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Experimental Investigation on the Effect of Clay in Sand for Flexural Behavior of R.C.C. Beams

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Abstract:
In the present day construction industry in developing countries, concrete has emerged as the most common building material. Hence careful consideration must be given to factors that affect its strength. For sand having above 3.4% of clay content used in a 1: 1: 2 (M-25) mix of concrete resulted in the production of concrete with target compressive strength less than 31.75N/mm2. The sand sample was divided into two parts. First part of the sand sample was washed free of clay and slit and sun dried, while clay and silt were sieved out of the second part using 2.36 mm sieve. The washed sand sample was divided into 8parts in such a manner that from each part, at least 3 cubes of 150mmx 150mm x 150mm can be made. Therefore, this study was conducted to investigate suitability of soil in place of sand in producing conventional concrete.
This research work mainly consist of two parts, In the first part, substitution of natural sand partially by clay/silt in concrete is done with replacement of 0%, 1%, 2%, 3%, 4%, 5%, 10% and 15%. The optimum value obtained for 3%-4% replacement of clay/silt content. The 28 days average compression strength was observed to increase by about 0.3% - 27.6%, split tensile strength by 10.5% - 30.6% when compared with control mix. In the second part, the flexural behavior of reinforced concrete beams with optimum clay/silt content is studied. The reinforced beam specimens used were 150 x 180 x 1200 mm, and tests were done at the curing age of 28 days. The reinforcement is varied from 0.62% - 0.89% in the flexure zone and the parameters like deflection, surface strain, cracking load, ultimate load and crack width of reinforced concrete beams was experimentally noted and compared with theoretical values as per code IS: 456-2000.
Finally, it is concluded Due to high water absorption rate of clay W/C ratio was increased as replacement percentage increases and compression and tensile strength of concrete was decreases. The sieved clay/silt is added to each of the parts of the washed sand from1% to 15% by weight of the sand. It was discovered that the higher the clay/silt content, the strength of concrete is decreases.

Keywords: *Clay/silt content, workability, compressive strength, split tensile strength, flexural strength, deflection, surface strain, crack width, cracking moment, ultimate moment*

1. Introduction

Concrete can be a strong durable building material that can be formed into many varied shapes and sizes ranging from a simple rectangular column, to a slender curved dome or shell, if the constituent materials are carefully selected. The constituent materials are: cement, fine aggregate, coarse aggregate and water. Concrete is a very variable material, having a wide range of strengths (1). Concrete generally increases its strength with age. The precise relationship will depend upon the type of cement used. (2). some codes of practice allow the concrete strength used in design to be varied according to the age of the concrete when it supports the design load. BS 8110 does not permit the use of strength greater than 28 – day value in calculations (3). It is important that the aggregates for making concrete should be clean of all sorts of impurities (4). Aggregates for concrete are usually specified to comply with requirements of BS 882, which gives test for suitable aggregate (5). The maximum percentage clay/silt of content of sand for which the target compressive concrete strength will not be less than 31.75N/mm^2 is 3.4%.
(1). For sand with percentage clay/silt contents of 5% and 10% will produce concrete with compressive strengths of 30.2N/mm^2 and 29.6 N/mm^2 respectively, and the higher the percentage of clay/silt in sand the lower the concrete strength. It is very important to control the quality of the aggregate to be used in concrete making. Most importantly, the effect of the clay/silt content of sand on the compressive strength of concrete must be controlled.

2. Experimental Programme

2.1. Materials Used

Ordinary Portland cement of grade 53 is used for this experimental work. The fine aggregates used was natural sand and clay/silt content. The basic material test was done as per code IS: 383-1970. Coarse aggregate used is locally available crushed angular aggregate of size 20mm and down. Campus water is used with pH value of 7.5. The Super plasticizer, conplast SP430 is used for this experimental work. The physical properties are given in table 1.

