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Bearing Strength of Steel Fibre Reinforced Black Marble Stone Waste Aggregate Concrete

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Abstract

Concrete is an artificial material in which the aggregates (fine and course) are bounded together by the cement when mixed with water. Concrete has unlimited opportunities for innovative applications in construction field. Due to fast developing of infrastructure the availability of quality aggregates is depleting day to day and this is scaring to the construction industry. In this context it is required to think innovate or reuse of waste materials as alternate materials to available materials. The present paper presents the compressive and bearing strength performance on steel fibre reinforced stone waste aggregate concrete. The stone waste is generated from the stone polishing industries and it is converted in to use full aggregate and the same is used in concrete with different replacement levels of natural coarse aggregate (25,50,75 and 100%) with and without steel fibres. From the experimental results it is observed that 50% replacement of natural aggregate by stone waste aggregate is desirable for concrete works. Some regression models were deduced for estimating the bearing strength of concrete. The results of the experimental works were also compared with IS 456-2000 code provision.

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Keywords: *Stone waste aggregate; steel fibres;compressive strength; bearing strength; regression models;IS 456 code*.

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1. Introduction

The large scale consumption of raw materials by the construction sector results the shortage of building materials and this may scare the future generation. Among the many sectors, the concrete industry is particularly responsible for consuming natural resources and energy. For this reason the civil engineers have been challenged to convert the industrial wastes to useful building and construction materials. Many research activities were directed to utilize the waste material into the construction industry with suitable technical support. For design aspect some researchers developed new methodologies for design of structural element with proper guidelines.Recent past literature is presenting here on utilization of waste material in concrete. Torres P et.al.[1], Romualdo R Menezws et.al.[2] studied the effect of granite wastes sludge on industrial porcelain tile formulation. The experimental results show that the incorporation of granite sludge in the porcelain tiles possesses the superior properties. Saboya F et.al.[3] conducted the experimental work on properties of brick ceramic, they used the marble powder as by product material in the brick ceramic. The research work results exhibited that, use of marble powder about 15 to 20% in red ceramic as raw material is best proportion in the aspect of critical properties. Nuno Almeida et.al.[4]used the stone slurry in the concrete works as replacement material for fine aggregate in the concrete mixtures. The test results show that the substitution of 5% of the sand content by stone slurry induced higher compressive, split tensile strength and modulus of elasticity of concrete. Mustafa Karasahin and SerdalTerzi [5] studied the effect of marble waste in the mixture of asphaltic concrete. The study showed that marble wastes, which are in the dust form, could be used as filler material in asphalt mixtures where they are available and cost of transportation is lower than ordinary filler materials. Huseyin Akbulut and CahitGurer[6] studied the use of aggregates produced from marble quarry waste in asphalt pavement. The results indicated that the physical properties of the aggregates are within specified limits and they also stated that, these waste materials can potentially be used as aggregates in light to medium trafficked asphalt pavement binder layers. HanifiBinici et.al.[7] studied the durability of concrete made with granite and marble as recycle aggregates. In their investigation they noticed that durability of concrete made with marble and Ground Blast Furnace Slag (GBFS) showed superiority over the control concrete and this may be due to marble, granite and GBFS provide a good condensed matrix. Finally the results illustrate the prospects of using these wastes by-products in the concrete production Kamel K. Alzboon and Khalid N.Mahasneh[8] studied the possible use of stone cutting sludge waste in concrete production. The results indicated that the use of slurry sludge as water source in concrete with a 25% of the total water content obtained successful slump and compressive strengths.Nabi M Al-Akhras et.al.[9] conducted the experimental work on mortar mixes using burnt stone slurry. The results indicated that the compressive and flexural strength of mortar increased with the increase of burnt stone slurry (0 to 15%) content of mortar exposed to moist and autoclaving curing. I.Marmol et.al.[10] examined the use of granite sludge waste for production of colored cement based mortars. The results showed that the use of sludge waste is attractive with good compressive strengths and also environmentally friendly method of managing granite sludge waste. H.Hebhoub et.al.[11] conducted the experimental work on concrete using waste marble aggregate as partial replacement for the natural aggregate. The results showed that the mechanical properties of concrete specimens produced using the marble waste were conforming to the concrete production standards and the substitution of natural aggregates by waste marble aggregates up to 75% of is beneficial for the concrete resistance. VenkataRamana et.al,[12,13] presented the technical feasibility approach and scope of research work on stone waste aggregate and powder. Nareshkumar et.al. [14]presented the performance of stone waste aggregate concrete under impact loading using slab elements. The results encouraging the use of stone waste aggregate for concrete works. From the above review it is observed that there is no work has been carried on bearing strength. To estimate the bearing strength of stone waste aggregate concrete an experimental work has conducted with and without steel fibres.

