BEHAVIOUR THRESHOLDS OF QUARRY-DUST BENTONITE MIXES

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ABSTRACT.

Bentonite was added to a locally available rock dust to study the behaviour thresholds of the binary mix. Thresholds may be defined as the critical fines content above which the system behaviour changes drastically. By understanding the threshold values of such binary mixtures will help us to have a better control over its behaviour. In this study, the hydraulic conductivity and the swelling behaviour of quarry dust mixed with increasing fractions of bentonite were studied. Index properties of quarry dust were determined by standard sieve analysis, mini-compaction and by cone penetration method. The specific gravity of the quarry dust was about 2.65. The addition of bentonite to quarry-dust has found to increase the maximum dry density and reduce the hydraulic conductivity by several orders. The swell potential of the various mix proportions was studied in an oedometer. Samples were of 14mm thickness and were given a hydration period of 24 hrs and were compacted at their OMC and MDD. Mixes with low bentonite contents such as a 5% and 10% showed no swelling. The substantial swelling was only observed with 15% bentonite and more.

Keywords: Bentonite, Quarry dust, thresholds.

1 Introduction

Almost all soils in the world are a combination of one or more types of soils. The success of any mixture design depends upon the mix ratio. A soil with too less fine fraction will be highly porous. This is because of the inability of the coarser fractions to form a compact system. But such soils might have a relatively better rigidity and less compressibility as compared to those with high fines content. It could be seen that a dominance of any of the fraction will result in a compromise of some or any favorable soil properties. Therefore we can understand there exists a suitable ratio of fines to the coarse fraction at which we can successfully attain any design requirements. Binary mixtures are those that comprises of two soil types. Binary mixtures find applications in various fields like a filter for dams, low permeability applications like waste retention plants and landfills, and also in flexible pavements. The fines to the coarse fraction of these binary mixtures have found to control its behaviour under mechanical and thermal loadings. For better decision making and to have a control over the mix behaviour we need to have a thorough knowledge of its fundamental behaviour. In this study, a binary mixture of quarry dust and bentonite are adopted in order to identify the behavioural thresholds, as in the transitional mix ratio at which a shift from the sand like to clay like property occurs. A behavioural threshold may be defined as a critical fines content at which a sudden change in the fines content will have a significant effect on the mixture properties.

1.1 Behaviour threshold.

As explained earlier a behaviour threshold is that transitional fines content beyond which the system changes are drastic. Researchers have broadened the concepts of traditional soil mechanics with concepts and theories from other fields of science. One such emergent theory is the percolation theory. Percolation theory mainly finds applications with binary mixes (John F. Peters, Ernest S. Berney 2010). It has wide applications from forest fires to banking and even in soil mechanics. It is a probabilistic approach, whose concepts when closely studied; the probability becomes the mix ratio for binary mixes. Thornton (2000), using the concepts of percolation theory and DEM analysis established the theory of force chains. Force chains are nothing but a series of interconnected coarse-grained particles that transmits the load. A soil skeleton is formed when there exist a number of force chains. Such systems will have good structural stability and the shear failure of which was explained as the failure of these force chains in buckling.

2 Materials used.

The materials used in this study are a) quarry dust b) bentonite.

The quarry dust is a poorly graded with a Cu value of 1.93 as indicated by the particle size distribution curve. The specific gravity of the quarry dust was found to be 2.65. The maximum particle size was less than 2mm. The bentonite used in the study had sodium as the major cation this ensured very high swelling nature. The index properties of the bentonite used are shown in table 1. The result of the hydrometer analysis of bentonite is given in figure 2.

Table 1 Index properties of the bentonite used

Property	Bentonite
Specific gravity	2.77
Liquid Limit (%)	218
Plastic Limit (%)	51
Plasticity Index (%)	167
Clay, <2 μm (%)	67
Silt, 75 to 2 μm (%)	33
USCS Soil classification	CH
Cation exchange capacity (meq/100g)	56.95
Maximum dry density (kN/m^3)	12.6
Optimum moisture content (%)	30

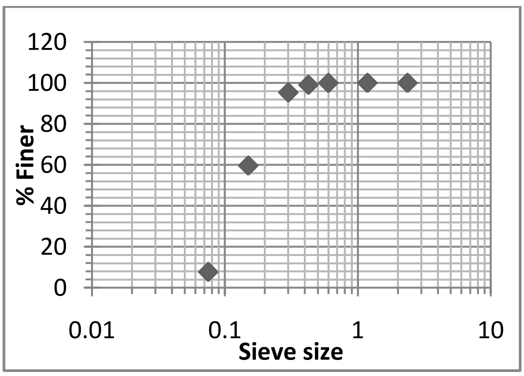

Fig 1 Particle size distribution curve for quarry dust

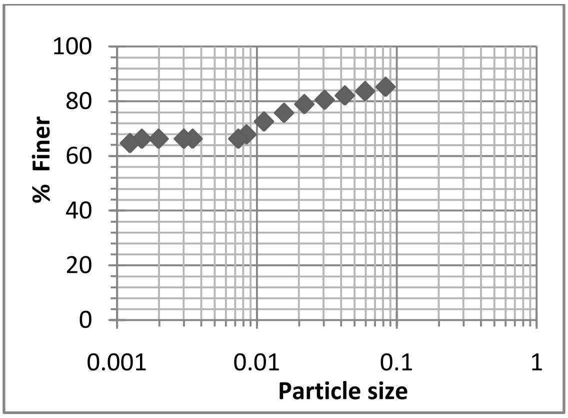

Fig 2 Hydrometer analysis of bentonite.

