DOI: 10.15415/jotitt.2015.31002

Effect of Aggregate Flakiness on the Compressive Strength of Concrete Cubes

HIMANSHU KUMAR MALVIYA RAHUL DHOKE AND K.K. PATHAK

National Institute of Technical Teachers' Training and Research, Bhopal (MP) India

E-mail: kkpathak@nitttrbpl.ac.in

Received: April 17, 2015| Revised: May 11, 2015| Accepted: May 30, 2015

Published Online: June 29, 2015

Abstract: In this paper effects of aggregate flakiness on the compressive strength of concrete cubes have been studied using experiments. Total 30 cubes have been cast using normal, 5% of 8 mm, 10 mm and 12 mm size of flaky aggregates and 10% of 12mm size of flaky aggregate. NDT of the cast cubes using rebound hammer and ultrasonic pulse velocity have been also carried out. All the cubes were tested for compressive strength. Based on these data, comparative studies have been carried out to quantify the effect of flakiness and salient conclusions are drawn.

Keywords: Concrete, Normal Aggregates, Flaky Aggregates, Compressive Strength, Concrete cube.

1. INTRODUCTION

Concrete is a composite material of sand, gravel, crushed rock, or other aggregate held together by a hardened paste of hydraulic cement and water. The thoroughly mixed ingredients, when properly proportioned, make a plastic mass which can be cast or molded into a predetermined size and shape. The shape and the surface texture of aggregates influence the properties of fresh concrete more than the hardened concrete. Generally, irregular textured, angular, and elongated particles require more cement paste than smooth and rounded particles to produce workable concrete mixture because of higher void contents. In addition, mixtures with rough textured or crushed aggregates have higher strength, especially tensile strength, at early ages than a corresponding concrete with smooth or naturally weathered aggregate of similar mineralogy since they are assumed to produce stronger physical bond with cement. But, at later ages, the effect of surface texture may be reduced because of the chemical

Journal on Today's Ideas – Tomorrow's Technologies, Vol. 3, No. 1, June 2015 pp. 27–40

CHITKARA UNIVERSITY

interaction starting to take place between the aggregate and the cement paste. Rough surfaces also tend to increase the water requirement to achieve a certain workability level; therefore, the small advantage due to better physical bond may be lost as far as the strength is concerned. An aggregate is termed flaky when its least dimension (thickness) is less than three-fifth of its mean dimension. The mean dimension of aggregate is the average of the sieve sizes through which the particles pass and are required, respectively. The particle is said to be elongated when its greatest dimension (length) is greater than nine-fifth of its mean dimension.