2. Experimental Program

The experimental program comprises of casting and testing of total 90 cubes, out of which,45 cubes were cast with stone waste aggregate with replacement levels of 0,25,50,75 and 100% of natural aggregate and remaining 45 cubes were cast in the above said replacement levels along with steel fibre of 1 and 2% by volume. For each mix six cubes are taken for testing, in the six cubes, 3 are tested for compressive strength and other 3 cubes tested for bearing strength. For experimental work the materials used, methodology of casting and testing procedure is present below

2.1 Materials

2.1.1Cement:

Ordinary Portland cement of 53 grade was used and it is conformed to IS12269. The specific gravity of cement was observed as 3.05. The initial and finally setting of times were found as 45 and 360 minutes respectively.

2.1.2Fine aggregate:

River sand from local sources was used as fine aggregate. The specific gravity of sand is observed as 2.58.

2.1.3Coarse aggregate:

(a) Natural Coarse Aggregate: Crushed granite metal with 50% passing 20mm and retained on 10mm sieve was used. The specific gravity of coarse aggregate was observed as 2.66.
(b) Stone waste coarse aggregate: The raw material of stone waste aggregate was obtained from stone polishing industries (figure 1.) To convert the waste as coarse aggregate the waste material was transported to crusher unit and made as 20.00 and 12.50mm aggregate (figure 2). To obtain a reasonably good grading, 50% of the aggregate passing through 20 mm I.S. sieve and retained on 12.5mm I.S. Sieve and 50% of the aggregate passing through 12.5mm I.S. Sieve and retained on 10 mm I.S. Sieve is used. The specific gravity of the combined aggregate is 2.68. The granite and stone waste aggregate can be viewed in figure 3 and figure4.

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Fig. 1. Generation of stone waste

Fig. 2. Stone crusher

2.1.4 Water:

Potable fresh water, which is free from concentration of acid and organic substances, was used for mixing the concrete

2.15 Fiber:

Steel Fibers are supplied by STEWOLS INDIA (P) LTD (ISO 9001: 2008 Company at Nagpur, India) were used in the present experimental work. The most important parameter describing a fiber is its Aspect ratio. "Aspect ratio" is the length of fiber divided by an equivalent diameter of the fiber, where equivalent diameter is the diameter of the circle with an area equal to the cross sectional area of fiber. In the present investigation crimped fibers were used with aspect ratio of 90.The physical properties for these fibres are presented in table 1 and the same fibres can viewed in figure 5.

Table 1. Physical properties of crimped steel fiber

Length of Fiber	50 mm
Aspect ratio	90
Diameter (d)	0.55 mm
Width (w)	2.5 mm
Tensile Strength	450 MPa
Physical form	Clear, bright and undulated along the length
Material Type	Low Carbon Drawn Flat Wire

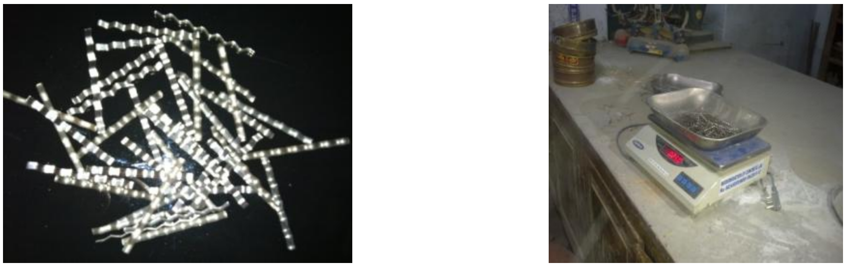

Fig. 5.Crimped steel fiber

2.2 Casting

The cubes were cast in steel moulds with inner dimensions of 150 x 150 x 150mm.The cement, sand, coarse aggregate and crimped steel fibers were mixed thoroughly. The mix proportion was adopted for all mixes as 1:1.91:3.17 and water cement ratio is taken as 0.5. This mix was arrived to M20 grade concrete. During mixing of concrete initially 25% of water required is added and mixed thoroughly till to obtain uniform mix. After that, the balance of 75% of water was added and mixed thoroughly with a view to obtain design mix. Care has to be taken in mixing to avoid balling effect.

