A Study on Effect of Mica Content on Engineering Properties of Sands

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Abstract. It is often necessary to understand the interaction of mica mineral with the fine aggregates which is often used for construction purposes. Mica is one of the known deterious minerals which affects the engineering properties of sand and which ultimately affects the concrete. Different research work has already being conducted by different researchers. In the present study, an attempt has been made to study the effect of mica on different engineering properties. Here, the percentage of mica by weight adopted for different test procedures are 2%, 4%, 6% and 8%. Direct shear test, Standard proctor test, CBR test and compressive strength test were conducted by percentage replacement of locally available sand by mica. From the laboratory test results, it established that the presence of mica in fine aggregates causes reduction of compressive strength and it increases the water demand. The dry density value, shear strength and the CBR value also reduces with the presence of mica content.

Keywords: Direct shear test, Standard proctor test, CBR, mica.

1 Introduction

By volume, about 75% of the concrete ingredients are occupied by the aggregates. Aggregates play a vital role in civil engineering constructions. But aggregates with high mica content are mechanically weak due to its platy shaped particles, and the fines content may increase significantly overtime due to the crushing under by the traffic loading and climatic weathering. Rock types with high mica content are often inhomogeneous.

Thus inclusion of platy particles in excess may affect the efficiency of the respective aggregates. There are several varieties of mica, but the two primary varieties are Muscovite, a hydrated silicate of aluminum and potassium and Biotite, a ferro-magnesium variety. Various researchers investigate the effect of presence of mica on the aggregates. Researchers like Harris et al. (1984), Hobeda and Bunsow (1974), Seethalakshmi P and Ajanta Sachan (2016), Frempong (1994), Frempong (1995), Mshali (2012) etc did some work in this domain. In this present study, percentage of mica by weight is increased and the relative variation in the engineering properties is studied. The purpose of this study was to determine relationships between mica content and critical engineering parameters of sand.

2 Test Programme

2.1 Mica- Mica is widely distributed and occurs in igneous, metamorphic and sedimentary regimes. The mica content in fine aggregates is found to be in free form. But in case of coarse aggregates mica is found to be in bonded forms with other minerals.

Scrap and flake mica is produced all over the world. Flake mica comes from several sources: the metamorphic rock called schist as a byproduct of processing feldspar and kaolin resources, from placer deposits, and from pegmatite. Sheet mica is considerably less abundant than flake and scrap mica, and is occasionally recovered from mining scrap and flake mica. The most important sources of sheet mica are pegmatite deposits.

The mica group of sheet silicate minerals includes several closely related materials having close to perfect basal cleavage. All are monoclinic, with a tendency towards pseudo hexagonal crystals, and are similar in chemical composition. The nearly perfect cleavage, which is the most prominent characteristic of mica, is explained by the hexagonal sheet-like arrangement of its atoms. Hobeda and Bunsow (1974) have studied the packing properties of mica minerals and found that it deteriorates with the increase in mica content.

2.2 Material Characterization

The material used in the experimental programme are-

1. Sandy soil, for the purpose of preparing sub grade
2. Mica mineral.

The sandy soil used to perform as sub grade is collected from the bank of the river Khulsi near Kukurmara, Assam. Various laboratory tests i.e. Grain size distribution, specific gravity test, proctor test and CBR test are performed as per Indian standard codes to determine the properties of sub grade soil which are given in Table 1.

Table 1. Properties of sub grade soil

Sl No	Property	Test value
1	Uniformity coefficient, C_u	2.67
2	Curvature coefficient, C_c	0.84
3	Effective size, D_{10}(mm)	0.6
4	D_{30}(mm)	0.9
5	D_{60}(mm)	1.7
6	Specific gravity, G	2.67
7	Optimum moisture content(%)	9.50
8	Maximum dry density(gm/cc)	1.97
9	Laboratory CBR value (unsoaked) (%)	16.18

Different percentage of mica is added to the Khulsi river sand and its characteristics behavior is analyzed. Different types of mica are available in the market. The mica used in this study is silicate of Aluminum and Potassium. An image of mica mat is shown in Fig.1.

Fig. 1. View of mica

Various properties of the mica sample used in this study is described in table 2.

