Investigation Into Use of Waste Materials in Pavement Sub-base

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ABSTRACT:
With enormous construction activities taking place, scarcity of high quality quarry aggregates has resulted into significant concern for researchers and engineers in the world of different countries including India. This results into urgency for finding out sustainable, viable alternative materials which could be considered as partial replacement to natural aggregates. Waste generated from construction and demolition waste (C & D waste) constituent major portion of landfills and if not recycled in proper way can significantly affect the environment. With aim of achieving reduction in demand of virgin aggregates or natural aggregates, significant efforts have been made to incorporate these waste materials generated and occurred from C & D waste and use them as alternatives to naturally available aggregates; as usage of these materials resulted into significant environmental benefits. In the present study, in order to evaluate their potential reuse as in highway sub base or base material, an attempt is made with extensive series of laboratory tests carried out on these materials included recycled concrete crushed aggregates (RCA/CCA) and Reclaimed Asphalt Pavement (RAP). Different blended mixture of virgin aggregates/ RAP+RCA were prepared with proportions of 100/0, 90/10, 80/20, 70/30 and 60/40 respectively. Also, in addition to these mixture, another set of samples prepared by replacing natural aggregates by 20% and 40% with two different moorum samples. Physical, compaction and CBR test were conducted on all of the samples. Results obtained indicated that for different sample prepared with NA/RAP+RCA Mixtures shown gradual decrease in water content and CBR values with increase in % replacement. Another blend mixes prepared with moorum samples yielded lower strength as compared with another samples containing RAP and RCA, still showing satisfactory performance and can be used as in pavement sub base applications.

Index Terms **- C & D waste, Reclaimed Asphalt Pavement, Base, Sub Base, Recycled Concrete Aggregates, locally available moorum**

I. INTRODUCTION

In recent decades, with the rapid growth in the population resulted into generation of more waste from which many of the materials will last long in the environment. Some of the non decaying materials produces waste disposal crisis which again owing to disposal crisis over the world. With the rapid growth in the population, need of good infrastructure based constructed roads network became prime importance to fulfil the requirement for rapid economical growth. The good constructed road network will help in to provide connectivity to remote areas; provides accessibility to markets, schools, and hospitals etc. Following the traditional way of practicing construction of pavements, both for conventional flexible pavements and rigid pavements will lead to consume more quantity of naturally available materials such as aggregates which are required for construction of base, sub base and wearing course of pavements.

Materials which used in the pavement construction also employed in for other construction activities (like building, dams, power houses etc). With respect to meeting the demand of construction activity of roads for base, sub-base and the wearing course, the natural stone aggregates available are heavily consumed and hence the depletion of these materials would likely to occur.

This depletion of natural resources not only leads to reduction of resources, but also consuming lot of energy depleting the energy sources also. Considering the current situation of depletion of natural resources, the need of using recycled materials obtained from the C & D waste, and industrial waste necessitates further uses following the recycling techniques available. Recycled concrete aggregates (RCA) obtained from construction and demolition waste and Reclaimed asphalt pavement (RAP) obtained from the partial or full depth reclamation process found to be one of the viable alternative for the natural resources to be implemented in the construction of base, sub base and wearing course of the pavement and has become increasingly adopted in the recent years for the different countries over the world.

II. Aim and Objectives of the Present work

From the suggestions given by most of the authors regarding use of waste materials such as obtained from construction and demolition waste (C&D Waste), recycling and reusing of Reclaimed Asphalt Pavement obtained from flexible pavement; attempts have been made to fulfill presented Aim and objectives as below:

The main aim of this research to find out the best suitable alternative materials for the pavement sub base application by investigating the reuse of waste material such generated from the recycling of the waste solid materials available.

The present work is focussed on the use of non conventional waste materials which are generated from the different construction and infrastructure activity and to use them as a base, sub base materials. With seeking out the scarcity of natural materials for construction and infrastructure activities, it is necessary to find out substitute for conventional crushed aggregates (of different nominal size) for use in the base or sub-base layer of the pavement which helps in conservation of natural materials and environment sustainability. Pertaining to this, the objectives of this work are:

- To Identify and investigate the presence of solid waste materials created by building and infrastructure operations.
- To investigate the performance and properties of recycled and reused waste materials.
- Determine the physical characteristics of waste materials and investigate their feasibility for use in pavement sub-bases.
- To assess the physical properties of locally accessible materials such as moorum, old used soil, and other similar materials, as well as their appropriateness for use in the pavement's sub-base layer.
- To determine the appropriateness and impacts of various waste materials for use as a basis or sub-base in conjunction with natural aggregates and other locally accessible waste materials.

III. Materials used

During this investigation the attempt is made to use waste materials in the forms of recycled concrete aggregates and reclaimed asphalt pavements with addition to the natural aggregates (virgin aggregates), which served as alternative to natural aggregates . In addition, locally available moorum collected from two different locations is also used.

3.1 Naturally Available Aggregates (Virgin aggregates)

Naturally available aggregates were obtained from a quarry and these aggregates used in the experimental work extensively used in for works such as surface, sub base and base course preparation of flexible and rigid pavements. The aggregates were then tested for their basic properties determination through the series of testing which included tests such as for water absorption and specific gravity, Impact value etc.