For all test specimens, moulds were kept on table vibrator and the concrete was poured into the moulds in three layers and compaction was done with a tamping rod, in addition to this table vibrator was is also used. The moulds were removed after twenty four hours and the specimens were kept in a curing pond. After curing the specimens in water for a period of 28 days the specimens were taken out and allow drying under shade.

2.3 Test set up and testing

2.3.1Cube compressive strength test

The test set up for conducting cube compressive strength test is depicted in Figure 6. Compression test on cubes is conducted with 2000kN capacity compression testing machine. The machine has a least count of 1.0 kN. The cube was placed in the compression-testing machine and the load on the cube is applied at a constant rate up to failure of the specimen and the corresponding load is noted as ultimate load. Then cube compressive strength of the concrete is computed by using stand formula.

2.3.2 Bearing strength test

The test for bearing strength is done by crushing 150mm cubes, loaded through 25mm thick machined steel plate. The size of the square plate (67.10mm) is so prepared that the ratio of bearing area to the punching area is 5. Compression testing machine was used for all the tests and the axial load is applied at a constant rate as laid down in IS: 516-1959. The bearing test set up can viewed in figure 7.

Fig. 6. Cube compressive test

Fig. 7. Bearing strength test

3. Discussion Of Test Results

3.1 Influence of stone waste aggregate on workability

The workability for different mixes has been measured by Compaction factor test. The values of compaction factors results are presented in Table 2. In the table the nomenclature of mixes can be read as

i) NC-0: Where NC refers to Natural Granite Aggregate Concrete, '0' refers to % replacement of Natural coarse aggregate by stone waste concrete.

ii) SWC-25: Where SWC refers to stone waste concrete and '25' refers to % replacement of granite aggregate by stone waste concrete.

iii) SWC50: Where SWC refers to stone waste concrete and '50' refers to % replacement of granite aggregate by stone waste concrete.

iv) SWC-75: Where SWC refers to stone waste concrete and '75' refers to % replacement of granite aggregate by stone waste concrete.

v) SWC-100: Where SWC refers to stone waste concrete and '100' refers to % replacement of granite aggregate by stone waste concrete. (Hereafter for other test results the same nomenclatures were used in the subsequent sections)

From the obtained results, it is observed that the compaction factor increase with increase in the % of stone waste aggregate in the concrete mix. HankfiBinci et.al.[7] has been also reported same type of result for marble concrete. The increase of workability may be due to lower water absorption and smooth texture surface of stone waste aggregate than the granite aggregate

Table. 2 Workability

S.No	Nomenclature	Compaction Factor(CF) 0% fibre	Compaction Factor(CF) 1% fibre	Compaction Factor(CF) 2% fibre
1.	NC	0.768	0.763	0.733
2.	SWC 25	0.792	0.776	0.742
3.	SWC 50	0.832	0.811	0.794
4.	SWC75	0.874	0.852	0.834
5.	SWC 100	0.921	0.873	0.851

3.2 Influence of stone waste aggregate on compressive strength

3.2.1 First crack (FC) stage

The compressive strength at first crack stage for all mixes is presented in Table 3.From the table it is observed that as the % of stone waste aggregate is increases the compressive strength is decreasing. For 0% of fibers, the compressive strength is decreased from 8 to 42% for 25 to 100% replacement of stone waste aggregate when compared with natural aggregate concrete. This may be due to smooth textural surface of aggregates, obviously the smooth surface aggregates possess the weaker bond between the cement mortar and aggregates.

