Comparative Study on Compressive and Flexural Strength of Sustainable Concrete Incorporating Ceramic Tile Waste

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I. INTRODUCTION

1.1 General

In accordance with conservation efforts, this research focuses on ceramic tile waste as partial coarse aggregates replacement for concrete production, prevention of environmental pollution with considering the elements of sustainable and cost-saving construction projects, especially material usage. Concrete is a composite material consist of mainly water, aggregate, and cement. The physical properties desired for the finished material can be attained by adding additives and reinforcements to the concrete mixture. Here we are replacing natural aggregate with artificial aggregate to increase the strength and make low weight concrete and also try to reduce the nature depleting. There are many material which are used in concrete to and make replacement of material.

Generally, there are many types of replacement carried out in concrete. That are as under

- Replacement of cement
- Replacement of aggregate

Aggregate is further divided in two part fine aggregate and coarse aggregate.

1.2 Problem

The demand of construction materials for project is increasing. Therefore, there is a need to explore alternative building materials from industrial waste materials that can be recycled. Ceramic tiles are often discarded as waste after defined as useless. But it can be recycled and can be used as a construction material in present world which is seeking for alternative construction materials which are economical, environment friendly as well as provides same quality as that of a normal aggregate made of regular aggregates. Ceramic tile waste has different application and ceramic tile has different chemical properties as per there material and their manufacture so on that base it’s hard to identify the chemical properties of the ceramic waste. So, we are focus on to find the material which can replace the natural aggregate. Here we are using ceramic material which is made from ceramic and known as grinding media.

1.3 Need of study

Aggregate is most widely used in reinforced concrete construction and there is demand on natural aggregate for the growing infrastructure industry, which creates problem of depleting Natural resources.

The coarse aggregate is natural material so one time may be shortage or finish in future, so we have to replace it with alternate material for coarse aggregate. We are replacing concrete with different material but that’s not good for long term and for practical purpose so we need to make or utilization of artificial aggregate.

1.4 Objective of study

This study was conducted to achieve the following objectives:

- To study the strength developments hardened concrete with ceramic artificial coarse aggregate.
- To determine the effect of various percentage of ceramic aggregate as partial coarse aggregates replacement towards compressive strength of concrete.
- To determine the water absorption of ceramic aggregate concrete containing various content of ceramic tile as partial coarse aggregates replacement material.

1.5 Scope of study

Efforts have been made in construction industry to use artificial aggregate as a partial replacement of the cement. And another advantage is that the new branch of manufacturing of artificial aggregate in ceramic industries.

The future scope of study is that we can manufacture artificial aggregate as per our requirements and our purpose The successful use of other industrial by products of wastes such as fly ash and silica fume in artificial aggregate set as good example for waste to be used in a different way.

Trials are also suggesting utilizing artificial aggregate usage in concrete as a partial replacement of the coarse aggregate.

1.6 Artificial aggregate

- The grinding media which are manufacture in ceramic industry for other use we have to use as an artificial aggregate in concrete replacement with natural aggregate.
- High Thermal Shock Resistance
- Better Impact Resistance
- A smoother, regular and uniform surface
- Very high chemical attack resistance
- Water absorption is very low.
- It’s available in different size.

Fig 1.1 Artificial Aggregate

1.7 Different application of artificial aggregate:

The material which I used in this project to replace with the natural aggregate has different application in market. This material is known as grinding media and Tambling media. I got material from Devson Industry, surendranagar.

Different application of grinding media (Ref. Devson Insulator Pvt. Ltd.)

- Vibrator and centrifugal machine manufacturing units
- Bearing cages, rollers and retainers hand tools
- Spectacle frames and components
- Ortho tools mfg.
- Clutch plate mfg.
- Buckle mfg.

this are the wild application off grinding media we have to use as artificial aggregate in concrete mix.

II. LITERATURE REVIEW

2.1. General

The reading and referring of different literature review according to our project content is quite useful for the future planning and research work. Literature review is one of major portion of research work from that we can found research gap on which we have to focus and we have to work on that way. By referring number of research work on concrete in case of replacement. We can summarize some points regarding fresh as well as hardened properties of concrete.

2.2 Mechanical properties of concrete utilizing waste ceramic as coarse by Derrick J. Anderson, Scott T. Smith, Francis T.K Au on 29 April 2016 In this paper the replacement of natural aggregate with ceramic waste in different proportion of 20%, 25%, 35%, 50%, 65%, 75%, 80% and 100% and measure compressive strength, tensile strength, flexural strength and modulus of elasticity. The result of this study indicates that the use of recycled ceramic aggregate as a replacement for coarse aggregate in concrete is certainly feasible. Ceramic material Arte more porous will exhibit a high-water absorption which will necessitate presoaking

The properties of coarse aggregate which are used in this paper are as under:

Table 2.2.1: properties of coarse aggregate

No	Test	Granite aggregate	Waste ceramic aggregate
1	Density kg/m3	2642	2263
2	Shape index	12	27
3	Crushing value	25.7	24.9
4	Water absorption	1.2	5.5

The conclusion of this research paper is that,

- The result of this study indicates that the use of recycled ceramic aggregate as a replacement for coarse aggregate in concrete is certainly feasible. Ceramic material Arte more porous will exhibit a high-water absorption which will necessitate presoaking.
- Ceramic material is denser so it strong in compression but brittle and will increase the elastic modulus of the concrete.
- Minimal change is compression strength even in 100% replacement of coarse aggregate.

2.3 Green concrete production with ceramic waste and laterite by Paul O. Awoyera, Joseph O. Akinmusuru, Julius M. Ndambuki on 26 April 2016 (Elsevier)

The usage of ceramic tiles in concrete was observed in this paper. In this, both the coarse and fine aggregates are replaced with ceramic fine and ceramic coarse aggregates obtained from construction sites of Ota, Lagos and Nigeria in various percentages. The ceramic fine and coarse aggregates are replaced in conventional concrete individually and the strength parameters are studied. Finally, it states that usage of ceramic waste in concrete gives considerable increase in strength compared to conventional concrete. Laterite is dominate soil material and ceramic waste material where replace in different proportion in concrete mix and measure its strength at 28 days. The concrete mix with 10% laterite content and 75% ceramic coarse aggregate yielded higher strength at 28 days than the reference concrete. Laterite is a product of tropical or sub-tropical weathering which is an abundant soil material in western part of Nigeria. Meanwhile concrete made with laterite being substituted as a partial replacement for sand is referred to as laterised concrete. Workability and strength characteristics of the concrete and microstructure of selected samples were obtained. Results showed that natural aggregate concrete was more workable than the laterised concrete. Both the compressive strength and splitting tensile strength increased with curing age, however, laterised concrete with 10% laterite content and 75% ceramic coarse aggregate yielded higher strength at 28 days than the reference concrete.

The properties of coarse aggregate which are used in this paper are as under:

Table 2.3.1: properties of coarse aggregate

No	Test	Granite aggregate	Laterite	Waste ceramic aggregate
1	Specific gravity	2.87	2.13	2.31
2	Water absorption	0.23	4.70	0.55
3	Fineness modulus	6.95	1.80	6.88
4	Aggregate crushing value	34.00	--	20.86
5	Aggregate impact value	24.00	--	27.00

The conclusion of this paper is, the concrete mix with 10% laterite content and 75% ceramic coarse aggregate yielded higher strength at 28 days than the reference concrete.

2.4 Mechanical behavior of nonstructural concrete made with recycled ceramic aggregates by J. De Brito, A.S. Pererira, J.R. Correia on 12 July 2004. In the present paper, the ceramic hollow bricks as aggregates for the production of nonstructural concrete. The strength of concrete decreases as the quantity of ceramic aggregate in concrete increase, since they are lighter and less resistant than the primary stone aggregates, and abrasion resistance of concrete made with ceramic recycled aggregates is higher than that of concrete made with limestone aggregate. The physical property of aggregate which are used in this project the detail of it on the next table on next page which content bulk density and the water absorption. Here the negative point of waste ceramic aggregate is that the bulk density of the ceramic waste aggregate has more than the natural aggregate.

