Challenge Journal of Concrete Research Letters

Research Article

Standardization the effect of shape of aggregates with respect to compressive strength of concrete

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ABSTRACT

It is proved that aggregate's types have the severe effect on physicomechanical properties of concrete as aggregate covered almost 70 to 80 percent of the total volume of concrete. The effect of Flaky and Elongated aggregates on strength, durability, and workability of concrete has often been qualitatively expressed. The aim of this work is establishing the same quantitatively. M25 grade concrete for different ratios of weights of Elongated to normal aggregate, Flaky to normal aggregate and combined Flaky & Elongated aggregate to normal aggregate was tested for compressive strength at 28 days concrete. Three different types of aggregates were employed in the investigation, namely; normal aggregate, Elongated aggregate, and Flaky aggregate. Density and water absorption also kept constant to identify the effects on properties of concrete only for differences in shape. Thirty-six concrete cylinder was cast at 28 days. Varying dosages of Normal aggregate (60%, 65%, 70%, 75%,80% 85%), flaky aggregate (40%, 35%, 30%, 25%, 20%, 15%), elongated aggregate (40%, 35%, 30%, 25%, 20%, 15%), by mixture volume and length of 12inch (304.8 mm) & diameter of 6inch (152.4 mm) cylinder were used to test. Compaction was done by temping rod. Concrete cylinder was tested at the age of 28 days of curing. This study proposed of mixing three different types of aggregate in concrete. Compressive strength of concrete was measured by the effect of three different shapes of aggregates of varying dosages.

ARTICLE INFO

Article history:
Received 28 December 2017
Accepted 24 March 2018

Keywords:
Normal aggregate
Elongated aggregate
Flaky aggregate
Compressive strength
Water-cement ratio
Curing

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 concrete. Generally, irregular textured, normal, 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 a smooth or naturally weathered aggregate of similar mineralogy. As aggregates constitute 60% to 80% of the volume of concrete, the study of the influence of their properties on the performance of concrete is important. The relative effect of these variations in the nature of coarse aggregates on the compressive strength achieved by the concretes has been investigated and presented in this study. The shape of aggregate have a remarkable bearing capacity on compressive strength and permeability of pervious concrete. The magnitude of this effect is determined by conducting laboratory experiments on mixes of pervious concrete prepared using aggregates of different shape with varying water cement ratio. The shape of the aggregate is measured in terms of its normality number which is a laboratory method intended for comparing the properties of different aggregates for mix design

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ISSN: 2548-0928 / DOI: https://doi.org/10.20528/cjcrl.2018.01.001

purposes. strength vary as a function of shape of the aggregate along with size of aggregate and water cement ratio in the mix which leads to the conclusion that shape of aggregate shall be considered as an important parameter in deciding the suitability of course aggregate to prepare mix. Shape of coarse aggregates is one of the most important characteristic that affects the properties of concrete. However, its influence on mix design has not been considered in ACI codes of practice for design of concrete mix (ACI 211.1-91). Shape is related to sphericity, form and roundness (Galloway, 1994).

Sphericity is a measure of how nearly equal are the three principal axes or dimensions of a particle. The form is the measure of the relation between the three dimensions of a particle based on ratios between the proportions of the long, medium, and short axes of the particle. Form, also called 'shape factor', is used to distinguish between particles that have the same numerical sphericity (Hudson, 1999).

Concrete is a composite material produced by the homogenous mixing of selected proportions of water, cement, and aggregates. Strength is the most desired quality of a good concrete. It should be strong enough, at hardened state, to resist the various stresses to which it would be subjected. Compressive strength of concrete, therefore, is the value of test strength below which not more than a prescribed percentage of the test results should fall (Kong and Evans, 1987).

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 normal 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.

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. Maximum compressive strength at total ages was noted with concrete made from quartzite aggregate tracked by river gravel and then granite aggregate.

Jain and Chouhan (2011) reported on the influence of shape of aggregate on compressive strength and permeability properties of permeable concrete. The shape of aggregate is measured in terms of normality 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.

Yong (2008) stated that smooth rounded aggregates was more workable but yielded a lesser compressive strength in the matrix than irregular aggregates with rough surface texture.

They were also of the opinion that a fine coating of impurities such as silt on the aggregate surface could hinder the development of a good bond and thus affects the strength of concrete. Chen and Liu (2004) as well as Rao and Prasad (2002) viewed aggregates as the skeleton of concrete and consequently persuaded that all forms of coatings should be avoided in order to achieve a good concrete.

Mansur and Islam (2002) reported an experimental study on the effects of different concrete specimen types on the compressive strength and established the interrelationships between their strengths.

The test carried out by Soroka (1993) revealed the variations between the compressive strengths of concrete made with crushed stone and uncrushed stone. He achieved a better compressive strength with the crushed stone than the uncrushed stone. This strength performance was as a result several factors like water/cement ratio, grading, surface texture, shape, strength, and stiffness of aggregates used.

