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BEARING STREGTH OF BASALT FIBRE REINFORCED RECYCLED AGGREGATE CONCRETE

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ABSTRACT

The present article aimed to evaluate the bearing strength of basalt fibre reinforced recycle aggregate concrete with bearing area ratio of 10 and 15. Total ten mixes are taken for experimental work, among them 5 mixes with basalt fibres and 5 other mixes without basalt fibres. The natural aggregate was replaced by the recycle aggregate in the volume proportion of 0,25,50,75 and 100% and the basalt fibres are added to the mixes in the proportion of $4 kg/m^3$.In addition to bearing strength, for all mixes compressive and split strengths are evaluated. For obtained bearing strength results, regression models are developed to estimate the bearing strength as function of cube compressive strength and % of basalt fibres. The results showed that, the bearing strength for 50% recycle aggregate concrete mix exhibited more strength when compared with all the mixes (without fibres) and with addition of fibres the strengths are increased for all the mixes.

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INTRODUCTION

Concrete is the most important part in structural construction, the aggregate content should be in a form of good strength for structural purposes. Concrete is made up of with combination of aggregate, cement and water in this combination, three-quarter of the mix is governed by aggregate. The aggregate itself is categorized as fine and course aggregate. In recent years certain countries have considered the re-utilisationof construction and demolition waste as a new construction material as being one of the main objectives with respect to sustainable construction activities. In resent the use of Recycled Concrete (RC) aggregate as a coarse aggregate fraction in structural and non-structural concrete is encouraging by the state and central government. In this view the present experimental was planned to use Recycle aggregate(RA) in different proportions in the place of natural aggregate (NA). From the literature it is also noticed that the strengths are varying by using the recycle aggregate in the place of natural aggregate.

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In order to enhance the strengths of RAC concretes, fibre incorporation studied are there in the literature. Many studies are there with incorporation of different fibres in the RAC concrete mixes. But with the use of basalt fibres in RAC are very few; hence the present experimental work has been planned with basalt fibres. Basalt fibre is a high performance non-metallic fibre made from basalt rock. With basalt rock can make chopped basalt fibres, basalt fabrics and continuous filament wire. Basalt rock originates from volcanic magma and volcanoes, a very hot fluid or semi fluid material under the earth's crust, solidified in the open air. Basalt is a common term used for a variety of volcanic rock, which are gray dark in colour. The molten rock is then extruded through small nozzles to produce continuous filaments of basalt fibre. The basalt fibres do not contain any other additives in a single producing process, which gives additional advantage in cost. In this study, the scope of research will be focused on the use of basalt fibre in concrete to overcome the drawbacks and to improve the performance of concrete. In the view of present work the resent past literature is presenting below to know the status of work in this area. Arivalagan. S, (2012) studied the compressive strength behaviour of basalt fibre concrete for

M20 and M30 grade concrete. Craig A. Scheffers and R. Sri Ravindrarajah (2009) studied the bearing strength of concrete for the ratio of total surface area to bearing area of two, four and six. E. ArunaKanthi *et al.* (2014) studied that the bearing strength for PET fibre reinforced recycle aggregate concrete. For a particular recycle aggregate content as the Polyethylene Terephthalate (PET) fibres increase the bearing strengths were increased. Hardik Gandhi *et al.* (2011) observed that higher percentage of RCA attained more early strength than normal concrete aggregate and the compressive strength is optimum with 60% replacement of the recycled coarse aggregate. VenkataRamana etal. (2016) 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. VenkataRamana (2017) studied the effect of steel fibers (i.e., 1 and 2%) in the concrete mixes along with the by- product material of silica fume. The compressive and bearing strengths were increased for steel fibre reinforced mixes when compared with respective replacement of silica fume concrete. Saravenakumar and Dhinakaran (2012) studied the compressive and Split tensile strength for recycle aggregate concrete and they reported that 50% replacement is effective for the concrete mix. Sri Ravindrarajah (1999) observed the effectiveness of polystyrene aggregate (PA) content for concrete and he noticed that the bearing strength was decreased for PA concrete. RifatRustom *et al.* (2007) conducted the experimental work on recycle aggregate concrete and they noticed that, the compressive strength (28days) is less about 27% - 30% than the strength of the concrete made with natural aggregates. Shelson (1957) conducted studies on bearing strength of concrete and form the experimental work it is observed as inverted pyramid failure in concrete under bearing loads using small bearing plates. Raghu Babu and VenkataRamana, (2016) used the Artificial Neural Network (ANN) approach to estimate the bearing strength of waste stone aggregate concrete for bearing are ratio of five.