Table 2.4.1: properties of coarse aggregate

No	Test	Granite aggregate	Waste ceramic aggregate
1	Density kg/m3	2029	2273
2	Water absorption	0.23	12

2.5 Properties of concretes produced with waste ceramic tile aggregate by D. Tavakoli, A. Heidari, M. Karimian on 10 October 2012 on Asian journal of civil engineering BHRC

In this experimental study, ceramic tile is used as coarse aggregate with replacement of 0, 10, 20, 30, and 40 % with natural aggregate. After that comparison was made between compression strength, water absorption and slump.

Physical property of aggregate which are used in this paper, are as under.

Table 2.5.1: properties of coarse aggregate

No	Test	Natural coarse aggregate	Ceramic coarse aggregate
1	Density (g/cm3)	2.55	2.33
2	Fineness modulus	--	--
3	Water absorption	0.2	4.8
4	Maximum size (mm)	25	25
5	Bulk density (kg/m3)	1597	1584
6	Aggregate abrasion value %	26.43	21.8

After comparing the properties of natural aggregate with ceramic tile waste which is replace in different proportion of 0, 10, 20, 30, and 40 % with natural aggregate. After that compressive strength will measure at 7 and 28 days of curing period.

Here C represents the plane concrete made with natural aggregate without replacement of aggregate. (100% NA + 0% CG)

And CG10, CG20, CG30, CG40 shows the ceramic ground (CG) aggregate replace the natural aggregate in different proportion of 10%, 20%, 30%, 40% respectively.

Strength of concrete block with different proportion replacement of ceramic ground aggregate are as under.

- Here NA natural aggregate
- CG ceramic ground aggregate

Table 2.5.2 strength of concrete for different proportion

No	Sample	Average strength Mpa	
		7 days	28 days
1	C	26.9	33.1
2	CG10	28.2	34.8
3	CG20	27	34.3
4	CG30	27.2	34.1
5	CG40	25.7	33

2.6 Strength of concrete based cement using recycle ceramic waste as aggregate by A.M. Mustafa Al Bakri, M.N. Norazian, H. Kamarudin, M.A.A. Mohd Salleh and A. Alida in 2013 at Trans tech publications, Switzerland.

The main focus of this research is to study the strength of concrete with ceramic waste as coarse aggregate. The sources of ceramic waste are obtained from the industrial in Malaysia. Presently, in ceramics industries the production goes as waste, which is not undergoing the recycle process yet. The potential of recycled ceramic waste as a substitute for coarse aggregates in concrete has been investigated. The recycle ceramic waste as aggregate was used. Concrete mixes with a 28 days characteristic strength of 20 MPa were prepared using water/cement ratio of 0.4, 0.5 and 0.7. The strength development of the concrete mixes containing recycled ceramic waste aggregates was compared to that of conventional concrete.

Result compression test for 28 days with different water cement ratio are shown in bellow table which content compressive strength and density of concrete mix to find out lighter concrete mix.

Table 2.6.1: compressive strength and density of concrete mix

No	w/c ratio	Conventional concrete		Concrete with recycle ceramic waste aggregate	
		Compressive strength (MPa)	Density (kg/m3)	Compressive strength (MPa)	Density (kg/m3
1	0.4	21.53	2350	17.46	2140
2	0.5	19.26	2200	18.76	2040
3	0.7	15.00	2230	10.36	2075

Conclusion

This paper presents the results of an investigation of the use of crushed recycled ceramic waste as aggregates in the production of paving blocks. Based on the results of this study, the following conclusions were drawn:

1. The use of crushed ceramic waste as aggregates reduced the density of the concrete.
2. The compressive strength of the concrete decreased as the proportion of crushed ceramic waste was increased.

2.7 Reuse of ceramic waste as aggregate in concrete by Prof. Shruthi. H.G, Prof. Gowtham Prasad. M. E, Samreen Taj, Sayed Ruman Pasha on July 2016 at IRJET

Ceramic tiles were obtained from manufacturing industries, from construction and demolition sites, this cause's environmental pollution. The utilization of crushed tile as a coarse aggregate in concrete would also have a positive effect on the economy. study, Ceramic tile waste was used in concrete as a replacement for natural coarse aggregate with 0%, 10%, 20% and 30% of the substitution and M20 grade concrete were used. The concrete moulds were casted and tested for Compressive Strength and Split Tensile Strength after a curing period of 3, 7 & 28 days. The results indicate that, the maximum compressive strength is obtained for the 30% replacement of ceramic tile aggregate with natural coarse aggregate.

The properties of aggregate which are used in this paper are as under.

Table 2.7.1 properties of coarse aggregate

No	Test	Normal aggregate	Waste ceramic aggregate
1	Specific gravity	2.68	2.22
2	Water absorption	0.6	14.4
3	Impact value	15%	24%
4	Shape	Angular	Flaky
5	Texture	Rough	All sides rough except top face

Conclusion of this paper are as under: here the result of compressive strength at 3, 7 and 28 days.

Table 2.7.1 result of compressive strength

No	% replacement of tile aggregate	3 days	7 days	28 days
1	0%	17.86	22.25	28.69
2	10%	16.22	18.67	24.04
3	20%	16.88	19.55	23.95
4	30%	18.86	23.24	32.03

- The result indicates that, the maximum compressive strength is obtained for the 30% replacement of ceramic tile aggregate with natural aggregate.
- Here main drawback is that the water absorption of ceramic tile is 14.4% where water absorption of natural aggregate is 0.6%.

2.8 literature summary:

- From all this research paper and literature review I found that we have need research on ceramic aggregate because we are just used ceramic waste and it has many application it has some drawback point which we are discuss in previous slide.
- The main negative point is, water absorption of ceramic waste material is high.
- Ceramic waste is strong in compression but are brittle so it's made wrong effect on concrete.
- The ceramic waste has different chemical properties according to their manufacture process and its application, so in waste it's hard to identify it.

III. MATERIAL PROPERTIES

3.1 Material used:

In this investigation, the following materials were used:

- Ordinary Portland Cement of 53 Grade cement conforming to IS: 169-1989
- Fine aggregate and coarse aggregate conforming to IS: 2386-1963.
- Water.
- Artificial aggregate (Ref Devson Industry)

3.2 Cement:

Ordinary Portland cement is the most common type of cement in general use around the world as a basic ingredient of concrete, mortar, stucco, and most non-specialty grout. It developed from other types of hydraulic lime in England in mid-19th century and

usually originates from limestone. It is a fine powder produced by heating materials to form clinker. After grinding the clinker, we will add small amounts of remaining ingredients. Many types of cements are available in market. When it comes to different grades of cement, the 53 Grade OPC Cement provides consistently higher strength compared to others. As per the Bureau of Indian Standards (BIS), the grade number of a cement highlights the minimum compressive strength that the cement is expected to attain within 28 days. For 53 Grade OPC Cement, the minimum compressive strength achieved by the cement at the end of the 28th day shouldn't be less than 53MPa or 530 kg/cm^2. The colour of OPC is grey colour and by eliminating ferrous oxide during manufacturing process of cement we will get white cement also.
Ordinary Portland Cement of 53 Grade of brand name Ultra Tech Company, available in the local market was used for the investigation. Care has been taken to see that the procurement was made from single batching in air tight containers to prevent it from being affected by atmospheric conditions. The cement thus procured was tested for physical requirements in accordance with IS: 169-1989 and for chemical requirement in accordance S: 4032-1988. The physical properties of the cement are listed in Table – 1

Table 3.1: Physical Properties of OPC,

Test	Result Required as per IS 12269-2013	Result Obtain
Initial setting time	More than 30 min	110 min
Final setting time	Less than 600min	200min
Specific gravity	More than 225m2/kg	3.15
Normal consistency	-	29.5
Soundness Lecha teller	Less than 10mm	1
Compressive strength 24 hr.	More than 20Mpa	22.5Mpa
Compressive strength 72 hr.	More than 27Mpa	43.5Mpa

Reference code: IS 4031, IS 12269-1987

3.3 Water:
Water plays a vital role in achieving the strength of concrete. For complete hydration it requires about 3/10th of its weight of water. It is practically proved that minimum water-cement ratio 0.35 is required for conventional concrete. Water participates in chemical reaction with cement and cement paste is formed and binds with coarse aggregate and fine aggregates. If more water is used, segregation and bleeding take place, so that the concrete becomes weak, but most of the water will absorb by the fibres. Hence it may avoid bleeding. If water content exceeds permissible limits, it may cause bleeding. If less water is used, the required workability is not achieved. Potable water fit for drinking is required to be used in the concrete and it should have pH value ranges between 6 to 9.