The objective of this work is to study the separately and combined effect of Elongated and Flaky of coarse aggregate on the compressive strength concrete and to establish a relation between strength of concrete with standard shape & proportion and irregular shape & proportion .The properties of the ingredients were determined as per ACI procedures and M25 grade concrete was designed. The coarse aggregate passing 40 mm and retained on 10 mm was considered for sorting into three parts – Elongated, Flaky and normal aggregates. Cylinders are casted for different ratios of weights of Elongated to normal, Flaky to normal & combined Elongated, Flaky aggregate and normal aggregate. Compressive strengths at 28 days were considered for study.

2. Mixture Proportions

A normal mix ratio of 1:2:4 (Cement: Fine Aggregate: Coarse Aggregate) was adopted for the purpose of this work and a water-cement ratio of 0.45 was used. The mix composition was computed using the absolute volume method from Eq. (1).

$$\left(\frac{W_W}{1000}\right)+\left(\frac{W_c}{1000SG_c}\right)+\left(\frac{W_{FA}}{1000SG_{FA}}\right)+\left(\frac{W_{CA}}{1000SG_{CA}}\right)=1\ (\mathrm{m}^3)\ . \quad (1)$$

where; W_W is weight of water (kg), W_C is weight of cement (kg), W_S is weight of sand (kg), SG_{FA} is specific gravity of sand, and SG_C is specific gravity of cement . Following cases were considered for this investigation work given in Table 1.

3. Experimental Investigation

The materials required for performing the project were procured. About 300 kg of coarse aggregate (20 mm passing and 4.75 mm retained), 150 kg of fine aggregates (passing 4.75 mm) and about 100 kg of 53 grade cement were procured. Preliminary tests on properties of these ingredients were done as per ACI procedures and the results are as follows:

Cement:

- Cement grade : 53 grade OPC [ACI 318:21.10.3.4]
- Fineness : 7.33% [ACI 211.1-91]
- Specific gravity : 3.04 [ACI 318:1904.2.2]
- Standard consistency : 28% [ACI 318:1903.3]
- Initial setting time : 87 minutes [ASTM C494]
- Final setting time : 515 minutes [ASTM C4 94]
- Soundness : 3 mm [ACI 211.1-91]

Table 1. Designation of different molds.

Designation	Description
M25-10	M-25 concrete mix with normal composition of concrete.
M25-40-10[1]	M-20 concrete mix with 60% normal coarse aggregate mix + 40% of Flaky aggregate retained on 10 mm aperture size.
M25-35-10[1]	M-25 concrete mix with 65% normal coarse aggregate mix +35% of Flaky aggregate passing from 10 mm aperture size.
M25-30-10[1]	M-20 concrete mix with 70% normal coarse aggregate mix + 30% of Flaky aggregate passing from 10 mm aperture size.
M25-25-10[1]	M-25 concrete mix with 75% normal coarse aggregate mix + 25% of Flaky aggregate retained on 10 mm aperture size.
M25-20-10[1]	M-20 concrete mix with 80% normal coarse aggregate mix + 20% of Flaky aggregate passing from 10 mm aperture size.
M25-15-10[1]	M-25 concrete mix with 85% normal coarse aggregate mix +15% of Flaky aggregate retained on 10 mm aperture size.
M25-40-10[2]	M-20 concrete mix with 60% normal coarse aggregate mix + 40% of Elongated aggregate retained on 10 mm aperture size
M25-35-10[2]	M-25 concrete mix with 65% normal coarse aggregate mix +35% of Elongated aggregate passing from 10 mm aperture size.
M25-30-10[2]	M-20 concrete mix with 70% normal coarse aggregate mix + 30% of Elongated aggregate passing from 10 mm aperture size.
M25-25-10[2]	M-25 concrete mix with 75% normal coarse aggregate mix + 25% of Elongated aggregate retained on 10 mm aperture size.
M25-20-10[2]	M-20 concrete mix with 80% normal coarse aggregate mix + 20% of Elongated aggregate passing from 10 mm aperture size.
M25-15-10[2]	M-25 concrete mix with 85% normal coarse aggregate mix +15% of Elongated aggregate retained on 10 mm aperture size.
M25-60-10[1]	M-25 concrete mix with 40% normal coarse aggregate mix +30% of Elongated +30% flacky aggregate retained on 10 mm aperture size.
M25-60-10[2]	M-25 concrete mix with 40% normal coarse aggregate mix +25% of Elongated +35% flacky aggregate retained on 10 mm aperture size.
M25-60-10[3]	M-25 concrete mix with 40% normal coarse aggregate mix +20% of Elongated +40% flacky aggregate retained on 10 mm aperture size.
M25-60-10[4]	M-25 concrete mix with 40% normal coarse aggregate mix +15% of Elongated +45% flacky aggregate retained on 10 mm aperture size.
M25-60-10[5]	M-25 concrete mix with 40% normal coarse aggregate mix +35% of Elongated +25% flacky aggregate retained on 10 mm aperture size.
M25-60-10[6]	M-25 concrete mix with 40% normal coarse aggregate mix +40% of Elongated +20% flacky aggregate retained on 10 mm aperture size.