For 1% of fibre content in the mix, the compressive strength decreases as the % of stone waste aggregate increases when compared with NC (with and without fibres). But the addition of 1%fibres for concrete mix marginally enhances the compressive strengths when compared with corresponding replacements with 0% fibre concrete. For 2% of fibre concrete the compressive strength is decreasing as the replacement stone waste aggregate content is increasing. The % of decrease is about 13 to 38, when compared with natural aggregate concrete containing 2% of fibre. The mix with 25% of stone waste aggregate along with 2% of fibre exhibits nearly the same strength of natural aggregate concrete without fibres i.e 0% fibre. From this it concluded that, as the fibre content increases the strength may enhances for stone waste aggregate concrete. In this mix the fibres placing major role to enhance the strength. This type of observations were noticed by S.AAl-Taan and J.A.Al-Hamdony[15] for steel fibre concrete. Initially the mix was designed for M20 and it is to be implicit that the mix should show minimum strength of 20N/mm2. The design strength line (20N/mm2) is shown in the Figure 9 this line touches the 0% curve nearly at 30% replacement of stone waste aggregate. Similarly for 1% and 2% fiber concrete, the plotted curves touch the design line at 60 and 80% of replacement of stone waste aggregate respectively. From this it is observed that the safe limits for replacement is 25, 50 and 75% for 0, 1 and 2% fibre concrete.

3.2.2: Ultimate stage (US):

The compressive strength at ultimate stage for all mixes is presented in Table 3.From this it is observed that as the % of stone waste aggregate is increases the compressive strength is decreasing. For 0% of fibers, the compressive strength is decreased from 9 to 42% for 25 to 100% replacement of stone waste aggregate when compared with natural aggregate concrete (NC). This type of observation was observed by HanfiBinici et.al.[7] for marble concrete. But Hebhoub et.al.[11] reported in different way for marble concrete. They reported that, at 75% replacement level the strength was enhanced when compared with other replacements and at 100% replacement level there was decrease in compressive strength. Whereas from present experimental work it is observed that there is continuously decrease in compressive strengths as percentage of stone waste aggregate increases in concrete mix. This may be due possessing of smooth textural surface of aggregate.

For 1% of fibre content in the mix, the compressive strength decreases as the % of stone waste aggregate increases when compared with natural concrete with and without fibres. But the addition of 1%fibres for concrete mix marginally enhances the compressive strengths when compared with corresponding replacements of stone waste aggregate with 0% fibre concrete. For 2% of fibre concrete the compressive strength is decreasing as the replacement stone waste aggregate content is increasing. The % of decrease is about 12 to 38, when compared with natural aggregate concrete containing 2% of fibre. The mix with 25% of stone waste aggregate along with 2% of fibre (32.84Mpa) exhibits marginally higher strength of natural aggregate concrete without fibres i.e 0% fibre(32.69Mpa). From this it concluded that, as the fibre content increases the strength may enhances for stone waste aggregate concrete. In this study the inclusion of 2% fibres for 25% of stone waste aggregate showed the nearly same strength of natural aggregate concrete without fibres at first crack and ultimate stages. This type of observations were noticed by S.A.Al-Taan and J.A.Al-Hamdony[15] for steel fibre concrete.The design strength line (20N/mm2) is depicted in figure 10, this line touches the 0% curve nearly at 90% replacement of stone waste aggregate. Similarly the 1 and 2% fiber curves are above the design curve. From this it is observed that, the safe limits for replacement stone waste aggregate in the mix is 75% for 0% fibres and for other 1 and 2% fibre concrete it may be 100%.

Table.3. Cube compressive strength at first crack and ultimate stages

S.No	Nomenclature	First Crack Stage Compressive Strength (N/mm^2)			Ultimate Stage Compressive Strength (N/mm^2)		
		0% fibre	1% fibre	2% fibre	0% fibre	1% fibre	2% fibre
1.	NC	23.31	25.29	26.83	32.69	35.88	37.04
2.	SWC 25	21.34	22.74	23.26	29.44	31.36	32.84
3.	SWC 50	17.26	21.34	22.83	24.20	28.89	31.02
4.	SWC75	16.41	17.94	20.81	22.39	24.46	27.67
5.	SWC 100	13.44	15.29	16.59	18.82	23.26	24.44

3.3 Influence of stone waste aggregate on bearing strength.

The allowable bearing stress depends on the bearing strength of concrete and this often controls the dimensions of the members. According to ACI: 318 the ultimate stress under concentrated forces is called bearing strength. In reality this type of forces are encountered in the area of missiles, projectiles and explosions (S.P Ray and B.Venkateswarulu[16]). In the present experimental work, it is focused to evaluate the bearing strength for pedestal purpose only.

