



EFFECT OF CLAY CONTAMINATION ON THE COMPRESSIVE STRENGTH OF CONCRETE

¹EBOSELE S. O., ²Omofuma, B. O., ^{*3}Airiofolo, I. R.

^{1,2,3} Department of Civil Engineering, Ambrose Alli University, Ekpoma, Edo State, Nigeria.

Corresponding author's address: raiforce2@gmail.com

ABSTRACT

This study examined the impact of clay contamination in fine aggregates on the compressive strength of concrete. Clay particles present in aggregates can disrupt the bond between the cement paste and aggregate surfaces, leading to reduced strength and durability. In this research, concrete mixes were prepared with varying clay contents (0%, 2%, 4%, 6% and 8% by weight of fine aggregate). Standard cube specimens were cast, cured and tested for compressive strength at 7days and 28days. The results revealed a consistent decline in compressive strength with increasing clay content. At 28days, concrete with 8% clay showed a strength reduction of over 40% compared to the control mix. These findings highlight the critical importance of clean, clay – free aggregates in ensuring the structural integrity of concrete. Fine aggregates should therefore, be tested and confirmed to contain less than 3% clay by weight, as recommended by ASTM C33 and IS 383, to ensure adequate concrete strength and durability.

Keywords: Clay contamination, Fine aggregate, Concrete, Compressive strength, Slump test, Sieve analysis.

1.0 INTRODUCTION

Concrete is the most widely used construction material globally due to its high compressive strength, durability and flexibility in application. Its performance is significantly influenced by the quality of its constituent materials, particularly fine and coarse aggregates. Among the common contaminants in fine aggregates, clay is one of the most detrimental due to its physical and chemical characteristics (Gashahun 2020).

Clay particles are ultrafine, possess a high surface area and can retain large amounts of water. These properties interfere with the hydration of cement and reduce the bond strength between the cement paste and the aggregates (Mindess, et al, 2003). As a result, the presence of clay can lead to increased porosity, reduced density and ultimately lower compressive strength in hardened concrete (Gashahun 2020). Clay particles have a higher surface area and absorb more water than clean aggregates, which increases the water demand for the mix (Kirthika, et al.,

2019). As a result, mixes with higher clay content require more

water to achieve the same consistency. However, excessive water retention leads to reduced flowability and increased cohesiveness, which lowers the slump value. Reduced workability can pose challenges in terms of mix handling and placement, potentially leading to incomplete filling of formwork, inadequate compaction and air pockets in the hardened concrete. Thus, using clay-contaminated aggregates compromises the ease of placing and compacting concrete (Gashahun 2020). According to ASTM C33/C33M-18, the permissible limit of clay lumps and friable particles in fine aggregates should not exceed 3% by weight. Exceeding this limit has been shown to significantly affect the mechanical properties of concrete (ASTM, 2018). Research by (Kirthika, et al., 2019), demonstrated that even small percentages of clay can result in up to a 20% – 40% reduction in compressive strength,

depending on the clay type and content. Despite these findings, the use of clay – contaminated sand is still prevalent in many regions due to economic constraints and limited access to high – quality natural aggregates. This research investigates the effect of clay contamination levels (0% to 8%) on the compressive strength of concrete, aiming to highlight the significance of aggregate cleanliness in concrete production and structural reliability in Ekpoma.

This study was conducted to evaluate how varying levels of clay contamination in fine aggregates affect the compressive strength of concrete.

2.0. MATERIALS AND METHOD

a) Study Area

The study was carried out in Ekpoma, the administrative headquarters of Esan West Local Government Area of Edo State, Nigeria. Ekpoma is located approximately at latitude 6.74°N and longitude 6.14°E. The town is situated in the central part of Edo State and is an important educational and commercial centre. The study area was selected because of the availability and use of locally sourced fine aggregates for concrete production. The investigation focused on assessing the effect of varying levels of clay contamination in fine aggregate on the compressive strength of concrete



Fig 2.1: Map of Ekpoma, Edo State (Google Map, 2026)

b) Materials

i) Cement: Ordinary Portland Cement (OPC) 42.5 grade, conforming to IS 8112 (BIS, 2013), was used. The cement was stored in a dry place to avoid hydration before use.

ii) Fine Aggregate: Clean River sand was used, with artificial clay contamination introduced in 2%, 4%, 6% and 8% proportions by weight. The sand met grading requirements as per IS 383 (BIS, 2016).