Coarse aggregates:
- Fineness modulus : 8.73 [ACI 211.1-91]
- Specific gravity : 2.79 (20 mm) [ACI 211.1-91]
- Water absorption value : 0.5% [ASTM C 128]
- Free surface moisture : NIL
- Flakiness index : 10% [ACI 211.1-91]
- Elongation index : 10.5% [ACI 211.1-91]
- Aggregate crushing value : [ASTM C 128]
- Aggregate impact value : [ACI 211.1-91]

Fine aggregates:
- Fineness modulus : 2.585 [ACI 211.1-91]
- Specific gravity : 2.71 [ACI 211.1-91]
- Water absorption : NIL [ASTM C 128]
- Free surface moisture : NIL 5 Zone of sand : II

Mix design procedure M25 grade concrete mix design was performed for the following design data.
- Grade designation: M25
- Type of cement: OPC 53 grade
- Maximum normal size of aggregate: 40 mm
- Minimum cement content: 300 kg/m3
- Maximum water cement ratio: 0.45
- Workability: 80 mm slump
- Exposure condition: mild
- Method of concrete placing: manual
- Degree of supervision: good
- Type of aggregate: normal aggregate, flacky aggregate, Elongated aggregate.

Table 2 shows the total ingredient of all mix proportions.

4. Results and Discussion

Thirty six batches of concrete cylinders were cast and compressive strength at 28 days curing were determined. The compressive strength test was performed as per ACI 318-02: 5.6.2.4.The results obtained in Table 3.

Table 2. Total ingredient of all mix proportions.

Water	Cement	Sand	Normal aggregate	Elongated aggregate	Flacky aggregate
28.5 lit.	63.5kg	142 kg	185kg	32kg	32kg

Table 3. Final results.

Designation Description	Ratio	Compressive strength (N/mm^2)
M25-10	-	27.42
M25-40-10^1	40 : 30 : 30	24.18
M25-35-10^1	40 : 25 : 35	25.41
M25-30-10^1	40 : 20 : 40	27.44
M25-25-10^1	40 : 15 : 45	27.86
M25-20-10^1	40 : 35 : 25	26.92
M25-15-10^1	40 : 40 : 20	26.64
M25-40-10^2	60 : 40 : 00	25.41
M25-35-10^2	65 : 35 : 00	26.94
M25-30-10^2	70 : 30 :00	28.13
M25-25-10^2	75 : 25 : 00	28.32
M25-20-10^2	80 : 20 : 00	28.05
M25-15-10^2	85 : 15 :00	27.56
M25-60-10^1	60 : 00 :40	26.84
M25-60-10^2	65 : 00 : 35	27.32
M25-60-10^3	70 : 00 :30	26.68
M25-60-10^4	75 : 00 : 25	27.54
M25-60-10^5	80 : 00 : 20	28.28
M25-60-10^6	85 : 00 :15	29.24

Fig. 1 shows that, compressive strength becomes high for the dosage of 25% flaky aggregate mixed with Normal aggregate and it becomes close to standard at 33% dosage. Fig. 2 shows that compressive strength becomes high for the dosage of 25% Elongated aggregate mixed with Normal aggregate and it becomes close to standard at 33% dosage. Fig. 3 shows that Angularity Number becomes high for the dosage of 15% elongated aggregate mixed with Normal aggregate and it becomes close to standard at 15% to 20% dosage. Fig. 4 shows that Compressive Strength rises with the increase in Angularity Number and decreases with the increase in Angularity Number after the value of 6. Fig. 5 shows that compressive strength becomes high for the dosage of 25% flaky aggregate mixed with Normal aggregate and it becomes close to standard at 22.5% & 30% dosages. Fig. 6 shows that compressive strength becomes high for the dosage of 25% flaky aggregate mixed with Normal aggregate and it becomes close to standard at 30% dosage. Fig. 7 shows that, Angularity Number becomes high for the dosage of 40% flaky aggregate mixed with Normal aggregate and it becomes close to standard at 15% to 30% dosage. Fig. 8 shows that Compressive Strength rises with the increase in Angularity Number and decreases with the decrease in Angularity Number. Fig. 9 shows that compressive strength becomes high for the dosage of 0.5 ratio of Elongated & Flaky Aggregate in the mix and it becomes close to standard at the ratio 0.8 & 2.8 dosages. Fig. 10 shows that compressive strength becomes close to standard at the ratio 0.8 & 2.8 dosages of Elongated & Flaky Aggregate in the mix. Fig. 11 shows that Angularity Number rises with the increase in dosages of Elongated & Flaky Aggregate in the mix. Fig. 12 shows that Compressive Strength rises with the decrease in Angularity Number and increases with the increase in Angularity Number after the value of 10.

5. Conclusions

After completion of the tests and analysis of the results regarding compressive strength of concrete using three different shapes of aggregates it is evident that shape of aggregate plays an important role in property of strength of concrete. With the variation of percentage of aggregate following conclusions can be deduced-

- Strength increased with the decrease of percentage of flaky aggregate from 40% to 25%, after the strength decreased.
- Strength increased with the decrease of percentage of elongated aggregate from 40% to 25%, after the strength decreased.
- The effect of elongated aggregates is more on the strength of concrete when compared to that of flaky aggregates.
- The strength of concrete when 100% perfectly Normal aggregate was used is found to be maximum and the maximum 28days characteristic compressive strength was observed to be 27.42 MPa.
- For a constant EA: FA ratio, density increases but characteristic compressive strength decreases with decrease in NA: TA ratio. For a constant NA: EA: FA ratio, characteristic compressive strength is maximum.