3.4 Fine aggregates:
Sand is a natural granular material which is mainly composed of finely divided rocky material and mineral particles. The most common constituent of sand is silica (silicon dioxide, or SiO2), usually in the form of quartz, because of its chemical inertness and considerable hardness, is the most common weathering resistant mineral. Hence, it is used as fine aggregate in concrete.
River sand locally available in the market was used in the investigation. The aggregate was tested for its physical requirements such as gradation, fineness modulus, specific gravity in accordance with IS: 2386-1963.The sand was surface dried before use.

Table 3.2: Basic Result of fine Aggregate

No	Fine aggregate	Result
1	Sand zone	2
2	Specific gravity	2.52
3	Moisture content	Nil
4	Maximum size of aggregate	4.75

Reference Code: IS: 2386-1963

Those fractions from 4.75 mm to 150 microns termed as fine aggregate. The river sand is used in the combination as fine aggregate conforming to the requirements of IS: 383. The river sand is washed and screens to eliminate extra materials and oversize particles.

Table 4.3: - Sieve Analysis of F.A

Sieve Analysis for F. A				
Sample Taken 500gm				
IS Sieve Size	Wt. retained on each sieve	Cumulative weight retains	% cumulative weight retained on each sieve	% passing
4.75	0	0	0	100
2.36	41	41	8.20	91.80
1.18	79	120	24.00	76.00
600 mi	115	235	47.00	53.00
300 mi	137	372	74.00	25.60
150 mi	95	467	93.40	6.60
pan	33	500	100	0

3.5 Coarse aggregates:

Crushed aggregates of less than 12.5mm size produced from local crushing plants were used. The aggregate exclusively passing through 12.5mm sieve size and retained on 10mm sieve is selected. The aggregates were tested for their physical requirements such as gradation, fineness modulus, specific gravity and bulk density in accordance with IS: 2386-1963. The individual aggregates were mixed to induce the required combined grading. The particular specific gravity and water absorption of the mixture are given in table.

Table 3.3: Basic result of Course Aggregate

Properties	Natural aggregate
Specific gravity %	2.69
Water absorption %	0.43
Impact value %	7.9
Crushing value %	19.68
Bulk density kg/m3	1447
Abrasion value	17.81

Reference Code: I.S.2386, I.S.383 & I.S.2430

3.6 Artificial coarse aggregates:

- The grinding media which are manufacture in ceramic industry for other use we have to use as an artificial aggregate in concrete replacement with natural aggregate.
- High Thermal Shock Resistance
- Better Impact Resistance
- A smoother, regular and uniform surface
- Very high chemical attack resistance
- Water absorption is very low.

3.6.1 Chemical properties of artificial aggregate:

- Material safety data sheet of ceramic media is manufactured by micro (Devson group) industrial ceramics.
- (Ref. Devson insulator Pvt. Ltd.)
- Wadhwan GIDC-2, Surendranagar.

Table 3.4: chemical properties of artificial Coarse Aggregate

Contain	percent value
Aluminum Oxide	35% - 45%
Silica	47% - 57%
Alumina Oxide + silica	>92%
Potassium Oxide	2% - 5%
Sodium Oxide	2% -5%
Cao	0% - 0.5%
Mgo	0% - 0.5%
Iron oxide	1% - 2%
Titanium Oxide	1% - 2%

Ref. Devson insulator pvt. ltd.

3.6.2 Mechanical properties:

As per Reference Code: I.S.2386, I.S.383 & I.S.2430 the mechanical properties of artificial aggregate are as under here the basic properties of artificial aggregate is mention here. The other properties of artificial aggregate are found after experimental done.

Table 3.5: Basic properties of Artificial Aggregate

Properties	Artificial aggregate
Specific gravity %	2.5
Water absorption %	0.2
Impact value %	12.98
Crushing value %	11.1
Bulk density kg/m3	1547
Abrasion value	12.92

Reference Code: I.S.2386, I.S.383 & I.S.2430

Round shape

Rhombus shape

Irregular shape

Fig 3.1 artificial aggregate

IV. EXPERIMENTAL PROGRAM

4.1 Introduction:

In this chapter we are perform experimental work on natural aggregate and compare with artificial aggregate. From that experimental result we know the different properties of coarse aggregate as per IS code for concrete mix. The experimental study is done and the list of experiment carried is as under.

4.2 Mix Design and Replacement:

4.2.1 Mix Design:

Here the M25 grade concrete is used for the test. so the mix design for m25 grade is as under. OPC 53 grade cement will used the zone of sand is 2. Pure water is used for concrete mix. (As per IS 10262)

- Cement: OPC 53 grade
- Nominal aggregate size: 20 mm
- Sand fine aggregate: zone 2
- Water: regular
- Water cement ratio: 0.45 assumed

Mix design for 1m3

A1 Stipulation:

(a) Grade: M25
(b) Type of cement: OPC 53
(c) Maximum aggregate size: 20mm
(d) Minimum cement contain: moderate condition 240 kg/m3
(e) Water cement ratio: 0.6
(f) Workability: 100 mm (medium IS 456 pg:17)
(g) Exposer condition
(h) Degree of supervision:
(i) Type of aggregate: angular natural aggregate and artificial aggregate
(j) Maximum cement contain: 450 kg/m3

A2 Test data for material:

A) Cement contains: 437.78 kg
B) Specific gravity of cement 3.15
C) Specific gravity of
1) Coarse aggregate: 2.83
2) Fine aggregate: 2.52
D) Water absorption
1) Coarse aggregate 0.59%
2) Fine aggregate 1.08%
E) Nil

Sieve analysis 20mm

Fine sieve analysis zone – 2 table 4 IS 456

A – 3 targeted strengths for mix proportion

Fck = fck' + 1.65 s

S = standard deviation

25 = 1.65 (4)

Fck = 31.6 n/mm2

A – 4 selections of water/cement ratio

From (IS 456 table 5)

Frome table 5…. w/c 0.6

Take w/c 0.45

A – 5 selections of water content

Table 2 maximum water content = 186 litre (slump range 25 to 50 mm)

Estimated water content = 186 + 6/100 * 186 (As per IS 10262 mix design)

= 197 litres

A – 6 calculate cement content

w/c ratio = 0.45

cement content = 197/0.45

= 437.78 kg/m3

Minimum cement content for moderate condition = 320 kg/m^3

A-7 Volume of coarse aggregate

(As per IS 10262 cause A7)

For 0.5 w/c ratio for 20mm aggregate size the coarse aggregate contain is 0.62

For change $\pm$ water ratio ± 0.05 for

$\mp$ of coarse aggregate ratio 0.01

Here in our mix design w/c is 0.45

So that coarse aggregate =0.63 for $1m^3$

Fine aggregate =0.37 for $1m^3$

A – 8 mix calculations

a) Volume of concrete = $1m^3$
b) Volume of cement = mass of cement / sp. Gravity of cement *1/1000

= 437.78 / 3.15 * 1 /1000

= 0.138 m^3

c) Volume of water = mass of water / sp. Gravity of water * 1/1000

= 140/1 * 1/1000

d) Volume of aggregate = 1 – 0.138 – 0.197

- C.A + F.A = 0.665 m^3
- C.A = 0.63 * 0.665 = $0.418m^3$
- F.A = 0.37 * 0.665 = 0.29 m3

e) mass of aggregate = volume of aggregate * specific gravity * 1000

1053.36 kg

f) mass of fine aggregate = 0.24 * 283 * 1000

= 679.2 kg

A – 9 mix proportion for trial number

- Cement = 437.78 kg/m^3
- C.A = 1053.36 kg
- F.A = 680 kg
- Water = 197 kg
- Multiply 1.52 to total volume for casting.