3.2 Recycled Concrete Aggregates (RCA)

These recycled concrete Crushed aggregates were obtained from a C & D Waste available through pavement rehabilitation project which obtained through the heep of concrete. This available concrete waste materials was then crushed and different size of crushed concrete aggregates were obtained through the arranging standard set of sieves given by as Indian standard code and obtained material was tested for physical and compaction properties .

3.3 Reclaimed Asphalt Pavement (RAP)

Reclaimed asphalt pavement (RAP) similarly was one of the waste materials which was incorporate into as one of the sub base material with natural aggregates. This RAP was collected from rehabilitation work undertaken for flexible pavement in area of Airoli, Navi Mumbai. The different properties of RAP was then determined and presented in table.

3.4 Locally Available Moorum

Locally available moorum was collected from two different locations located in areas of Airoli and Bhingarwadi and for investigating its potential as a sub base material, was used as replacement material to natural aggregates in two different proportion of 80/20 and 60/40 respectively.

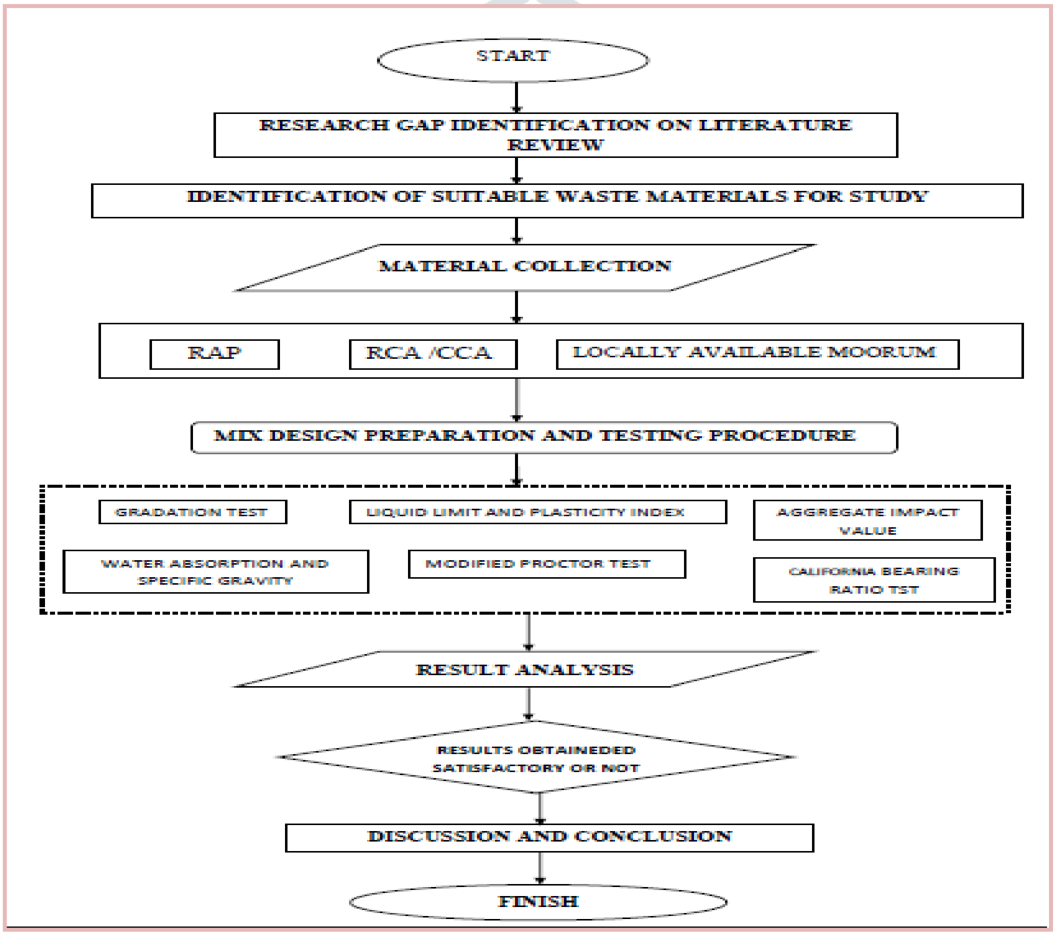
IV. Laboratory Testing Programme

After collecting the required materials for experimental investigation work, in order to evaluate their potential use as pavement sub base material, a series of laboratory experimental tests was conducted to determine their physical, compaction and CBR values of blended mix samples prepared. The main steps involved in the testing program are:

- Physical properties and characterisation determination of materials taken for study such as Recycled concrete aggregates (RCA), Reclaimed asphalt Pavement (RAP) and locally available moorum.
- Compaction testing on different samples prepared with modified proctor test
- California bearing ratio (CBR) test

4.1 Testing Methodology:

The laboratory testing methodology work included determination of physical properties of individual materials collected which included tests for determining gradation, Atterberg limit, water absorption and specific gravity which was helpful during further investigation for used them as sub base material in pavement . Similarly different samples prepared using natural aggregates and waste materials were also tested for strength testing by conduction of compaction and California Bearing Ratio (CBR) tests respectively on each mixes.