Table 2. Properties of mica

Mica properties	Description
Chemical composition	Silicate of alluminium or Potassium
Crystal system	Monoclinic
Cleavage	Perfect
Streak	Colourless
Lusture	Pearly
Hardness	2-2.5
Specific Gravity	2.7-3

2.3 Test set up

2.3.1 Standard Proctor test – This test is performed as per IS code 2720 (part 8)-(1980). Standard Proctor test is used to determine the dry density with change in moisture content. The water content corresponding to maximum dry density gives the OMC value.

2.3.2 Direct shear test- The maximum value of shear stress that can be mobilized within a sand mass is known as shear strength of sand. If the shear stress in any plane or surface at a point exceeds the value of shear strength, failure will occur in the sand. This test is performed as per IS 2720-13-(1986).

2.3.3 CBR Test-The California Bearing Ratio test is a penetration test used to evaluate the subgrade strength of roads and pavements. The results of these tests are used with the empirical curves to determine the thickness of pavement and its component layers. To keep the uniformity in different tests, the sub grade was kept at its optimum moisture content 9.50% and within a field density range of 1.96 gm/cc to 1.98 gm/cc This test is performed as per IS 2720 (Part 16)-1987.

2.3.4 Compressive strength Test- Compressive strength of concrete is the maximum amount of compressive load a material can bear before fracturing. The test is performed as per IS 516-(1959).

Different conditions for laboratory tests and its designation is listed in Table 3.

Table 3. Various conditions for lab tests and its designation

Designation	Test bed condition
A	Sandy soil
B	Sandy soil + 2% mica
C	Sandy soil + 4% mica
D	Sandy soil + 6% mica
E	Sandy soil + 8% mica

3 Test Results

3.1 OMC

With the increase in mica content, OMC is increasing. It may be due to the reason that mica has a water retaining property and it starts swelling with increase in mica content. There is also approximate linear decrease in dry density with increase in mica content.

Graphical representation of variation of dry density with moisture content is shown in figure 2. The variation of dry density and moisture content with mica content is shown in Table 4 and it infers that with increase in mica content dry density value decreases.

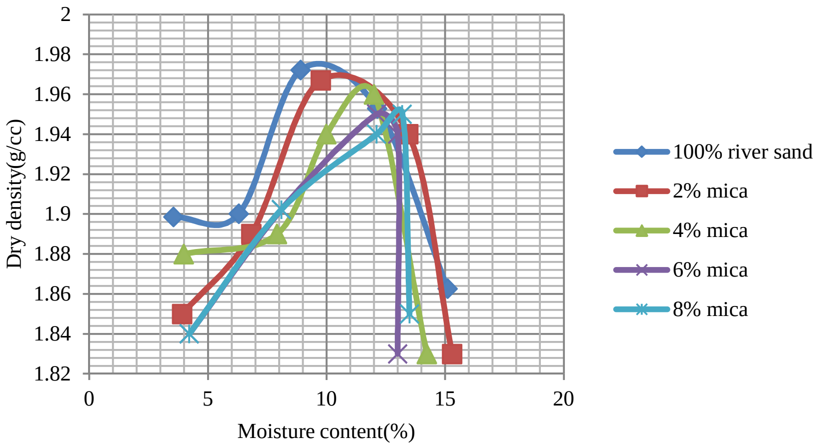

Fig. 2. Graph showing the variation of and OMC and dry density with increase in mica content

Table 4. Variation of dry density and moisture content with mica content

Sl No.	Material	Dry density(g/cc)	Optimum Moisture content(%)
1.	A	1.975	9.5
2.	B	1.970	10.5
3.	C	1.965	11.5
4.	D	1.955	12.0
5.	E	1.950	13.0

3.2 Determination of shear strength

Shear strength parameter is determined from the cohesion value and the angle of internal friction value. For its calculation, direct shear test is done on the river sand and with different mix of mica. The graphical representation of shear stress versus displacement for 0.5kg/cm^2,1kg/cm^2 and 1.5kg/cm^2 is shown in figure 3.The variation of shear stress with normal stress for material A is shown in Table 5 and its graphical representation is shown in figure 4 and figure 5. And the variation of cohesion and angle of internal friction with mica content is shown in Table 6 which reflects that the cohesion value for al the condition is same but the angle of internal friction shows a decreasing trend.

