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# Effect of Hand Mixing on the Compressive Strength of Concrete

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**Abstract**

This paper presents the effect of hand mixing on the compressive strength of concrete. Before designing the concrete mix, sieve analysis of sharp sand and chippings was carried out and their fineness moduli were determined. Also the dry weight of chippings and the specific gravities of both sand and chippings were determined. A designed concrete mix of 1:2:4 was used and the number of turnings of the mixture over from one end to another by hand mixing was varying from one time up to and including seven times. The strengths were measured at the curing ages of 7, 14, 21 and 28 days respectively using 150mm concrete cubes cast, cured and crushed. The results revealed that the compressive strengths of concrete cubes appreciably increased with increase in number of turnings from one to four times but remained almost constant beyond four times of turning for all the ages tested. For example, at 1, 2, and 3 times turning; the compressive strengths at 28 days were 4.67, 13.37 and 20.28N/mm$^2$ respectively while at 4, 5 and 6 times turning; the compressive strengths at 28 days were 21.15, 21.34 and 21.69N/mm$^2$. From the data, adequate strengths were not developed at turnings below three times of hand mixing, concluding that a minimum of three times turning is required to produce concrete with satisfactory strength.

**Keywords**

Compressive; Concrete; Curing; Hand-Mixing; Strength; Turning

## Introduction

Simply, concrete is a structural material widely used in the construction industry. It consists essentially of cement, fine aggregate (sand) and coarse aggregate (Natural gravels or chippings). These constituent materials properly proportioned are mixed together with water to form the concrete. The cement serves as the binder to the aggregates while the aggregates serve as the filler materials that give strength to concrete. Concrete has the unique distinction of being the only construction material manufactured on the site, whereas other materials are merely shaped to use at the work site [1].

The compressive strength of concrete depends on the aggregate grading, aggregate/cement ratio as well as the water/cement ratio. The freshly mixed concrete should be workable to be properly placed and the hardened concrete needs to be durable and attain a specific compressive strength [1]. The aim of concrete mix design is to achieve concrete that meets a specified strength. The most important variables affecting the strength of concrete at a given age are the water/cement ratio and the degree of compaction. When concrete is fully compacted its compressive strength is inversely proportional to the water/cement ratio. Workability, durability, resistance to compressive stress and ability to protect steel against rusting are the four most important properties of concrete [1]. To develop these potential properties fully requires concrete to be proportioned appropriately and effective production method is required in order to produce good concrete with the above properties.

Concrete can be produced by employing either mechanical or manual mixing methods. In Nigeria like all developing countries, hand mixing which involves turning over the mixture of the concrete materials from one end of the mixing tray or platform to the other is a popular method. The compressive strength of concrete depends so much on the consistency achieved through mixing [2]. The question is how many times the mixture of the concrete ingredients can be turned over from one side to another. Adequate strength requirement is one of the major properties of concrete and this strength depends on the consistence of the mixing. Definitely, inability to achieve the design or required strength in concrete will seriously affect the structure negatively.

Hand mixing method for production of concrete, using a designed mix 1:2:4 was employed in this study. 150mm size concrete cubes were produced and crushing for compressive strengths was carried out for 7, 14, 21 and 28 days. The degree of mixing

measured in terms of the number of times the concrete was turned over from one end of the mixing tray to the other was varied from one time to seven times.

It is important to know the minimum number of times required in turning concrete over from one end of the mixing tray to the other, in order to produce concrete uniform in composition and of satisfactory strength. It is very necessary to have a good understanding on the relationship between the degree of mixing by hand and the compressive strengths of concrete. Most literatures recommend mixing the concrete until the mixture is consistent and uniform in nature based on physical observation. This recommendation may not be completely a good measure of proper mixing since observers have different views on when concrete is consistent and uniform in nature. For example, BS 1881 part 125 states "After adding all the water, mix the whole batch for at least 3 minutes or until the concrete appears homogeneous". The speed is not the same for all mixers, so timing may not be an appropriate measure of degree of mixing by hand. The effort employed in hand mixing as well as the degree of homogeneity are not the same for all mixers and thus, this recommendation may not be a proper yard stick for measuring the degree of mixing concrete by hand. In machine mixing, the minimum mixing time necessary to produce a concrete uniform in composition and of satisfactory strength can be determined for a particular mixer [2] but this is more difficult in hand mixing because the speed of turning over the concrete differs for different mixers. This research is to find out the effect of hand mixing, measured in terms of the number of times the concrete is turned over from one end of the mixing tray to the other on its compressive strength.

