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# Effect of Cement Content on Swelling Properties of Bentonite

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***Abstract*—For the construction of foundations in weak grounds, the engineering properties of foundation soil is to be improved. Grouting is one of the effective methods for improving the engineering property of the soil. Cement is most widely used as the grout material for the sandy soil formation. Cement improves the strength and make the sand formation impermeable. If the permeability reduction is the primary objective the use of cement in large quantity cost more. Hence the use of bentonite as additive will give a grout with more effective in the permeability reduction. The swelling property make the bentonite a perfect grout material for reducing the permeability. But the stability of bentonite at higher hydraulic head is questionable. The combination of cement for strength and bentonite for reducing the permeability will be an economical combination for the grouting to reduce the permeability. The presence of cement in bentonite will affect the swelling property of the bentonite. This paper evaluates the presence of cement content in the swelling property of bentonite.***

***Index Terms*—Grouting; cement; bentonite; swelling**

## I. INTRODUCTION

The success of grouting depends upon the properties of grouting materials, grouting medium and the grouting technique. The mechanical permeance, penetrability and strength are the specific mechanical properties which are important for the selection of grout for a specific job [1]

The basic requirements of the grouting materials are

(1) The enough small particle size (in suspension) and the sufficient viscosity should enable the mix to penetrate and to travel sufficient distance the soil.
(2) During the life of the soil structure the penetrated grout which formed a deposit in the soil will not eroded by the pressure gradient imposed.

If the grouting medium chosen is the granular and grout shall be the suspension grout. The grouting materials, preparation of sample and testing methods are discussed in this section.

The water cement ratio, the rate of bleeding and subsequent ultimate strength of the grout is affected for the satisfactory performance of cement-based grout. Although water may be giving mobility for the grout, if in excess may cause separation of ingredients of grout leading to high bleeding and low strength. Water-cement ratio with a proper proportion of admixtures or fillers leads to a good ultimate strength.

Cement grouts are usually formed from ordinary Portland cement and water. The water cement ratio may be varied from about 0.5:1 to 5:1 depending upon the ground conditions and required strength. The OPC grouts are suitable only in fissured rock, gravel and coarse sands.

The shear strength of the loose sandy soil steadily increases with increase in cement content and also with curing period. The effect of curing period is more significant at higher percentage than at lower percentage [2].

The free swell index bears a unique relationship both with liquid limit and percent swell for compacted specimens [3]. The bentonite is one of the most common additives used in cement-based suspension grouts. The authors affirm that bentonite should be used as a pre-hydrated slurry. They found out that if the bentonite is not pre-hydrated first, it will lead to the cracking of the cured grout. Even if bentonite is introduced as a slurry, it should always be entered first in the mix. The mixing order has an impact on the rheology and even strength of the cured grout. When bentonite is introduced as the last component, its stabilizing effects are vastly reduced [4]. The cement grouting not only increase the strength of the foundation but also controls the seepage [5].

Bentonite in known to have fine particle size an extremely low permeability and self-healing ability, and can provide effective long-term sealing. The water - bentonite ratio may be varied between 4:1 to 10:1. This suspension is suitable for gravel to fine sand. When the objective of grouting is only to reduce permeability Bentonite grouts can be used.

The permanence of Bentonite grouts under high hydraulic gradients is questionable and often cement is added to bentonite to improve its permanence.

## II. MATERIALS

Since this study is on the permeability of the grouted sandy soil, type of grouting medium is granular and hence the grouting material normally used are the cement and bentonite. In the present work sand was used as the grouting medium and the cement and bentonite were used as the grouting materials.

**Cement**

53 grade Ordinary Portland cement (Coromondal) confirming to IS: 12269-1987 was used for the preparation of

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the cement grout. These were stored in air tight bins.

**The physical properties of cement**

The physical properties of cement were found out in accordance with IS 269:1989, IS 4031: 1988 and IS: 12269-1987.The values are presented in Table 1 and the grain size distribution curve is given in figure 1.

(a) Fineness (Blaines's air permeability)

By Blaines air permeability apparatus the fineness of the cement was determined and as represented by specific surface expressed as total surface are in $cm^2$ /g. The specific surface was determined according to the procedure and expression given in IS 4031(part 2): 1999.