Particular	Natural Sand	Coarse Aggregate
Specific gravity	2.60	2.65
Water absorption (%)	1	0.5
Fineness modulus	2.61	7.30
Bulk density (g/cc)	1.47	-
Percentage of voids	43.46	-
Grading	Zone II	-

Table 1: Physical Properties of Fine and Coarse Aggregates

2.1.1. Clay

There has long been concern that clay particles may be harmfulto concrete because of their ability to absorb water and swell, which increases the water demand in fresh concrete.

Particular	Physical Properties of Clay
Specific gravity	2.08
Water absorption %	18.3
Fine material	5.9
Fineness modulus	3.07
Los angles	-
Practical size distribution in (mm)	-
19mm	-
12.5mm	-
9.5mm	-
4.75mm	100
2.36mm	80.5
1.18mm	51.2
600µm	31.3
300 µm	20.3
150 µm	9.7

Table 2: Physical Properties of Clay

Silicon dioxide / silica (SiO_2) : 60.34-72.6
Aluminum oxide/alumina ($Al_2 O_3$): 4.67-6.5
Calcium oxide : 1.75- 3
Magnesium oxide : 5.98-7.3
Sodium oxide : 8.56-9.1
Manganese : 0.127- 0.26

2.2. Mix Design

The mix proportion chosen for this study is M25 grade (1:2.01:3.56) with water-cement ratio of 0.45. Cubes of standard size 150x150x150mm of total 48 no. and cylinders of standard diameter 150mm and height 300mm of total 48 no. are casted and cured for 7 and 28 days and tested as per code IS: 516-1959 and IS: 5816-1999.

Unit of batch	Water (liter)	Cement (kg)	Sand (kg)	Coarse aggregate (kg)	Super plasticizer
Meter cube content	168	380	765	1356	3.75
Ingredient ratio	0.45	1	2.01	3.56	1%

Table 3: Mix Proportion for M25 Grade Concrete

2.3. Workability

Slump test was conducted to determine the workability of concrete. In this experimental work, as the percentage of clay/silt content increases, the workability of concrete mix also increases. The slump value obtained from different percentage of clay/silt content mixes are shown in figure 1.

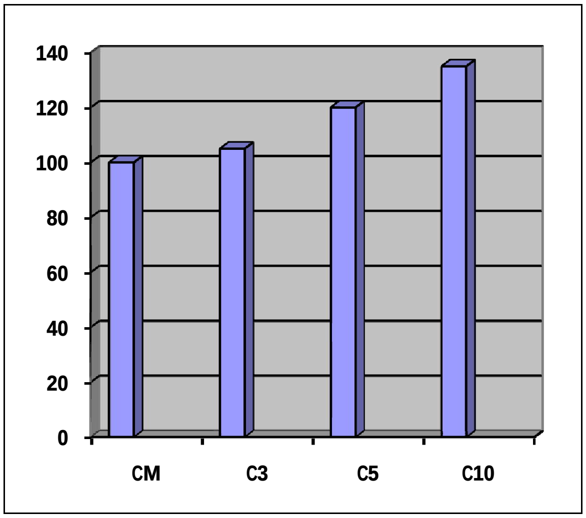

Figure 1: Slump Values for Different Mix Proportions

2.4. Compressive Strength Test

The compressive strength test is carried out on various mixes by varying the percentage of clay/silt content by 0%, 1%, 2%, 3%, 4%, 5%, 10% and 15% and keeping all other parameters as constant. Cubes of standard size 150x150x150mm is casted and for each mix 3 cubes were cased and cured for 7,14 and 28 days. Test was conducted using 2000kN compression testing machine as per code IS: 516-1959. The maximum value obtained for 3-4% replacement of clay/silt content with natural sand.