## Materials and Method:

*Sand*: The sand collected from a river in Bosso village, Minna, Nigeria and used as fine aggregate was clean, sharp, free from clay and organic matter and well graded in accordance with [4].

*Cement:* The cement used was Ordinary Portland Cement (OPC) bought from a cement depot at Bosso road Minna, Nigeria and it conformed to [5] as confirmed by [6].

*Crushed Stones*: Coarse aggregate used was crushed stones with 20mm maximum size supplied from Triacta Quarry in Minna, Nigeria and it conformed to [4] recommendation.

*Water:* Tap water was used for the mixing and it was properly examined to ensure that

it was clean, free from contaminants either dissolved or in suspension and good for drinking as specified in [7].

***Laboratory Tests***

Laboratory tests on the sand and crushed stones for the purposes of characterization and classification include determination of particle size distribution, natural moisture content and specific gravity, were carried out in accordance with [8]. The determination of bulk densities and water absorption of the sand and crushed stones was carried out in accordance with [9].

***Preparation of Specimens*:**

Mix design is the consideration of the most economical use of available materials to produce concrete of desirable workability, durability and strength [10]. In designing the concrete mix, air entrained concrete under mild exposure conditions was used to improve the workability. A maximum size of 20mm aggregate and a water/cement ratio of 0.53 were adopted, for the desired workability of slump 30mm-50mm. Absolute volume method was used in the determination of the quantity of sand. The mix design resulted in a mix ratio of 1:2:4, which was used in the manual production of 140 concrete cubes of 150 mm size used for the compressive strength test. Preparation of materials, mixing and sampling were carried out in accordance with [11].

***Slump Test***

Before mixing the concrete for casting the cubes, a trial mix was carried out to determine the slump. Slump test is very useful in detecting variations in the uniformity of a mix of a given nominal proportions [10]. It is a popular method used all over the world on the day-to-day, hour-to-hour variation in the materials being fed into the mixer or mixing platform if by hand. In this study, a slump of 40mm was measured in accordance with [12] and it satisfied the value adopted in the design.

***Hand Mixing***

The batch mix of 1:2:4 by volume of materials as designed were mixed by hand on a hard, clean and non-porous galvanized iron tray. The sand and cement were mixed properly

before the coarse aggregate was added and mixing continued until uniformity was achieved by turning the mixture from one side to another for three times. Finally, water was added and the mixture turned over again from side to side, until it appeared uniform in colour and consistence. Water was gradually added so that it could neither escape by itself nor with cement [1]. The mixing was varied for 1, 2, 3, 4, 5, 6 and 7 times turning. For each number of turning, twenty (20) cubes of 150mm size were cast and cured for 7, 14, 21 and 28 days respectively. A total of 0.52m$^3$ of concrete was prepared to produce 140 cubes in accordance with [13] used for the compressive strength test.

### *Compressive Strength Test*

An electrically operated Seidner compression machine was used for the crushing test on the concrete cubes in accordance with [14], at the curing ages of 7, 14, 21 and 28 days. Five cubes were crushed in each day for each number of turning and the average compressive strength was determined. In crushing test, care was taken to ensure that the cubes were properly positioned and aligned with the axis of the thrust of the compression machine to ensure uniform loading on the cubes [1].

## Results and Discussion

### *Identification of Sand and Crushed Stones*:

The properties of sand and crushed stones used for the study are summarized in Table 1 while Figures 1 and 2 show their particle size distribution. The sand was well graded and classified in zone 1 in accordance with [4] classification for aggregates. The fineness modulus of sand and crushed stones are 3.41 and 3.36 respectively, while their specific gravities are 2.64 and 2.68 which is in good agreement with the recommendation of [8] for clean quartz and flint sands. Also Shirley [15] reported that normal-density aggregates generally have specific gravities between 2.5 and 3.0. The bulk density of the crushed stones is 1855kg/m$^3$ and it conforms to [4] recommendation for aggregates from natural sources for concrete.