3.3.1: First crack (FC) stage

The bearing strength at first crack stage for all mixes is presented in Table 4 and from this it is observed that as the % of stone waste aggregate is increases the bearing strength was decreased. For 0% of fibers, the bearing strength is decreased from 15 to 61% for 25 to 100% replacement of stone waste aggregate when compared with natural aggregate concrete. For 1% of fibre concrete mix, the bearing strength decreases as the % of stone waste aggregate increases when compared with natural concrete with and without fibres. But the addition of 1%fibres for concrete mix, the bearing strength marginally enhances when compared to corresponding replacements with 0% fibre concrete. The mix with 25% of stone waste aggregate along with 1% of fibre exhibits more strength (58.9N/mm2) when compared with natural aggregate concrete without fibres i.e 0% fibre (55.00N/mm2). But for mix with 50% of stone waste aggregate along with 1% of fibre showed marginally lesser strength (54.20N/mm2) of natural aggregate concrete without fibres i.e 0% fibre (55.00N/mm2).For 2% of fibre concrete the bearing strength is decreasing as the replacement stone waste aggregate content is increasing. The% of decrease is about 2 to 28, when compared with natural aggregate concrete containing 2% of fibre. The mix with 50% of stone waste aggregate along with 2% of fibre exhibits nearly the same strength of natural aggregate concrete without fibres i.e 0% fibre. From this it concluded that, as the fibre content increases the bearing strength may enhances for stone waste aggregate concrete. In this mix the fibres placing major role to enhance the strength. This type of trends were noticed by S.A.Al-Taan and J.A.Al-Hamdony[15] for steel fibre concrete. From the above results, it concluded that the presence of steel fibres in concrete mix showed good performance up to 50% replacement level i.e. it is as good as natural aggregate concrete. So the designer can be take the concrete mix with stone waste aggregate up to 50% replacement with 1 and 2% of fibers.

3.3.2: Ultimate stage (US):

The bearing strength at ultimate state for all mixes is presented in Table 4. From table it is observed that as the % of stone waste aggregate is increases the bearing strength is decreased. The behavior of concrete at ultimate stage is similar to first crack stage. For 0% of fibers, the bearing strength is decreased from 15 to 61% for 25 to 100% replacement of stone waste aggregate when compared with natural aggregate concrete.For 1% of fibre concrete mix, the bearing strength decreases as the % of stone waste aggregate increases when compared with natural concrete with and without fibres. But the addition of 1%fibres for concrete mix, the bearing strength significantly enhances when compared with corresponding replacements with 0% fibre concrete. The mix with 25% of stone waste aggregate along with 1% of fibre exhibits more strength (81.8N/mm2) when compared with natural aggregate concrete without fibres i.e 0% fibre (76.30N/mm2). But the mix with 50% of stone waste aggregate along with 1% of fibre showed marginally lower strength (75.30N/mm2) when compared with natural aggregate concrete without fibres (76.30N/mm2).For 2% of fibre concrete the bearing strength is decreasing as the replacement stone waste aggregate content is increasing. The% of decrease is about 2 to 28, when compared with natural aggregate concrete containing 2% of fibre. The mix with 50% of stone waste aggregate along with 2% of fibre exhibits higher strength (77.4Mpa) of natural aggregate concrete without fibres i.e 0% fibre(76.3Mpa). From this it concluded that, as the fibre content increases the bearing strength may enhances for stone waste aggregate concrete. In this mix the fibres placing major role to enhance the strength. The loss of strength in stone waste aggregate can be gained by incorporation of steel fibres, this may be due to a law of mixture and good energy absorption of steel fibre matrix. This type of results were noticed by S.A.Al-Taan and J.A.Al-Hamdony[15] for steel fiber concrete.

Table .4. Bearing strength at first crack and ultimate stages

Sl.No	Nomenclature	First Crack Stage Bearing Strength (N/mm^2)			Ultimate Stage Bearing Strength (N/mm^2)		
		0% fibre	1% fibre	2% fibre	0% fibre	1% fibre	2% fibre
1.	NC	55.00	64.80	66.30	76.30	90.10	92.20
2.	SWC 25	46.30	58.90	64.80	64.50	81.80	90.02
3.	SWC 50	34.30	54.20	55.70	47.70	75.30	77.40
4.	SWC75	30.50	49.50	52.50	41.20	66.80	71.00
5.	SWC 100	21.20	43.30	47.60	29.20	59.60	65.50

3.4. Relationship between bearing and compressive strength.

The bearing strength of concrete is most important parameter during the design of axially loaded elements. For normal concrete the IS 456-2000 code recommended the following equation to estimate the bearing strength.