- From the results, it can be concluded that the effect of flaky and elongated aggregates on strength is considerable. Even though, the work is done on one particular grade of concrete, it can be considered that the nature of variation may not change with grade of concrete.
- Results indicate that strength concrete varies as a function of shape of the aggregate along with size of aggregate and water cement ratio in the mix which leads to the conclusion that shape of aggregate shall be considered as an important parameter in deciding the suitability of course aggregate to prepare pervious concrete.

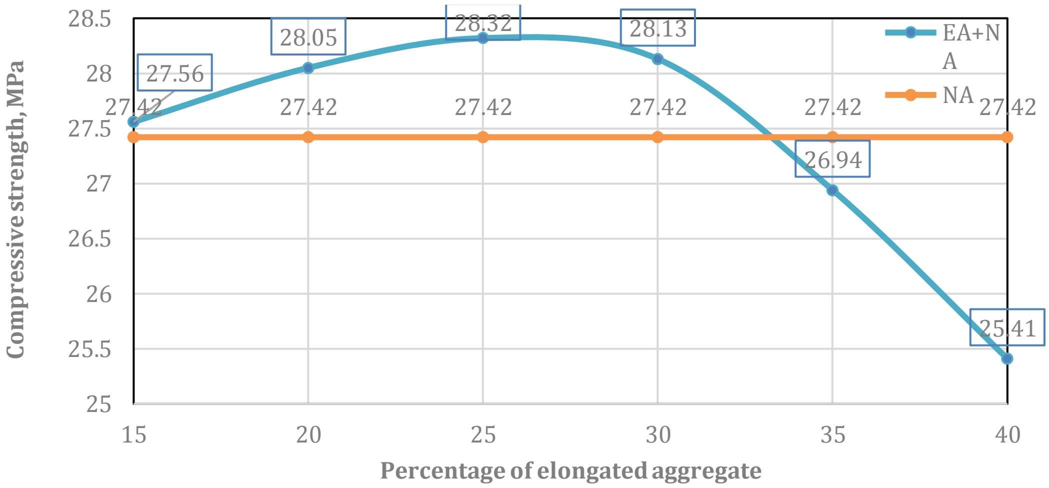

Fig. 1. Percentage of Elongated Aggregate in the mix Vs Compressive Strength, MPa.

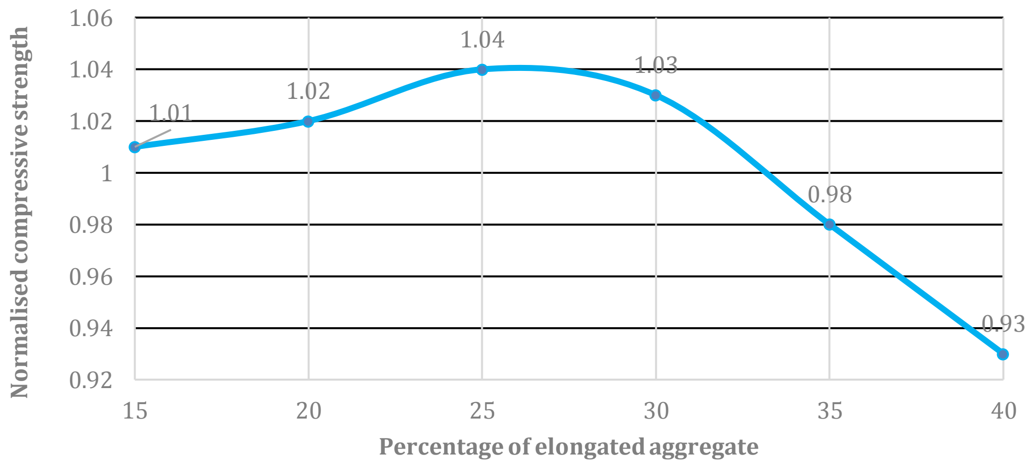

Fig. 2. Percentage of Elongated aggregate in the mix Vs Normalized Compressive Strength.

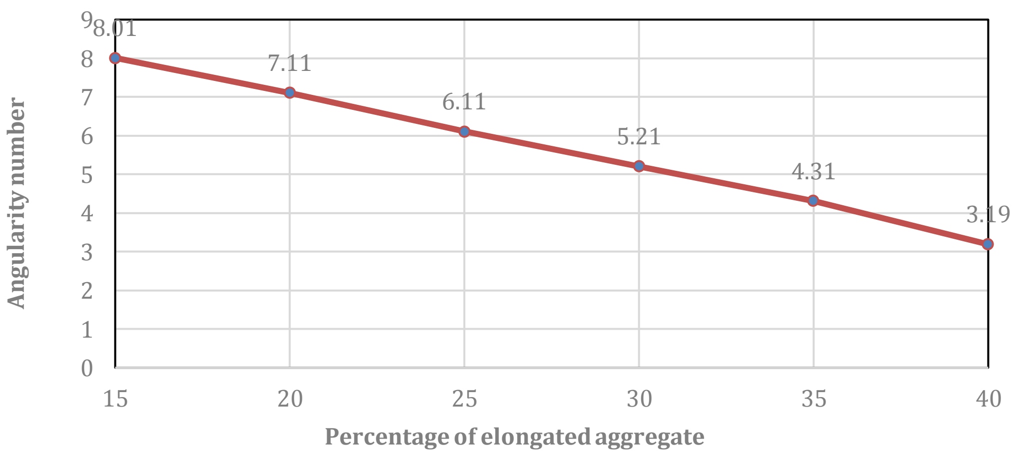

Fig. 3. Percentage of elongated aggregate in the mix Vs Angularity Number of coarse aggregate.