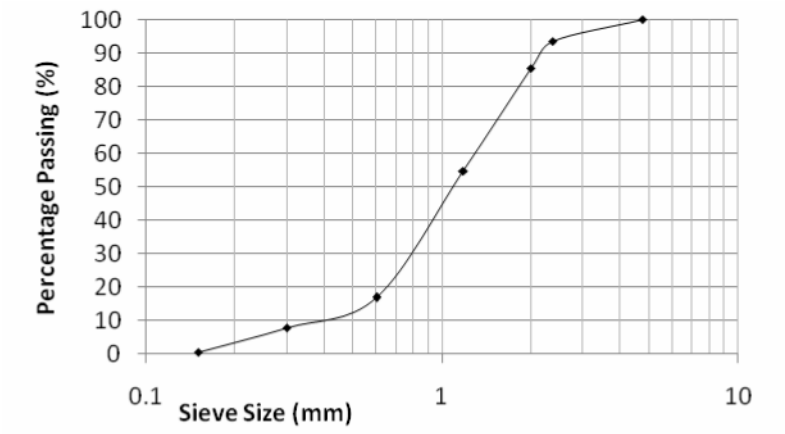


***Figure 1**. Particle size Distribution Curve for Sand*

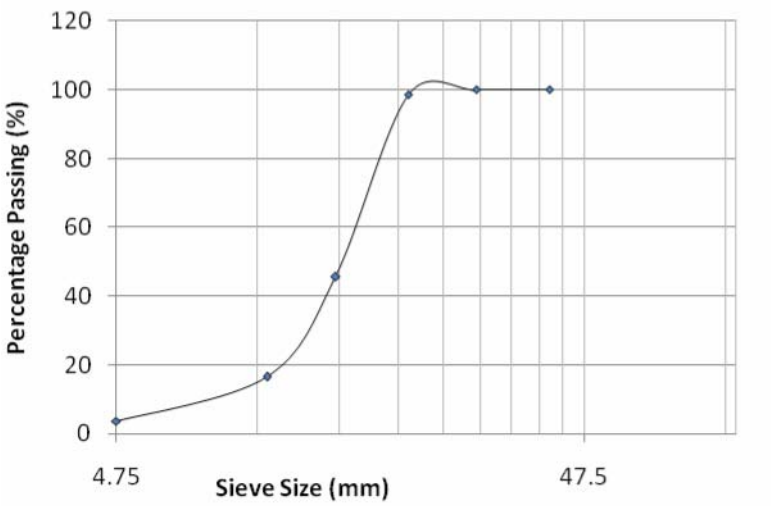


***Figure 2**. Particle size Distribution Curve for Crushed Stone*

### *Compressive Strength*

Results of the compressive strength test on concrete produced by hand mixing are presented in Figure 3. The degree of mixing was measured in terms of the number of turnings of concrete over from one end to the other on the mixing tray. It can be seen that adequate strength was achieved after turning the mixture of all constituent materials from one end to another for three times of continuous mixing.

**Table 1**. Properties of Cement, Sand and Crushed Stones

| Property | Cement | Sand | Crushed Stones |
|---|---|---|---|
| Natural moisture content (%) | | 21.15 | 0.54 |
| Water absorption (%) | | 1.5 | 0.25 |
| Fineness modulus | | 3.41 | 3.36 |
| Specific Gravity | 3.15 | 2.64 | 2.68 |
| Density of crushed stones (kg/m$^3$) | | | 1855 |