This study is to evaluate the effect of the flaky and normal aggregates having different mix condition on the compressive strength of concrete cubes. Some of the background studies, related to this work are discussed below: Ponnada (2014) studied the effects of various types of aggregate quantitatively. M25 grade of concrete for various ratios of weights of elongated aggregate to flaky aggregate and angular aggregate to overall aggregate were checked for compressive strength, density and workability. The results expose that the effect of elongated aggregates is more than flaky aggregates, on the characteristic compressive strength of concrete. Concrete with 1:1 ratio of flaky to elongated aggregates has minimum weight. For a constant EA: FA ratio, density growths but characteristic compressive strength and compaction factor reduction with decrease in AA: TA ratio. For a constant AA: TA ratio, specific compressive strength and compaction factor are maximum density of concrete is minimum for an EA: FA ratio of 1:1. Still the outcomes or results and explanations cannot be generalised within the scope of this work, they can absolutely impress on the structural engineers and editors of standard codes of preparation of various countries that the flakiness and elongation indices have to be calculated for course aggregate being used in concrete and essential strength reduction factors have to be adopted. Abdullahi (2012) reported the effect of aggregate category on compressive strength of concrete. Three types of coarse aggregates used i.e., quartzite, granite, and river gravel, were used. The fine aggregate is normal type sand found from a borrow pit. Preliminary laboratory analysis was conducted to establish the suitability via the aggregates for construction related works. Tests conducted contain sieve analysis, bulk density, and specific gravity. Concrete nominal mix (1:2:4) was accepted for this work and mix compositions were calculated by absolute or accurate volume method. For all type of coarse aggregate, 75 cubes (150 x 150 mm) were cast to permit the compressive strength to be observed at 3, 7, 14, 21, and 28 days. The results obtained from tests show that concrete made by river gravel has the maximum workability followed by crushed quartzite and crushed granite aggregates. Maximum compressive strength at total ages was noted with concrete made from quartzite aggregate tracked by river gravel and then granite aggregate. Compressive strength models were proposed as a function of age at curing. Where concrete practitioners have options, aggregate made from quartzite is desirable to be used for concrete work. Highest compressive strength was achieved from concrete containing crushed quartzite, followed by concrete containing river gravel. Concrete containing crushed granite shows the least strength development at all ages. Jain and Chouhan (2011) reported on the influence of shape of aggregate on compressive strength and permeability properties of permeable concrete. In this paper the magnitude of this effect was determined by conducting laboratory trials on mixes of permeable concrete prepared by using proper aggregate differ in shape with different water cement ratio. The shape of aggregate is measured in terms of angularity number. Result indicate that strength and permeability of concrete vary as function of shape of aggregate alongside with aggregate size and water cement ratio in the mix. Vyawahare and Modani (2009) improved the workability of concrete with flaky and elongated aggregates using super plasticizer and mineral mixture and determined the permissible percentages of these aggregates in the concrete mixes without adversely affecting the characteristics of the mix. The 20% replacement of normal aggregate with flaky and elongated aggregate has proved to be equally good as concrete made up with normal aggregate. Rogers and Gorman (2008) reported a flakiness test for fine aggregate. This paper describes the development of a test for measuring the amount of flaky particles in fine aggregate. Commercially available slotted sieves for testing grain or seeds are used. Material in the pass 4.75 mm to 2.36 mm fraction is tested on a 1.8 mm slotted sieve and material in the pass 2.36 mm to 1.18 mm portion is tested on a 1.0 mm slotted sieve. The results show that the high amounts of flaky particles in a fine aggregate may warn of difficulty in compacting asphalt mixtures in which the material is used by itself as the fine aggregate. Mansur and Islam (2002) reported an experimental study on the effects of different concrete specimen types on the compressive strength and established the inter-relationships between their strengths. Each of a total eleven test data sets generated in this study consists of five strength values for the five different types of test specimens. Each strength value was calculated by averaging the strength of at least three identical specimens. In this experimental study, two different high-strength concrete mixtures were used. The expected cube compressive strength of concrete mixes is M15 and M20. From the literature review, it is observed that researches have been attempted on various aspects of flakiness of the aggregates. But it is observed that very few literatures are available on the effect of flakiness on the cubes strength using destructive and non-destructive method. In this study attempt would be made to carry out experimental study on standard concrete cubes. Effect of flakiness will be studied using various destructive and non-destructive tests for two grades of concrete i.e. M15 and M20.

2. METHODOLOGY

In this study two types of aggregate, normal and flaky were used in preparing cube specimens. Two types of mixed proportions M15 and M20 were used. The concrete prepared using normal aggregate and 5% and 10% of flaky aggregate of different size 8mm, 10mm, 12mm were used for cubes. These cubes were tested on 7 and 28 days. The compressive strength of this cubes are determined with the help of destructive and non-destructive testing. The cement used in all mixers is Portland pozzolana cement and natural sand is used. The sizes of sand vary from 2mm to 4.75 micron.

The ultrasonic pulse velocity and rebound hammertest (non-destructive) and compressive strength using universal testing machine (destructive) were performed on 30 specimens prepared using different concrete mixtures. In order to determine the effect of flakiness, cube specimens with standard dimensions were tested at 2 ages, i.e.7 and 28 days. The determination of the strength of each mixture and specimen ages are based on the average of 3 specimens.

The comparative study is carried out to evaluate the compressive strength of cube of M15 and M20 grade of concrete mix with flaky and normal aggregates having five type mix conditions including nominal mix and four types of special mix conditions.