VenkataRamana. N (2017) conducted the compressive strength studies on stone waste aggregate (it is by product of polishing stone industries) concrete with incorporation of steel fibres and form the experimental work, it is observed that the % of marble stone waste aggregate content increases in the mix (without steel fibres) the strengths were decreased. But with incorporation of steel fibres, the strengths are enhanced for the same mixes of concrete. VenkataRamana (2017) has presented a review on basalt fibre reinforced concrete, from this it is noticed that many works have been taken to evaluate engineering properties of concrete and comparison was made with pre-existing of fibre reinforced concrete. From the recent past literature it came to know that, many work are taken up on concrete by using, by-product materials which are generated from the industries and also studies are noticed along with fibres for concrete mixes to enhance the engineering properties.

But no work has been identified on recycled aggregate concrete with incorporation of basalt fibres. So in this connection research work has planned to study the performance of fibre recycled aggregate concrete to evaluate bearing strength of concrete. The detail experimental program is furnishing below.

EXPERIMENTAL PROGRAM

The following variables were considered for the experimental programme and same were presented in Table 1.

Table 1. Variables for Experimental work

Sl.No	Factors for the Experimental work		
1	% of Recycle Aggregate Variation	0,25,50,75 and 100%	
2	Dosage of Basalt fibre	4 Kg/m^3	
3	Total number of mixes	10	
4	Mix Ratio as per ACI 211.1-91code	1:2.64:2.96 for 0% NAC mix	Water cement ratio for all mixes is 0.57
		1:2.69:2.91 for 25% RAC mix	
		1:2.76:2.84 for 50% RAC mix	
		1:2.80:2.80 for 75% RAC mix	
		1:2.81:2.79 for 100% RAC mix	
5	Bearing Area Ratio	10 and 15	
6	Strength evaluation	Compression, Split tensile and Bearing strengths	
7	Type of specimens cast	Cubes (30 numbers for compression and 60 numbers for bearing strength) and Cylinders (30 numbers)	
8	Strength evaluation day for all mixes	28th day from the date of casting	

MATERIAL USED

The following material were used for the present experimental work

Cement: Ordinary Portland cement conforming to IS 8112:1989 was used. The specific gravity of the cement was noticed as 3.12.

Fine Aggregate: Locally available river sand passing through 4.75 mm I.S .Sieve is used. The specific gravity of the sand is found as 2.75 and it was conformed to zone II.

Natural Coarse Aggregate: Crushed granite aggregate available from local sources has been used. 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 in preparation of NA. The specific gravity of the combined aggregate is 2.70.

Recycled concrete aggregate: The raw material of Recycled concrete aggregate was obtained from demolished cement concrete pavement. The generated waste material was is not able to use as it is, as coarse aggregate in the concrete. So there is a need to develop as graded aggregate to use in concrete. To convert the waste as coarse aggregate the waste material was transported to crusher unit and made as 20 and 12.5 mm aggregate. 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 combined aggregate was observed as2.56.

Water: Potable fresh water available from local sources was used for mixing and curing.

Basalt Fibers: The used basalt fiber can be viewed in below figure1. The properties are presented in the Table 2, which were obtained from the supplier.

