A Study on Use of Locally Available Moorum in Pavement Base and Sub-Base

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Abstract

Because of enormous construction activities scarcity of natural stone aggregate resources has resulted in a significant concern for engineers in many countries including in India. In the present laboratory study, an attempt has been made to explore possible utilisation of locally and abundantly available lateritic soil called moorum that fits to some extent to gravel, in the sub-base and base courses of a pavement. Conventional stone aggregates have also been used in combination with moorum to satisfy the desired grading as per the specifications. The optimum percentage of moorum that can be used in base or sub-base layer is found to be around 50%. Because of the relatively high plasticity index of moorum, ordinary Portland cement has been used for modification as well as stabilisation. The unconfined compressive strength test was conducted for the cement treated moorum-aggregate blends as per relevant specifications. It has been observed that the locally available moorum used in conjunction with normal stone aggregates modified/stabilised with cement has satisfactory engineering properties and hence can be used in the road base and sub-base applications.

Key words: moorum, cement stabilization, unconfined compressive strength, cube specimens

1. INTRODUCTION

Traditionally, materials used in highway construction are also used in other construction activities (like buildings, industrial set-ups, dams, power houses etc.). Aggregates for base and sub-base courses usually comprise of sand, crushed stone chips, gravels or natural materials that provide the necessary strength and durability. With respect to meeting the enormous demands of construction activities, the natural stone resources are heavily consumed. As reported by Indoria (2011), the extraction of aggregates from hills through quarrying operations, crushing and transportation etc. is not only responsible for the environmental degradation in the form of loss of forest lands, vibrations, dust, noise, pollution hazards etc., but also the process consumes a large amount of energy depleting the energy sources too.

In view of the above, attempts are made to utilise industrial wastes or by-products, locally available materials to at least partially replace the natural aggregates in base or sub-base applications, as these materials are available in huge quantities at a nominal cost. These materials may not match the desired standards or specifications but provide a prospect for their optimal utilization in road construction. Use of the above materials may result in a decrease in the construction cost of roads, satisfying the quality requirements and could also rather help in improving the strength and durability of the pavement.

As per Ranshinchung et al. (2014), moorum is a fragmented weathered rock that occurs with varying proportions of silt and clay, and is a low-grade marginal material having low bearing capacity and high water absorption value in comparison to that of the conventional natural aggregates. India is rich in hard moorum, but the quality differs significantly from place to place. As per the study of Ranshinchung et al. (2014), moorum was mixed with Ganga sand and stabilised with cement for use in wet mix macadam (WMM) base course. The physical properties of moorum, Ganga sand, aggregate and stone dust were earlier determined and the proportions of individual ingredients were determined so that the mixture would satisfy the desired gradation in respect of specifications of Ministry of Road Transport and Highways, Govt. of India (MORTH). Ordinary Portland cement was used as a stabiliser with varying concentrations. The results of the mixes showed very high CBR value of 423% and unconfined compressive strength of 18.55 kg/cm^2 at 9 per cent cement content.

Portelinha et al. (2012) studied on modification of a lateritic soil with cement as an economical alternative for flexible pavement layers. They observed that the PI value reduced with cement content upto 3 per cent in the soil and the strength of soil increased with cement content of 2-3 per cent.

In the current study, the locally available hard moorum has been tried for possible use in base and sub-base courses of a pavement with modification/ stabilization by cement to develop mixes for cement treated cement treated base (CTB) and cement treated subbase (CTSB).

2. MATERIALS AND METHODS

In this study, the suitability of locally available moorum with a combination of normal aggregate samples for possible use in the road base or sub-base has been explored by conducting some physical tests. The nominal sizes of aggregates used in this study were of 40 mm, 20 mm, 10 mm and 6 mm. Ordinary Portland cement (OPC 43 grade) is used for modification/ stabilisation. The unconfined compressive strength of the cement treated blended mix of moorum and aggregates, was assessed by making cube specimens as applicable to normal concrete.

