Effect of Aggregate Shapes on the Characterstics of Concrete

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Abstract:

More than 90% of concrete is made up of aggregates, which also heavily influence the material's strength. In this work, elongation and thickness gauge are used to calculate shape properties such flakiness and elongation. Granite was employed as the study's aggregate. Concrete is subjected to slump testing, water absorption tests, compressive strength tests, and flexural strength tests while aggregate is subjected to aggregate crushing value and aggregate impact value tests. For the compressive strength test, a total of 30 concrete cubes made from 1:1.5:3 mixes are created, and for the flexural strength test, 5 reinforced concrete beams are created. The slump for each sample tested is verified as accurate. It has been discovered that a low proportion of flaky and elongated aggregate has a higher compressive strength than a big percentage, and that the percentage has a significant impact on the compressive strength of the concrete cube.

Keywords: Concrete, aggregate, flaky, flexural and compressive strengths.

INTRODUCTION:

Concrete is regarded as the most widely used man-made material in the world, seconded only to water as the most utilized substance. One of the most crucial building elements, it is also very affordable, simple to fabricate, provides continuity and solidity, and binds to other materials quickly. It is composed in the right quantities of cement, fine aggregate (sand), coarse aggregate (crushed or uncrushed stones), and water. The raw materials needed to manufacture the concrete are the secret to good quality concrete. The water-cement ratio, slump, cement-to-aggregate ratio, cement quality, aggregate gradation, and curing procedure effectiveness have all been found to have a significant impact on the strength of concrete. The characteristics of wet and hardened concrete are greatly impacted by the specific gravity, particle size analysis, shape, and surface texture of the aggregates, whereas the hardened state of concrete is greatly influenced by the mineralogical composition, toughness, and elastic modulus.

The particle form of fine and coarse aggregate with reference to water demand for sufficient hydration of concrete was examined in an effort to understand variations in mixing water requirements as it affects aggregate. The form of the fine aggregate was shown to have a greater impact on water requirements than the coarse aggregate.

From the preceding and when considering the permissible levels, it was discovered that the fine aggregate's particle size distribution had a bigger impact on the qualities of concrete than did coarse aggregates. Given that river sand, the most frequent fine aggregate used in the manufacture of concrete, has become exceedingly expensive and relatively scarce, the selection of the proper type of fine aggregate for concrete production is of great significance. Therefore, there is a huge need for substitute materials made from industrial wastes, including grit, also known as quarry dust, which is locally accessible at various quarry sites.

LITERATURE REVIEW:

Aves and A Jr (2022)

- A study examined the concrete's compressive strength built with fine and coarse particles from five different regions. Several physical tests were used to assess the impact of these aggregates on the concrete's compressive strength, including those for specific gravity and absorption, sieve analysis, abrasion testing, workability testing, and compressive strength testing.
- The results showed that the average concrete's compressive strength formed from fine and coarse aggregates from natural river quarry sites was 23.465 MPa, and that provided crushed fine and coarse particles had an average compressive strength of 19.555 MPa. The aggregates from rivers that occasionally experienced saline water intrusion had a lower average compressive strength (18.54 MPa). For 7, 14, and 28 days, compression strength observations were made.

Pertiwi et.al (2021)

- The impact of coarse particles on the concrete's compressive strength was studied in a research paper. Two concrete samples—CS1 and CS2—were made utilising natural river sand as the fine aggregate, regular Portland cement as the coarse aggregate, and polymer admixture to maintain workability. The coarse aggregate combinations used were 5 mm–10 mm and 10 mm–20 mm. The planned concrete slump flow was 60± 5 mm, and the water-cement ratio of 1: 2: 4 and 0.55 was maintained.
- The test for compressive strength of a 300 x 300 mm concrete cylinder after 28 days of curing revealed the highest compressive strength of 33.28 MPa for CS1, followed by 36.10 MPa for CS2. Resizing the coarse aggregate produced these various compressive strength characteristics, indicating the impact of coarse aggregate size on concrete.