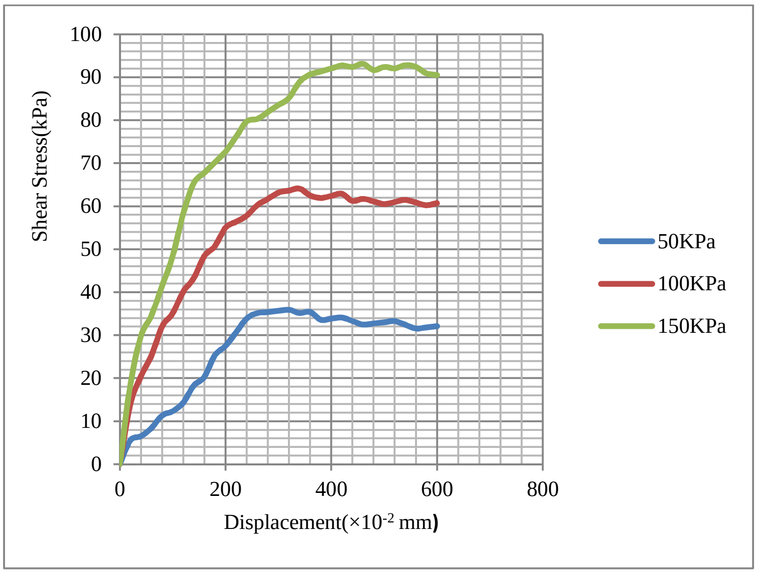

Fig. 3. Graph for shear displacement vs shear stress for river sand Khulsi

Table 5. Variation of shear stress with normal stress

Normal Stress (kPa)	Proving Ring Reading	Load	Corrected Area, A_c	Shear Stress = Load/A_c (kPa)
50	35	1155	32.88	35.13
100	62	2046	32.40	63.15
150	87	2871	31.68	90.63