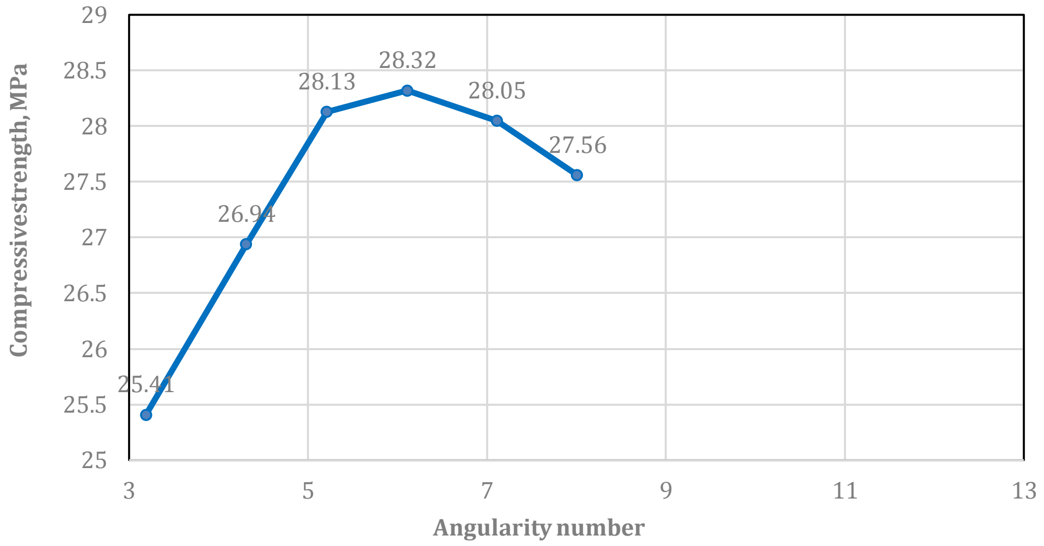

Fig. 4. Angularity Number of coarse aggregate in the mix Vs Compressive Strength, MPa.

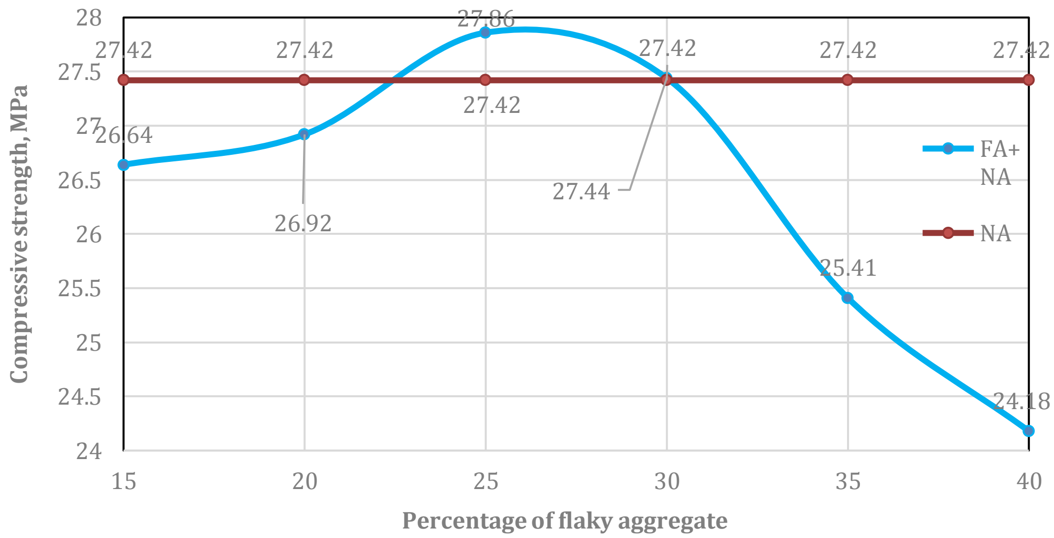

Fig. 5. Percentage of flaky aggregate Vs Compressive Strength.