(b) Standard Consistency

The standard consistency of the cement paste is defined as the consistency which will permit the specific Vicat plunger to penetrate to a point 5 to 7 mm from the bottom of the Vicat mould. The test was conducted according to the IS: 4031(Part4)-1988

(c) Initial setting time

The starting of the setting process of a cement paste is based on this property. This is the time elapsed between the time when the water added to the cement paste and time at which the needle failed to penetrate the required amount and is reported as the initial setting time. The initial setting time was determined according to the procedure described in IS: 4031(Part 5)-1988.

(c) Final setting time

This is the time to describe the stiffening of the cement paste. This is time elapsed between the time when the water is added and the time at which the needle alone makes the impression on the cement paste prepared but the attachment did not make the impression. The final setting time was determined according to the procedure described in IS: 4031(Part 5)-1988.

(d) Compressive strength

The compressive strength is the important property which gives an idea about the mechanical strength of the hardened cement. Compressive strength of the cement was determined by conducting tests on mortar cubes according to the provisions in IS 4031 (Part 6)-1988.

(e) Specific gravity

Specific gravity of the cement was determined using a Le-Chartelier flask. The specific gravity was calculated as the ratio of the weight of cement in grams to the weight of an equal volume of distilled water.

The various physical properties of the cement used is discussed in Table 1.

**Table 1** Physical properties of cement

| SL. No | Properties | Obtained value | Remarks as per IS Code |
|---|---|---|---|
| 1 | Fineness (Blaines's air permeability) | 295 $m^2$/kg | ≥225 m2/kg |
| 2 | Standard consistency | 28.5% | |
| 3 | Initial setting time | 135 min | ≥ 30 min |
| 4 | Final setting time | 335 min | ≤ 600 min |
| 5 | Fineness modulus | 0.07 | ≤ 0.10 |
| 6 | 3 days Compressive strength | 28.5 MPa | ≥ 27 MPa |
| 7 | 7 days compressive strength | 39 MPa | ≥ 37 MPa |
| 8 | 28 days compressive strength | 55 MPa | ≥ 53 MPa |

**Bentonite**

Bentonite used in this study is commercially available, highly expansive one and showed great affinity towards moisture. The bentonite was preserved in polythene bags and was stored in air tight bins.

**The physical properties Bentonite**

(a) Atterberg limits

The liquid limit and plastic limit were determined according to the IS 2720: Part 5: 1985.The plasticity index also worked out accordingly.

(b) Grain size distribution

The grain size distribution of the grout suspension plays an important role in grouting. Sedimentation analysis was done using a hydrometer as per IS: 2720 (Part 4)-1985.

(c) Swell index

Free swell index, Modified free swell index and Free swell ratio were found out as per the IS 2720 Part (XL) 1977

The various properties are given in Table 2.

**Table 2** Physical properties of bentonite

| SL.No | Properties | Obtained value |
|---|---|---|
| 1 | Liquid Limit (%) | 350 |
| 2 | Plastic Limit (%) | 40 |
| 3 | Plasticity Index (%) | 310 |
| 4 | Free Swell Index (%) | 245 |
| 5 | Modified Free Swell Index (cc/g) | 5 |
| 6 | Free Swell Ratio | 3.45 |

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**Cement-Bentonite mix**

Cement is considered to be an effective grouting material in sandy medium. Figure 1 shows the grain size distribution curves of medium sand, cement and bentonite. From the figure it is evidently clear that the pores of the medium sand can be filled by the grains of cement. Also, the voids of the cement grains can be filled by the more finer bentonite particle. Hence the combination of cement and bentonite can be a very effective grouting material for granular soil.

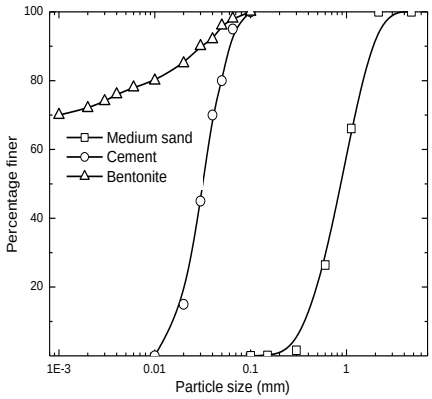


**Fig. 1** Grain size distribution curves

## III. TESTING METHODS

The physical properties of grout materials and combined properties of cement and bentonite were determined. The various tests conducted for this study are discussed in detail below.