iii) Clay: Commercial clay soil passed through a 75µm sieve to simulate typical fine clay contaminants as per ASTM C117 (ASTM, 2017).

iv) Coarse Aggregate: Crushed granite with a nominal size of 20mm, clean and well – graded, complying with IS 383.

v) Water: Potable tap water free from impurities harmful to cement hydration or aggregate performance, per IS 456 guidelines (BIS, 2000).

c) Method

To determine particle size distribution of aggregates, Sieve Analysis was carried out according to IS 2386 Part I specifications while the Slump Test was conducted on fresh concrete to monitor workability across different clay contents according to IS 1199 standard. The concrete was designed based on a nominal mix ratio of 1:2:4 (cement: sand: coarse aggregate) with a water – cement ratio

of 0.5. Five mix batches were prepared with clay content levels of 0%, 2%, 4%, 6% and 8% by weight of the fine aggregate. 150mm cube specimens were cast for each mix and tested at 7days and 28days. Each mix had three replicates per age, giving reliable average compressive strength results. The concrete was mixed manually in a clean, non – absorbent tray. Dry materials (cement, sand and aggregates) were mixed first, followed by the addition of water. The mix was thoroughly blended until uniform. Thereafter, it was poured into oiled steel moulds in three

layers, each compacted using a 16mm tamping rod. Specimens were demoulded after 24hours and placed in water tanks for curing until the testing days (7days and 28days). The compressive strength was tested using a 2000kN capacity Compression Testing Machine (CTM) as per IS 516 (BIS, 1959) standards. The average of three specimens was taken to report the compressive strength for each clay content at both curing ages.

3.0 RESULTS AND DISCUSSION

The findings from these tests are as tabulated.

Table 1: SIEVE ANALYSIS TEST RESULT

Clay content (%)	Passing 75um sieve (%)	Passing 150um sieve (%)	Total fines (%)
0 (Control)	0.5	2.3	3.4
2	2.1	3.2	5.3
4	3.4	4.7	7.8
6	4.8	6.1	10.9
8	6.3	8.3	14.6

As the clay content increased, the percentage of fines passing the 75µm and 150µm sieves also increased significantly. Clay particles, being finer than sand, contribute to a higher percentage of material passing through the finer sieves. The results show a clear increase

in the fine material with higher clay content, which could affect the mix properties, including workability and strength. Higher fines content (due to clay) could influence the packing density and water demand of the concrete mix also

Table 2: SLUMP TEST RESULT

Clay content (%)	Slump (mm)
0 (Control)	75
2	70
4	60
6	50
8	40

The slump values progressively decrease with increasing clay content. Concrete mixes with higher clay content exhibited lower slump values, indicating reduced workability.

The mix with 8% clay showed the lowest slump, suggesting that the concrete had become much stiffer, which could cause difficulties during placement and compaction.

Table 3: COMPRESSIVE STRENGTH TEST

Clay content (%)	7 – Day Strength (Mpa)	28 – Day Strength (Mpa)
0 (Control)	26.7	32.5
2	23.8	29.4
4	20.6	25.1
6	17.5	21.7
8	14.9	18.3