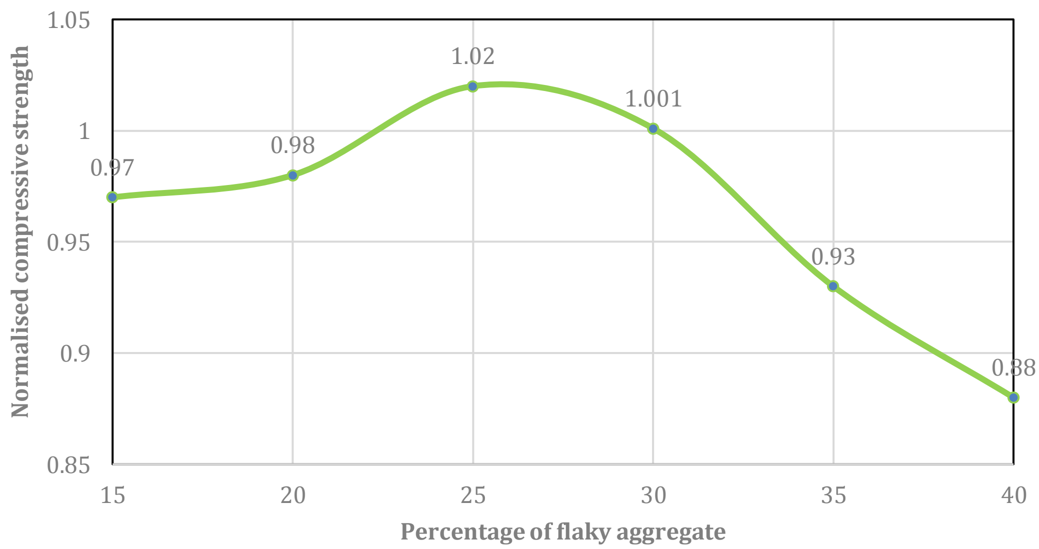

Fig. 6. Percentage of flaky aggregate Vs Normalized Compressive Strength, MPa.

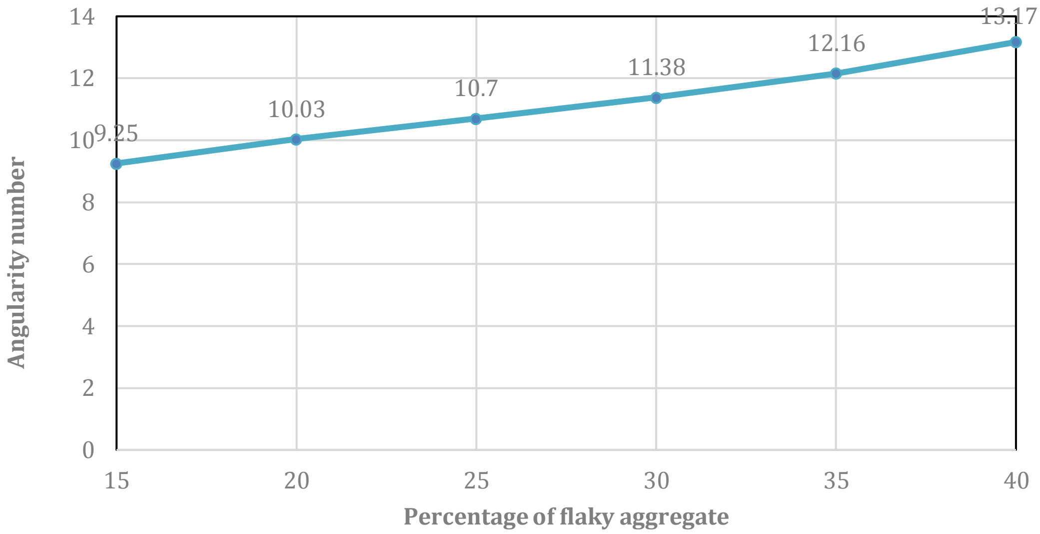

Fig. 7. Percentage of flaky aggregate Vs Angularity Number coarse aggregate in the mix.

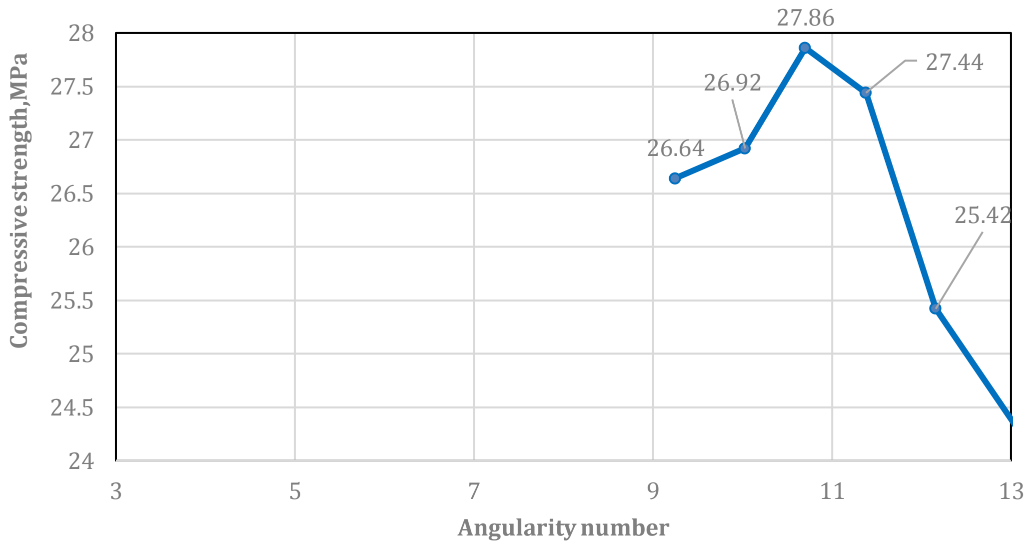

Fig. 8. Angularity Number of coarse aggregate in the mix Vs Compressive Strength, MPa.