Bian et.al (2021)

- The response surface methodology is used in the study work to create the regression equations for the peak stress and elastic modulus of recycled concrete. The coarse aggregate content, maximum aggregate size, and aggregate shape are used as design factors. The impact of aggregate qualities on the mechanical properties of recycled concrete was examined using experiments, theoretical analysis, and numerical modelling.
- The results revealed that when the coarse aggregate content is 45 percent, the maximum coarse aggregate size is 16 mm, and the regular round coarse aggregates occupy 75 percent, the peak stress and elastic modulus of recycled concrete reach their best.

Nisa and Kumar (2021)

- The workability and compressive strength of cement concrete for stiff pavements have been correlated in the research paper with the morphology of coarse aggregate particles.
- The experimental data showed a strong relationship between some aggregate shape parameters, workability, and compressive strength. The concrete built from various forms of coarse particles showed the highest compressive strength at various ages.

Oluwasola et.al (2020)

- The research paper investigated for the compressive strength test, a total of 122 concrete cubes made from 1:2:4 and 1:3:6 mixes were created, and for the flexural strength test, 48 reinforced concrete beams were created.
- The slump test results indicated increased percentage of flaky and elongated aggregates reduces workability. Considering the result of water absorption, flaky aggregates absorb more water compared to elongated aggregate.
- The highest compressive strength, 15 N/mm2 is in compliance with the concrete compressive strength of normal 1:2:4 mix. It was observed that the flexural strength was high with 30% flaky and 30% elongated aggregate, as opposed to a higher percentage of flaky and elongated aggregate, which provides lower flexural strength.

Prajapati and Karanjit (2019)

- The purpose of the study was to look at the effects of coarse aggregate types on the compressive strength of various nominal mix concrete grades.
- The majority of coarse aggregates had an angular shape, whereas a few varieties were sub-angular and flaky. Three distinct grades of nominal mix, M1 (1:2:4), M2 (1:2:3), and M3 (1:1.5:3) by weight, were used to create a total of 90 concrete cubes measuring 15 cm.
- The observations demonstrate that depending on the source of coarse aggregate, the compressive strength of various nominal mix concrete classes changes dramatically. Lean mix concrete (1:2:4 & 1:2:3) has a comparatively wide range of compressive strength when compared to rich mix concrete

(1:1.5:3). Concrete cubes from samples A and B fell due to crushing of the coarse aggregate, whereas cubes from samples C, D, and E primarily broke due to bond failure.

George and Asha K (2018)

- The strength parameters of M30 grade concrete were studied. Castings of cubes, beams, and cylinders were made by partially replacing natural coarse aggregate with manufactured fly ash aggregate in amounts of 25%, 30%, 35, 40%, 45, and 50%. The compressive strength, flexural strength, and split tensile strength of the cast cubes, beams, and cylinders were all assessed independently.
- According to the results, fly-ash aggregates are more workable than angular-shaped natural aggregates. Fly-ash aggregates have a lower aggregate crushing and impact value than is permitted. For a substitution of 30–35 percent, the compressive strength of FAA concrete is roughly 80% that of a typical concrete mix, and it continues to decline for increasing percentage replacement.

Ogundipe et. al (2018)

- In a research report, the impact of aggregate size on concrete's compressive strength was examined. Concrete cubes made with 6, 10, 12,5, 20, and 25 mm aggregates for the two nominal mixes were constructed and tested for compressive strength after 7, 21, and 56 days of curing. Two nominal mixes, 1:2:4 and 1:3:6, were employed in the analysis. The investigation discovered that the strength development for both nominal mixtures followed the same pattern.
- According to the results, compressive strength rises with increasing aggregate size up to 12.5 mm, with 20 mm concrete having a higher compressive strength than 25 mm concrete. Concrete's compressive strength improves along with the size of the aggregate used in the mix.
- It was discovered, however, that there is a specific aggregate size that will provide the optimal performance and utilising an aggregate size bigger than it will not produce the desired outcome.