METHODOLOGY CHART

4.1.1 Gradation of sample:

Sieve analysis testing were performed on all of the waste materials collected; Reclaimed asphalt pavement (RAP), Recycled crushed concrete aggregates (RCA) and locally available moorum collected from two different locations. Fig.1 (a) and (b) represented particle size distribution curves for recycled crushed concrete aggregates (RCA) and reclaimed asphalt pavement (RAP) respectively passing through set of sieves arranged according to table 400.1 of MoRTH Specification. Similarly natural aggregates used for investigation were blended together for obtaining the blended mix as per gradation I of MoRTH specification.Figure2 represents the obtained blended mix of natural aggregates of different size blended together.

4.1.2 Atterberg limit:

Liquid limit test was performed on the materials collected in accordance with IS 2720: (part5). The liquid limit test summary for all of the waste material samples was represented in table 1.

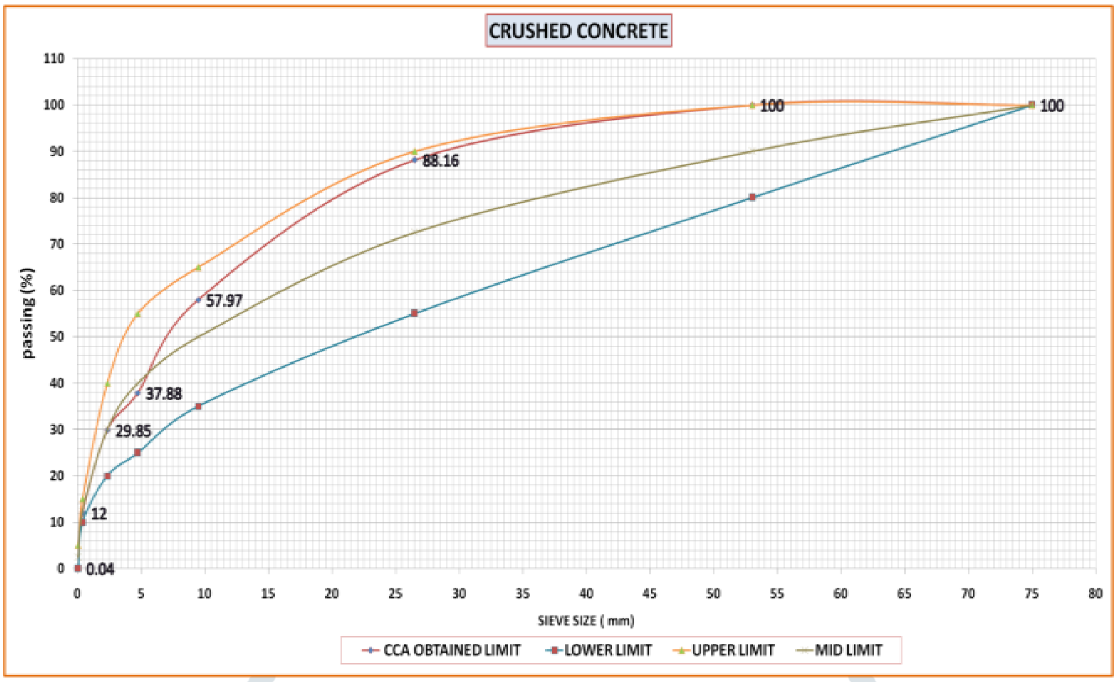


Fig.1 (a): Sieve Analysis of Crushed Concrete Aggregates

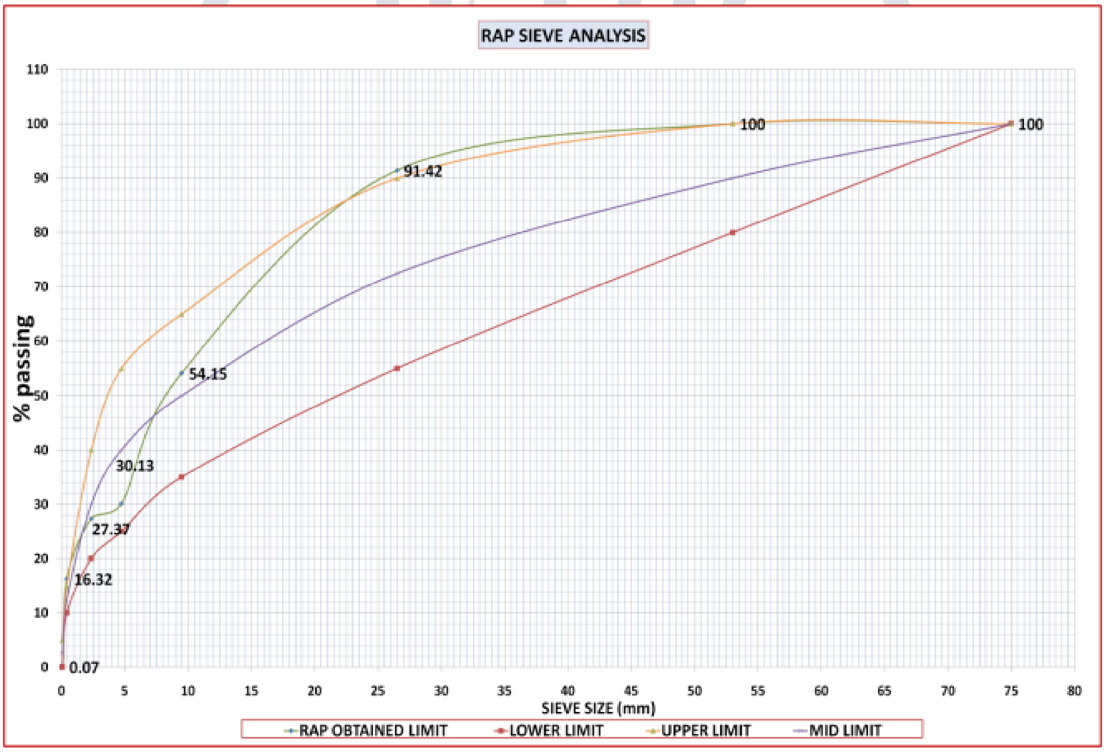


Fig. 1(b): sieve analysis of RAP Aggregates

4.1.3 Other Physical properties:

Other physical properties such as water absorption, specific gravity, and impact value test data on RAP, RCA, and natural aggregates used in the study were also determined. Other physical properties of two different moorum samples were also determined. Natural aggregates used for testing had a water absorption value of between 1.80 and 1.90 percent, which was lower than that of reclaimed asphalt pavement and recycled crushed concrete aggregates. Individual materials' specific gravity values were also determined, with all values falling between 2.0 and 3.