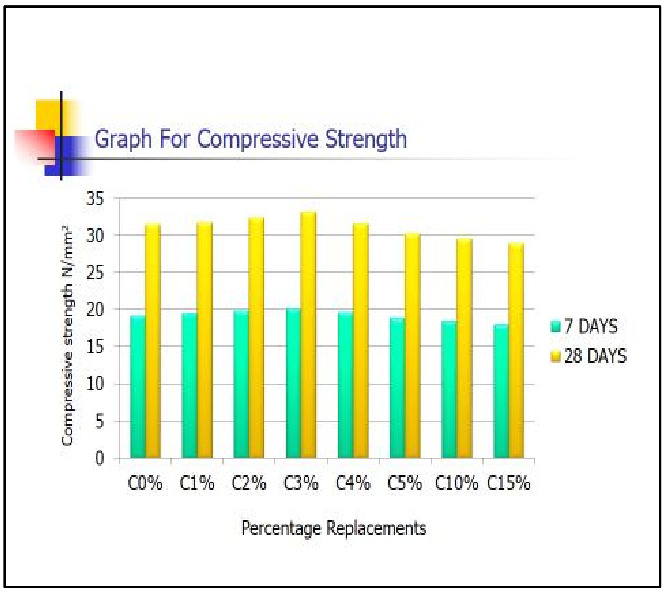

Figure 2: Compression Strength Variation of Different Mix for 7 & 28 Days

2.5. Split Tensile Strength Test

The size of cylinder used for this test was of diameter 150mm and height 300mm. For each mix, 2 cylinders were casted and cured for 28 days. Then testing was done in 2000kN compression testing machine as per code IS:516-1959.The calculation was done by using the formula $f_{cr}=(2P)\div(\pi dl)$.

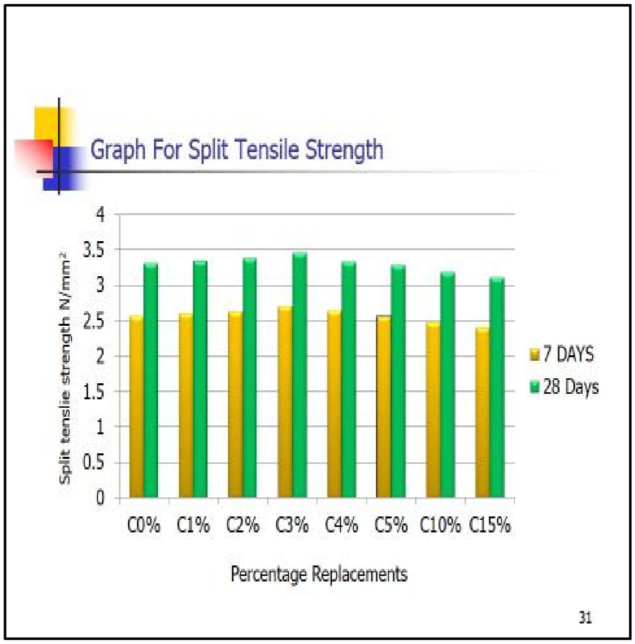

Figure 3: Split Tensile Strength Variation of Different Mix

2.6. Flexural Behavior of Reinforced Concrete Beam

The dimension of the test beam having overall length 'L' as 1200mm, effective length 'L_{eff}' as 1000mm, total depth 'D' as 180mm, effective depth 'd' as 150mm, breadth 'b' as 150mm and clear cover 'c' a 20mm is used. High yield strength deformed (HYSD) bars having 500 N/mm^2 yield strength is used in two different ways in test beam.

