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Cost Implication of Mitigating the Effect of Clay/Silt Content of Sand on Concrete Compressive Strength

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ORIGINAL ARTICLE

ABSTRACT: In Nigeria, reinforced concrete is one of the major building materials been used in the construction of buildings. In the specification of concrete, prescribed mix is normally used. However, tests carried out on different batches of concrete produced, using prescribed mix 1:2:4 of concrete show that the concrete did not acquire the 20N/mm^2 expected strength at the age of 28 days. Depending on the type of sand used for the production of the concrete, the acquired strength after 28 days is between 25% and 60% of the expected strength. This reduction in strength will ultimately affect the functionality and durability of structure constructed from such concrete. To mitigate the effect of clay/silt content of sand, the sand can be washed free of clay/silt or the cement is increased in proportion to the percentage content of clay/silt in the sand. Since the mitigation of the clay/silt content of sand on concrete strength comes with extra cost, there is need to determine this cost in other to be able to build effective and safe structures. The author evaluates the cost implication of mitigating this reduction effect of the type of sand used on concrete strength. The extra cost incurred in the production of 1m^3 of concrete (using mix ratio 1:2:4) in terms of washing the sand free of clay/silt is 22.5%, while that of cement increment is between 2.22% and 27.75% depending on the percentage of clay/silt content of sand. Mathematical models, which can be used to estimate the cost implication of this mitigation, are derived.

Keywords: Reinforcement, Concrete, Sand, Silt, Strength

1. INTRODUCTION

The constituent materials for concrete are: cement, fine aggregate, coarse aggregate and water. Concrete is a very variable material, having a wide range of strengths. Concrete generally increases its strength with age. The precise relationship between strength and age will depend upon the type of cement used (Mosley et al., 2007). It is important that the aggregates for making concrete should be free of all sorts of impurities (British Standards, 1992). As with most rocklike substances, concrete has a high compressive strength and a very low tensile strength. Hence concrete is usually used in conjunction with steel reinforcement which provides the tensile strength lacking in the concrete.

One of the major disadvantages of concrete is that there are lots of factors that affect its strength. Factors such as type of fine aggregate, type and size of coarse aggregate, grading of aggregate, type of cement, water - cement ratio and aggregate – cement ratio all come to play as far as the strength of concrete is concerned. Therefore, different values of strength of concrete have been recorded for a particular mix ratio from literature. Olanitori and Olotuah (2005) recorded concrete strengths between 5.94N/mm^2 and 24.13N/mm^2 for mix ratio 1:2:4 with water- cement ratio of 0.55, depending on the clay/silt content of the sand. Olanitori (2006) recorded average concrete strength of 22.55N/mm^2 for washed pit sand, using mix ratio 1:2:4 with water – cement ratio of 0.55. Ahmad and Mahmood (2008) recorded average concrete strength of 17.93N/mm^2 for concrete using natural sand and, 34.48N/mm^2 for concrete using stone dust, for mix ratio 1:2:4, with water – cement ratio of 0.55. Also Ukpata et al. (2012), recorded average concrete strength of 20.4N/mm^2 for concrete using 25% laterite and 75% stone dust, and 19.9N/mm^2 for 50% laterite and 50% stone dust, using mix ratio 1:2:4 and water – cement ratio of 0.6 respectively.

A concrete mix is the proportion in which the constituent materials of a concrete is combined together. It is usually in the ratio of cement: sand: gravel. The fundamental requirement of a concrete mix is that it should be satisfactory both in the fresh as well as in the hardened state, possessing certain minimum desirable properties like strength, workability and durability. Besides these requirements it is essential that the concrete mix is prepared as economically as possible by using the least possible amount of cement content per unit volume of concrete, with due regard to the strength and durability requirements. The usual primary requirement of good concrete is a satisfactory compressive strength in its hardened state. Many desirable properties like durability, impermeability, abrasion resistance are highly influenced by the strength of concrete. For the purpose of mix design, the strength of concrete is usually considered to be solely dependent on the water/cement ratio for low and medium strength concrete mixes (Raju, 2009).