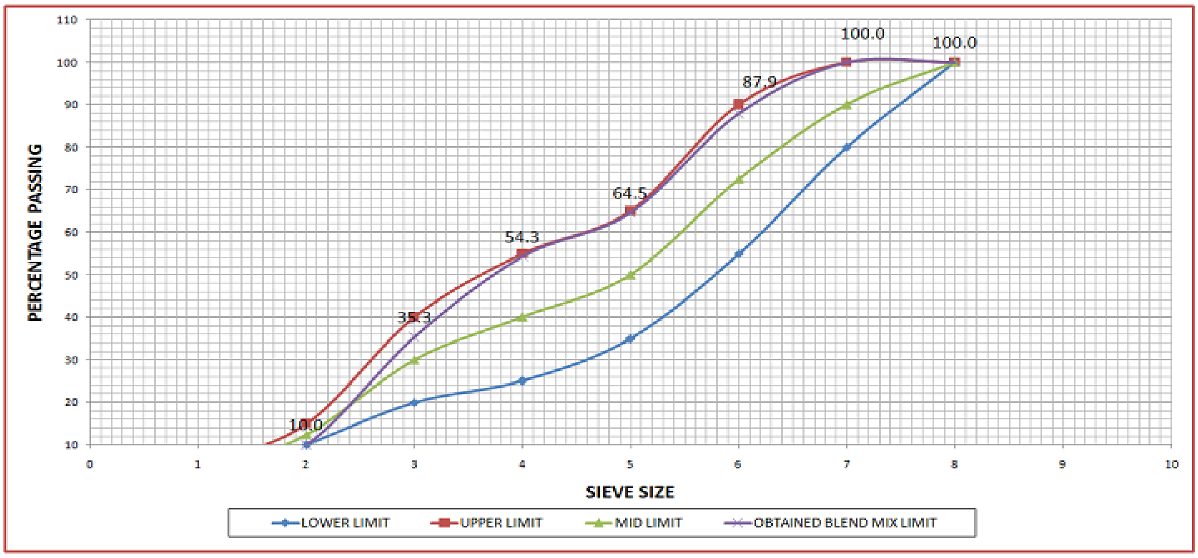


Fig. 2 Blending of natural aggregates for meeting the Gradation Requirement (as per MoRTH table 400.1)

Table 1: Atterberg limit test data for individual materials

Sr No	Description	Liquid Limit (%)	Plasticity Index (%)
1	Natural Aggregates	N/P	N/P
2	Reclaimed Asphalt Pavement (Rap)	N/P	N/P
3	Recycled Crushed Concrete Aggregates	N/P	N/P
4	Moorum Sample No 1	36.5	18.510
5	MoorumSample No 2	29.5	14.13

Table 2: New Blended Samples prepared with Material Ratio

Blended sample name	Natural aggregate (% by mass)	RCA and RAP (% by mass)	moorum Samples used (% by mass)	
			Sample 1 (WMA)	Sample2 (WMB)
SCM 100/W0	100	0	0	0
SCM 90/W10	90	10	0	0
SCM 80/W20	80	20	0	0
SCM 70/W30	70	30	0	0
SCM 60/W40	60	40	0	0
SCM 80/WMA20	80	0	20	0
SCM60/WMA40	60	0	40	0
SCM 80/WMB20	80	0	0	20
SCM60/WMB40	60	0	0	40

4.2 Test Sample Preparation

4.2.1 Compaction testing

By adding different percentages of waste materials (percent by mass) to natural aggregates, different samples were prepared for laboratory compaction testing. These new blended mixes were thoroughly mixed, and samples were prepared as shown in table 2 for compaction testing using the modified proctor test procedure specified in IS:2720 (PART 8).The ratio of natural aggregates to waste materials used was kept as with proportions of 100/0, 90/10, 80/20, 70/30 and 60/40 respectively. Another set of samples was made by substituting natural aggregates for 20% and 40% of the moorum in order to test its suitability as a pavement sub base material.