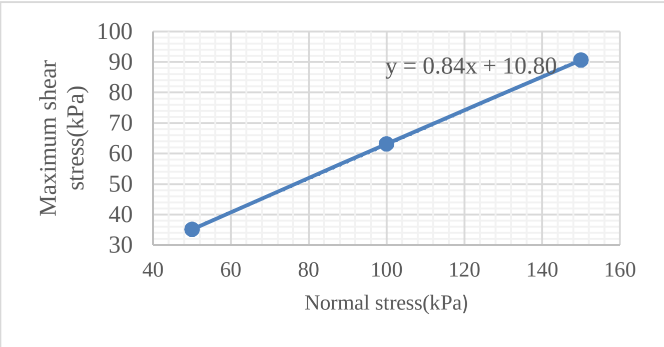

Fig. 4. Graph of normal stress vs shear stress for river sand

From the graph,

Angle of Internal Friction, $\varphi = 40.03^0$

Cohesion, $c = 10.80$ kPa = 0.113 kg/cm^2

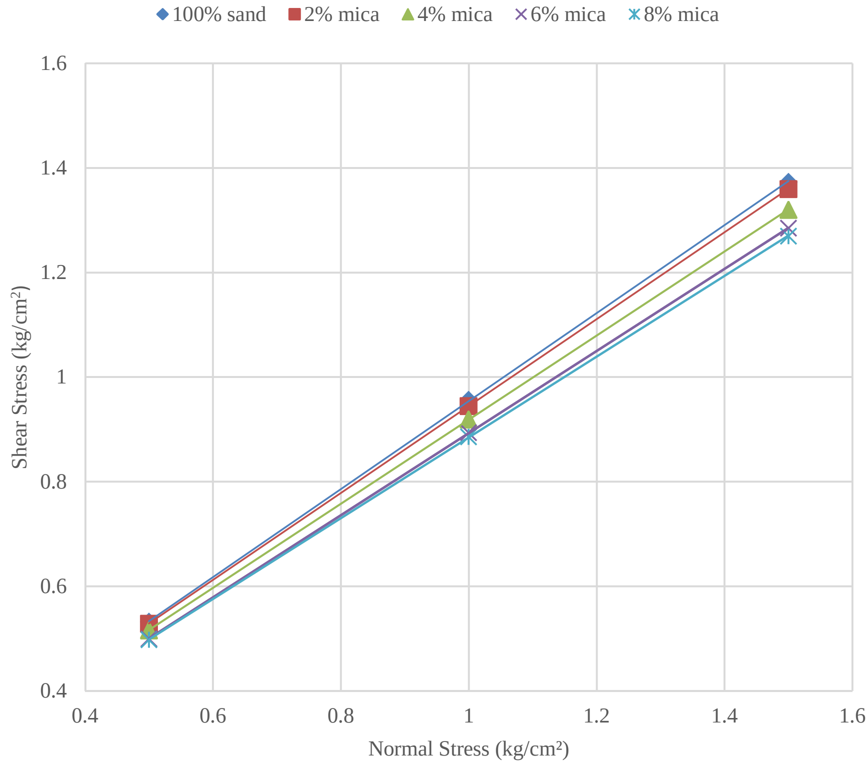

Fig. 5. Variation of angle of internal friction with mica content

Table 6. Variation of cohesion and angle of internal friction with mica content

Sl No.	Material	Cohesion(kg/cm^2)	Angle of internal friction(φ)
1.	A	0.11	40.03^0
2.	B	0.11	39.72^0
3.	C	0.11	38.79^0
4.	D	0.11	38.13^0
5.	E	0.11	37.82^0

3.3 CBR test results

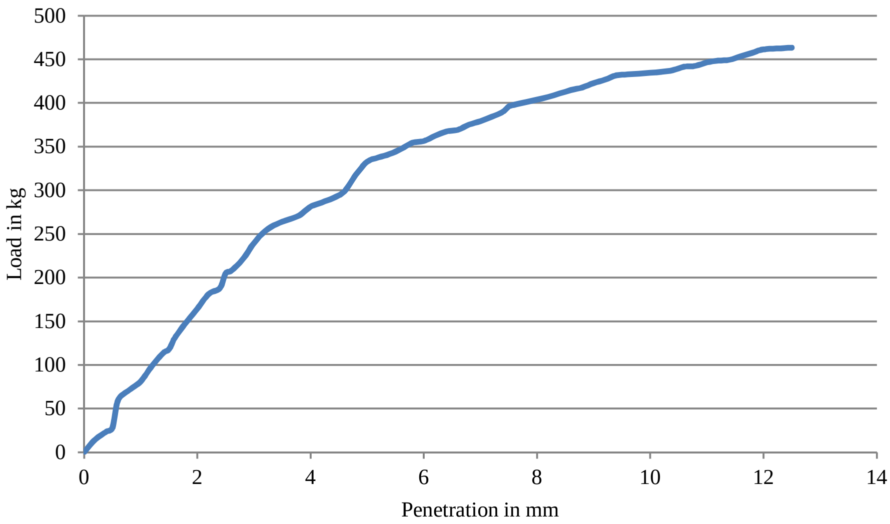

Fig. 6. Load vs. Penetration curve for River Sand (Khulsi)

The load versus penetration curve for sample A is shown in figure 6.
Test load at 2.5 mm penetration= 204.93 kg
Standard load at 2.5 mm penetration=1370 kg
CBR at 2.5 mm penetration= $\frac{204.93}{1370}$ x 100 = 14.95 %
Test load at 5 mm penetration= 332.64 kg
Standard load at 5 mm penetration=2055 kg
CBR at 5 mm penetration=$\frac{332.64}{2055}$ x 100 = 16.18 %
CBR value for sample (5mm penetration) = 16.18 %

The variation of CBR values with mica content for different materials is tabulated in Table 7 and it shows that the CBR value is least for material E with 8% mica content.

Table 7. Variation of CBR values with mica content

Sl No.	Material	CBR (%)
1.	A	16.18
2.	B	15.87
3.	C	15.54
4.	D	15.02

5.	E	14.9 6

3.4 Compressive strength

Cement used – Dalmia cement
Water cement ratio – 0.5
Concrete used- M20
Fineness Percentage – 94.67%
Initial setting time – 1hour 30 minutes.
Final setting time - 3 hour 30 minutes.

Table 8 shows the variation of compressive strength with increase in mica content. It indicates that with increase in mica content there is a approximate decreasing trend in its 28 days compressive strength.