(volume reduction due to water)

Volume of one cubic = 0.003375 * 1.52

= 0.00513

4.2.2 REPLACEMENT PROPPORTION:

Mix design of M25 grade with different replacement:

- Mix design:M25
- Mix design for $1m^3$
- Cement: OPC 53
- Zone of sand:2
- Nominal aggregate size: 20mm

Table 4.8 Mix design of M25 grade with different proportion

proportion	Cement (kg)	F.A. (kg)	C.A. natural (kg)	Replacement artificial aggregate	Water (kg)	W/C ratio
0%	437.78	604.8	1182.94	0.0	197	0.45
20%	437.78	604.8	946.35	236.58	197	0.45
40%	437.78	604.8	709.76	473.18	197	0.45
80%	437.78	604.8	236.58	946.35	197	0.45
100%	437.78	604.8	0.0	1182.94	197	0.45

4.3 Slump test:

Work ability means easily work with concrete the good workability of the concrete sure that concrete easily placing into the formwork and it requires minor tamping for the compaction. Super plasticizer and plasticizer increase the workability of the concrete but the good workability has negative side of the decrease in the strength.

The slump test is the easiest way to measures the workability on the field and the construction site. Slump test is giving the result of concrete weather it is workable or the cohesive

Procedure: -

Test is performed as per IS: 1199-1959. The internal surface of mould and base plate is cleaned and free from the flow moisture. The cone stands on the base plate. Use the scoop to fill the mould about its one fourth height of mould. This layer is tamped 25 times using 16mm diameter road. This procedure is repeated until the mould is filling fully by concrete. Use steel float and strike of the surplus concrete. Clean the base plate without disturbing of the foot hold or clamping device. Hold the cone handles firmly pushing downwards and release foot hold or clamps. Hold the cone handles and carefully and lift the cone straight up till such time concrete is released from within the cone. Turn the cone upside down and place it close to slumped concrete on the base plate. Rest mould inverted at near the concrete and measured by the temping road. If distance is measured about 75mm so it's called slump value is 75mm

4.4 Compressive strength:

Compressive strength procedure:

Prepare the concrete in the required proportions and make the specimen by filling the concrete in the desired mould shape of 15cm s 15cm x 15cm cube with proper compaction, after 24 hrs place the specimen in water for curing.

- Take away the specimen from water when such as natural process time and wipe out excess water from the surface.
- Take the dimension of the specimen to the closest 02m.
- Clean the bearing surface of the testing machine.
- Place the specimen within the machine in such a fashion that the load shall be applied to the other sides of the cube forged.
- Align the specimen centrally on the bottom plate of the machine.
- Rotate the movable portion gently by hand so it touches the highest surface of the specimen.
- Apply the load step by step while not shock and incessantly at the speed of incessant 140kg/cm2/minute until the specimen fails.
- Record the utmost load and note any uncommon options within the form of failure.
  compressive strength = (load area) in N/sq.mm

Fig 4.5: compressive strength

4.5 Flexural strength test:

Prepare the concrete in the required proportions and make the specimen by filling the concrete in the d mould shape of 10x10x50cm prism with proper compaction. After 24 hrs place the specimen in water for curing.

- Remove the specimens from water after specified curing time and wipe out excess from the surface.
- Leave the specimen in the atmosphere from 24hours before testing.
- The specimen is then placed in the machine in such a manner that the load is applied to the uppermost surface as cast in the mould, along the two lines spaced 20 0cm a part The axis of the specimen is carefully aligned with the axis of loading devices.
- The load is then applied without shock and increasing continuously at a rate of 400kg/min

Calculation: the flexural strength of the specimen shall be expressed as the module of the rupture fb, which if ‘a’ equals the distance between the line of fracture and the nearer supports, measured on the centre line of the tensile side of the specimen in cm shall be calculated to the nearest 0.5kg/sq.

$$Fb=pl/bd2$$

When ‘a’ is less than 20.0 cm for 15.0 cm specimen, or greater than 13.3cm for a 10.0 cm specimen
b= measured width in cm of the specimen
d=measured depth in cm of the specimen at the point of failure
l=length in cm of the span on which the specimen was supported
p=maximum load in kg applied to the specimen


Fig 4.6 split tensile test


Fig 4.7: Flexural strength

4.6 Split tensile test:

The spilt tensile strength of the concrete is also tested on the compression testing machine. This test is performed as per IS: 516-1959. This test is performed on the Universal Testing Machine (UTM) of 400 KN capacity. Due to specimen by holding devices introduce secondary stresses which cannot be ignored direct tension tests of concrete are never carried out. The specimen used for this test is of size 150 mm diameter and 300 mm height. The specimen is subjected to compression loads along two axial lines which are directly opposite. The load is continuously applying to the specimen until it fails. The compressive stress produced the transverse tensile stress, which is uniform along the vertical diameter. This test is performed after 28 days of casting. Unit of split tensile strength is N/mm2. A cylinder is placed between two steel plates.

The measured splitting tensile strength fc, of the specimen shall as below.

Tensile strength=2P/pi*D*L

Where p= Maximum load in Newton applied to specimen,

l= Length of the specimen,

d=Cross sectional dimension of the specimen

the difference is that in place of the cube the cylinder of the size diameter of 150mm by length 300mm is put on the machine with help of the two-steel plate size of 30cm long and 20mm thick

Procedure

The spilt tensile strength test is carried out under the specification of the IS:516 1959. First of the specimen is kept out from the curing tank and surface dry in the sun light and here the specimen size is 150mm dia.*300mm length. The cylinder is set into the compression testing machine by using the two steel plates on bottom and top of the cylinder's length sides. The machine is set into the locked condition then after the load is uniformly slower rate is applied to the cylinder. The load is applied up to the time until the cylinder is not failure. And in the other side of it the load readings are noted down into the book.

The spilt tensile strength is calculated by the following formula.

Tensile strength=2P/pi*D*L

Were,

P=load at failure

D=dia. Of cylinder

L=length of cylinder

Observation:

The cylinder is failed at the its highest load carrying capacity when the cylinder is failed its crack pattern is in longitudinal direction

4.7 Pull out test:

This test is performed as per IS: 2770-1-1967. This test is performed on the universal testing machine. This standard (Part I) covers the method for comparison of bond resistance of different types of reinforcing bars with concrete by means of a pull-out test.

Procdure

This test is carried out under the specification of the IS 2772-1967 part-1.the pullout test is carried out for the determination of the pullout load at the failure and bond strength between the reinforcement bar and the concrete The pullout test of concrete is in this research work is generally adopted in the cylinder of the size of length 300mm by the diameter 150mm with the reinforcement of 16mm dia. Is used and it's embedding up to 15cm into the cylinder. The pull-out test is generally performed with the help of the universal testing machine. The upper side of the cylinder consisting the rod is generally fixed into the upper part of UTM and bottom concrete part of the cylinder is taken free the load is slower rate and uniformly applied to the element until it breaks down. The failure was marked by the splitting of the cover and slipping of the reinforcement. The nominal bond strength was calculated as below

The bond strength of the concrete is calculating by the following formula.

Bond Strength=P/PI*Ø*L

Were,

P= load at failure

Ø=dia. Of bar

L=embed length of concrete

Observation during Process: -

When the cylinder put on the universal testing machine a cylinder is taken a loading after some time. After few loading cracks are observe on cylinder and load increase cracks are increased then after few minutes cylinder crack into centre.