2.1. Physical Properties

The gradations of the moorum and aggregate samples used in this study were taken up using Indian Standard (IS) sieves. In this study, the moorum samples were blended with aggregates for possible use in the base and filter (lower) layer of the sub-base satisfying the desired gradation requirement as per MORTH (Ministry of Road Transport and Highways) specifications. For both layers a closed grading for Granular sub-base (GSB), i.e. GSB-II as per the MORTH specifications was considered. Hence, accordingly the particle size distribution curves for different ingredient materials considered are shown in Figure 1.

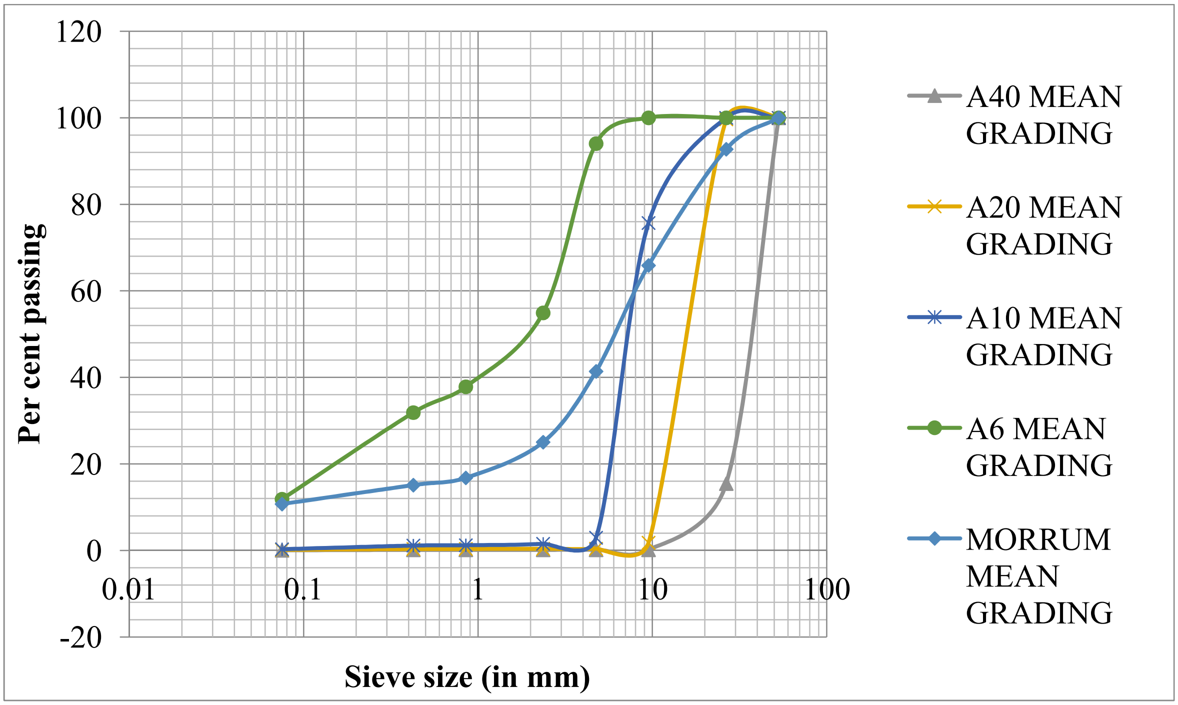

Figure 1. Gradation curves of individual aggregate and moorum samples

The important physical properties of moorum and aggregates as determined following Indian Standard (IS) codes are listed in Table 1.