Sample type	Compressive strength (N/mm^2)					
	3 days strength (N/mm^2)	Average (N/mm^2)	7 days strength (N/mm^2)	Average (N/mm^2)	28 days strength (N/mm^2)	Average (N/mm^2)
A	16.35 19.55	17.95	23.11 22.40	22.75	34.84 30.57	32.70
B	15.46 17.06	16.26	22.04 23.46	22.75	31.28 32.35	31.81
C	17.80 18.80	18.30	22.10 23.05	22.57	33.73 32.20	32.96
D	16.30	17.25	22.05	22.50	33.13	32.60

Table 8. Variation of compressive strength with mica content

	18.20		22.95		33.08	
E	18.70	18.39	23.25	22.67	32.23	31.68
	18.08		22.10		31.14	

3.5 Petrographic analysis

Table 9. Petrographic analysis

Mineral Constituents	Approximate Amount(%)	Shape	Size	Surface Texture	Colour
Quartz	86%	Rounded to Sub – Rounded	Coarse Grained	Even to uneven	White
(Rock Fragments)	9%	Elongated		Irregular and Rough	Play of Colours
Feldspar	2%	Elongated		Irregular boundary	Greyish
Biotite	1%	Flaky		Irregular Boundary	Light Brown
Muscovite	1%	Flaky		Irregular Boundary	Greyish
Others	1%	-		-	-

The petrographic test result for the sample A is tabulated in Table 9 which shows the approximate percentage of different mineral constituents with its shape, texture and colour. The microphotographs of sample A is shown in figure 7.

7(a) 7(b)

Fig.7. Microphotographs showing different petrographic characteristics of Khulsi river sand (X25): (a) sample 1 (b) sample 2

4 Discussion

From the values of dry density, shear strength and CBR values of various test samples (river sand and with percentage inclusion of mica); it was observed that the inclusion of mica reduces the strength.

Table 4 indicates that maximum dry density decreases with increase in mica content. This may be due to the inclusion of platy particles of mica with irregular boundaries. As a result of which void spaces increases resulting in decrease in dry density.

Rogers (1995) has examined the relation between mica content and permeability and found out that mica particles have the ability to retain water. This ability explains by the flat shape of the grains which provides the large specific surface per unit weight. Optimum moisture content shows a increasing trend with increase in mica content. It may be due to its water retaining power.

Shear strength and CBR values also shows a decreasing pattern which increase in mica content. A very small value of cohesion is found from direct shear test. The influencing parameter is the angle of internal friction which reduces with inclusion of platy mica. The analysis is in accordance with the research work done by W. G. Harris, J. C. Parker and L. W. Zelazny.

Compressive strength of concrete with increase in mica content does not show a proper trend.

Percentage variation of different engineering properties with increase in mica content (material B, C, D and E) is tabulated in Table 10, Table 11 and Table 12.

Table 10. Percentage change in dry density values and OMC values with mica content

Material	% decrease in γ_d	% increase in OMC
B	0.25	10.52
C	0.50	21.05
D	1.01	26.31
E	1.26	36.84

Table 11. Percentage change in angle of internal friction values

Material	% decrease in angle of internal friction
B	0.77
C	3.09
D	4.74
E	5.50

Table 12. Percentage change in CBR values

Material	% decrease in angle of inter-

	nal friction
B	1.91
C	3.95
D	7.16
E	7.54

5 Conclusions

Much research work has been reported on the effect of mica content on various engineering properties of crushed stone and river sand all over India. By studying on mica particles and its probable effects on engineering properties of fine aggregates, it has been tried to observe the variation of various engineering properties, which may be due to the presence of different proportion of mica content. The work is just an overview of probable effect of mica on fine aggregates. Indian Standards are also not providing the permissible limit of mica and its various effect on engineering properties of aggregate, so lot of experimental work is still required on this field. Some writers like P.C Varghese in his book 'Building Materials' mentioned that 2% to 3% of mica are allowed in fine aggregates for mortar and concrete. Therefore every text regarding aggregates should be checked individually to find out the actual effect of mica.

All the test results shows a decreasing trend in its values. So, it can be assumed that presence of mica in increasing amount can detoriate the engineering properties of fine aggregates. However, this study can be further extended towards different test conditions considering other Geotechnical parameters also.

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