Fig. 1. Basalt Fiber

Table 2. Physical properties of Basalt Fibers

Sl. No	Property	Units	Value
1	Equivalent length	Mm	50
2	Filament diameter	Micro meter	9-15
3	Specific gravity	No units	2.8
4	Tensile strength	MPa	3000-4840
5	Young's modulus	GPa	79.3-93
6	Ultimate elongation	%	3.1

CASTING AND CURING

The cubes were cast in steel molds with inner dimensions of 150 x 150 x 150mm, the cylinders were cast in steel molds with inner dimensions of 150mm diameter and 300mm height. All the materials are weighed as per mix design and kept aside separately. The cement, sand, coarse aggregate and recycled concrete aggregate were mixed thoroughly till to reach uniformity to the concrete mix. The fibers are added to concrete ingredients in dry state. After achieving uniform mix then the water is added to the mix and mixed with hand operation till to get homogenous mix. For all test specimens, molds were kept on table vibrator and the concrete was poured into the molds and the compaction was adopted by mechanical vibrator. The specimens are de-molded after twenty four hours and were exposed to water bath for 28 days in curing pond. After curing the specimens in water for a period of 28 days, the specimens were taken out and allowed to dry under shade. Three cubes and three cylinders were cast for each mix.

TESTIING

Compaction Factor Test

The compaction factor test apparatus consists of two hoppers, each in the shape of frustum of a cone and one cylinder. The upper hopper is filled with concrete this being placed gently so that no work is done on the concrete at this stage to produce compaction. The second hopper is smaller than the upper one and is therefore filled to overflowing. The concrete is allowed to fall in to the lower hopper by opening the trap door and then into the cylindrical mold placed at the bottom. Excess concrete across the top of the cylindrical mold is cut and the net weight of the concrete in cylinder is determined. This gives the weight of partially compacted concrete. Then the cylindrical mold is filled with concrete and compaction was done by tamping rod. The fully compacted weight is then determined and compaction factor (C.F) is calculated by using the standard formula (refer any standard text book of Concrete Technology).

Cube Compressive Strength Test

Compression test on cubes is conducted with 2000kN capacity compression testing machine. The machine has a least count of 1kN. The cube was placed in the compression-testing machine and the load on the cube is applied at a constant rate till to failure of the specimen and the corresponding load is noted as ultimate load. Then cube compressive strength of the concrete mix is then computed by using stand formula (this test has been carried out on cube specimens at 28 days).

Split Tensile Strength

The cylinder is placed on the bottom compression plate of the testing machine and is aligned such that the center lines marked on the ends of the specimen are vertical. Then the top compression plate is brought into contact at the top of the cylinder. The load is applied at uniform rate, until the cylinder fails and same load is taken in to account as ultimate load. From this load, the splitting tensile strength is calculated for each specimen by stand formula.

Bearing Strength

The test for bearing strength is conducted on cubes. The compressive load was applied through 25mm thick machined steel plate. The size of the square plate is prepared as bearing to the punching area is 10 (size of plate over cube is 47.4x47.4mm) and 15 (size of plate over cube is 38.7x38.7mm). This arrangement is simulates to column and footing in real structures and also sometimes it may treat as the heavy point load acts on plane surface. A 2000 kN 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. Tested specimens can be viewed in figure 2(a) and 2(b) along with bearing plate.

Fig 2(a): Tested cube for bearing area ratio 10

Fig 2(b): Tested cube for bearing area ratio 15

RESULTS AND DISCUSSION

Workability

The workability of different mixes has been measured by Compaction factor test. The values of compaction factors results are presented in figure 3.From these it is observed that the compaction factor decreases with increase in the % of recycled concrete aggregate in the concrete mix.

The decreases of workability may be due to higher water absorption of recycled concrete aggregate than the normal aggregate. The effect of workability in recycled concrete aggregate with fibers can also observed in figure 3 .From this it can be noticed that as the % of fibers increase the workability is decreases when compared to concrete without fibers. In the presence of the basalt fibers in recycled concrete aggregate concrete the workability is decreases. This may be due to effect fibers, generally the fibres gives dimensional stablity to the mixes, same was happened in the mixes.

Compressive strength

The compressive strengths results are presented in Table 3, from this; it can be observed that the 28 days compressive strength increases with the increase in the percentage of recycled up to 50%. For 25, 50 recycled concrete aggregate there is a increase in compressive strength about 4.59%, 11.2% and for 75,100% recycled aggregate there is a decrease in compressive strength about 0.9, 4.2% respectively over reference concrete. From the same table it also observed that, for fiber added mixes, the compressive strength increases at every % of recycled concrete aggregate. From a law of rule of mixture the strength enhancement is expected for the mixes.