Table 1. Physical properties of moorum and aggregates used

Property		Standard	Moorum	A40	A20	A10	A6
LL, PL & PI, %	Liquid Limit (LL)	IS: 2720 (Part V)-1985	40.7	-	-	-	17.60
	Plastic Limit (PL)		20.6	-	-	-	-
	PI=LL-PL		20.1	NP	NP	NP	NP
Water Absorption, (%)	Coarse	IS: 2386 (Part III)-1963	4.60	0.22	0.30	0.41	0.76
	Fine		4.90				
Specific Gravity (Bulk)	Coarse		2.74	2.76	2.75	2.74	2.65
	Fine		2.64				
Specific Gravity (Apparent)	Coarse		3.14	2.78	2.78	2.77	2.66
	Fine		2.92				
Aggregate Impact Value, %		IS: 2386 (Part IV)-1963 and IS: 5640 (1970)	33	13	20	23	-

The physical properties of the combined samples of moorum and aggregates in appropriate proportions were also determined following the standard procedure after the blending of ingredients for achieving the desired grading was taken up. As the water absorption value of moorum was found to be more than 2%, the wet aggregate impact test was taken up as per IS: 5640 (1970).

Modified Proctor test was conducted as per the IS: 2720 (Part 8) -1983 to determine the maximum dry density (MDD) and optimum moisture content (OMC). Compaction of materials (up to a maximum size of 37.5 mm) was done taking a larger size mould (volume equal to 2250 cm^3), compacting the materials in 5 layers and giving 55 blows to each layer.

2.2. Unconfined Compression Strength (UCS) Test

The unconfined compression strength (UCS) test was used to determine the compressive strength of the cement treated moorum-aggregate blends using cube specimens following relevant IS procedures.

The compressive strength of the cement treated specimens (cubes: 150 mm ×150 mm ×150 mm) was determined as per IS: 4332 (Part V) -1970. Specimens were prepared to the predetermined maximum dry density taking materials up to a maximum size of 37.5 mm compacted at the optimum moisture content. The compaction was done through a vibratory hammer fitted to three tampers with specified heights (as shown in Figure 2) for compaction in three layers (each of 50 mm) of the cube.

As shown in Figure 2, the height A is different for different tampers used for compaction of materials in different layers. The tampers with A=150 mm, 100 mm and 50 mm were used for compaction of the bottom 50 mm, the middle 50 mm and the top 50 mm of a given cube respectively. During the compaction of the top layer, another open ended cube (without a base plate) was placed squarely on the top of the cube to disallow spillage of any materials. After required compaction, the surface was levelled off with a trowel, covered with a metal plate and stored at 27±2°C for 24 hours. Then the specimen was removed from the mould and stored for curing in a curing tin (160 mm x 160 mm x 155 mm deep with well-fitting lid sealed with tape to maintain the moisture content) at 27±2°C. The difference in weight before storage and after removal (7 days from the time of compaction) was found to be within 2 g (which is well within the allowable limit of 10 g) for all the specimens. The specimens after removal from the tin were then immediately placed in the compression testing machine at a constant rate of loading (35 $kgf/cm^2/min$) until failure. Figure 3 gives the sequences involved in preparation of UCS specimens and testing of UCS of cube specimens.