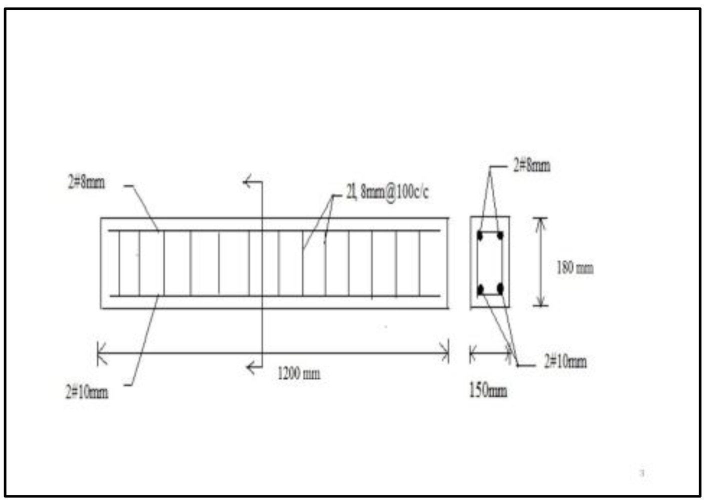

Figure 4: Reinforcement Details of Test Beam-1, 2, 3,4

The test beams are white washed in lime and markings are made such as to indicate the support points, centre of beams and also to measure surface strain. Then the test beam is placed in loading frame on the supports. Then steel roller is kept on the loading frame points and eccentricity is checked. Then channel ISMC 250 is rested on the roller and hydraulic jack is placed on it centrally. The load is applied at the interval of 2kN and the deflection for every 2kN is noted by using digital dial gauge and surface strain is measured using demec gauge. The loading is continued till the test beam fails.

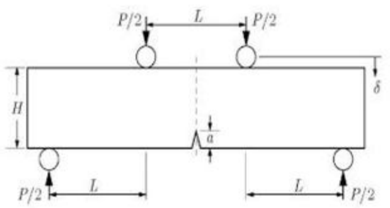

Figure 5: Set-Up of Test Beam in Loading Frame

3. Results and Discussion

3.1. Crack Pattern and Modes of Failure

All the test beams were designed as under reinforced section. As the load was applied the beams started cracking at the tension zone and as the load was increased the crack started propagating toward the neutral axis. The mode of failure of all the beams were flexural failure. There was no horizontal crack at the level of the reinforcement, which shows that there was no bonding failure.

3.2. Experimental Results

Structural parameters like cracking load, service load and ultimate load with their deflections are investigated. Totally 8 no. of test beams were casted and tested, in that 2 were control mix of 10 diameter bars, 2 were copper slag-40% of 10 diameter bars, 2 were control mix of 12 diameter bars, 2 were copper slag-40% of 12 diameter bars. The results of the deflections are shown in the table III and in figure 7.

					Experimental Results					
Beam Designation	Ast (%)	Pcr (kN)	Δcr (mm)	Wcr (mm)	P_s (kN)	Δ_s (mm)	W_s (mm)	P_u (kN)	Δ_u(mm)	W_u (mm)
Test Beam – 1	0.62	18	0.83	0.01	38	3.53	0.14	56.3	9.478	0.23
Test Beam – 2		22	1.33	0.01	40	3.70	0.19	60.0	9.691	0.29
Test Beam – 3	0.62	24	1.44	0.01	40	3.52	0.21	58.3	9.725	0.32
Test Beam – 4		26	1.90	0.01	40	3.87	0.16	59.6	10.63	0.26

Table 4: Experimental Results of Cracking Load, Service Load Andultimate Load with Thier Respective Deflections and Crack Width