Ajamu and Ige (2015)

- The research examined at how varying coarse aggregate sizes affected concrete beams' compressive and flexural strengths. Concrete cubes and beams with varying aggregate sizes of 9.0mm, 13.2mm, 19mm, 25.0mm, and 37.5mm were made using standard moulds with internal dimensions of 150x150x150mm for the concrete cubes and 150x150x750mm for the reinforced concrete beam in accordance with BS 1881-108 (1983) and ASTM C293 standards.
- A 1:2:4 mix ratio was used, maintaining a water cement ratio of 0.65. All of the generated specimens underwent a 28-day water cure before being put through a compressive and flexural strength test on a universal testing machine.
- According to the results, the compressive strength of cubes for coarse aggregate sizes of 13.2mm, 19mm, 25.0mm, and 37.5mm was 21.26N/mm2, 23.41N/mm2, and 24.31N/mm2, respectively. Test beams have respective flexural strengths of 4.93N/mm2, 4.78N/mm2, 4.53N/mm2, 4.49N/mm2, and 4.40N/mm2. The results led to the conclusion that concrete should be composed with finer coarse particles if it is to be used primarily to resist flexural loads.

Aginam et.al (2013)

- Three distinct kinds of coarse materials, with a maximum size of 20 mm, were utilised in the experiment: crushed granite, washed gravel, and unwashed gravel. Investigated were the relative densities and grading of the aggregates.
- For the investigation, a mix ratio of 1:3:6 and a water/cement ratio of 0.6 were used, respectively. At 28 days, the goal mean strength was 15N/mm2. For each type of coarse aggregate, 12 concrete cubes (150 mm x 150 mm x 150 mm) were cast, and four of them were crushed after 7, 14, 21, and 28 days of maturation.
- After seven days of curing, every cube had acquired the desired mean strength. The concretes prepared using crushed granite, washed gravel, and unwashed gravel had corresponding 28-day strengths of 25.1 N/mm2, 20.0 N/mm2, and 16.9 N/mm2.

Polat et.al (2013)

- The impact of different aggregate types on the compressive strength of concrete was examined using aggregate shape indices such aspect ratio, elongation, flatness, form factor, roundness, shape factor, and sphericity. Four different types of coarse aggregate and natural aggregate were used to make the concrete for testing.
- The test results showed a strong correlation between compressive strength and several aggregate shape characteristics. It was shown that the particle shape factors are capable of measuring the combined

effect of many particle shape characteristics, including as flatness, elongation, and sphericity, on the compressive strength of an aggregate. Spherical particles were favoured for concrete's improved compressive strength, UPV, unit weight, and slump values. The aggregate becomes more spherical the higher the values supplied.

Jain and Dr. Chouhan (2011)

- The compressive strength and permeability of pervious concrete are significantly influenced by the shape of the aggregate used in its production. By conducting laboratory experiments on previous concrete mixtures made with aggregates of various shapes and variable water-cement ratios, the size of this effect was ascertained.
- Results show that shape of the aggregate should be taken into consideration as an important parameter in determining the suitability of course aggregate to prepare pervious concrete because strength and permeability of pervious concrete vary as a function of shape of the aggregate along with size of the aggregate and water cement ratio in the mix.

OBJECTIVES:

This research is focused on analyzing the behaviour of concrete using aggregates of different sizes. The primary objectives of this research are stated below:

I. To investigate hardened concrete, the shape and texture of the aggregate influence the qualities of new concrete.
II. To analyze the majority of naturally occurring riverbed or seashore sands and gravels are rounded and smooth, making them excellent aggregates.
III. To identify the behaviour of the shape of aggregate in concrete
IV. To identify the concrete's compressive strength with different shapes of aggregate.
V. to identify the flexural strength of concrete with different shapes of aggregate.