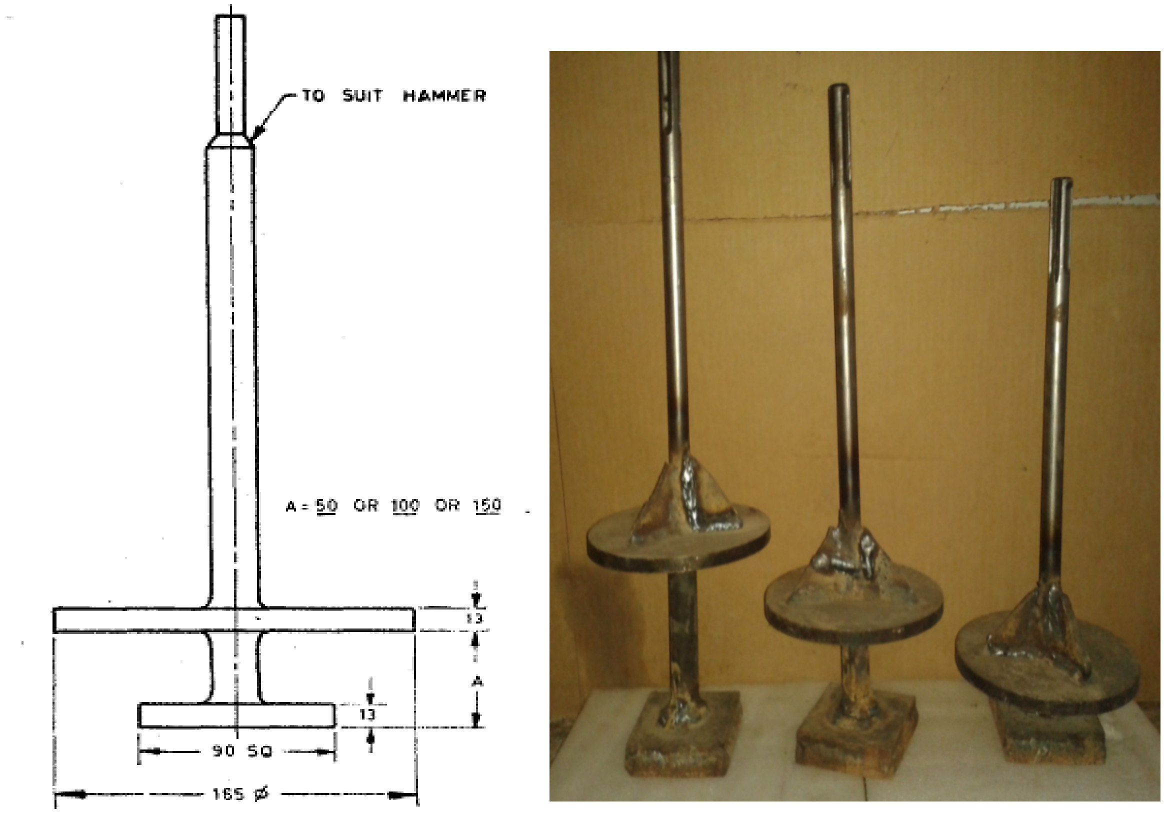

Figure 2. Tampers for cube specimen preparation using vibrating hammer

3. TEST RESULTS AND DISCUSSION

3.1. Blending Procedure

Blending of moorum and aggregates was done to meet the requirements of GSB grading II as given in Table 2, for use in the cement treated base course and the filter layer of sub-base course. In this study, the blend corresponding to GSB grading II has only been considered, as this grading can be used for two purposes, i.e., as a filter-cum-separation layer with less cement content (approx. 2%) and base course with little higher cement content (approx. 4%). The proportions of materials were selected for which the grading was best fitted within the desired limits. But in case of moorum, the fines content was found to be very high and during blending it was difficult to satisfy the limits of grading II taking the quantity of moorum more than 20 % of the total weight of aggregates. So the blending of moorum and aggregates was tried not only to achieve a grading as close as possible to the desired grading of GSB grading II but also to satisfy the grading requirements for cement bound base and sub-base materials (Grading III) as per Indian Roads Congress (IRC) specification SP: 89 (2010). In Table 2 is also presented, the requirements of grading III as per IRC SP:89, used for cement stabilized base and subabse.