In this way, there are five types of mix ingredients and three cubes are cast for each mix.Five sample mixes were prepared, namely-

Nominal mix i.e. water + cement + fine aggregate + coarse aggregate.
Special mix 1 i.e. water + cement + fine aggregate + coarse aggregate (5% 8 mm, flaky aggregate + 95% coarse aggregate).
Special mix 2 i.e. water + cement + fine aggregate + coarse aggregate (5% 10 mm, flaky aggregate + 95% coarse aggregate).
Special mix 3 i.e. water + cement + fine aggregate + coarse aggregate (5% 12 mm, flaky aggregate + 95% coarse aggregate).
Special mix 4 i.e. water + cement + fine aggregate + coarse aggregate (10% 12 mm, flaky aggregate + 95% coarse aggregate).

First mix condition is nominal mix condition as per IS code considerations using cement, sand, aggregate and water. Second, third and fourth mix condition is special mix condition, in this mix uses of 95% of normal aggregate with 5% replacement

Figure 1: Flow chart of the proposed methodology.

of flaky aggregates of 8, 10 and 12 mm size passing in flaky sieve apparatus with cement, sand, and water. Similarly fifth type of mix conditions having 90% of normal aggregate with 10% replacement of flaky aggregate of 12 mm size. Results have been compared on the basis of NDT and UTM based results.
Following procedure is adopted for the study using flaky and normal aggregate-

1. Making of concrete mix with water, cement, sand and aggregates (flaky + normal).
2. Selection of mould and mouldpreparation for casting of cubes.
3. Compaction of concrete mix, compact each layer by using tampering rod.
4. Demoulding of cubes.
5. Curing of the cubes for 28 days in the curing tanks.
6. Testing of the cubes with help of NDT and UTM.
7. Comparative analysis of results in terms of flaky and normal aggregates with different mixing conditions.
8. Critical study of results.

Figure 1 shows the flow chart of the proposed methodology

3. EXPERIMENTAL PROGRAM

3.1 Selection of Material

Selection of material for making of concrete mixes are given below-

1. Cement – PPC (Portland pozzolona cement) was used.

Following tests were conducted, on cement:

- Consistency limit test:- Three samples were tested and results are given in Table 1
- Initial setting time and final setting time: Results are given in Table 2.

2. Sand

Sieve analysis for the sand was carried out in the laboratory as per the procedure mentioned in IS 2386 (part-I)-1963. The sizes of sand vary between 2 mm to 4.75 micron.

4. AGGREGATES

For this study the locally available coarse aggregate was used. Grading of natural coarse aggregate considered as per IS: 456:2000. Following tests were conducted, on aggregates.

4.1 Aggregate Impact Test

This test has been designed to evaluate the toughness or the resistance of stones aggregate to breaking down under repeated application of impact. Aggregate impact value specifies a relative quantity of the conflict of aggregate to impact. The aggregate impact test apparatus and procedure have been standardized by the Bureau of Indian Standard (BIS).

The aggregate impact value is the ratio of fines passing 2.36 mm sieve expressed in terms of total weight of sample. The impact value of the aggregate obtained is **20.9%.**

4.2 Selection of Flaky Aggregates

For flaky aggregate, bar sieve is used for passing different shape of flaky aggregates as given below;

1. 8 mm sieve passing,
2. 10 mm passing, and
3. 12 mm passing

Table 1: Consistency limit test result.

Type of cement	Standard consistency limit		
	As per IS code IS: 4031 (part 4) 1988	As per lab test	
Portland-pozzolona cement	30.5	Sample 1	**26**
		Sample 2	**31.5**
		Sample 3	**30**

Table 2: Standard initial and final setting time of cement.

Type of cement	Initial setting time			Final setting time		
Portland-pozzolona cement	As per IS code (IS 4031: PART 5)		Test time	As per IS (IS 4031: PART 5)		Test time
	Minimum	Maximum		Minimum	Maximum	
	30 min	55 min	**52 min**	190 min	600 min	**579 min**

Figure 2 and 3 shows appearance of flaky aggregatesand flakiness index test apparatus.

5. WATER

The water content of concrete is influenced by a number of factors, such as aggregate size, aggregate shape, aggregate texture, workability, water-cement ratio, cement and other supplementary cementitious material type and content, chemical admixture and environmental conditions. In this study potable water was used.

6. PREPARATION OF CONCRETE

Nominal mix of concrete of 1:1.5:3 and 1:2:4 were used for making M20 and M15 grade concrete. The concrete was mixed by hand in the laboratory, in such a manner as to avoid loss of water or other materials, each batch of concrete is such a size as to leave about 10 percent excess after moulding the desired number of test specimens. To determine the workability of concrete

Figure 2: Flaky aggregates.