$fb=0.45(fck)\sqrt{(A_1/A_2)}$

In the above expressions

fck = Characteristic compressive strength (N/mm2)

A_1= Supporting area for bearing of footing (i.e. cube surface area)

A_2=loaded area at the column base (i.e. steel plate surface area)

$\sqrt{(A_1/A_2)}$ should not be greater than 2

The validity of the above equations was demonstrated in Table 5. From this table it is observed that the IS code is underestimate the strength. Hence there is a necessity to develop a regression model (RM) to suit the experimental values for stone waste aggregate concrete. In this view a regression modal with a correlation coefficient R2=0.99 (for all % of fibres) was developed and presented below.

fb= 2.29(fck)-0.15(%of replacement)+1.49---------------- for 0% fibre (Equation-1)

fb= 0.68(fck)-0.20(%of replacement)+65.8------------------ for 1% fibre (Equation-2)

fb= -2.03(fck)-0.50(%of replacement)+168.7----------------for 2% fibre (Equation-3)

In the above expressions

fb = Bearing strength (N/mm2)

fck = Characteristic compressive strength (N/mm2)

The performance of the proposed model is presented in Table 5. From this table it is observed that the ratio between EXP and RM is about 0.98 to 1.00. The ratio inferences the proposed model is best suited to the experimental values and also may concluded that it is better than IS code formula.

3.5 Failure Mode

The compression test was conducted on cubes. The cubes with 0% fibres were shown lower load when compared with cubes containing with 1 and 2% fibre. Among the 1 and 2% fibre cubes the cubes with 2% showed higher load carrying capacity. In 0% fibre cubes the concrete was peel off at edges and this can be viewed in the figure 8, whereas the cubes containing fibres showed there is no peel off. As percentage of fibre increases in the concrete mix the crack width and less damage was observed during experimentation. For bearing test, radial cracks were observed on cubes during experimentation and this can be viewed from figure 9.This type of cracks were also observed by S.A.Al-Taan and J.A.Al-Hamdony[15] for steel fiber concrete. The dimensional stability is increased as the steel fibre content increases in the mixes and also the crack width is decreased.

Table.5. Performance of regression model

Sl.No.	% Fibre	% Stone waste aggregate	Bearing strength (N/mm2) IS456-2000	Exp Bearing strength (N/mm2)	Exp/IS456-2000	Bearing strength (N/mm2) as per RM	Exp/RM
1		0	29.42	76.30	2.59	76.30	1.00
2		25	26.49	64.50	2.43	64.30	1.00
3	0%	50	21.78	47.70	2.19	47.60	1.00
4		75	20.15	41.20	2.04	41.10	1.00
5		100	16.93	29.20	1.72	39.06	0.74
6		0	32.29	90.10	2.79	89.90	1.00
7		25	28.22	81.80	2.89	81.80	1.00
8	1%	50	26.00	75.30	2.89	75.50	0.99
9		75	22.01	66.80	3.03	67.40	0.99
10		100	19.29	59.60	3.08	60.30	0.98
11		0	33.84	92.20	2.72	92.30	0.99
12		25	29.55	90.02	3.04	90.20	0.99
13	2%	50	27.90	77.40	2.77	77.90	0.99
14		75	24.90	71.00	2.85	71.70	0.99
15		100	20.90	65.50	3.13	66.40	0.98

Fig. 8. Tested Cube under Compression loading

Fig. 9.Failure mode of cube under bearing loading

Conclusions

The following conclusion were drawn from the experimental work

- As the % of stone waste aggregate increases in the concrete mix the compressive and bearing strengths were decreased.
- The compressive strength at first crack and ultimate stages , the % of decrease is about 8 to 42% for 25 to 100% stone waste aggregate when compared with natural aggregate concrete.
- The bearing strength at first crack and ultimate stages, the % of decreases about 15 to 61% for 25 to 100% stone waste aggregate when compared with natural aggregate concrete
- The bearing strength regression model presented in this paper is well matched with the experimental results.
- From the present research work, it can be concluded that the utilization of stone waste aggregate can be

used for concrete works upto 50% of replacement of natural aggregate.

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