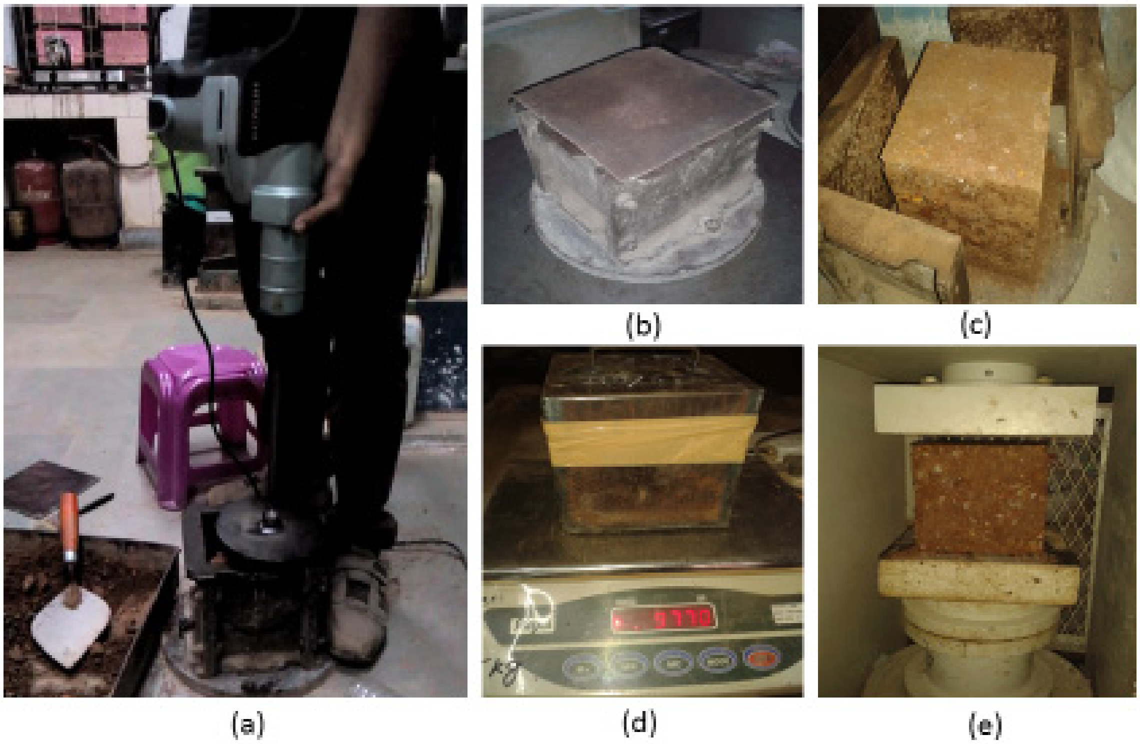

Figure 3. Sequences involved in preparation of cube specimens and testing of UCS
(a) Compaction of materials in a cube mould using a vibratory hammer, **(b)** cube mould covered with a metal plate (160 mm× 160 mm× 3 mm), **(c)** removal of specimen from the mould after 24 hours, **(d)** weight measurement of cube specimen inside a properly sealed curing tin (160 mm x 160 mm x 155 mm), **(e)** Unconfined compression test of specimen (after 7 days)

From different trials, the optimum proportion of moorum that can be used in base and sub-base fitting as closely as GSB Grading II, was found to be 50 percent of the total weight of aggregates satisfying the above grading requirements. The grading of the mix obtained by using 50% of moorum, 15% of 10 mm nominal size aggregate and 35% of 6 mm nominal size aggregate by weight has been represented in Table 2 as well as in Figure 4.

Table 2. Blending of moorum and aggregates

Sieve Size, mm	GSB Grading II Limits (MORTH)		Grading III Limits for Cement Bound Materials (IRC SP: 89)		BLENDING RESULT
	%passing (L)	%passing (U)	%passing (L)	%passing (U)	Moorum=50%: A10=15%: A6=35%
53	100	100	100	100	100
26.5	70	100	70	100	96.37
9.5	50	80	50	80	79.29
4.75	40	65	40	65	54.06
2.36	30	50	30	50	31.97
0.425	10	15	15	25	18.88
0.075	0	5	3	10	9.56