In Nigeria, the structural engineer, architects and the quantity surveyors are faced with the problem that they do not have a 'Nigerian Code of practice' for concrete production and designing of reinforced concrete structures. According to CP114 (British Standards, 1957), concrete mix ratios 1:2:4, $1:1\frac{1}{2}:3$ and1:1:2 are expected to have strength of 21N/mm^2, 25.5N/mm^2 and 30N/mm^2 respectively (Reynolds and Steedman, 1981). In codes such as CP110 (British Standards, 1972) and BS 8110 (British Standards, 1997) that superseded CP114 (British Standards, 1957), concrete grades are only recommended, and the means of achieving such grade of concrete has to be through investigation of the locally available aggregates with several trial mixes carried out. Nigerian Engineers still refers to CP114 (British Standards, 1957) when recommending strength for a particular concrete produced from certain mix ratios, thereby producing a lower grade of concrete than the one recommended.

In the recommendation of strength for a particular concrete mix ratio, using the prescribed mix method, the Nigerian engineer did not take into consideration, the peculiarity of our locally available aggregates and the percentage of clay/silt content of sand, which affects the strength of concrete. The maximum percentage of clay/silt content of sand for which the compressive concrete strength will not be less than 20N/mm^2 is 3.4% for mixed ratio 1:2:4 (Olanitori and Olotuah, 2005). For sand with percentage clay/silt contents of 5% and 6% will produce concrete with compressive strengths of 17.7N/mm^2 and 16.3N/mm^2 respectively, and the higher the percentage of clay/silt in the sand the lower the concrete strength (Olanitori and Olotuah, 2005). It is very important that 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.

Concrete mix design consists in selecting and proportioning the constituents to give the required strength, workability and durability. Mixes are defined in BS5328-2 (12): Methods of Specifying Concrete mixes. The types are:

1. Designed mix, where strength testing forms an essential part of the requirements for compliance
2. Prescribed mix, in which proportions of the constituents to give the required strength and workability are specified; strength testing is not required.

The water-to-cement ratio is also another important factor affecting concrete strength. The actual water-to-cement ratio used generally ranges from 0.45 to 0.6. The aggregate-to-cement ratio also affects workability through its influence on the water-to-cement ratio (McCormac and Nelson, 2006).

There are two basic methods which the effect of clay/silt content of sand on the, compressive strength of concrete can be controlled. These are by washing the sand free of clay/silt or by adding some extra percentage of cement to neutralize the effect of the clay/silt content. For sand with 10% silt/clay content need 50% cement increment in order to attained compressive strength not less than 20N/mm^2, while for 4% clay/silt content of sand, 4% increment of cement is needed (Olanitori, 2006).

2. MATERIALS AND METHODOLOGY

2.1 Material Collection

The concrete components used for the experimental works are cement (Ordinary Portland Cement), fine aggregate (Pit Sand from a borrow pit in Akure) and coarse aggregate (Crushed granite rock, maximum size of 19mm). Portable water was used in the production of the concrete.

2.2 Experimental Works

The method of specifying the concrete used for this work is the prescribed mix method being the most popular method in the Nigeria. The mix ratio used was 1:2:4, with water-cement ratio of 0.55. The research work followed the under listed algorithm:

a. Field settlement test on the fine aggregate was carried out to determine the percentage clay/silt content of the sand.

b. The sand was washed free of clay/silt, and sun dried for 7 days to make it moisture free. The sand sample is divided into two parts.

c. In washing the sand sample, the time and liter of water needed to wash free a specific volume of sand was determined. Also the washed clay/silt was collected and sundry for about a week to make it moisture free.

d. The first part of the washed sample is termed sample A and was divided into eleven parts, namely Sample A1 to A11.

e. Sample A1 is assumed to have zero clay/silt content, using the sun dried clay/silt, and there is introduction of clay/silt into Samples A2 to A11 from 1% to 10%.

f. Ten cube samples were cast for each Samples A1 to A11, and the cube strengths determined at 28 days.