4.2.2 California Bearing Ratio test (CBR)

After obtaining the values of the corresponding Optimum moisture Content (%) and Maximum Dry density (gm/cc) for each of the different compacted samples prepared by replacing waste materials in respective percentages (by mass) in proportions of 100/0, 90/10, 80/20, 70/30, and 60/40, respectively, CBR tests were performed on each of the blend mixes prepared in accordance with IS: 2720(PART 16) specifications and procedure. The load vs penetration values were recorded and noted down for each of the specimen's o.5 mm penetrations until the penetration reached 12.5 mm value. Each of the samples prepared was checked for soaked and un-soaked CBR values, and to determine the soaked CBR value of the samples prepared, the samples were kept cured in water for 96 hours. Following completion of which, the specimen sample was removed and a testing procedure was followed in which these specimen samples were kept on the loading machine and the corresponding load vs penetration was recorded for each of the samples prepared.

V. RESULTS AND DISCUSSION

Detailed investigation for physical and strength properties of waste material compared with natural aggregates needed for accessing its suitability as pavement sub base material. After examining the individual materials and different blended mix samples prepared for their respective testing, the results obtained are represented in following figures and discuss further.

5.1 Compaction Testing

After preparing samples with various proportions of natural aggregates and waste materials, the materials mixes were subjected to a series of modified proctor tests to determine the relationship between optimum moisture content and dry density for all of the samples.

The optimum moisture content for different blended mix samples is shown in Fig. 3(a) and (b). In the case of fig. 3(a), the samples prepared by replacing natural aggregates in various proportions (percent by mass) with a mixture of RAP and RCA show that the water content of the blended mix prepared decreases with every 10% increase in waste materials; whereas the sample prepared with 40% replacement had the least amount of water content (8.40%). This trend suggested that increasing the proportions of waste materials by another 10% could result in a further reduction in the water content of the next blend mixes to be prepared.

With In fig.3 (b), the samples prepared by replacing natural aggregates with two different moorum samples show a similar trend. The water content of a standard control mix made entirely of natural aggregates was found to be 11.5 percent; however, when compared to other samples made entirely of moorum and natural aggregates, the water content of each of the other samples increased with increasing moorum content. As a result, adding more moorum to natural aggregates is likely to result in an increase in water content. This increase in water content most likely makes the sample more clayey, making it unsuitable for use as a sub base material and causing settlement of this specific layer.

In terms of the results obtained for the maximum dry density of various blends prepared, from figure 4(a), it is observed that the range of different samples prepared remains above 2.1 gm/cc, with the maximum value observed for replacement of waste material by 40% (by mass) of sample with 2.215, indicating that further addition of waste material may result in a gradual increase in dry density of subsequent blending mixes.Similarly, in the case of samples prepared with the replacement of moorum samples collected from various locations, as shown in figure 4(b), adding 20% of moorum from sample 1 resulted in the highest dry density value of 2.214gm/cc, which was higher than all other samples prepared. The sample prepared with 40 percent (by mass) moorum collected from sample 1 has the lowest value of 2.106.

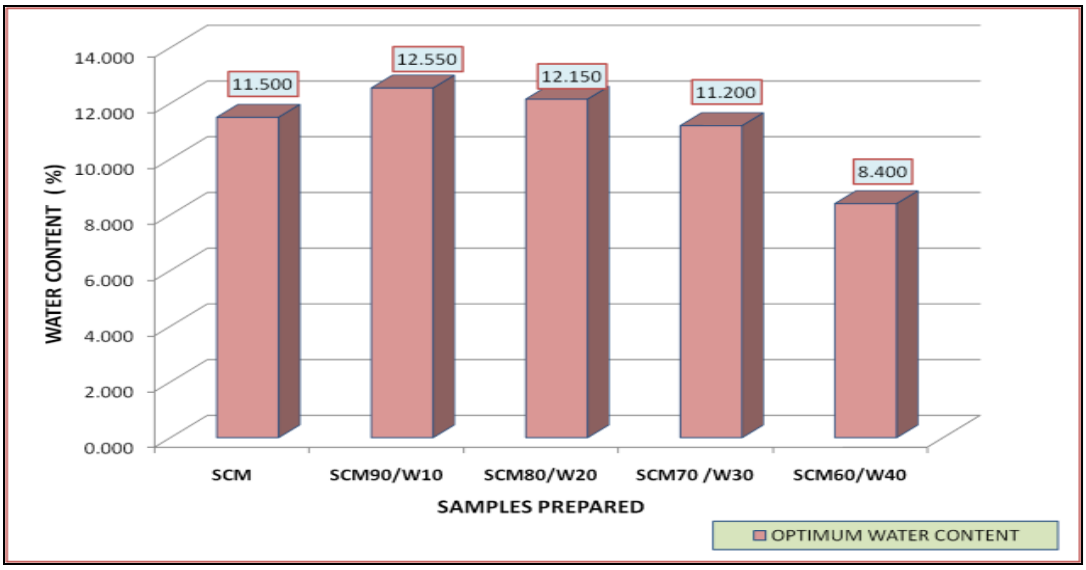


Fig.3 (a) optimum water content of different blended mix of GSB prepared with RAP and RCA