Figure 3: Bar sieve.

Figure 4: Cube sample after casting.

Figure 5: Test of rebound hammer.

Figure 6: Test of pulse velocity.

Figure 7: Compressive testing of beam.

compaction factor test was carried out. This test is suitable for mixtures having medium and low workability i.e. compaction factor in between 0.91 to 0.81,

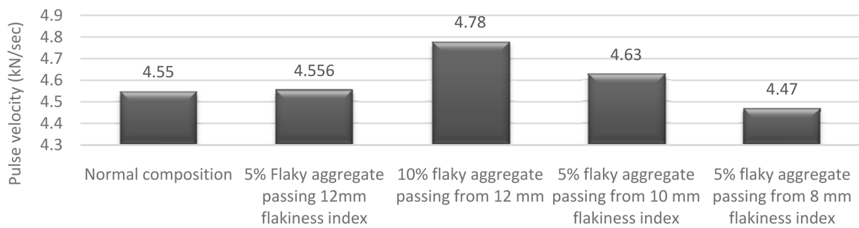

Figure 8: Pulse velocity of M15 test specimen having different compositions of aggregate at 7 days.

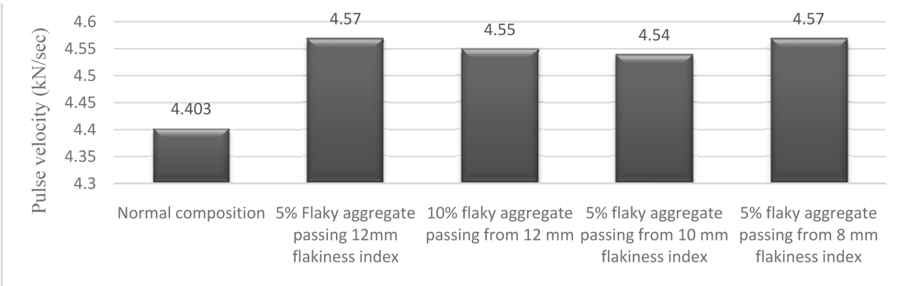

Figure 9: Pulse velocity of M 20 test specimen having different compositions of aggregate at 28 days.

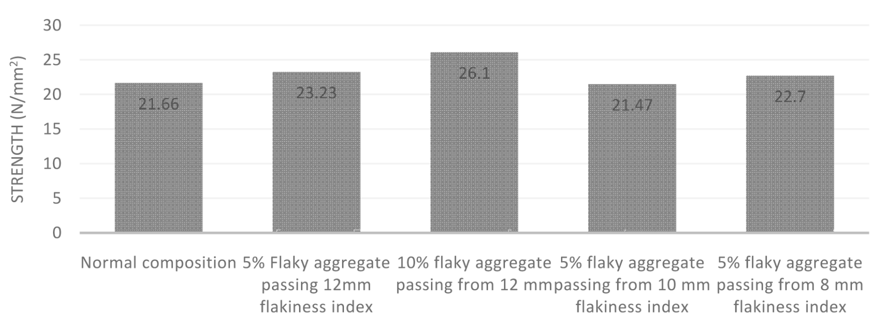

Figure 10: Rebound value for different composition of aggregate after 7 days of casting the cubes of M15 grade.

but is not appropriate for concretes with very low workability, i.e. compaction factor below 0.71. Compaction factor obtained for three samples are 0.83, 0.83, and 0.81.

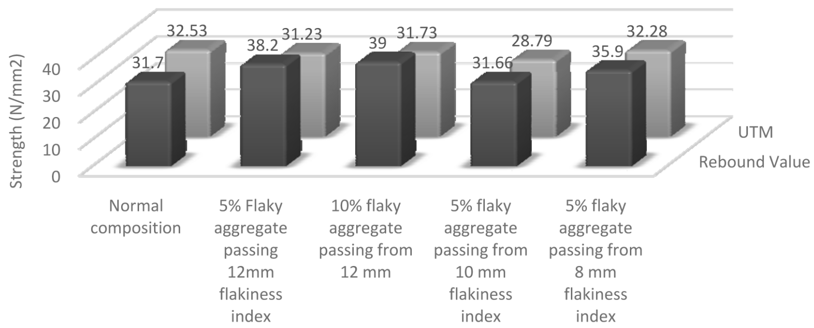

Figure 11: Rebound and UTM values obtained for different composition of aggregate after 28 days of casting the cubes.