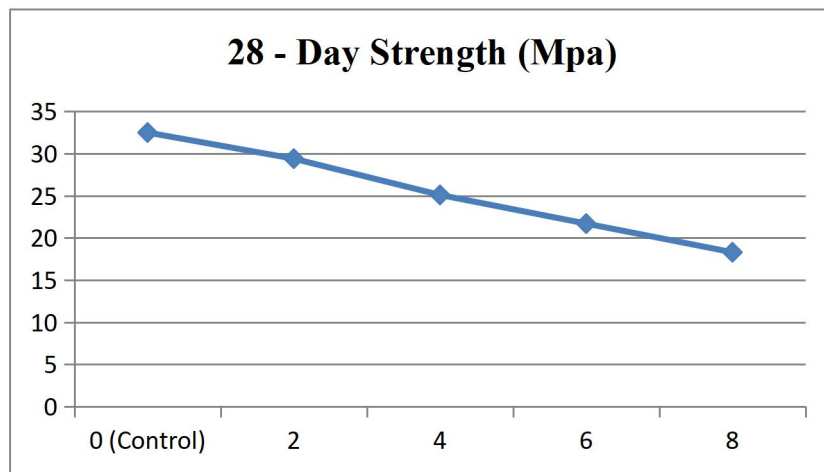


Fig 1: 7 – Day Compressive Strength

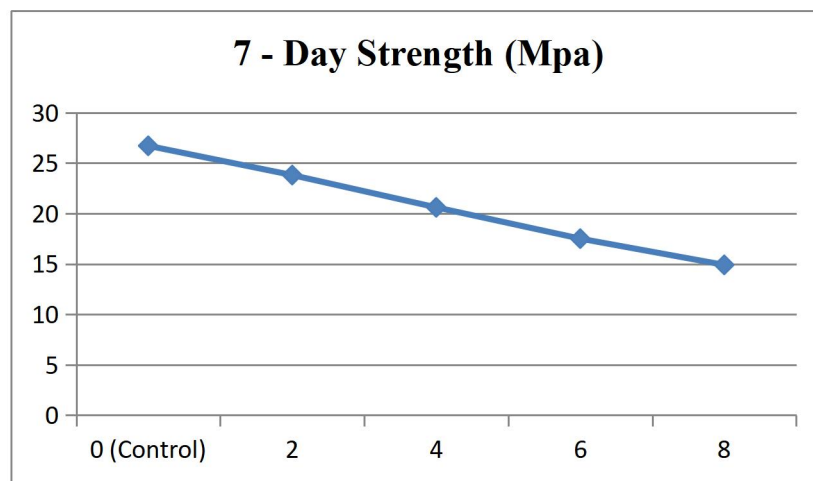


Fig 2: 28 – Day Compressive Strength

The test results clearly demonstrate a progressive reduction in compressive strength with increasing clay content in the fine aggregate. The control concrete containing 0% clay recorded compressive strengths of 26.7MPa and 32.5MPa at 7days and 28 days, respectively. With the addition of 2%, 4%, 6% and 8% clay, the 28 – day compressive strength decreased to 29.4MPa, 25.1MPa, 21.7MPa and 18.3MPa, respectively. This represents reductions of approximately 9.5%, 22.8%, 33.2% and 43.7%, respectively, compared with the control concrete. This suggests that small amounts of clay contamination may have a limited effect, but excessive contamination

can substantially compromise the load-carrying capacity of concrete. Kirthika et al. (2019) similarly established that the presence and amount of clay in fine aggregates influence concrete performance and that excessive clay is undesirable for concrete production

The progressive reduction in strength indicates that increasing clay contamination has a negative effect on the mechanical performance of concrete. The reduction may be associated with the coating of aggregate particles by clay, which interferes with the proper adhesion between the cement paste and aggregate. Clay particles also have a relatively high surface area and water –

retaining capacity, which can increase the water demand of the concrete and affect the quality of the cement paste – aggregate bond. Shi et al. (2024) similarly reported that increasing clay content can adversely affect the mechanical properties of concrete, with more significant deterioration occurring at higher clay contents. Their findings support the trend observed in the present study.

The observed reduction in compressive strength also has important implications for structural concrete. The control concrete achieved 32.5MPa at 28 days, whereas the concrete containing 8% clay achieved only 18.3MPa. Therefore, the use of highly clay-contaminated sand without appropriate treatment or adjustment of the mix could prevent concrete from achieving its intended strength. Gashahun (2020), in an investigation of sand quality and concrete strength, reported that sand containing excessive silt and clay impurities produced significant reductions in concrete compressive strength. The similarity between that study and the present investigation indicates that the quality and cleanliness of fine aggregate are important factors in achieving the required concrete strength.

These results were consistent with findings from previous studies (Neville, 2011; Mindess et al., 2003), which reported that clay particles impair hydration, increase water absorption and lead to discontinuous bonding in the cement matrix. Moreover, the presence of clay reduces the effective cementitious contact area, contributing to reduced compressive strength. Specimens with higher clay content showed more surface cracks and irregular failure patterns after compression, supporting the observation of weaker internal bonding.

The findings of the present study were also consistent with the more recent work of Wu et al. (2025), who investigated the effect of

different mud/clay contents on concrete compressive strength. Their results showed that increasing mud content was associated with a reduction in concrete strength and that the relationship between mud content and compressive strength was nonlinear. This agrees with the progressive reduction observed in the present study, particularly at the higher clay contamination levels.