Table 3. Compressive Strength

Sl. No	Nomenclature	First Crack Load (kN)	First Crack Compressive Stress(N/mm^2)	Average Stress (N/mm^2)	Ultimate Load(kN)	Ultimate Compressive Stress(N/mm^2)	Average Stress (N/mm^2)
1	NAC-0	524.30	23.30	21.85	821.20	36.50	33.30
		452.30	20.10		706.50	31.40	
		498.70	22.16		720.00	32.00	
2	RAC-25	532.30	23.79	22.26	877.50	39.20	34.83
		432.00	19.20		675.00	30.30	
		535.50	23.80		787.50	35.00	
3	RAC-50	500.90	22.26	22.31	821.25	36.50	37.03
		590.40	26.24		920.50	41.60	
		504.00	22.44		742.50	33.00	
4	RAC-75	532.30	23.79	21.45	877.50	39.30	33.60
		446.40	19.84		697.50	31.00	
		466.70	20.74		686.25	30.50	
5	RAC-100	425.50	18.91	20.45	697.90	31.20	31.90
		518.50	23.04		810.00	36.50	
		428.50	19.04		630.00	28.00	
6	FNAC4-0	555.80	24.70	22.94	911.50	40.80	36.77
		495.00	22.00		765.00	34.00	
		543.20	24.14		798.75	35.50	
7	FRAC4-25	562.70	25.01	23.93	922.50	41.00	37.33
		517.50	23.00		810.00	36.00	
		535.50	23.80		787.50	35.00	
8	FRAC4-50	540.00	24.10	24.55	911.25	40.50	38.33
		510.70	22.70		785.00	35.00	
		604.30	26.86		888.75	39.50	
9	FRAC4-75	549.00	24.40	22.89	900.00	40.00	36.00
		522.00	23.20		832.50	37.00	
		474.30	21.08		697.50	31.00	
10	FRAC4-100	507.80	22.57	22.09	832.50	37.00	32.50
		540.00	24.00		708.57	31.50	
		443.70	19.72		652.50	29.00	

Spilt Tensile Strength

The 28 days split tensile strength of recycled aggregate concrete mixes are presented in Table 4. From this it is observed that, the split tensile strength increases with the increase in the percentage of recycled aggregate up to 50% and for other mixes the strengths are decreased. For 25, 50% of recycled there is increase in split tensile strength by 4%, 7.4% over the reference concrete. For 75% and 100%, the split tensile strength has decreased by 7.74% and 9.04 %respectively over reference concrete (NAC-0). From the Table 3 it is also observed that as the % of volume fraction of fibres increases the split tensile strength increases at every % of recycled concrete aggregate.

The fibres are act as crack arresters and those may take more time to failure and also takes more loads to failure.

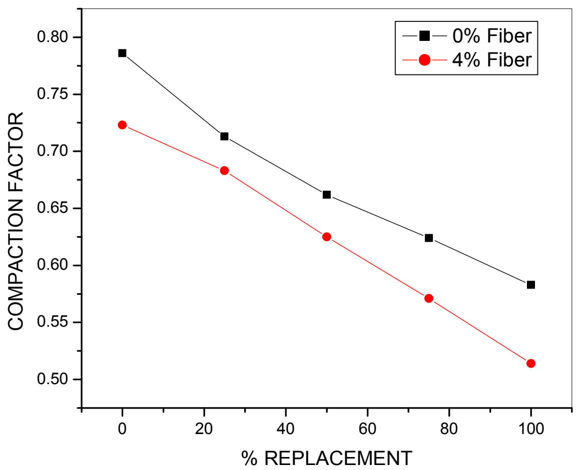

Fig. 3. Compaction factor Vs % of replacement

Bearing strength

Bearing Area Ratio 10

The bearing strength results for area ratio of 10 are presented in Table 5. From these it is observed that the bearing strength increases with the increase in the percentage of recycled aggregate up to 50% and later stages the bearing strengths are decreased.