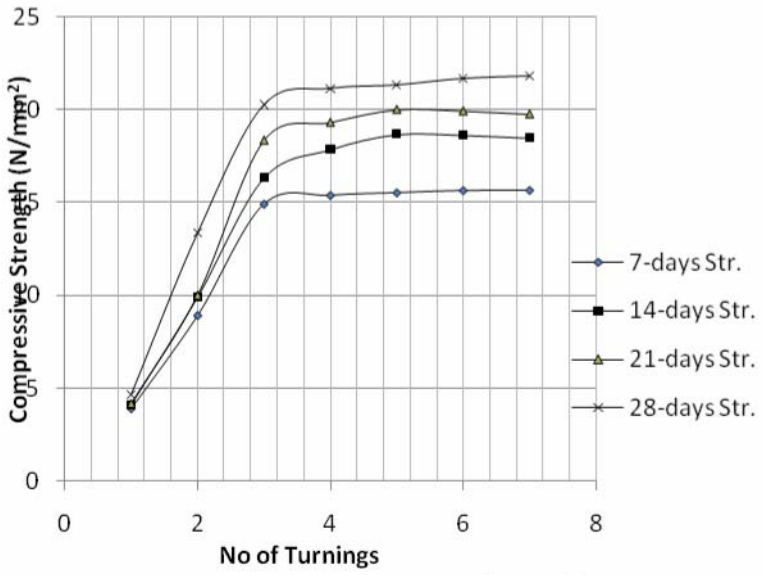


***Figure 3**. Compressive Strength-No of Turnings Relationship for Concrete*

The compressive strengths of concrete cubes appreciably increased with increase in number of turnings from one to four times but remained almost constant beyond four times of turning for all the ages tested. It can be observed too that low strength was recorded at two times turning of the mixture. This indicates that below three times turning, concrete uniform in composition and of satisfactory strength may not be achieved. A compressive strength of 20.28N/mm$^2$ was achieved at 28 days for 3 times turning and this satisfies the recommendation of [15] that the minimum strength for reinforced concrete with normal aggregate should be 20N/mm$^2$.

The number of turnings was recorded from the time when all the solid materials have been put on the mixing hard surface [2] and water is gradually added. It can be seen that the greatest increase in compressive strength was recorded at the age of 14 days for all the number of turnings. This indicates that concrete develops greater strength rapidly at the early age of 7 to 14 days and this result is in conformity with the report by [16]. Also from Figures 4-6, it can be seen that usual increase in compressive strengths with age of curing was recorded all cases. This trend agrees with the relations developed by [17] based on experimental investigations that the strength of concrete increases with time and temperature.