The practical implication of these findings is that the quality of fine aggregate used for concrete production should be carefully assessed before use. Where sand contains significant clay contamination, washing or other appropriate treatment should be considered before it is incorporated into structural concrete. The results also demonstrate that the effect of clay contamination should not be ignored during concrete production, particularly where locally available sand is used. Maintaining clean fine aggregate will improve workability, aggregate – cement bonding and the ability of concrete to achieve its required compressive strength.

Overall, the results of this study agree with recent international studies which have established that excessive clay or mud contamination negatively affects concrete performance. The present investigation further demonstrates this relationship using clay contamination levels of 0%, 2%, 4%, 6% and 8%. The 43.7% reduction in 28-day compressive strength at 8% clay contamination clearly demonstrates the potential structural implications of using highly contaminated fine aggregate.

4.0 CONCLUSION

This study investigated the effect of clay contamination in fine aggregates on the compressive strength and workability of concrete. The presence of clay in fine aggregates significantly reduced the compressive strength of the concrete. A

steady decline in strength was observed with increasing clay content, with the 28 – day strength decreasing by approximately 43.7% at 8% clay content compared to the control mix. Slump test results showed a substantial decrease in workability as clay content increased. The reduction in slump from 75mm (0% clay) to 40mm (8% clay) indicates that mixes became increasingly stiff and difficult to handle. The sieve analysis revealed a rise in fines passing the 75µm sieve with increasing clay content. This led to higher water demand, poor aggregate – cement bonding and increased porosity, contributing to strength loss and lower durability. Therefore, excessive clay contamination compromises the fresh and hardened properties of concrete. Poor workability can lead to insufficient compaction and the weakened bond between aggregates and paste can reduce structural performance. It is therefore recommended that fine aggregates should be tested and confirmed to contain less than 3% clay by weight, as recommended by ASTM C33 and IS 383, to ensure adequate concrete strength and durability and where clay – contaminated sand is unavoidable, it should be thoroughly washed or treated before use to minimize its impact on concrete properties. Also, in cases where minor clay contamination cannot be avoided, the use of plasticizers or water – reducing admixtures can help maintain workability without increasing the water – cement ratio.

5.0 REFERENCES

- Ajagbe W. O., Tijani M. A., & Agbede O. A. (2018): “Compressive Strength of Concrete Made from Aggregates of Different Sources”, *Journal of Research Information in Civil Engineering*, 15(1), 1963 – 1974
- ASTM, (2017): “Standard Test Method for Materials Finer than 75-µm (No. 200) Sieve in Mineral Aggregates by Washing”, (ASTM C117), ASTM International.
- ASTM, (2018): “Standard Specification for Concrete Aggregates” (ASTM C33/C33M-18), ASTM International.
- Bureau of Indian Standards (BIS), (1959): “IS 516: Method of Tests for Strength of Concrete”, New Delhi.
- Bureau of Indian Standards (BIS), (1963): “IS 2386: Methods of Test for Aggregates for Concrete”, New Delhi.
- Bureau of Indian Standards (BIS), (1980): “IS 1199: Methods of Sampling and Analysis of Concrete”, New Delhi.
- Bureau of Indian Standards (BIS), (2000): “IS 456: Code of Practice for Plain and Reinforced Concrete”, New Delhi.
- Bureau of Indian Standards (BIS), (2013): “IS 8112: Specification for 43 Grade Ordinary Portland Cement”, New Delhi.
- Bureau of Indian Standards (BIS), (2016): “IS 383: Specification for Coarse and Fine Aggregates from Natural Sources for Concrete”, New Delhi.
- Gashahun, A. D. (2020): Investigating Sand Quality Effect on Concrete Strength: A Case of Debre Markos and Its Vicinities. *International Journal of Construction Management*, 22(12), 2234 – 2242.
- Kirthika, S. K., Surya, M., & Singh, S. K. (2019): Effect of Clay in Alternative Fine Aggregates on Performance of Concrete, *Construction and Building Materials*, 228, 116811.
- Shi C., Zhao R., Wang X., Wang W., & Ding K. (2024): Effect of Clay Content on Concrete Properties, *Case Studies in Construction Materials*, 20, e03341.
- Wu W., Chen S., Wu Y., Zhang X., Kong D., & Wen J. (2025): Effect of Different Clay Additions to Concrete on Its Ultrasonic Acoustic Parameters and Compressive Strength. *Scientific Reports*, 15, 2848.