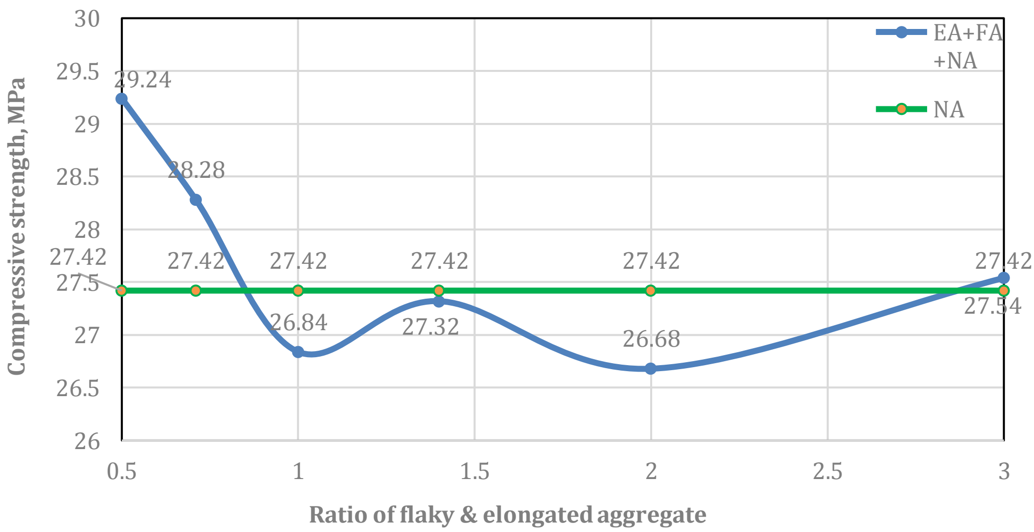

Fig. 9. Ratio of Elongated & Flaky Aggregate in the mix Vs Compressive Strength, MPa.

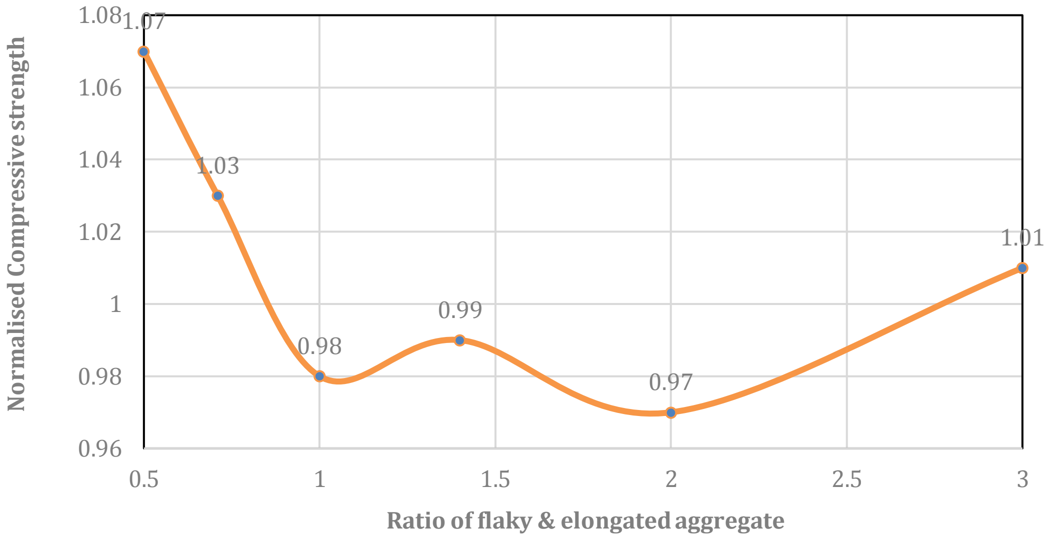

Fig. 10. Ratio of Elongated & Flaky Aggregate in the mix Vs Normalized Compressive Strength.