4.8 Drop impact test:

The testing apparatus, illustrated in Figure, consists of three main components, a base, drop-weight guide system and drop hammers. Four different masses of steel hammers were used in this study, 0.875, 0.8, 0.675 and 0.5 kg, respectively. The drop-height was 400 mm. A very small gap was left between the guide rail and drop-hammer. Acetone or alcohol was used to clean the guide rail and drop-hammer, in order to minimize the friction between them. The U-shape specimen was fixed in two square grooves of the steel support. The drop-weight impact tests reported here were carried out by using a hammer from the same height of 400 mm repeatedly on a hardened steel pounding head with a hemispherical surface, which is placed on the top of the middle of U-shape specimen as shown in Figure,

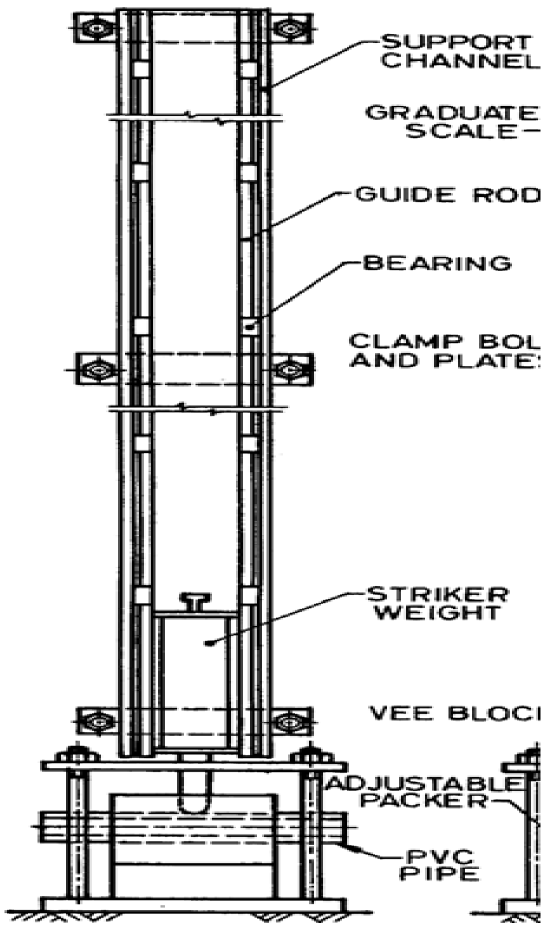


Fig 4.8: Drop impact test

Procedure

In all tests, the same mass was dropped repeatedly from the same height until final failure occurred. For each U-shape specimen, two values should be recorded corresponding to initial and ultimate failure. The former value measures the number of blows required to initiate a visible crack, whereas the latter measures the number of blows required to ultimate failure, which should be declared when the specimen is separated into halves. Result of drop impact test shown in chapter 5 result and discussion.

Fig 4.1 water absorption test

Fig 4.2 abration test

V. RESULT AND DISCUSION

5.1 Results and discussion

From the experimental work which is done and shown in pervious chapter we conclude that the artificial aggregate can used as replacement aggregate in concrete. Based on the results of the experimental investigation, it is concluded that artificial aggregate partially replaced as a coarse aggregate in concrete mix. Water absorption of artificial aggregate is less than natural aggregate. Mechanical property such as specific gravity and crushing is lower than natural aggregate but the other property such as impact value and bulk density is less than the natural aggregate.

Here the compression of natural aggregate and artificial aggregate of their properties like specific gravity, water absorption etc are describe. From that table we got the possibilities of replacement of artificial aggregate with natural aggregate.
Results of all experiment are shown in below table:

5.2 Compression: artificial aggregate vs natural aggregate:

Table 5.1: Compression: artificial aggregate Vs Natural aggregate

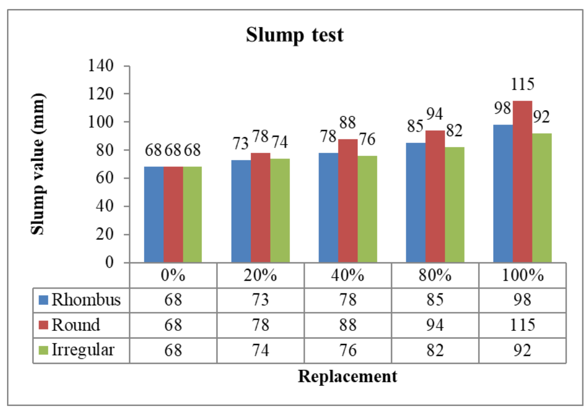
Properties	Artificial aggregate	Natural aggregate
Specific gravity %	2.5	2.69
Water absorption %	0.2	0.43
Impact value %	12.98	7.9
Crushing value %	11.1	19.68
Bulk density kg/m3	1547	1447
Abrasion value	12.92	17.81

5.3 Slump test
The table of Slump test which s+-how's the workability of concrete. Slump value test is experiment done on fresh concrete. The value of slump test shows below;

Table 5.2: slump value test

No.	Replacement	Slump Value (mm)		
		Shape of artificial aggregate		
		Rhombus	Round	Irregular
1	0%	68	68	68
2	20%	73	78	74
3	40%	78	88	76
4	80%	85	94	82
5	100%	98	115	92

- Workability of concrete is measured by slump test. In M25 grade of concrete, with increment of artificial aggregate of from 20%, 40%, 80%, 100% replacement with natural aggregate; there is increase in slump in Rhombus shape: 68, 73, 78, 85, 98 mm; in round shape aggregate: 78, 88, 94, 115 mm; & irregular shape 74, 76, 82, 92 mm.
- Slump value gradually increases with increase in replacement of percentage of artificial aggregate from (0%, 20%, 40%, 80%, 100%)
- Slump value is increase from 68mm to 98mm in rhombus shape, 68mm to 115mm in round shape and in irregular shape is increase from 68mm to 92mm.
- The result shows that at 100% replacement of artificial aggregate with natural aggregate gives maximum value of slump because artificial aggregate as low water absorption.
- As per the result round shape gaining maximum slump respect to rhombus and irregular shape



Graph: 5.1 Slump value test

5.4 Bulk density of concrete:

Table 5.3: Bulk density of concrete

No	Replacement	Density of concrete Kg/m^3					
		Rhombus		Round		Irregular	
		Weight of cube	Density of concrete	Weight of cube	Density of concrete	Weight of cube	Density of concrete
1	0%	8.335	2469.63	8.335	2469.63	8.335	2469.63
2	20%	8.331	2468.44	8.329	2467.85	8.305	2460.741
3	60%	8.326	2466.96	8.332	2468.74	8.352	2474.667
4	80%	8.33	2468.15	8.328	2467.56	8.348	2473.481
5	100%	8.328	2467.56	8.325	2466.67	8.342	2471.704

Bulk density of concrete with artificial aggregate is quite similar to bulk density of concrete with natural aggregate around 2400 Kg/m^3 because; the density of artificial aggregate is near to density of natural aggregate about 1500Kg/m^3.

5.5 Compressive strength 7 days & 28 days result for all shape of aggregate:
Compressive strength result at 7 days as under;

Table 5.4: Compressive strength result at 7 days

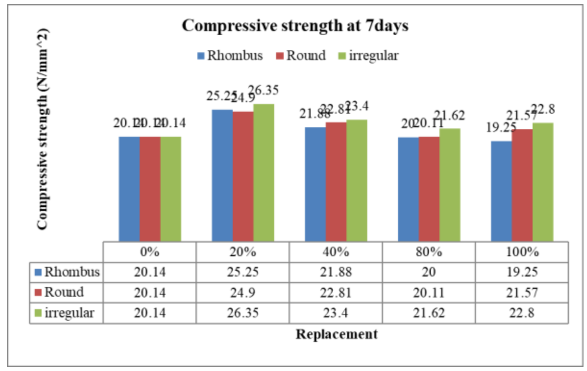
No	Replacement	Compressive strength at 7days (Mpa)		
		Rhombus	Round	Irregular
1	0%	20.14	20.14	20.14
2	20%	25.25	24.9	26.35
3	40%	21.88	22.81	23.40
4	80%	20	20.11	21.62
5	100%	19.25	21.57	22.8

Compressive strength result at 28 days as under;

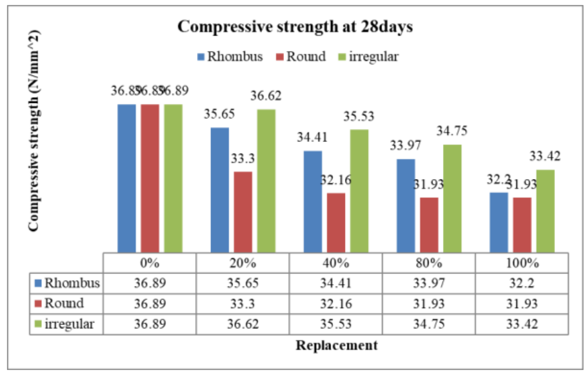
Table 5.5: Compressive strength result at 28 days