**Free swell index tests for the combination of cement and bentonite.**

Bentonite is to known to have fine particle size; very high swelling and self-healing ability lead to low permeably. But the ordinary Portland cement shows shrinkage in the presence of water. Hence swelling properties of the cement-bentonite mix was found out.

10 g cement- bentonite mix at 0, 25, and 50,100% were taken and put in 100ml jars. The jars were filled with water to 100ml and kept for a day. The swelled volume of the mix was taken and recorded. Next set similar of mix were taken and filled with kerosene. These samples were also kept for a day and volumes were measured. Thus, the swell ratio of these mix was found out.

Free swell index, percent,

$F.S = [(V_d - V_s) / V_s] \times 100$

Free swell ratio = $V_d / V_s$

Modified free swell index = $V_d / W_s$

Where

$V_d$ = The volume of the soil specimen read from the graduated cylinder containing distilled water.

$V_s$ = The volume of the soil specimen read from the graduated cylinder containing kerosene.

$W_s$ = The dry weight of the soil specimen.

Figure 2 shows the variation of free swell index with varying proportion of cement and bentonite. From the graph it is clear that free swell index goes on reducing as the cement content increases.100% bentonite has the swelling index of 250% and it reduces to zero for the zero-bentonite content.

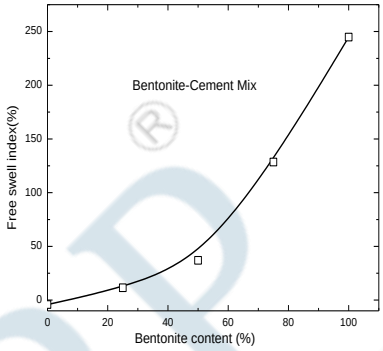


**Fig. 2** Effect of bentonite content on free swell index (%) of bentonite.

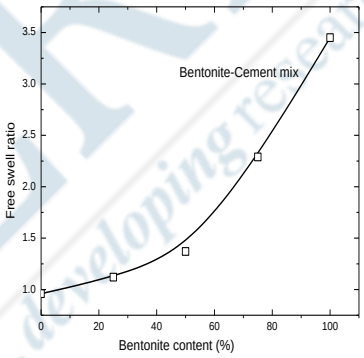


**Fig. 3** Effect of bentonite content on free swell ratio of bentonite

Figure 3 shows the variation of free swell ratio of bentonite with varying proportion of cement and bentonite. Here free swell ratio goes on reducing as the cement content increases.100% bentonite has the free swell ratio of 3.5 and it reduces to 0.8 for the zero-bentonite content.

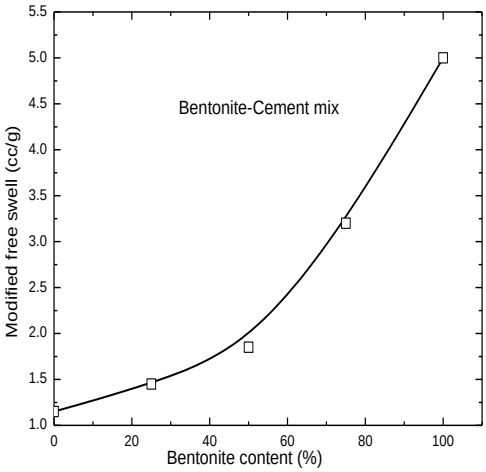


**Fig 4** Effect of bentonite content on modified free swell of bentonite

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Figure 4 shows the variation of modified free swell ratio of bentonite with varying proportion of cement and bentonite. Here also modified free swell index goes on reducing as the cement content increases.100% bentonite has the modified free swell ratio of 5and it reduces to 1.25 for the zero-bentonite content.

Bentonite is a material with very high swelling property and loses its swelling when it is mixed with cement as clear from the above three figures.

## IV. CONCLUSION

Based on the experimental results the following conclusions are arrived.

- The free swell index of bentonite will reduce by 250% for an increase of 0% to 100% of cement content.
- The modified free swell ratio of bentonite will reduce to $1/4^{th}$ of the original value as the cement content increases from 0% to 100%.
- The free swell ratio of the bentonite will also reduce to $1/4^{th}$ of the original value as the cement content increases from 0% to 100%.

Hence these results can be effectively used for proportioning the bentonite cement mix so as to get an efficient grouting material..

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