g. The second part of the washed sample is termed sample B, and was divided into seven parts, namely, Sample B1 to B7. The percentage clay/silt content of Sample B was gradually increased from 0% to 10%. With sample B1 having 4% clay/silt content, Sample B2, having 5%, while samples B3, B4, B5, B6 and B7 having 6%, 7%, 8%, 9% and 10% clay/silt content respectively.

h. The cement content of the concrete for sample B using prescribed mix ratio 1:2:4 with water-cement ratio of 0.55 is increased at 2% interval until 20N/mm^2 strength is achieved at 28 days for samples B1to B3, while for samples B4 to B7, increment was at 4% interval until 20N/mm^2 strength is achieved at 28 days. Ten cubes each were made for each of the trial mixes.

i. Mathematical models were derived to determine the cost implications of both washing of sand free of clay/silt and increase in the cement content of concrete.

3.0 ANALYSIS AND DISCUSSION OF RESULTS

3.1 Compressive Strength Tests for Varying Clay/Silt Content of Sand

The result of the tests carried out on sample A is presented in Table 3.1. From Table 1, the maximum compressive strength of 22.35N/mm^2 was attained with 0% clay/silt content and minimum of strength of 10.15N/mm^2 with 10% content of clay/silt in the sand. The results obtained are in tandem with Olanitori and Olotuah (2005).

The compressive strength is inversely proportional to the increase in the clay/silt content of the sand.

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Table 1. Average Compressive Strength test on Sample A with varying % of Clay/Silt.

Samples	Average Weigth (kg)	Clay/Silt Content (%)	Average Compressive Strength (N/mm^2)
A1	8.4	0	22.35
A2	8.5	1	21.95
A3	8.5	2	21.25
A4	8.4	3	20.85
A5	8.2	4	19.00
A6	8.0	5	17.25
A7	8.3	6	16.55
A8	8.3	7	15.42
A9	8.4	8	12.18
A10	8.4	9	10.61
A11	8.3	10	10.15

3.2 Compressive Strength of Concrete with Varying Percentage Increment in Cement Content

The Percentage Clay/Silt Content of Sand and corresponding Percentage Increase in Cement to achieve Compressive Strength not less than 20N/mm^2 is shown in Table 2. With 4% clay/silt content in sand, 4% cement increment is required, while for 10% clay/silt content, 50% cement increment is required. The results of the compressive test carried out on sample B is presented Tables A1 to A7 of the appendix.

Table 2. Percentage Clay/Silt Content of Sand and corresponding Percentage Increase in Cement to achieve Compressive Strength not less than 20N/mm^2

Samples	% Clay/Silt Content in Sand	% Percentage Cement Incremaent
B1	4	4
B2	5	14
B3	6	20
B4	7	24
B5	8	32
B6	9	40
B7	10	50

APPENDIX A: The results of the Average Compressive Strength Tests for Sample B, with varying increment cement percentage.

Table A1: The results of the Average Compressive Strength Tests for Sample B1, with varying increment cement percentage.

Samples	Average wt (kg)	Percentage clay/silt content (%)	Cement increment (%)	Average compressive strength (N/mm^2)
1	8.4	4	2	19.25
2	8.0	4	4	20.34
3	8.2	4	6	20.65
4	8.4	4	8	21.25
5	8.3	4	10	21.82

Table A2: The results of the Average Compressive Strength Tests for Sample B2, with varying increment cement percentage.

Samples	Average wt (kg)	Percentage clay/silt content (%)	Cement increment (%)	Average compressive strength (N/mm^2)
1	8.5	5	2	17.55
2	8.2	5	4	18.43
3	8.2	5	6	18.85
4	8.3	5	8	19.25
5	8.4	5	10	19.52
6	8.4	5	12	19.86
7	8.4	5	14	20.50

Table A3: The results of the Average Compressive Strength Tests for Sample B3, with varying increment cement percentage.