Table 4. Split Tensile Strength

Sl. No	Nomenclature	First Crack Load (kN)	First Crack Split Tensile Stress (N/mm^2)	Average Stress (N/mm^2)	Ultimate Load (kN)	Ultimate Tensile Stress (N/mm^2)	Average Stress (N/mm^2)
1	NAC-0	086.73	1.23	1.51	139.80	1.98	2.29
		096.43	1.37		148.40	2.10	
		136.40	1.93		197.80	2.80	
2	RAC-25	087.60	1.24	1.70	141.30	2.00	2.38
		101.10	1.43		155.40	2.20	
		143.80	2.44		208.40	2.95	
3	RAC-50	092.00	1.30	1.61	148.30	2.10	2.46
		133.10	1.89		204.80	2.90	
		117.00	1.66		169.56	2.40	
4	RAC-75	091.10	1.29	1.39	146.90	2.08	2.12
		110.20	1.56		169.50	2.40	
		093.00	1.31		134.20	1.90	
5	RAC-100	092.00	1.31	1.37	148.30	2.10	2.10
		112.00	1.57		170.00	2.40	
		087.80	1.24		127.17	1.80	
6	FNAC4-0	113.90	1.61	1.65	183.69	2.60	2.38
		101.20	1.43		155.43	2.20	
		134.10	1.90		194.28	2.35	
7	FRAC4-25	122.60	1.74	1.55	197.82	2.80	2.40
		096.50	1.37		148.36	2.10	
		112.10	1.56		162.49	2.30	
8	FRAC4-50	127.10	1.80	1.61	204.88	2.90	2.47
		097.00	1.37		149.00	2.10	
		118.00	1.67		170.97	2.42	
9	FRAC4-75	113.90	1.61	1.54	183.69	2.60	2.35
		112.60	1.60		173.10	2.45	
		097.50	1.40		141.30	2.00	
10	FRAC4-100	096.40	1.36	1.47	155.40	2.20	2.25
		119.40	1.70		183.70	2.60	
		095.40	1.35		137.70	1.95	

Table 5. Bearing Strength

Sl. No	Nomenclature	Bearing Area Ratio 10			Bearing Area Ratio 15		
		Ultimate Load (kN)	Ultimate Bearing Stress (N/mm^2)	Average Bearing stress (N/mm^2)	Ultimate Load (kN)	Ultimate Bearing Stress (N/mm^2)	Average Bearing Stress (N/mm^2)
1	NAC-0	157.59	70.14	68.93	122.03	81.48	83.46
		152.20	67.74		122.32	81.67	
		154.82	68.91		129.64	86.56	
2	RAC-25	167.41	74.51	73.51	132.15	88.24	90.13
		163.77	72.89		136.31	91.01	
		164.33	73.14		136.48	91.13	
3	RAC-50	184.48	82.11	80.25	135.36	90.38	93.47
		177.97	79.21		141.96	94.79	
		178.48	79.44		142.63	95.23	
4	RAC-75	176.71	78.65	77.79	130.92	87.41	86.80
		172.75	76.89		132.15	88.24	
		174.81	77.81		126.91	84.74	
5	RAC-100	162.69	72.41	71.27	122.03	81.48	83.46
		157.68	70.18		123.31	82.33	
		160.06	71.24		129.64	86.56	
6	FNAC4-0	160.46	71.42	71.21	130.92	87.41	86.80
		157.81	70.24		132.15	88.24	
		161.69	71.97		126.91	84.74	
7	FRAC4-25	171.29	76.24	77.88	135.36	90.38	93.47
		173.85	77.38		141.96	94.79	
		179.78	80.02		142.63	95.23	
8	FRAC4-50	185.35	82.50	82.34	143.83	96.03	96.81
		188.12	83.73		148.63	99.24	
		181.53	80.80		142.50	95.15	
9	FRAC4-75	182.25	81.12	80.11	132.15	88.24	90.13
		184.58	82.15		136.34	91.03	
		173.15	77.07		136.48	91.13	
10	FRAC4-100	171.51	76.34	75.66	130.92	87.41	86.80
		173.53	77.24		132.05	88.17	
		164.91	73.40		126.91	84.74	