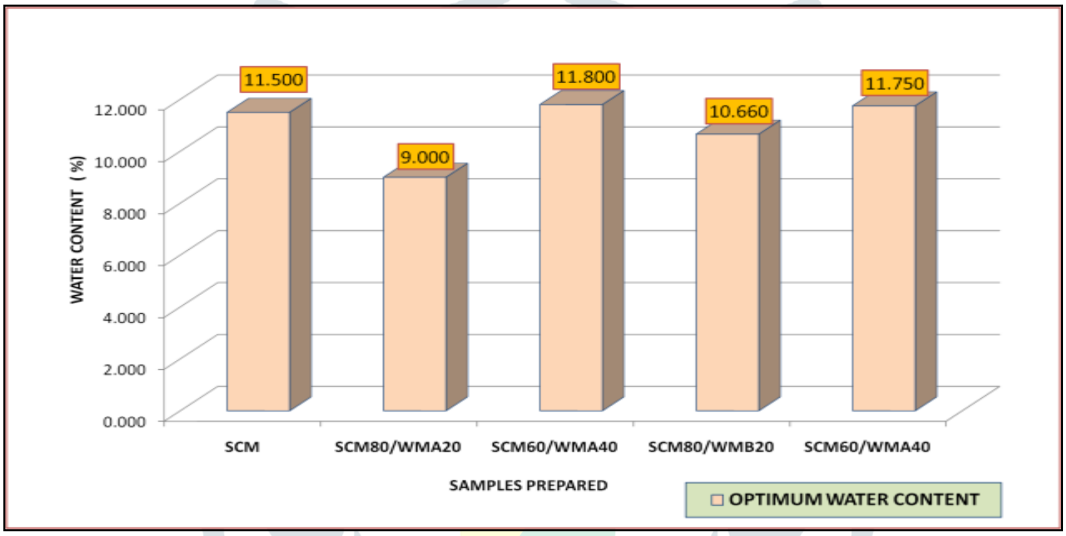


Fig.3 (b) optimum water content of different blended mix of GSB prepared with moorum samples

The sample prepared with moorum from sample no 1 shows a drop in dry density when the amount of moorum is increased from 20% to 40%, but the sample prepared with moorum from sample 2 shows a steady increase in dry density.

5.2 California Bearing Ratio testing (CBR Test)

Two different sets of samples were prepared for California bearing ratio tests. One set of samples was made up of a mixture of natural aggregates and RCA with RAP aggregates, while another set was made up of a mixture of natural aggregates and moorum in various proportions. Samples made with a blending mix of natural aggregates and a combined mixture of RAP and RCA were tested for un-soaked CBR and soaked CBR, respectively, with the percentage of waste materials replaced ranging from 0% to 40% for different blends, each increasing by 10%. Similarly, another set of samples was prepared using two different moorum samples that replaced natural aggregates by 20% and 40%, respectively.

Referring to fig.5(a), different samples prepared by partially replacing natural aggregates with a combined mixture of RAP and RCA, each increasing by 10% percentage when checked for both un-soaked and soaked CBR values. This shows a decrease in the obtained CBR, with the lowest being 66.48 percent for un-soaked CBR samples and 64.52 percent for soaked CBR samples prepared with 40 percent replacement, respectively. This suggests that as the amount of waste materials increases, the strength of CBR samples prepared for both un-soaked and soaked samples will decrease.

Similarly from fig. 5(b) ,the samples prepared when observed and checked for both ; soaked and un-soaked values of CBR test performed following IS: 2720 (PART 16) shows similar pattern . Increasing the amount of two types of moorum added from 20% to 40% in different samples prepared resulted in a decrease in CBR values for both un-soaked and soaked samples, indicating that adding more of these two moorum samples into subsequent blends can reduce sample strength.

According to the results obtained and as shown in fig.5 (a) and (b) for un-soaked and soaked CBR values, it is observed that the blended mix prepared using a combination of natural aggregates and RCA with RAP exhibits comparatively higher CBR values than samples prepared using a blending mix of natural aggregates and moorum samples.