EXPERIMENTAL SETUP:

Slump Test

Concrete consistency is assessed using the slump test, which can be performed in a lab or on-site. The results of a slump test reveal if concrete in various batches is uniform. Concrete slumps' shapes reveal details about the material's quality and usability. Making a few tamping or blows by tapping a rod on the base plate can also be used to assess the qualities of concrete with regard to its inclination to segregate. Because the equipment is inexpensive and the process is straightforward, this test has been in use since 1922. The Slump cone's design demonstrates how easily concrete can be worked. British Standard: Indian standard for slump cone testing is IS 1199-1959.

Procedure of Slump Test

The steps for the Slump test are as follows:

- The internal surface of the mould is first cleaned, made dry, and free of any other previous concrete sets.
- After that, set the mould on the flat, straight, absorbent surface.

- Fresh concrete is then poured into the mould in four levels, each of which is tapped 25 times with a tapping rod before the top is levelled with a trowel.
- In order to avoid disturbing the concrete cone, the mould is then gradually pushed vertically and removed from the concrete.
- Due to the effect of gravity, this unbound concrete deformed the entire surface, causing it to subside.
- There is an SLUMP of concrete in the area where the concrete is subsiding.
- The sinking value of concrete is the height difference, expressed in millimetres, between the mould cone and the height of the concrete.

The sample's recorded slump value is = mm.

Compressive Strength

The ability to support loads on the surface of a material or structure without cracking or deforming is known as compressive strength. An object's size will decrease when it is compressed, but it will lengthen when it is under tension. Concrete is tested for compressive strength in accordance with (IS:516-1959).

Cross-sectional Area / Load equals Compressive Strength.

Apparatus for Compressive Strength Test

Fig 1 Apparatus for Compressive Strength Test

Procedure for Concrete Cube Test

- After the designated curing time, remove the samples from the water, and wipe off any excess water from the surface.
- The samples' size was measured to the closest 0.2m.
- The testing device's bearing surface has to be cleaned.
- Place the sample in the apparatus so that the opposing sides of the cube's cast receive the load.
- Align the sample's centre with the base plate of the device.
- Turn the movable part slowly by hand until it reaches the specimen's top side.
- until the sample fails, gradually apply load at a rate of 140kg/cm2 per minute.
- The failure's maximum load, as well as any odd activity, are noted.

Split Tensile Strength

Tensile strength is one of the crucial characteristics of concrete because structural loads make it susceptible to tensile cracking. Steel is utilised to carry the tension forces since the tensile strength of concrete is substantially lower than its compressive strength. According to estimates, the tensile strength of concrete is equivalent to around 10% of its compressive strength. Due to the complexity of the direct approach, indirect methods are used to calculate the tensile strength. It should be noted that the results of these procedures are better than the results of the uniaxial tensile test. The split cylinder test and the flexural test are two examples of these indirect approaches.

Equipment

Compression testing machine, two packing strips of plywood 30 cm long and 12 mm wide, moulds, a tamping bar (a 60 cm long, 16 mm diameter steel bar), a trowel, and a piece of glass or metal are all required.

