a layer by kneading effect thus simulating field method of compaction. It has two dispatch able rollers, one a smooth wheeled uniform diameter roller for compaction and another rutting roller with two discs mounted on steel bar representing axle of vehicle. These rollers can be used as per the requirement, can apply a constant pressure varying from 0.6N/mm2 up to 3 N/mm2. It has a set of vertical and horizontal transducers which are capable of measuring movements and there is a Programmable Logical Circuit with control screen for monitoring, recording and operating. They prepared Bituminous Concrete (BC) grade-2 specimens using Marshall Hammer, Superpave Gyratory compactor (SGC) and Roller Compactor cum Rut Analyzer (RCRA). Optimum binder content (OBC) of specimens by these three different methods of compaction were compared, SGC specimens resulted in lowest OBC followed by RCRA for the same binder and air voids. SGC specimens had the highest stability, and those by RCRA were close to SGC followed by Marshall Hammer which were too low, the same trend was observed in density too. Whereas in case of rutting test using RCRA, specimens prepared at OBC by RCRA carried highest number of passes, those at OBC by SGC carried slightly less followed by those at OBC by Marshall Hammer which carried very less number of passes. In case of fatigue test, specimens at OBC by SGC & RCRA outperformed those by Marshall Hammer.

Erol Tutumluer, et al., (2016)[3] conducted cyclic loading test on non bituminous layer to evaluate effectiveness of geo-synthetic fibre reinforcement in case of unpaved roads. Steel mould measuring 2x2x2m was fabricated to house pavement material to be tested. A cyclic loading arrangement consisting of jack and a steel plate of 300 diameter capable of applying up to 40kN load at a particular load pulse frequency was mounted over the steel box. A set of transducers and load cells measured vertical movement of plate and number of cycles. Weak subgrade soil was placed in layers and each was compacted with appropriate quantity of water, final thickness of this subgrade soil layer was 140cm. Tests were conducted in two sets, in the first they varied thickness of granular sub-base layer placed over subgrade and in the later triaxial geogrid of 40mm triangular aperture made from polypropylene was placed at varying depths of 1/3, 2/3 and one times diameter of steel plate from surface, cyclic load tests was performed for each case to measure permanent deformation. Authors concluded that as the thickness of granular layer increases permanent deformation decreases, where as with increase in number of cycles they noticed severe deformation. In case of geogrid reinforced layer, it was observed that nearer the geogrid from surface lesser was the permanent deformation. In both cases it was clearly evident that for initial loading cycles rate deformation is high and which decreases at later stages of loading.

Faisal I. Shalabi, et al., (2016)[4] evaluated the efficiency of steel slag in improving performance of local clayey soil of Saudi Arabia. Steel slag aggregates from various steel industries were collected and basic tests were performed. Clayey soil was mixed with varying percentages of steel slag, Atterberg limits, free swell index, shear parameters, compaction characteristics and CBR were obtained by experimental study. It was observed that with increase in steel slag content the treated clayed soil was observed to have a lower plasticity index and free swell index, where as Maximum Dry Density (MDD) and California Bearing Ratio (CBR) values increased. Unconfined Compressive Strength (UCS) initially decreased with increase in steel slag content, reached a minimum value and then slightly increased. Cohesion value decreased with rise in steel slag content, while increase in friction angle was noticed.

G.Ramulu, et al., (2012)[5] studied influence of gradation of mix, moisture content of subgrade, field density, California Bearing Ratio (CBR) and traffic volume on rutting behaviour of Water Bound Macadam (WBM). The authors selected a total of fifteen 500m stretches spread across three districts of Andra Pradesh having different geological and climatic conditions for field studies using various destructive and non destructive methods and post data analysis using appropriate software tools they developed response models. Road inventory, structural and functional evaluation of pavement and volume count was carried on these stretches. Functional parameter roughness was expressed in terms of International Roughness Index (IRI) and some data was collected from secondary sources too. It was noticed that closer the gradation curve to upper limit lower was the rut depth. Moisture content of subgrade was observed to have a direct relationship with rut depth where as field density had an inverse relationship. Based on the literature study it is clearly evident that more investigations on rutting characteristics of non-bituminous courses are required as unsealed surfaces are more susceptible to deformation than sealed roads. An attempt is made to carry out rutting studies on non-bituminous course i.e. WBM while making use of steel slag.

Conclusion

We can evaluate basic properties of soil as binder and steel slag as aggregate as strength of WBM comprising of conventional aggregates and soil as binder. To evaluate strength of WBM with partial replacement of conventional aggregates by steel slag and soil as binder. Performance on rutting tests by using RCRA for WBM containing only conventional aggregates and that with partial replacement by steel slag. Also Compare strength and rutting characteristics of both combinations is possible. In the present investigation suitability of steel slag as aggregate and soil as binder in WBM Grade-3 is studied. California Bearing Ratio (CBR) test and Rutting test using RCRA is carried out on WBM to evaluate its strength and rutting characteristics

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