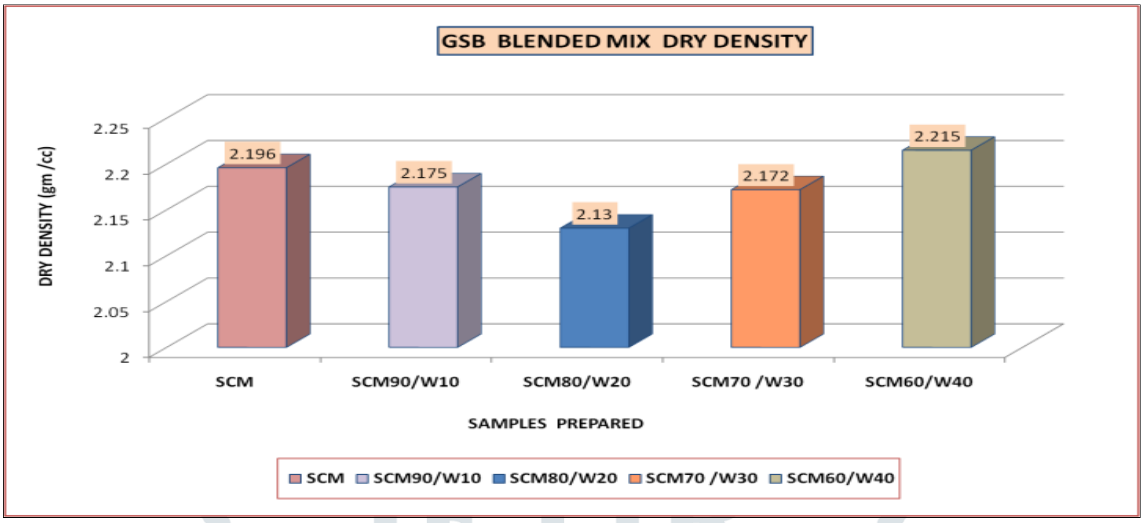


Fig. 4 (a) Dry Density of sample prepared using blending mix of natural aggregates and RAP with RCA

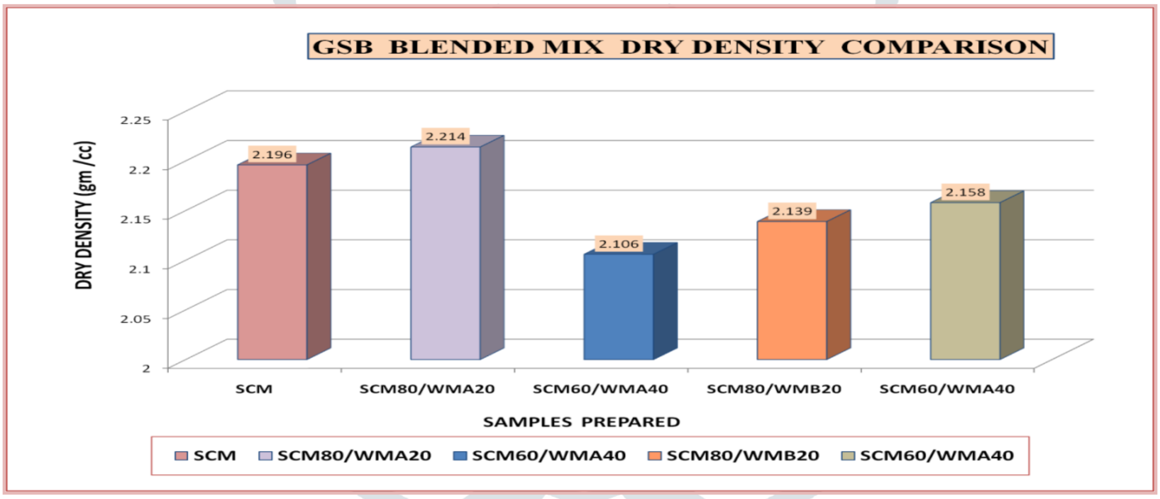


Fig. 4 (b) Dry density of sample prepared using combination of Natural Aggregates and two different moorum samples.