No	Replacement	Compressive strength at 28 days TMS (31.6) (MPa)		
		Rhombus	Round	Irregular
1	0%	36.89	36.89	36.89
2	20%	35.65	33.3	36.62
3	40%	34.41	32.16	35.53
4	80%	33.97	31.93	34.75
5	100%	32.2	31.93	33.42

- In M25 grade, in rhombus shape aggregate replacement of 20% aggregate gives maximum compressive strength of 35.65Mpa; Whereas in round shape 205 replacement of aggregate gives maximum compressive strength value as 33.3mpa & in Irregular shape 20% replacement of aggregate gives maximum compressive strength of 36.62Mpa.
- In M25 artificial aggregate i.e. in rhombus shape gives maximum compressive strength of 25.25 N/mm^2 at 20% replacement of artificial aggregate.
- Analysis of result irregular shape artificial aggregate gain more compressive strength as compare to round and rhombus shape aggregate.
- At 100% replacement of artificial aggregate to natural aggregate compressive strength is all most near to target mean strength of M25 grade. (TMS 31.6)



Graph 5.2: Compressive strength at 7 days



Graph 5.3: Compressive strength at 28 days

5.6 Comparison table of flexural test result of round, rhombus and irregular shape:

Table 5.6: flexural test at 7 days

No	Replacement	flexural strength at 7 days (MPa)		
		Rhombus	Round	Irregular
1	0%	2.48	2.48	2.48
2	20%	2.61	2.7	2.75
3	40%	2.69	2.69	2.71
4	80%	2.55	2.49	2.58
5	100%	2.43	2.67	2.92

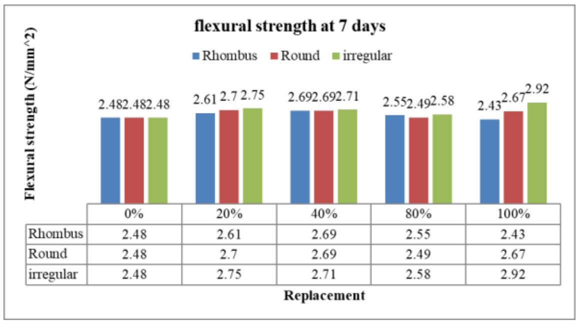
Table 5.7: flexural test at 7 days

No	Replacement	flexural strength at 28 days (MPa)		
		Rhombus	Round	Irregular
1	0%	4.21	4.21	4.21
2	20%	3.93	3.77	4.12
3	40%	3.78	3.69	4.05
4	80%	3.75	3.58	3.94
5	100%	3.46	3.43	3.69

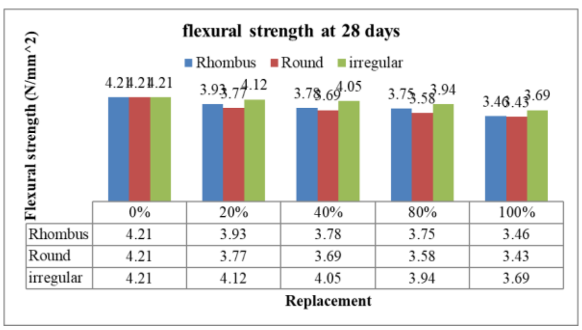
- In M25 grade, in rhombus shape aggregate replacement of 100% aggregate gives flexural strength of 3.46MPa; Whereas in round shape 100% replacement of aggregate gives flexural strength value as 3.43MPa & in Irregular shape

20% replacement of aggregate gives flexural strength of 3.69Mpa

- At 100% replacement of artificial aggregate to natural aggregate, I irregular shape give more flexural strength.
- Result shows flexural strength at 28 days gradually decrease with increasing percentage replacement of artificial aggregate to (0%, 20%, 40%, 80%, 100%)



Graph 5.4: 7 days flexural test result for all shape of aggregate:



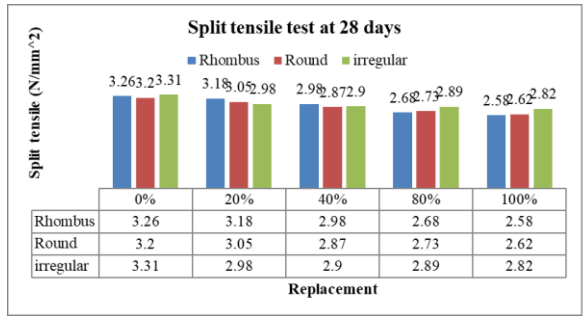
Graph 5.8: 28 days flexural test result for all shape of aggregate:

5.7 Comparison table of split tensile test result of round, rhombus and irregular shape:

Table 5.8: Split tensile strength 28 days result:

No	Replacement	split tensile test at 28 days (MPa)		
		Rhombus	Round	Irregular
1	0%	3.26	3.2	3.31
2	20%	3.18	3.05	2.98
3	40%	2.98	2.87	2.9
4	80%	2.68	2.73	2.89
5	100%	2.58	2.62	2.82

- As per the result split tensile strength of irregular shape of artificial aggregate is higher than round & rhombus shape of artificial aggregate.
- In all three shapes of artificial aggregate; split tensile strength decreases uniformly with the increase percentage replacement of artificial aggregate to (0%, 20%, 40%, 80%, 100%)
- Result shows split tensile strength value varies from 3.18 to 2.58.



Graph 5.9: 28 days split tensile test result for all shape of aggregate:

5.8 Pull out test result:

Pullout test is performed as per IS: 2770-1-1967. The bond strength of the concrete is calculating by the following formula bond strength=

Bond Strength=P/Pi*Ø*L

Were,

P= load at failure

Ø=dia. of bar

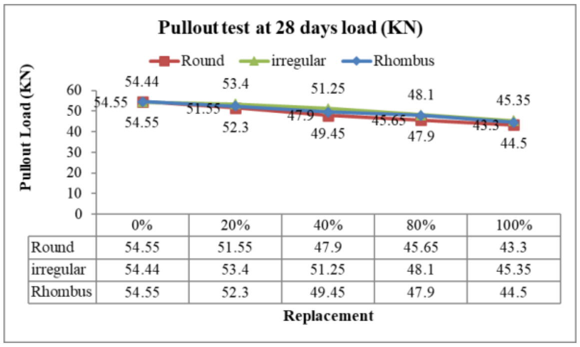
L=embed length of concrete

Table 5.9: Pullout test load (KN) at 28 days in all shape

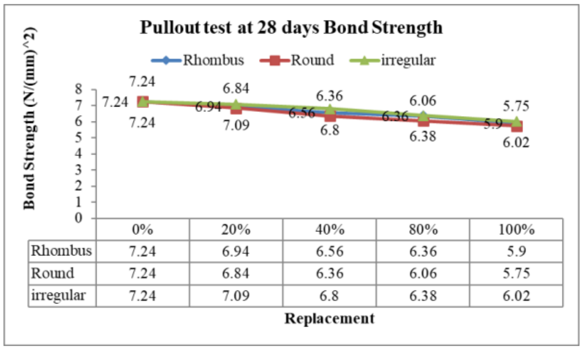
No	Replacement	Pullout Load (KN)		
		Rhombus	Round	irregular
1	0%	54.55	54.55	54.44
2	20%	52.30	51.55	53.40
3	40%	49.45	47.90	51.25
4	80%	47.90	45.65	48.10
5	100%	44.50	43.30	45.35

Table 5.10: Pullout test Bond strength at 28 days in all shape

No	Replacement	Bond Strength (N/(mm)^2)		
		Rhombus	Round	irregular
1	Normal concrete	7.24	7.24	7.24
2	20%	6.94	6.84	7.09
3	40%	6.56	6.36	6.80
4	80%	6.36	6.06	6.38
5	100%	5.90	5.75	6.02



Graph5.10: Pullout test at 28 days load (KN)