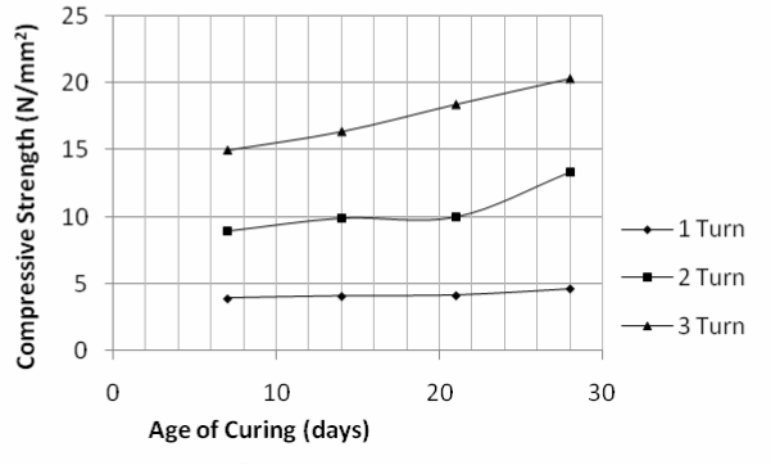


***Figure 4.*** *Age of Curing-Compressive Strength Relationship for Concrete at 1, 2, 3 times Turning*

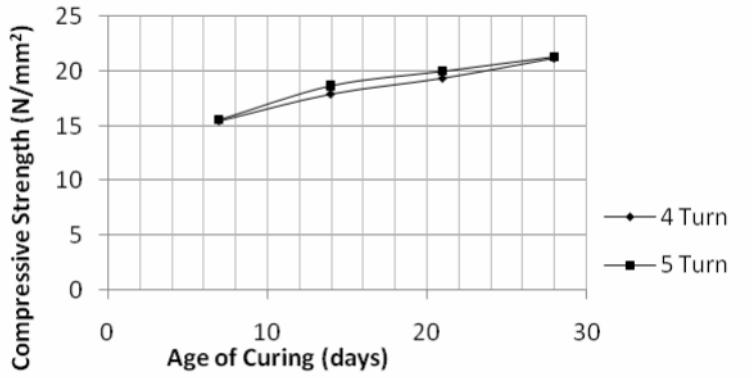


***Figure 5.*** *Age of Curing-Compressive Strength Relationship for Concrete at 4,5 times Turning*

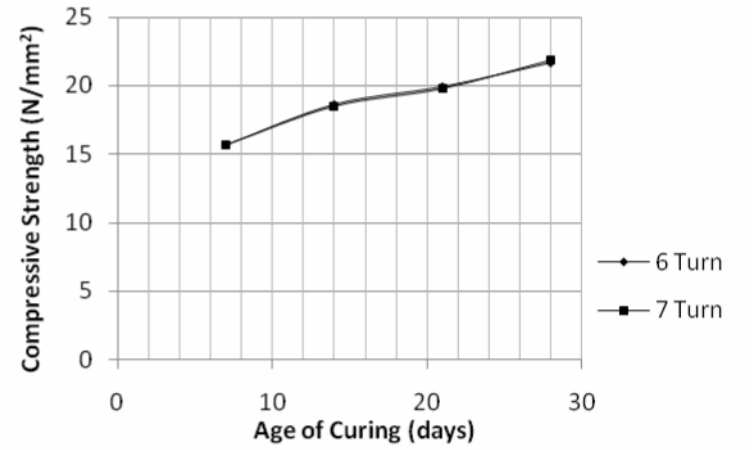


***Figure 6.*** *Age of Curing-Compressive Strength Relationship for Concrete at 6,7 times Turning*

## Conclusions

The overall conclusions emerging from the present study are that:

1. Compressive strength of hand mixed concrete increased with increase in degree of mixing recorded in terms of number of turnings of concrete over from one end to other end of the mixing tray. The maximum strength was recorded at four times turning for all the ages and there was no significant increase in compressive strength beyond the four times turning.
2. Adequate compressive strength of 20.28N/mm$^2$ was achieved at 28 days for 3 times turning concluding that a minimum of 3 times turning is required to produce concrete uniform in composition with satisfactory strength.
3. Low compressive strengths were recorded at all the curing ages for turnings below three times, concluding that hand mixing below three times turning is not satisfactory.
4. There was normal increase in compressive strengths of concrete with age of curing for all the number of turnings by hand mixing.

## References

1. Neville A.M., *Properties of Concrete*, 4th Edition, 39 Parker Street, London, Pitman Publishing Ltd, 2000.
2. Aguwa J.I., *Effect of Critical Variable-Time on Concrete Production*, Journal of Science, Technology and Mathematics Education, 2006, Vol. 8, No 2, p. 23-39.
3. BS 1881 part 125, *Methods for mixing and sampling fresh concrete in the laboratory* British Standards Institution, 389 Chiswick High road London, W4 4AL,1986.
4. BS 882, *Aggregates from natural Sources for concrete*, British Standards Institution, 2 Park Street, London, 1983.
5. BS 12, *Portland cement (ordinary and rapid-hardening)*, British Standards Institution, 2 Park Street, London, 1978.
6. Yahaya M.D., *Quantitative Analysis of the Chemical Compositions of Selected cement brands in Nigeria*, Proceedings of Biennial Engineering Conference, FUT Minna,

Nigeria,2008, p. 100-104.

7. BS 3148, *Tests for water for making concrete*, British Standards Institution, British Standard House, 2 Park Street, London, WIY 4AA, 1980.
8. BS 1377, *Methods of Testing Soils for Civil Engineering Purposes*, British Standards Institution, 2 Park Street, London, 1990.
9. BS 812 Part 2, *Determination of Bulk Density for mineral aggregates, sand and fillers*, British Standards Institution, 2 Park Street, London,1975.
10. Raju N.K., *Design of Concrete Mixes*, 3rd Edition, 485 Bhola Nath Nager Shandra Delhi-1100032, CBS Publishers and Distributors, 1996.
11. BS 1881: Part 2, *Method of Testing Fresh Concrete*, British Standards Institution, British Standard House, 2 Park Street, London, WIY 4AA, 1970.
12. BS 1881: Part 102, *Method for determination of slump of fresh concrete*, British Standards Institution, British Standard House, 2 Park Street, London, WIY 4AA, 1983.
13. BS 1881 part 108, *Methods for making test cubes from fresh concrete* British Standards Institution, 389 Chiswick High road London, W4 4AL, 1983.
14. BS 1881 Part 116, *Methods for Determining Compressive Strengths of Concrete Cubes*, British Standards Institution, 2 Park Street, London, 1983.
15. Shirley D.E., *Introduction to Concrete*, Wexham Springs,Slough SL3 6PL,Cement and Concrete Association, 1975.
16. CP 110, *The Structural Use of Concrete*, British Standard Institution British Standards Institution, 2 Park Street, London, 1972.
17. Plowman J.M., *Maturity and Strength of Concrete*, Magazine of Concrete Research, 1956, 22, p.13-22.