Samples	Average wt (kg)	Percentage clay/silt content (%)	Cement increment (%)	Average compressive strength (N/mm^2)
1	8.2	6	2	16.25
2	8.2	6	4	16.85
3	8.4	6	6	17.45
4	8.3	6	8	17.82
5	8.5	6	10	18.32
6	8.2	6	12	18.66
7	8.2	6	14	19.00
8	8.3	6	16	19.45
9	8.2	6	18	19.90
10	8.5	6	20	20.55

Table A4: The results of the Average Compressive Strength Tests for Sample B4, with varying increment cement percentage.

Samples	Average wt (kg)	Percentage clay/silt content (%)	Cement increment (%)	Average compressive strength (N/mm^2)
1	8.3	7	4	16.50
2	8.5	7	8	17.35
3	8.5	7	12	17.86
4	8.4	7	16	18.75
5	8.4	7	20	19.50
6	8.2	7	24	20.22

Table A5: The results of the Average Compressive Strength Tests for Sample B5, with varying increment cement percentage.

Samples	Average wt (kg)	Percentage clay/silt content (%)	Cement increment (%)	Average compressive strength (N/mm^2)
1	8.3	8	4	12.45
2	8.5	8	8	13.35
3	8.5	8	12	14.66
4	8.3	8	16	15.75
5	8.4	8	20	17.40
6	8.3	8	24	18.22
7	8.5	8	28	19.35
8	8.5	8	32	20.35

Table A6: The results of the Average Compressive Strength Tests for Sample B6, with varying increment cement percentage.

Samples	Average wt (kg)	Percentage clay/silt content (%)	Cement increment (%)	Average compressive strength (N/mm^2)
1	8.0	9	4	11.65
2	8.4	9	8	12.75
3	8.5	9	12	13.66
4	8.5	9	16	14.45
5	8.4	9	20	15.42
6	8.3	9	24	16.22
7	8.5	9	28	16.75
8	8.5	9	32	17.75
9	8.4	9	36	18.80
10	8.4	9	40	20.15

Table A7: The results of the Average Compressive Strength Tests for Sample B7, with varying increment cement percentage.

Samples	Average wt (kg)	Percentage clay/silt content (%)	Cement increment (%)	Average compressive strength (N/mm^2)
1	8.2	10	4	10.95
2	8.4	10	8	11.75
3	8.4	10	12	12.56
4	8.4	10	16	13.45
5	8.3	10	20	14.42
6	8.3	10	24	15.35
7	8.5	10	28	15.85
8	8.5	10	32	16.75
9	8.3	10	36	17.50
10	8.3	10	40	18.25
11	8.2	10	44	19.50
12	8.3	10	48	20.00
13	8.5	10	52	20.80

3.3 Cost Analysis for Washing of Sand free from Impurities

In any construction work, cost is one of the major factors to be considered. The aim is to have a concrete of an acceptable compressive strength but economical. The cost of washing off impurities in the sand Sample A in the production of $1m^3$ of concrete is analyzed for prescribed mix ratio 1:2:4.

3.3.1 Data for analysis

The analysis of data is as follows:

Time taken to wash a head pan of sand (15kg) 20mins

Amount of water required for washing a head pan of sand 30litres

For $1m^3$ of concrete using ratio 1:2:4:

Cement required 300kg

Sand required 550kg

15kg of sand sample will be washed under 20mins, hence:

550kg will take $\frac{550x20}{15x60} = 12.22hrs$

Since labour can only work for 7hrs/day, hence to wash 550kg of sand will take two days.

The rate of labour per day is N1, 500.00.

Wages of 2 labours required to wash 550kg of sand under 7hrs N3, 000.00

Cost of water to be used (1100litres) N1, 500.00

Total amount required to wash $1m^3$ of sand N4, 500.00

Cost of $1m^3$ of concrete without washing N20, 000.00

Hence the cost of $1m^3$ of concrete with washed sand will cost N24, 500.00

The percentage increment of cost for washing $= \frac{4500}{20000} x100 = 22.5\%$