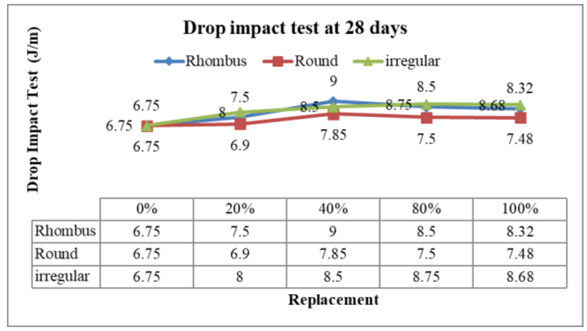
Graph 5.10: pullout test at 28 days bond strength value

- The bond resistance of reinforcing bars with concrete is measured by Pullout test. In M25 grade of concrete, with increment of artificial aggregate of from 20%, 40%, 80%, 100% replacement with natural aggregate; there is increase in pullout load in Rhombus shape: 54.55, 52.30, 49.45, 47.9, 44.5 KN in Round shape aggregate: 54.55, 51.55, 47.9, 45.65, 43.30 KN; & irregular shape 54.44, 53.4, 51.25, 48.10, 45.365 KN.
- Pullout test load value gradually decreases with increase in replacement of percentage of artificial aggregate from (0%, 20%, 40%, 80%, 100%).
- Bond strength in pullout test also decreases with increase with percentage replacement of artificial aggregate increase.
- Bond strength test is as explained in chapter-4. Apparently artificial aggregate has lower resistance against friction because of smooth surface; so, load carrying capacity decreases as % of replacement increase.

5.8 Drop impact test:

Table 5.11: Drop impact test

No	Replacement	Drop impact test J/m		
		Rhombus	Round	Irregular
1	0%	6.75	6.75	6.75
2	20%	7.50	6.90	8.00
3	60%	9.00	7.85	8.50
4	80%	8.50	7.50	8.75
5	100%	8.32	7.48	8.68



Graph5.11: Drop impact test at 28 days

- In M25 grade, in rhombus shape aggregate replacement of 100% aggregate gives drop impact value 8.32 J/m; Whereas in round shape 100% replacement of aggregate gives drop impact value 7.48 J/m & in Irregular shape 20% replacement of aggregate gives drop impact value 8.68 J/m.
- In irregular shape of artificial aggregate maximum drop impact value achieved is 8.75 J/m at 80% replacement of artificial aggregate.
- After result analysis its shows that the drop impact value in irregular shape to artificial aggregate is comparatively high as compared to rest to other.
- The value of drop impact test varies randomly in all the shapes of artificial aggregate as replacement as (0%, 20%, 40%, 80%, 100%).

Photos during casting 1

Photo flexural test experiment

Manufacturing of irregular shape aggregate

5.10 Percentage variation

5.10.1: Percentage variation of slump test wrt to normal mix:

No.	Replacement	Slump Value (mm)					
		Shape of artificial aggregate					
		Rhombus	% variation wrt normal mix	Round	% variation wrt normal mix	Irregular	% variation wrt normal mix
1	0%	68	0	68	0	68	0
2	20%	73	7.35	78	14.71	74	8.82
`3	40%	78	14.71	88	29.41	76	11.76
4	80%	85	25.00	94	38.24	82	20.59
5	100%	98	44.12	115	69.12	92	35.29

5.10.2: Percentage variation of Compressive strength at 28 days wrt to normal mix:

No	Replace ment	Compressive strength at 28 days TMS (31.6) (MPa)					
		Rhombus	% variation wrt normal mix	Round	% variation wrt normal mix	Irregular	% variation wrt normal mix
1	0%	36.89	0	36.89	0	36.89	0
2	20%	35.65	-3.36	33.3	-9.73	36.62	-0.73
3	40%	34.41	-6.72	32.16	-12.82	35.53	-3.69
4	80%	33.97	-7.92	31.93	-13.45	34.75	-5.80
5	100%	32.2	-12.71	31.93	-13.45	33.42	-9.41

5.10.3: Percentage variation of flexural strength at 28 days wrt to normal mix:

No	Replacement	flexural strength at 28 days (MPa)					
		Rhombus	% variation wrt normal mix	Round	% variation wrt normal mix	Irregular	% variation wrt normal mix
1	0%	4.21	0	4.21	0	4.21	0
2	20%	3.93	-6.65	3.77	-10.45	4.12	-2.14
3	40%	3.78	-10.21	3.69	-12.35	4.05	-3.80
4	80%	3.75	-10.93	3.58	-14.96	3.94	-6.41
5	100%	3.46	-17.81	3.43	-18.53	3.69	-12.35

5.10.4: Percentage variation of split tensile test at 28 days wrt to normal mix:

No	Replacement	split tensile test at 28 days (MPa)					
		Rhombus	% variation wrt normal mix	Round	% variation wrt normal mix	Irregular	% variation wrt normal mix
1	0%	3.26	0	3.2	0	3.31	0
2	20%	3.18	-2.45	3.05	-4.69	2.98	-9.97
3	40%	2.98	-8.59	2.87	-10.31	2.9	-12.39
4	80%	2.68	-17.79	2.73	-14.69	2.89	-12.69
5	100%	2.58	-20.86	2.62	-18.13	2.82	-14.80

5.10.5: Percentage variation of Pullout Load (KN) at 28 days wrt to normal mix:

No	Replacement	Pullout Load (KN)					
		Rhombus	% variation wrt normal mix	Round	% variation wrt normal mix	irregular	% variation wrt normal mix
1	0%	54.55	0	54.55	0	54.44	0
2	20%	52.3	-4.12	51.55	-5.50	53.4	-2.11
3	40%	49.45	-9.35	47.9	-12.19	51.25	-6.05
4	80%	47.9	-12.19	45.65	-16.32	48.1	-11.82
5	100%	44.5	-18.42	43.3	-20.62	45.35	-16.87

5.10.6: Percentage variation of Bond Strength (N/(mm)^2) at 28 days wrt to normal mix:

No	Replacement	Bond Strength (N/(mm)^2)					
		Rhombus	% variation wrt normal mix	Round	% variation wrt normal mix	irregular	% variation wrt normal mix
1	0%	7.24	0	7.24	0	7.24	0
2	20%	6.94	-4.14	6.84	-5.52	7.09	-2.07
3	40%	6.56	-9.39	6.36	-12.15	6.8	-6.08
4	80%	6.36	-12.15	6.06	-16.30	6.38	-11.88
5	100%	5.9	-18.51	5.75	-20.58	6.02	-16.85

5.10.7: Percentage variation of Drop impact test J/m at 28 days wrt to normal mix:

No	Replacement	Drop impact test J/m					
		Rhombus	% variation wrt normal mix	Round	% variation wrt normal mix	Irregular	% variation wrt normal mix
1	0%	6.75	0	6.75	0	6.75	0
2	20%	7.5	11.11	6.9	2.22	8	18.52
3	60%	9	33.33	7.85	16.30	8.5	25.93
4	80%	8.5	25.93	7.5	11.11	8.75	29.63
5	100%	8.32	23.26	7.48	10.81	8.68	28.59

VI. CONCLUSION AND RESULTS

6.1 Conclusion

A. Rhombus shape aggregate:

- According to results of slump test in rhombus shape of artificial aggregate the results are gradually increasing by percentages 0% to 44.12% from 0% to 100% replacement of artificial aggregate.
- In M25 grade of concrete the compressive strength at 0% replacement is 36.89 MPa and at 100% replacement is 32.2 MPa. Even though if we used

100% rhombus shape artificial aggregate, compressive strength is more than its target mean strength.
- In M25 grade of concrete the flexural strength at 0% replacement is 4.21 MPa and at 100% replacement is 3.46 MPa.
- In M25 grade of concrete the split tensile strength at 0% replacement is 3.26 MPa and at 100% replacement is 2.58 MPa.
- In M25 grade of concrete the pullout test load at 0% replacement is 54.55KN and at 100% replacement is 44.56 KN.
- From the results rhombus shape of artificial aggregate of concrete, the bond strength of normal concrete is 7.24 and at 100% artificial aggregate bond strength decrease up to 5.94.
- As per the result rhombus shape of artificial aggregate of concrete the drop impact test result is 6.75 J/m and at 100% artificial aggregate drop impact value is 8.32 J/m but maximum drop impact value is gained at 60% replacement of 9 J/m.