3 Experimental program.

The experimental program involved in the establishment of the threshold values in the basic properties such as hydraulic conductivity, compaction as well as in the swelling behaviour of the soils. The experiments were carried out on the samples by varying the bentonite content in proportion to weights. All the samples were mixed at OMC and MDD as determined by the standard mini compaction apparatus

3.1 Compaction behaviour.

The compaction behaviour of the quarry dust bentonite mixtures was carried out in a mini compaction apparatus as shown in figure 3. The procedure adopted was as per A. Sridharan and P Sivapullaiah (2005). Although the apparatus was developed for the determination of dry densities of highly fine-grained materials it could as be applied for materials as per the literature.

Fig 3 Mini compaction apparatus.

3.2 Swell potential.

The swell potential all the samples were evaluated using a standard oedometer apparatus. All the samples with varying mix proportions were mixed at OMC and a period of 24hrs was provided for hydration, towards the end of which the samples were compacted to their mean densities. The samples were filled only up to 1.4 cm from the bottom porous stones as per the guidelines mentioned in the IS 2720 Part XLI. The additional 6 mm is to provide for the expected swelling.

4 Results and Discussion.

4.1 Compaction behaviour.

The results of the compaction behaviour are shown in figure 4. The results indicate that at lower contents of bentonite the mean dry densities were increasing this is attributed to the fact that at lower bentonite contents the pores spaces in the quarry dust are being occupied by the bentonites. As a result of this, the packing of the binary mix becomes more compact. At lower percentages of bentonite like 5%, 10% etc the volume of swelling is not enough to disturb the soil skeleton.

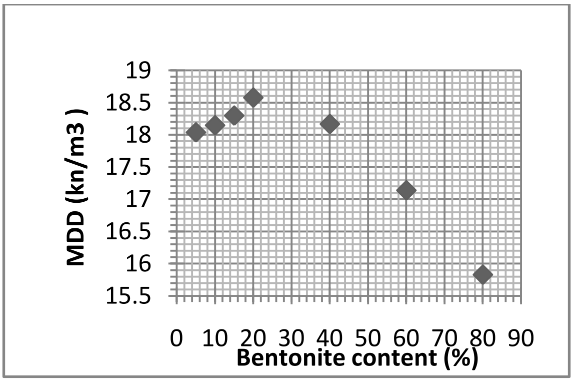

Fig 4 Dry density vs. bentonite content.

As such the existing force chains are only being strengthened by the swollen mass of bentonite and also by those stone particles that does not take part in the force chain percolation. This aspect was suggested by Thornton in 2000 based on his DEM studies

At higher bentonite contents this may not hold valid as the high swelling nature of the bentonite will result in the destruction of this force chains. At higher bentonite replacements the swollen mass will start to replace the coarser grains from the unit volume (Yang, S., Lacasse, S., and Sandven, R. 2006). At this stage, the voids present in the binary mix will primarily be that of the clay content (Simpson D C, Evans T M. 2015). The soil skeleton slowly loses its integrity and falls apart. This will result in the reduction of the dry density. At 20% bentonite content, this transition can be observed. Beyond 20% bentonite content any compactive effort given to the binary mixture was dissipated by the clay fraction and more or less behaved like stiff clay. This critical fines fraction may be identified as one of the threshold limits of this binary mixture.

4.2 Swell potential.

The swell potential of the binary mixture was examined using a standard oedometer apparatus. The sample mixed at OMC and MDD after 24hrs of hydration in a desiccation chamber was filled into the oedometer rings. The sample thickness was kept around 1.4 cm as per IS 2720 Part XLI. The swell pressure tests were conducted for bentonite replacements of 5%, 10%, 15 %, 40% etc. For lower bentonite contents of 5% and 10%, there was no observed swelling. This does not imply that the bentonite added did not swell, but instead this suggests that the swollen volume is less than the void volume in these mixes. Only at 15% bentonite any substantial swelling could be identified a critical fines content of 20% meant that the force chains were completely absent as the coarser fractions were displaced from unit volumes

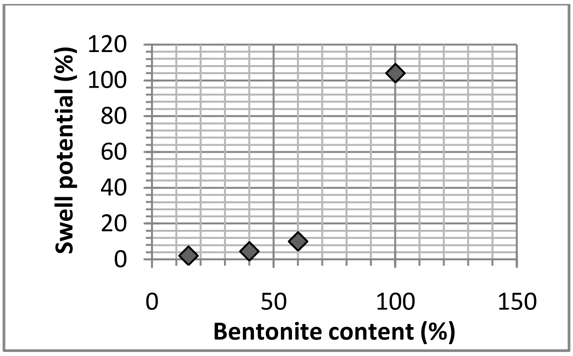

Fig 5 Maximum swell potential vs. bentonite content

Figure 5 shows the 21-day swell potential data at different bentonite contents. From figure 5 it is clearly understood that beyond 50% fines content the swollen volume of bentonite is considerably more as a result of which this can be identified as the transitional fines content for swelling for this binary mixture.

5 Conclusions.

This study was mainly intended to analyze and study the behavioural thresholds of binary mixes. A locally available quarry dust and an industrial grade sodium bentonite were selected to form a binary mixture. The bentonite was mixed with quarry dust as 5%, 10% replacement by weights etc. and were subjected to compaction tests as well as swell potential evaluation. From both the tests critical fines content was able to be identified beyond which the sand like behaviour changed to clay like behaviour. In the case of compaction characteristics beyond 20% bentonite content, the mean density started to decrease. As in the case of swell potential, the binary mixture could only behave as a swelling noncohesive soil at 15% bentonite. Thus these can be identified as the behavioural thresholds were the system behaviour drastically changes. It should be remembered that any variations in the binary mix will result in the variations of the thresholds.

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