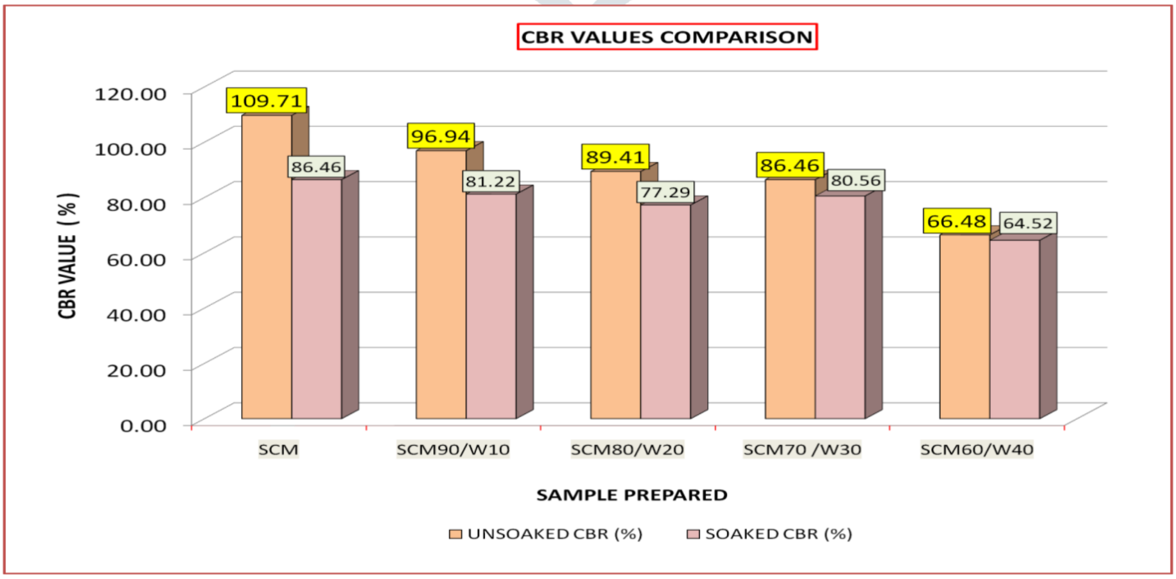


Fig.5 (a) CBR values comparison for samples prepared from blend of natural aggregates with RAP with RCA

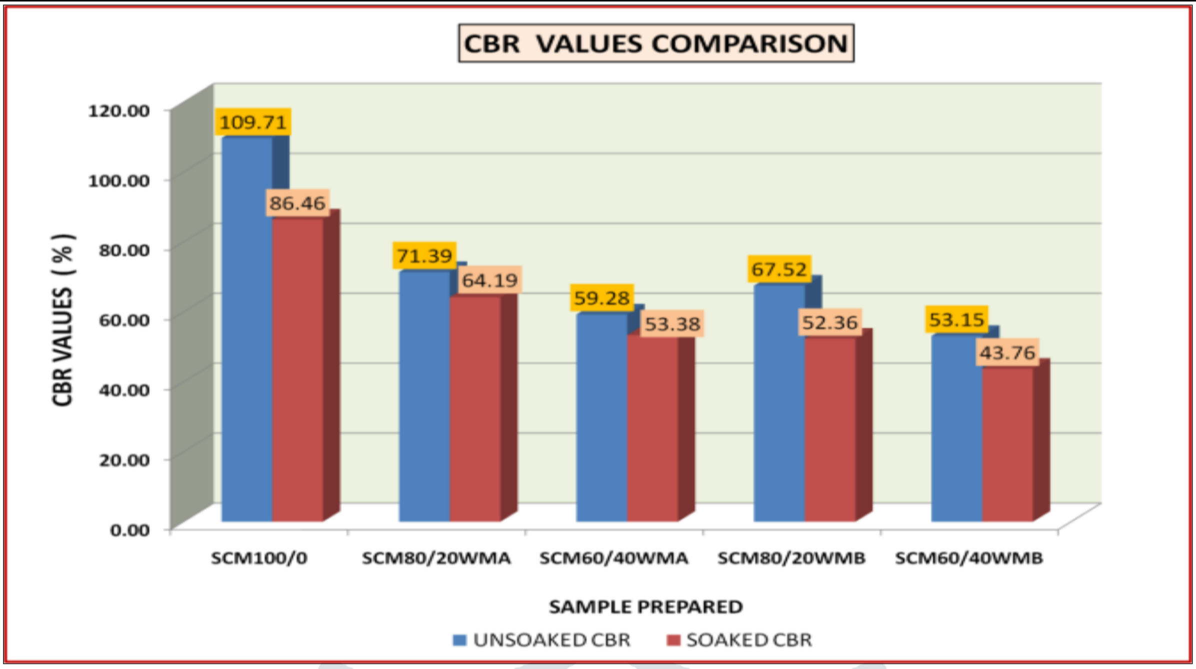


Fig. 5 (b) CBR values comparison for samples prepared from natural aggregates and moorum

VI. CONCLUSIONS

From the experimental work carried out in the present study, it is observed that:

1. The addition of waste materials as a partial replacement for natural aggregates was discovered to be a good and viable alternative as a pavement sub-base material, which can help to reduce scarcity of naturally available aggregates required in the construction of various pavement layers.

2. The water content decreased as the amount of waste materials such as RAP and RCA in combination with natural aggregates was increased by 10% for each blending mix sample prepared, with the lowest value of 8.40% observed for blending mix prepared with 40% waste material replacement.

3. When a set of samples consisting of a blending mix of natural aggregates and two different moorum samples is compared to a set of samples consisting of waste materials (RCA and RAP) and natural aggregates in different proportions with partial replacement of 0 percent to 40% respectively, the set of samples consisting of a blending mix of natural aggregates and two different moorum samples achieves a higher amount of water content..Also the water content found to be increased with increasing the quantity of respective two different moorum samples from 20% to 40%.

4. Following the results of the modified proctor test, it was discovered that all of the samples made from combining waste materials had a dry density greater than 2.10gm/cc, with the highest value being 2.215gm/cc for samples containing RAP and RCA.and value of 2.214gm/cc for sample prepared of natural aggregates and moorum sample no-1 with 20% replacement (SCM80/WMA20) respectively.

All the same, it has been observed that, In case of CBR values observed for the both soaked and un-soaked samples, for different blended mix with natural aggregates and RAP in addition with RCA is found to be more with other set of samples. Also with increase in the quantity of moorum reduction is in strength of blended mix samples is observed.

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