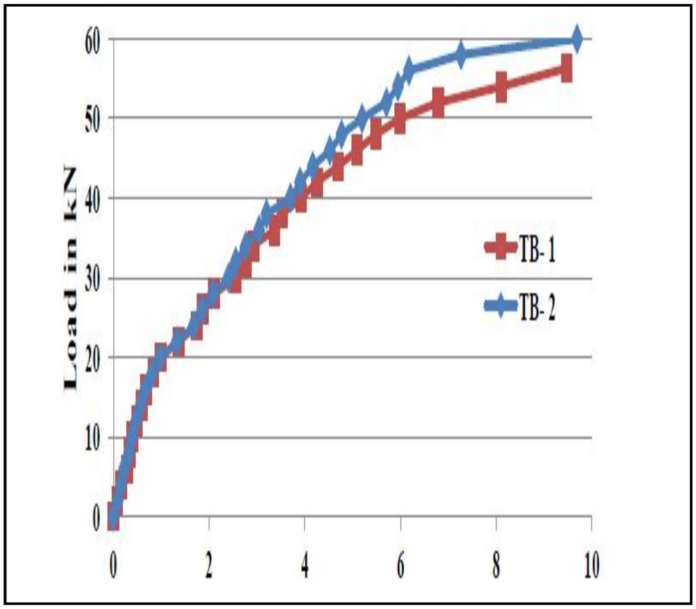

Figure 6(a)
Deflection at mid span in mm

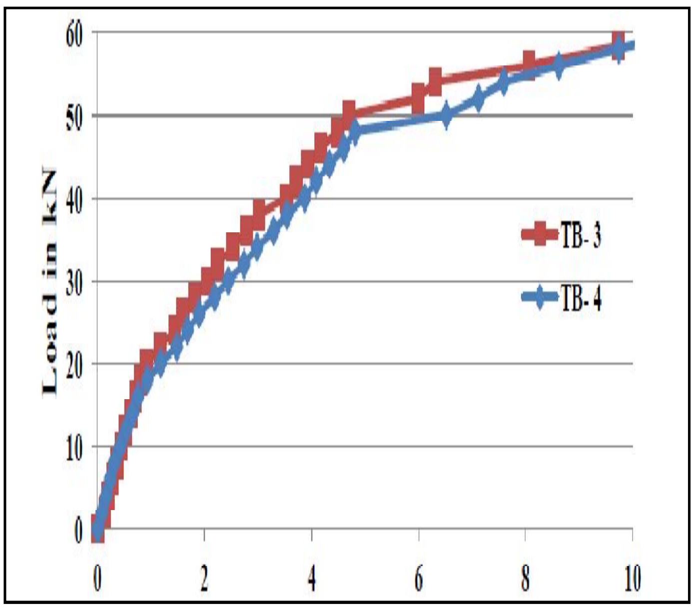

Figure 6(b): Average Deflection of All Test Beams
Deflection at mid span in mm

The surface strains were measured using demec gauge. The strain reading was taken at approximately 95% of the failure mode. The load at which the first crack was observed was calculated as cracking moment. The load at which the beam fails and the crack observes was calculated as ultimate moment.

Beam Designation	**Load** (kN)	**Maximum Surface Strain**		**Avg Cracking** moment (kNm)	**Avg Ultimate** moment (kNm)
		Compression	Tension		
Test beam -1	52	-0.000126	0.000158	5	14.50
Test beam -2	54	-0.000183	0.000324		
Test beam -3	54	-0.000241	0.000312	6.25	14.75
Test beam -4	54	-0.000269	0.000283		

Table 5: Experimental Results of Surface Strain, Cracking Moment and Ultimate Moment

4. Conclusion

Based on the experimental investigations, the following conclusions were drawn.

1. The control mix for M25 grade and the replacement of clay/silt content by 0%, 1%, 2%, 3%, 4%, 5%, 10% and 15% by weight of natural sand were designed.
2. The optimum level of replacement of clay/silt content was found to be 3-4% and the results were better than that of control mix.
3. The workability of fresh concrete decreases with increase in the replacement of clay/silt content for the additional dosage of super-plasticizer is required.
4. The compressive strength gradually increases from 0%, 1%, 2%, 3% replacement of clay/silt content and decreases for above 5% replacement of clay/silt content.
5. The 28 days average compressive strength obtained for clay/silt content mix concrete shows 0.3% to 27.6% increase in compressive strength when compared to control mix concrete.
6. The 28 days average split tensile strength obtained for clay/silt content mix concrete shows 10.61% to 36.8% increase in split tensile strength when compared to control mix concrete.
7. The maximum strain at service load should not exceed 0.0035 as per code IS: 456-2000. Therefore the experimental results shows that the maximum strain in all test beams are well within the limits.
8. The flexural results show that there is an increase in cracking moment by 31.84% for 0.62% tensile reinforcement.
9. The ultimate moments obtained from experimental results are greater that the theoretical results by 27.58%.
10. Concrete incorporating clay/silt content exhibits good mechanical properties and therefore up to 3-4% by weight of natural sand can be replaced by clay/silt content.
11. Based on their test results, a higher limits of impurities (5%) in fine aggregate was recommended.

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