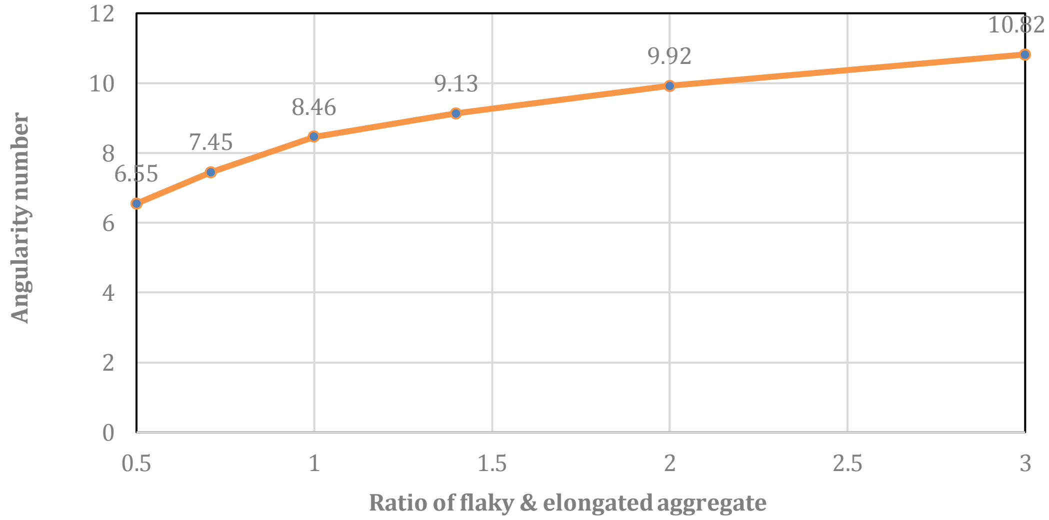

Fig. 11. Ratio of Elongated & Flaky Aggregate Vs Angularity Number of coarse aggregates.

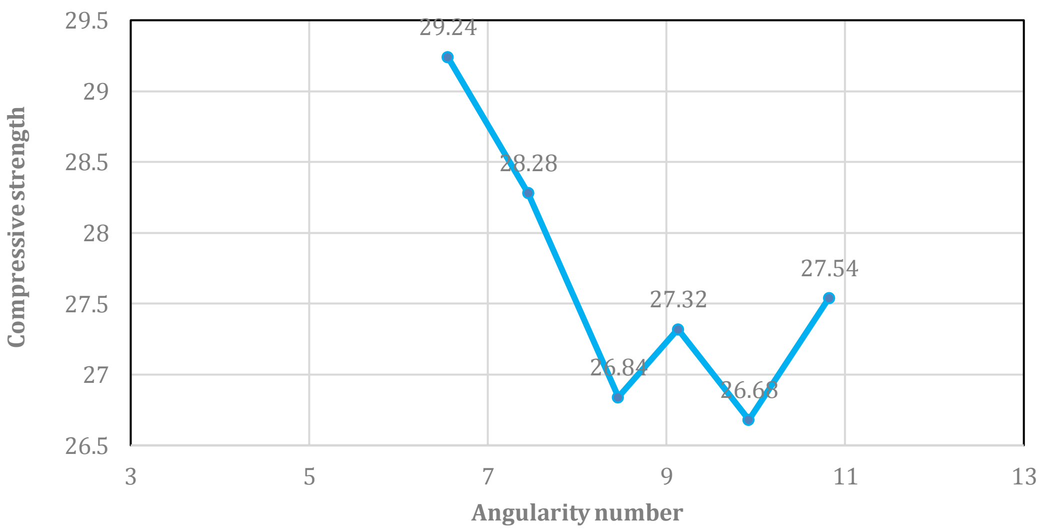

Fig. 12. Angularity Number of coarse aggregate in the mix Vs Compressive Strength, MPa.

References

Abdulahhi M (2013). Effects of aggregate type on compressive strength of concrete. *International Journal of Civil and Structural Engineering*, 2(3), 791-800.

Aginam CH, Chidolue CA, Nwakire C (2013). Investigating the effects of coarse aggregates types on the compressive strength of concrete *International Journal of Engineering Research and Applications*, 3(4), 1140-1144.

Chen B, Liu J (2004). Effect of aggregate on the fracture behavior of high strength concrete. *Construction and Building Materials*, 18(8), 585-590.

Galloway Jr JE (1994). Grading, shape, and surface properties. *ASTM Special Technical Publication*, No. 169C, 401-410, Philadelphia.

Hudson B (1999). Modification to the fine aggregate normality test. *Proceedings of Seventh Annual International Center for Aggregates Research Symposium*, Austin, TX, USA.

Jain AK, Chouha JS (2011). Effect of shape of aggregate on compressive strength and permeability properties of pervious concrete. *International Journal of Advanced Engineering Research and Studies*, 1(1), 120-126.

Jimoh AA, Awe SS (2007). A study on the influence of aggregate size and type on the compressive strength of concrete. *Journal of Research Information in Civil Engineering*, 4(2), 157-168.

Kong FK, Evans RH (1987). Reinforced and Prestressed Concrete. Pitman Publishers, London, UK.

Mansur MA, Islam MM (2002). Interpretation of concrete strength for non-standard specimens. *Journal of Materials in Civil Engineering*, 14(2), 151-155.

Muhit B, Haque S, Rabiul Alam MD (2013). Influence of crushed aggregates on properties of concrete. *American Journal of Civil Engineering and Architecture*, 1(5), 103-106.

Ponnada MR (2014). Combined effect of flaky and elongated aggregates on strength and workability of concrete. *International Journal of Structural Engineering*, 5(4), 314-325.

Rangaraju P, Balitsaris M, Kizhakommudon H (2013). Impact of aggregate gradation on properties of Portland cement concrete. *Final Report*, Clemson University, Clemson, South Carolina, USA.

Shetty MS (2008). Concrete Technology. S. Chand Publication Company Ltd., New Delhi, India.

Soroka I (1993). Concrete in Hot Environments. Alden Press, London, UK.

Yong TL (2008). Performance of Concrete Containing Engine Oil. *M.Sc. Thesis*, University of Technology, Kuala Lumpur, Malaysia.