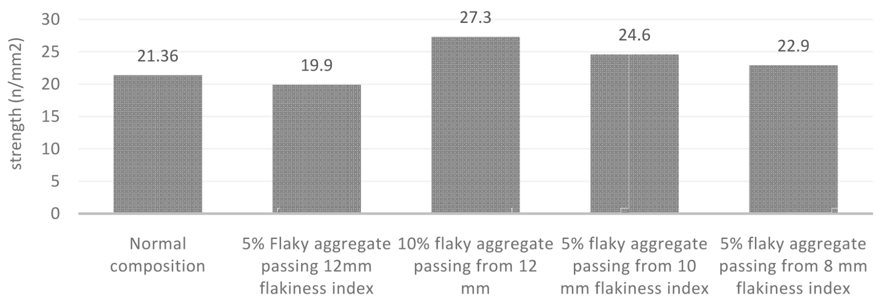

Figure 12: Rebound value obtain for different composition of aggregate after 7 days of casting the cubes.

7. CASTING OF CUBE SPECIMENS

The casting of cube was done in single stage. All cubes were cast for M15 and M20 grade of concrete mix. The cubes were cast in mould of size 150 X 150 X 150 mm. First entire cubemould is oiled, so that the formwork is easily removed from the mould after 24 hours. The compaction is done until the mould is completely filled and no gaps left. The cube is removed from the mould after 24 hours. After demoulding the cubes are cured for 28 days.

Figure 4 shows the cube specimen after casting.

All the cubes specimens were tested using NDT and UTM at 7 and 28 days. Tests of rebound hammer, pulse velocity and compressive strength are shown in Figure 5, 6, and 7 respectively.

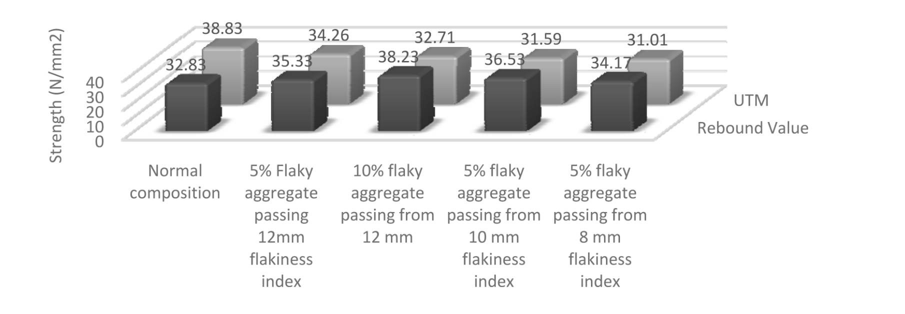

Figure 13: Rebound and UTM values obtained for different composition of aggregate after 28 days of casting the cubes.

8. RESULTS AND DISCUSSION

Various tests were performed on the prepared specimens. Results extracted from all these experiments are illustrated below on the basis of following sub-heads:

a) Ultrasonic-Pulse Velocity Test

The UPV test results for concrete cube with normal and flaky aggregate mix for 7 days and 28 days are shown in figure 8 and 9 respectively.

For M15 concrete, it can be observed that the pulse velocity is maximum for higher size and high percentage flaky aggregate and the minimum velocity is obtained for minimum size flaky aggregate.

For M20 concrete, it can be observed that UPV results aremaximum in lower percentage of flaky aggregate irrespective of the size of the aggregate.

b) Rebound Hammer and Compressive Strength Test

The rebound hammer and universal test results for concrete cube with normal and flaky aggregate mix for 7 and 28 days are shows in Figure 10, 11, 12 and 13.

(i). M15 Grade of Concrete
It is observed that rebound strength is maximum for 10 % flaky aggregate passing from 12 mm and it lowers down as aggregate size reduces for 7 and 28 days. But UTM strength is maximum for normal aggregate.