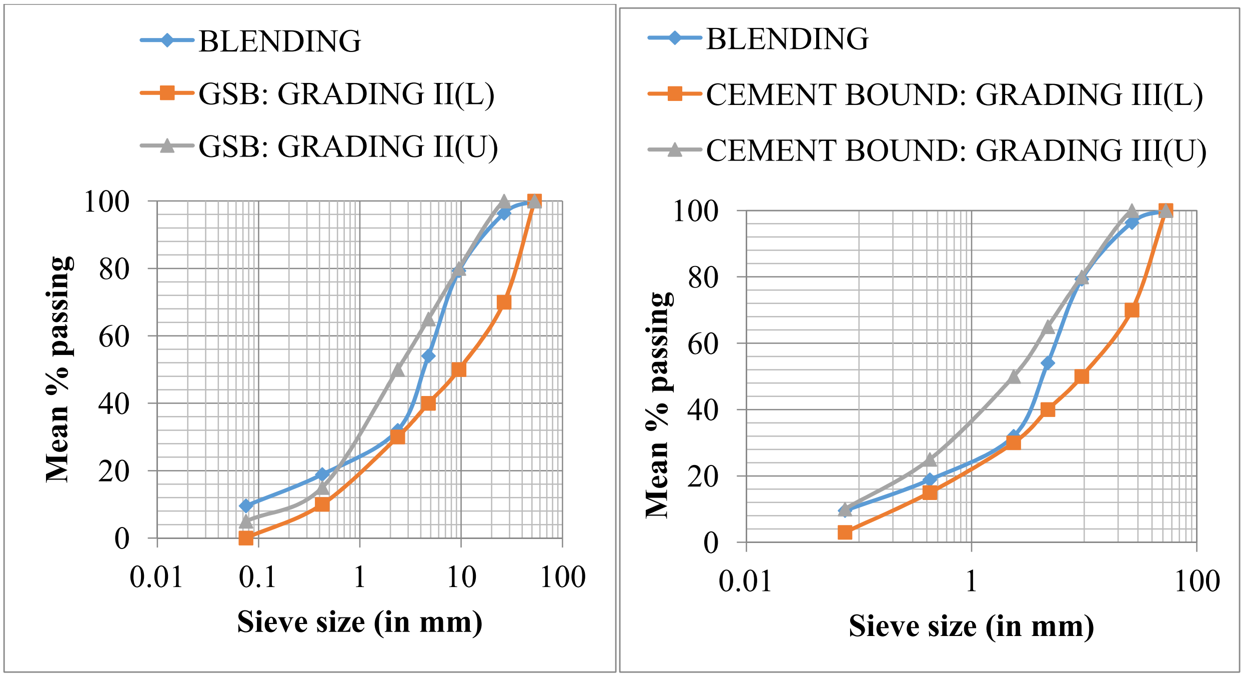

Figure 4 (a). Blending of moorum and aggregates (GSB Grading II)

Figure 4 (b). Blending of moorum and aggregates as per IRC SP: 89(2010)

3.2. Results of UCS Test

The variations of unconfined compressive strength (UCS) values (cube specimens) of the blend of moorum and aggregate for use in cement treated base and filter layer of cement treated sub-base with varying cement contents are presented in Table 3 and Figure 5.

Table 3. UCS Test results of cube specimens (7 days)

Cement treated Base (GSB II)		**Cement treated Sub-base Filter layer (GSB II)**	
OMC=7.04% MDD=23.3 kN/m^3		OMC=6.35% MDD=23.1 kN/m^3	
Cement content (%)	UCS value (MPa)	Cement content (%)	UCS value (MPa)
3.50%	4.0	2.00%	2.8
4.00%	4.9	2.50%	3.1
4.50%	5.4	3.00%	3.3
5.00%	5.2	3.50%	3.5

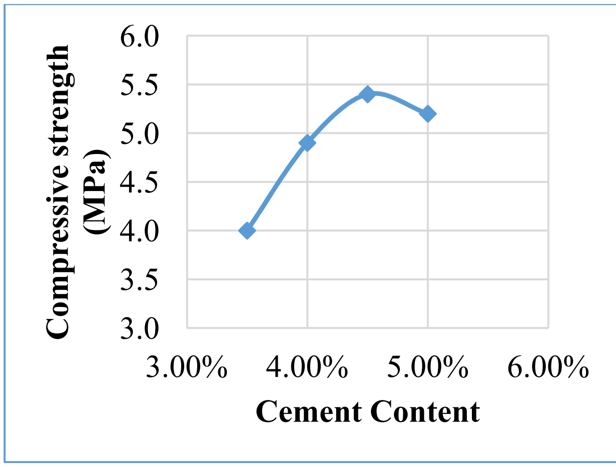

Figure 5 (a). Variation of UCS values with cement content (CTB)