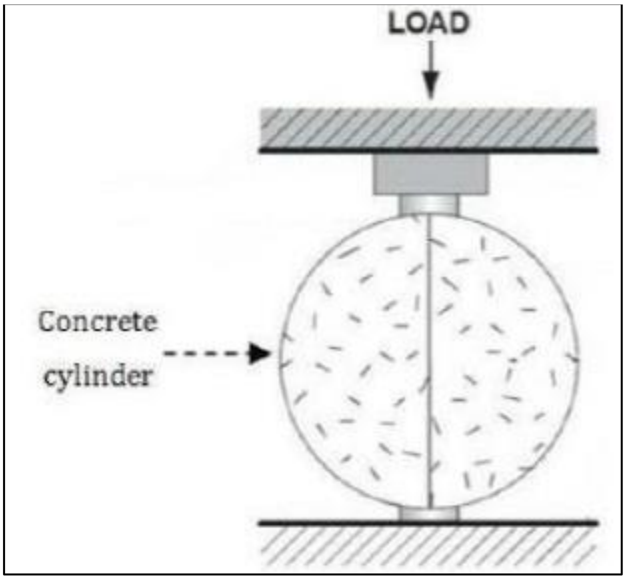

Fig 2 Splitting Tensile Strength Test

RESULTS AND DISCUSSION

UPV Test Results

Table 1 UPV Test Results Average

Concrete Mix	28 Days	120 Days
M20 Normal Mix	3.63	3.85
M20 5% 8 mm size	3.32	3.37
M20 5% 10 mm size	3.4	3.52

M20 5% 12 mm size	3.45	3.62

Discussion: It can be observed that the maximum velocity (km/sec) is in the case of normal aggregate and the minimum is in the case of 5% of flaky aggregates having 8 mm size and 95% of normal aggregates mix in concrete admixture, and similarly increasing in order to 5% of flaky aggregate with 95% of normal aggregate having 10 mm size then after 12 mm size also.

Compressive Strength

Table 2 Compressive strength of the concrete produced using different aggregate sizes with age for nominal mix 1:1.5:3

Aggregate Size	7 days	21 days	28 days	56 days
6 mm	4.15	8.73	10.02	9.89
10 mm	13.29	16.02	17.55	19.71
12.5 mm	13.35	17.21	22.53	24.19
20 mm	18.31	21.31	22.72	23.02
25 mm	21.41	22.45	23.9	25.25

Discussion: The concrete cube test's compressive strength gives an understanding of all the properties of concrete. One can determine whether concrete pouring was done correctly or not by using this one test. In commercial and industrial structures, concrete's compressive strength ranges from 15 MPa (2200 psi) to 30 MPa (4400 psi) and higher. Maximum compressive strength was visible for the aggregate size of 12.5 mm even after 56 days for the mix 1:1.5:3.

Flexural Strength

Table 3 Flexural Strength Test

Concrete Mix	Flexural Strength for 120 days
M20 Normal Mix	89.07
M20 5% 6 mm size	80.46
M20 5% 10 mm size	83.56
M20 5% 12.5 mm size	86.8
M20 5% 20 mm size	87.2
M20 5% 25 mm size	88.98