(ii). M20 Grade of Concrete
It is observed that rebound strength is maximum for 10% flaky aggregate passing from 12 mm flakiness index and it lowers down as aggregate size reduces for 7 and 28 days. UTM results show greater compressive strength in

normal aggregate concrete and strength reduces as the percentage and size of aggregate reduces.

9. CONCLUSIOIN

From the results of destructive and non-destructive tests, following salient conclusions can be drawn:

a) Rebound hammer

1. Rebound hammer reading for flaky aggregate are higher than normal aggregate cubes for M15 and M20 grade of concrete.
2. Maximum value is recorded for 10% flaky aggregate passing from 12 mm bar sieve.
3. Rebound value for M15 and M20 are almost same for 7 and 28 days respectively

b) Ultrasonic pulse velocity

1. Ultrasonic Pulse velocity reading for flaky aggregate is higher than normal aggregate cubes for M15 and M20 grade of concrete.
2. Maximum value is recorded for 10% flaky aggregate passing from 12 mm bar sieve for M15 grade of concrete.
3. Maximum value is recorded for 5% flaky aggregate passing from 12 mm and 8 mm bar sieve for M20 grade of concrete.
4. Ultrasonic Pulse velocity for M15 and M20 are almost same for 7 and 28 days respectively.

c) Universal testing machine

1. Highest value of compressive strength is obtained for normal aggregate.
2. Compressive strength increases with the decrease in the size of flakiness index for M15 and M20 grade of concrete.
3. Compressive strength for normal aggregate concrete is higher than its rebound strength. For flaky aggregate the trend is reversed.

REFERENCES

[1] A Abdullahi. M, The Effect of aggregate type on Compressive strength of concrete, International Journal of Civil and Structural Engineering, Volume **2**, No **3**, pp. 791-800, 2012. http://dx.doi.org/10.6088/ijcser.00202030008

[2] Bureau of Indian Standards: IS- 516: 1959, Methods of Test for Strength of Concrete, New Delhi, 2003.

[3] Bureau of Indian Standards: IS- 456-2000, Indian Standard Plain and reinforced concrete-code of practice (fourth revision), New Delhi, July 2000.

[4] Bureau of Indian Standards: IS- 2386-1963(Part-I), Indian Standard methods of test for aggregates for concrete, New Delhi.

[5] Bureau of Indian Standards: IS- 10262-1982, Indian Standard Recommended Guidelines for concrete mix design, New Delhi.

[6] Bureau of Indian Standards IS: 4031: Part 4, Methods of physical tests for hydraulic cement, Part 4- Determination of consistency of standard cement paste, New Delhi, 1988.

[7] Bureau of Indian Standards: IS 4031: Part 5, Methods of physical tests for hydraulic cement, Part 5- Determination of initial and final setting times, New Delhi, 1988.

[8] Kaplan, M F, The effect of the properties of coarse aggregate on the workability of concrete, Magazine of concrete research, Volume **10**, no. **29**, pp. 63-74, 1958. http://dx.doi.org/10.1680/macr.1958.10.29.63

[9] M Mansur M. A., Islam M. M., Interpretation of concrete strength for non-standard specimens. J. Mater. Civil Eng. AS CE, Vol.**14**, No.**2**, pp. 151–155, 2002. http://dx.doi.org/10.1061/(ASCE)0899-1561(2002)14:2(151)

[10] M Mathew B S, Bhuduru S and Issac K P, Influence of Flaky and Elongated Aggregates on the properties of Bituminous Concrete Mix, IE (I) Journal-CV, Vol. 87, pp.54-58, November 2006.

[11] M Markandeya Raju Ponnada, Combined effect of flaky and elongated aggregates on strength and workability of concrete, International Journal of Civil and Structural Engineering, Volume **5**, no.**4**, pp. 314-325, 2014. http://dx.doi.org/10.1504/IJSTRUCTE.2014.065915

[12] R Rogers, Chris and Gorman Bob, A flakiness test for fine aggregate, 16th Annual ICAR Symposium. Austin, Texas: International Center for Aggregates Research, 2008.

[13] Vyawahare. M. R, Modani. P. O, Improvement in workability and strength of concrete with flaky and elongated aggregate, 34th International Conference on our World in Concrete and Structure, 16-18, August 2009 Singapore.