B. Round shape aggregate:
- According to results of slump test in round shape of artificial aggregate the results are gradually increasing 68mm at 0% to 115mm at 100% replacement round shape of artificial aggregate.
- In M25 grade of concrete the compressive strength at 0% replacement is 36.89 MPa and at 100% replacement is 31.93MPa. Even though if we used 100% round shape artificial aggregate, compressive strength is more than its target mean strength.
- In M25 grade of concrete the flexural strength at 0% replacement is 4.21 MPa and at 100% replacement is 3.43 MPa; and its less than the flexural strength of rhombus shape artificial aggregate at same replacement.
- In M25 grade of concrete the split tensile strength at 0% replacement is 3.26 MPa and its decrease with increase the replacement of aggregate, at 100% replacement is 2.62 MPa.
- In M25 grade of concrete the pullout test load at 0% replacement is 54.55KN and at 100% replacement is 43.3 KN.
- From the results round shape of artificial aggregate of concrete, the bond strength of normal concrete is 7.24 and at 100% artificial aggregate bond strength decrease up to 5.75.
- As per the result round shape of artificial aggregate of concrete the drop impact test result is 6.75 J/m and at 100% artificial aggregate drop impact value is 7.48J/m but maximum drop impact value is gained at 60% replacement of 7.85 J/m.

C. Irregular shape aggregate:
- According to results of slump test in irregular shape of artificial aggregate the results are gradually increasing 68mm at 0% to 92mm at 100% replacement round shape of artificial aggregate.
- In M25 grade of concrete the compressive strength at 0% replacement is 36.89 MPa and at 100% replacement is 33.42 MPa. Even though if we used 100% irregular shape artificial aggregate, compressive strength is more than its target mean strength.
- In M25 grade of concrete the flexural strength at 0% replacement is 4.12 MPa and at 100% replacement is 3.69 MPa; and its more than the flexural strength of round shape and rhombus shape of artificial aggregate at same replacement.
- In M25 grade of concrete the split tensile strength at 0% replacement is 3.31 MPa and its decrease with increase the replacement of aggregate, at 100% replacement is 2.82 MPa.
- In M25 grade of concrete the pullout test load at 0% replacement is 54.55KN and at 100% replacement is 45.35 KN.
- From the results irregular shape of artificial aggregate of concrete, the bond strength of normal concrete is 7.24 and at 100% artificial aggregate bond strength decrease up to 6.02 N/mm^2
- As per the result irregular shape of artificial aggregate of concrete the drop impact test result is 6.75 J/m at 0% replacement and at 100% replacement artificial aggregate drop impact value is 8.68J/m but maximum drop impact value is gained at 60% replacement of rhombus shape of artificial aggregate value is 9 J/m.

6.1.1 Common Conclusion
- Workability of concrete is measured by slump test. In M25 grade of concrete, with increment of artificial aggregate of from 20%, 40%, 80%, 100%

replacement with natural aggregate; there is increase in slump in Rhombus shape: 68, 73, 78, 85, 98 mm; in Round shape aggregate: 78, 88, 94, 115 mm; & irregular shape 74, 76, 82, 92 mm. Maximum slump measured at 100% replacement of round shape artificial aggregate.

- Bulk density of concrete with artificial aggregate is quite similar to bulk density of concrete with natural aggregate around 2400 Kg/m^3
- In M25 grade, in rhombus shape aggregate replacement of 20% aggregate gives maximum compressive strength of 35.65Mpa; Whereas in round shape 205 replacement of aggregate gives maximum compressive strength value as 33.3mpa & in Irregular shape 20% replacement of aggregate gives maximum compressive strength of 36.62Mpa.
- In M25 artificial aggregate i.e. in rhombus shape gives maximum compressive strength of 25.25 N/mm^2 at 20% replacement of artificial aggregate.
- In M25 grade, in rhombus shape aggregate replacement of 100% aggregate gives flexural strength of 3.46MPa; Whereas in round shape 100% replacement of aggregate gives flexural strength value as 3.43MPa & in Irregular shape 20% replacement of aggregate gives flexural strength of 3.69Mpa
- Result shows flexural strength at 28 days gradually decrease with increasing percentage replacement of artificial aggregate to (0%, 20%, 40%, 80%, 100%)
- The bond resistance of reinforcing bars with concrete is measured by Pullout test. In M25 grade of concrete, with increment of artificial aggregate of from 20%, 40%, 80%, 100% replacement with natural aggregate; there is increase in pullout load in Rhombus shape: 54.55, 52.30, 49.45, 47.9, 44.5 KN in Round shape aggregate: 54.55, 51.55, 47.9, 45.65, 43.30 KN; & irregular shape 54.44, 53.4, 51.25, 48.10, 45.365 KN.
- In M25 grade, in rhombus shape aggregate replacement of 100% aggregate gives drop impact value 8.32 J/m; Whereas in round shape 100% replacement of aggregate gives drop impact value 7.48 J/m & in Irregular shape 20% replacement of aggregate gives drop impact value 8.68 J/m.
- In irregular shape of artificial aggregate maximum drop impact value achieved is 8.75 J/m at 80% replacement of artificial aggregate.

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Appendix-A Chemical Properties of Artificial Aggregate

MATERIAL SAFETY DATA SHEET (MSDS)

Ceramic Media (Polishing White) Manufactured by Micro Industrial Ceramics

. For Sizes:

01	Product and Chemical name and Company identification	Ceramic Media Micro Industrial Ceramics. Plot No: 1713, GIDC Phase-4, Wadhawancity-363035. Dist Surendrangar, Gujarat. India.
02.	Chemical Composition	

CAS #	Component	Percentage
60676-86-0	silica	47 to 57
1344-28-1	Aluminum Oxide	35 to 45
12136-45-7	Potassium Oxide	2 to 5
1313-59-3	Sodium Oxide	
1309-48-4	Magnesium Oxide	0 to 0.5
1305-78-8	Calcium oxide	
1309-37-1	Iron Oxide	1 to 2
13463-67-7	Titanium Dioxide	

03	Fire & Explosive Hazard Data	Non- hazardous, non-poisonous and non-Inflammable. No special precautions are therefore required While Trasporting, Handling& Loading of the material.
04.	Extinguishing Media	All extinguishing agents can be used. Ceramic materials do not present any particular risk in the event of a fire. Use media appropriate for surrounding fire.
05.	Accidental Release Measure	Personal Precaution: Do not breath dust. Avoid contact with eyes. Environmental Precautions: This product does not present any particular risk to the environment.
06.	Emergency and First Aid	Product ingestion is unlikely to occur if proper safety/hygiene procedures are followed. Skin Contact: Wash affected areas with soap and water. If irritation developed, Obtain medical attention. Eye contact: Immediately rinse with plenty of water for a prolonged period (at least 15 minutes) while keeping the eyes wide opens. If necessary obtain medical attention. Ingestion: Rinse mouth out with water. If necessary obtain medical attention. Inhalation: Remove affected person to. fresh air. If respiratory problem Develop, obtain medical attention.
07.	Usage	It is used as absorbent, as catalyst and as catalyst support.
08.	Handling & Storage	Does not require any specific or particular measure. To guarantee the quality and properties of the product store in tightly closed protected from humidity and bad weather bad condition and properly labeled containers. Avoid formation of dust.
09.	Exposure Controls Personal Protection:	No specific measure required provided the product is handled accordance with the general rules of occupational hygiene and safety. Respiratory protection: use respiratory protective device with particle filter while handling of large quantities of product. Skin Protection: Use gloves to avoid prolonged or repeated skin contact. Eye protection: safety glasses or goggles as necessary to prevent eye contact.
10.	Toxicological Information	Local Effect: Slightly irritating to the respiratory system. The dust is irritating to the eyes.
11.	Disposal consideration	May be disposed of with non-hazardous industrial waste.