Table 3. Percentage increment of cost of washing and cost of cement increment

%Clay/silt content	%Cement increment to achieve 20Nmm^2 strength	Cost of washing sand (N)	Cost of cement increment	%Cost increment for washing sand	%Cost of cement increment
4	4	4,500	444	22.5	2.22
5	14	4,500	1,554	22.5	7.77
6	20	4,500	2,220	22.5	11.1
7	24	4,500	2,664	22.5	13.32
8	32	4,500	3,552	22.5	17.76
9	40	4,500	4,440	22.5	22.2
10	50	4,500	5,550	22.5	27.75

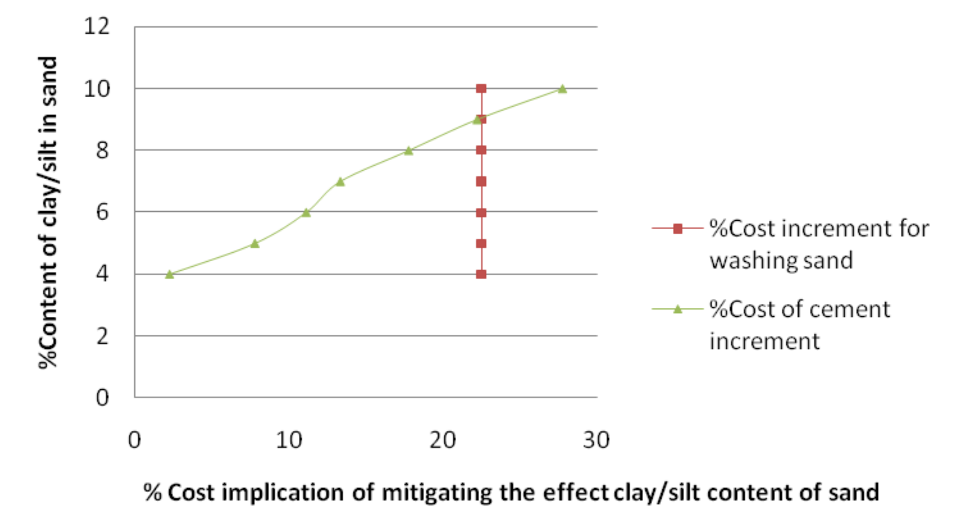

Figure 1: % Content of clay/silt and cost implication curve

3.3.2 Mathematical model of the cost of washing sand

The cost of washing sand free of its clay/silt content can be estimated using equation 1 below.

$$C = [\{1.4w + (\frac{X * y}{7})Z]$$

Equation 1

Where:

C – Cost of washing sand

w – Quantity of water required for washing (litres)

X – Time taken for washing (hours)

y - Cost of labour per day per head

Z – Quantity of concrete required to be prepared (m^3).

Example: using the parameters in section 3.3.1, evaluate the cost of washing 550kg of sand.

Using Equation 1

$$C = [1.4 * 1100 + (\frac{14 * 1500}{7}) * 1] = 4,540$$

3.3.3. Mathematical model of the cost of cement increment

The cost evaluation for cement increment can be done using equation (2) below.

$$C = 0.06 * X * Y * Z$$

Equation 2, Where:

C – Cost of cement increment for various % clay/silt content of sand

X – % increase in cement content of concrete

Y - Cost of a bag of cement

Z – Quantity of concrete required to be prepared (m^3).

Example: For a sample containing 10% of clay/silt content, determine the cost of cement increment to achieve $20N/mm^2$.

Using Equation 2:

C = 0.06*X*Y*Z

Substituting for X, Y and Z we have:

C = 0.06 x 50 x 1850 x 1 = N5, 550.00.

With the above cost analysis, it would cost N4, 500 to wash off clay/silt content of 550kg of sand sample irrespective of the percentage clay/silt content. The cost implication of increasing cement content in a concrete mix with varying clay/silt content in order to achieve the acceptable concrete compressive strength of $20N/mm^2$ is given in Table 3. From figure 1, there is equilibrium of percentage cost increment at 22.5% at 9% of clay/silt content in sand.