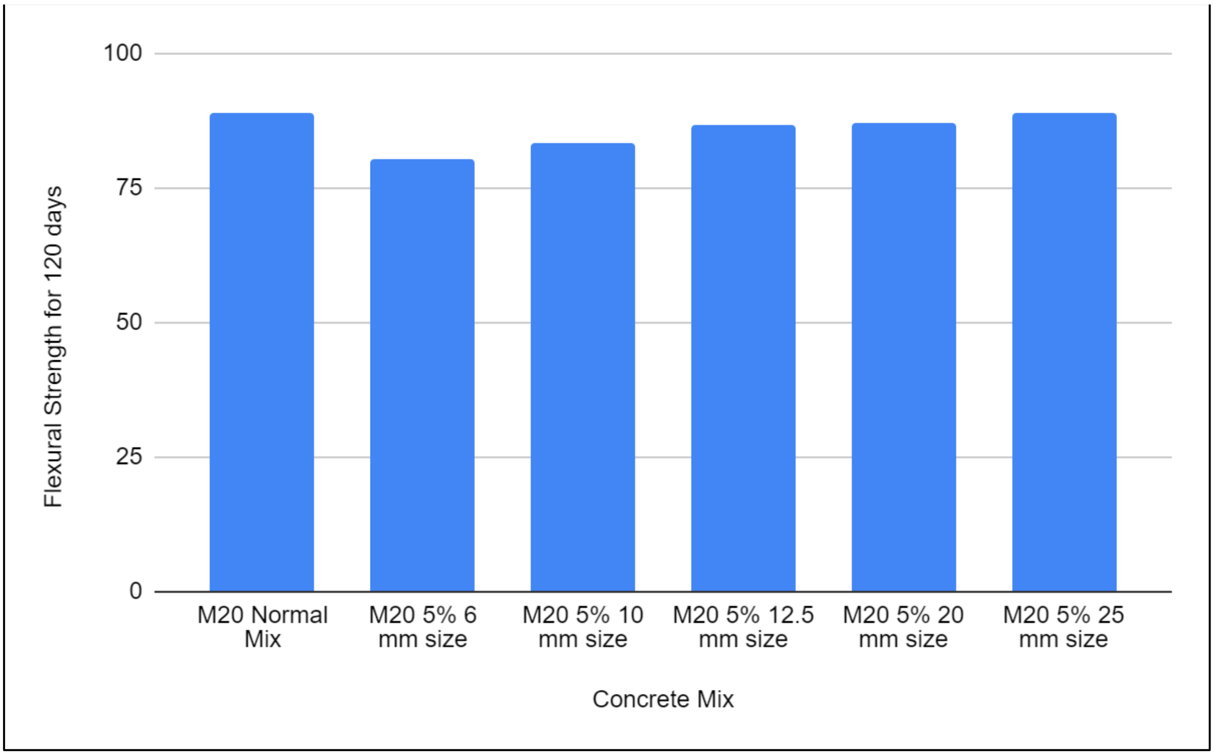

Fig 3 Flexural Strength for 120 days

Discussion: It can be observed that maximum of flexural strength is in the case of normal aggregate and minimum is in the case of 5% of flaky aggregates having 8 mm size and 95% of normal aggregates mix in concrete admixture, and similarly increasing in order to 5% of flaky aggregate with 95% of normal aggregate having 10 mm size then after 12.5 mm size also.

CONCLUSION:

Following are the salient conclusions of the study:-

a) Rebound hammer

1. It can be observed that RCC concrete beams show higher strength with normal aggregate concrete mix.

2. Rebound strength reduces by adding the flaky aggregates in all the cases.

3. Rebound strength in flaky aggregates concrete is found to be higher with increase in aggregate size.

b) UPV test

1. It can be observed that RCC concrete beams show higher pulse velocity with normal aggregate concrete mix.

2. Pulse velocity reduces by adding the flaky aggregates in all the cases.

3. Pulse velocity in flaky aggregates concrete is found to be higher with increase in aggregate size.

c) Flexural test

1. It can be observed that RCC concrete beams show higher strength with normal aggregate mix.

2. Normal aggregate mix shows the less strength with flaky aggregate due to size variation.

3. Flexural strength in flaky aggregates concrete is found to be higher with increase in aggregate size which is same as rebound hammer result.

d) Compressive Strength

The study investigates the effects of the size of aggregate on the concrete's compressive strength. It was found that strength development takes place beyond the 28-day used for specifications. Also, the study shows that as the size of aggregate used in concrete increases, the compressive strength also increases. However, it was found that there is a particular aggregate size that will give the best performance and using aggregate size greater than it will not give the desired result. The present study shows that the concrete produced with the 20 mm aggregate size has the highest compressive strength.

FUTURE SCOPE

The presence of flaky aggregates is considered in the thesis opens a future scope of work for the followings:

- The present research has been carried out only for the M20 grade of concrete mix having normal aggregates with mixture of 5% flaky aggregates in three different sizes (8 mm, 10 mm, 12 mm). The scope of research could be further extended and research needs to be carried out on different percentages and grades also.
- The research needs to be further extended for cubical and cylindrical specimens also.
- This quality control system should be developed to be used in the construction of bridges, flyovers, tunnels and various concrete structures etc. using flaky aggregates.
- Effect of flakiness may be also studies for impact and thermal loadings.

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