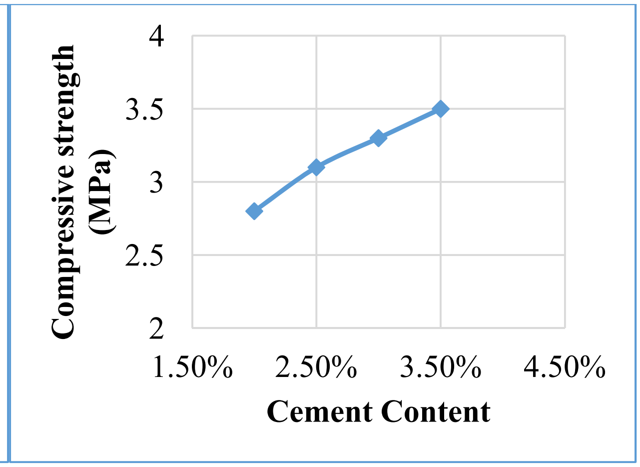

Figure 5 (b). Variation of UCS values with cement content (CTSB)

As per Indian specification, IRC SP: 89 (2010), the 7 days UCS values for cement bound materials should be between 4.5 to 7 MPa for use in the base and between 1.5 to 3 MPa for use in sub-base (drainage or filter layer). As seen in Table 4 and Figure 5, the UCS values resulted more or less satisfy the requirements specified. Hence depending on the required UCS value for construction of a particular layer the corresponding cement content can be selected to satisfy the requirements. In the present case, minimum cement contents of 4% and 2.5% can be considered for cement treated base and subbase courses respectively.

3.3 Physical properties of blended mix

After getting the optimum cement content as desired in the given blend, the physical properties of the mix were determined and the results are listed in Table 4. It is observed that the physical properties of the treated blend are satisfactory as per the relevant IRC specification.

Table 4. Physical properties of the blend of moorum and aggregates

Property	Cement treated base (GSB II) (4.5% cement)	Cement treated sub-base Filter layer (GSB II) (2.5% cement)	Remarks
	Moorum=50%+ A10=15% +A6=35%	Moorum=50%+ A10=15% +A6=35%	MOTRH / IRC Limits
Liquid Limit (LL), %	21.00	21.00	<45
Plasticity Index (PI), %	NP	NP	<20
Aggregate Impact Value, %	23.01	23.01	<40
Wet Impact Value, %	31.45	31.45	<40
Optimum Moisture Content (%)	7.04	6.35	-
Max. Dry Density (kN/m^3)	23.3	23.1	-

As this study is based on utilisation of moorum in base and lower subbase layers which are not intended for drainage, the conduct of the permeability test was not considered.

SUMMARY

From the experimental investigations conducted on the locally available moorum samples and subsequent analysis of the test results, the following summary is made.

- The quantity of finer fractions of moorum (passing 425 micron) being quite significant, the amount of moorum that can be used for base and sub-base courses had to be limited to 50% in the total blend considering the GSB Grading-II of MORTH.
- Attempt was made to utilise the cement treated blend in the base course and also in the separation-cum-filter layer of subbase using the same GSB Grading II. The blend could not satisfy the requirements of gradation of MORTH specifications for the lower fractions, i.e. passing 425 micron by a low margin. However, the grading thus designed for the blend satisfies the grading requirement specified in IRC specification for cement treated base and sub base, and hence the same design proportion was used in this study.
- The impact value of the aggregates and moorum blend is within the maximum limits for road base or sub-base applications.
- The specific gravity of moorum is comparatively more than that of the aggregates. Hence, the MDD values are also higher in the moorum-aggregate blend.
- Cement has been used as a modifier as well as stabilizer of moorum. The UCS values of the cement treated specimens made with the designed blends of moorum and aggregates satisfy the minimum requirements for use in the cement treated base or sub-base. Based on UCS test results, the cement contents for CTB and CTSB (Filter layer) are found to be 4.5% and 2.5% respectively.

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