4.0 CONCLUSION AND RECOMMENDATIONS

4.1 Conclusion

From the discussion of results above, clay/silt, when present in sand above some certain percentage (3%) have detrimental effect on the strength of concrete produced from such sand. Hence there is the need to mitigate this detrimental effect of clay/silt content of sand on concrete strength. The process of mitigation will increase the cost of production of $1m^3$ of concrete by 22.5% if washing method is used and between 2.22% and 27.75% if cement increment method is used, depending on the clay/silt percentage present in the sand. From figure 1, there is equilibrium of percentage cost increment at 22.5% at 9% of clay/silt content in sand. Therefore, for sand containing less than 9% clay/silt content, it is more economical to use the cement increment method of mitigation, while on the other hand, for sand containing more than 9% clay/silt content, it is more economical to use the washing method of mitigation. Hence in order to have a safe building industry, this percentage increment should be taken into consideration by all the stake holders in the industry, especially the consultant structural engineer, consultant quantity surveyor and the client.

4.2 Recommendations

Based on the conclusion above, the following recommendations are made:

i. Field Settlement Test should be carried out on any sand to be used in Akure and its environs to ascertain the percentage of clay/silt content of the pit sand.

ii. If the percentage of clay/silt content of the sand is more than 3%, then remedial measures such as washing or cement increment should be taken so as to mitigate the effect of clay/silt content of the sand.

iii. Mechanism should be set up, which will make intending contractors to indicate the areas where they intend to source for their sand. This will afford the consultant structural engineer to carry out appropriate test on the sand from such area and recommend means of mitigating the effect of the clay/silt content of such sand if necessary.

iv. The recommendation of the consultant structural engineer should guide the consultant quantity surveyors in preparing the tender documents.

v. Research should be carried out on the possibility of producing a machine capable of washing sand locally.

REFRENCES

Ahmad S. and Mahmood S. (2008); Effects of Crushed and Natural Sand on the Properties of Fresh and Hardened Concrete. 33rd Conference on Our World in Concrete & Structures. 25 – 27 August 2008, Singapore. Pp 405-410.

British Standards (1957): *The Structural use of Concrete in Buildings*. *CP114*. British Standards Institution, London, UK.

British Standards (1972): *Code of Practice for the Structural use of Concrete - Part 1: Design, Materials and Workmanship*. *CP110: Part 1*. British Standards Institution, London, UK.

British Standards (1992): *Specification for Aggregates from Natural Sources for Concrete.* BS882:1992. British Standards Institution, London, UK.

British Standards (1997): *Concrete: Part2: Methods for Specifying Concrete Mixes. BS5328: Part1*. British Standards Institution, London, UK.

British Standards (1997): *Structural use of Concrete-Part 1: Code of Practices for Design and Construction*. *BS 8110 Part 1*. British Standards Institution, London, UK.

McCormac J.C. and Nelson J.K.(2006): Design of Reinforced Concrete. 7th Edition. ACI 318-05 Code Edition. John Wiley & Sons Inc.

Mosley, W.H., Bungey, J.H, and Hulse, R, (2007): Reinforced Concrete Design, 6th Edition. BookPower with Palgrave Macmillan.

Olanitori L.M. (2006): Mitigating the Effect of Clay Content of Sand on Concrete Strength; 31st Conference on Our World in Concrete and Structures; 15-17 August 2006, Singapore. Pp 344-352.

Olanitori L.M. and Olotuah A.O (2005): The effect of clayey impurities in sand on the crushing strength of concrete (a case study of sand in Akure metropolis, Ondo State, Nigeria). *Proceedings of 30th Conference on 'Our World in Concrete and Structures'*, Singapore, 23-24 August. Pp 373-376.

Raju, N. K, (2009): Design of Concrete Mixes, 3rd Edition, Delhi, India. CBS Publishers & Distributors.

Reynolds, C.E, and Steedman, J.C. (1981): Reinforced Concrete Designer's Handbook, 9th Edition. Viewpoint Publication. London.

Ukpata J.O, Ephraim M.E. and Akeke G.A. (2012): Compressive Strength of Concrete Using Lateritic Sand and Quarry Dust as Fine Aggregate. ARPN Journal of Engineering and Applied Sciences, Vol.7, No 1. Pp 81-92.

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