Table 6. Performance of Regression Model

Sl. No	Nomenclature	Bearing Area Ratio 10			Bearing Area Ratio 15		
		Experimental (EXP) Bearing Stress (N/mm^2)	Regression Model (RM) Bearing Stress (N/mm^2)	EXP/RM	Experimental (EXP) Bearing Stress (N/mm^2)	Regression Model (RM) Bearing Stress (N/mm^2)	EXP/RM
1	NAC-0	69.00	73.80	0.93	83.46	85.95	0.97
2	RAC-25	73.00	75.60	0.97	90.13	88.53	1.02
3	RAC-50	80.00	78.30	1.02	93.47	92.30	1.01
4	RAC-75	78.00	74.10	1.05	86.80	86.42	1.00
5	RAC-100	71.00	71.90	0.99	83.46	83.50	1.00
6	FNAC4-0	71.00	78.00	0.91	86.80	91.84	0.95
7	FRAC4-25	78.00	78.70	0.99	93.47	92.82	1.01
8	FRAC4-50	82.00	79.90	1.03	96.81	94.53	1.02
9	FRAC4-75	80.00	76.90	1.04	90.13	90.54	1.00
10	FRAC4-100	76.00	72.60	1.04	86.80	84.53	1.03

For 25, 50% of recycled there is increase in bearing strength by 9.36% and 5.72% over the natural aggregate concrete. For 75% and 100%, the bearing strength has decreased by 2.7% and 5.55% respectively over granite aggregate concrete (RAC-0). With addition of basalt fibres the strengths for all mixes are increased and the increment of strength is more up to 50% RA concrete mix subsequently for other mixes the strengths are decreased when compared with fibre reinforced natural aggregate concrete(FNAC-0). The % of increase for 25 and 50% RAC mixes is about 9 to 5% respectively when compared with FNAC-0 mix. The fibres are the source to enhance the strengths and they may act as crack arresters and also required more energy to fail.

Bearing Area Ratio 15

The bearing strength results for recycled aggregate concrete mixes are presented in Table 5. From this it is observed that, the bearing strength increases with the increase in the percentage of recycled aggregate up to 50% and later % of RAC mixes it was decreased. Here also same trend was followed as it happened in the bearing ratio of 10. For 25, 50% of recycled there is increase in bearing strength by 7.68% and 3.57% over the Natural aggregate concrete (NAC-0). For 75% and 100%, the bearing strength has decreased by 6.9% and 3.69% respectively over granite aggregate concrete (NAC-0) For fibre incorporation mixes the bearing strengths are increased for all mixes of recycle aggregate concrete, but the trend is similar to RAC mixes without fibres. Among the FRAC mixes the mix with 25 and 50% shown higher bearing strengths compared to other two mixes of 75 and 100%. The % of increase in bearing strength for 25 and 50% RAC mixes is about 9 to 5% when compared with FRAC-0 mix. The same enchantment of strength is also observed for bearing strength of 10 tested specimens. The enhancement of strength for 50% RAC mix may be due to better bond (surface texture) between the RA and NA and the arrangement of aggregates in the mass of concrete.

Regression Model to Estimate Bearing strength

The following regression models were established to estimate the bearing strength of concrete and the models are tested with experimental results. In general strength parameters (flexure, shear, split tensile strength etc.) are related to cube compressive strength. Hence here in also the authors would like to develop regression models to estimate the bearing strength as function of cube compressive strength. From this intension the models are developed and furnished below. The performance of regression models are presented in Table 6. From this table it is noticed that, the experimental values are varying about ±5%. From the results it is noticed that the

$F_b = 33.02+1.218\,(f_{ck})$ -------------Eq (1) for Bearing ratio 10

$F_b = 28.765+1.716(f_{ck})$ -------------Eq (2) for Bearing ratio 15

$f_{ck} = 33.277+0.0135296(R)+0.57306(BF)$

Where

f_{ck}=compressive strength in MPa,

R=% replacement of recycled concrete aggregate

BF= Basalt fibre in kg/m^3.

F_b=Bearing stress in MPa.

The above equations are subjected to constraints of

$0 \leq R \leq 100$

$0 \leq BF \leq 4$

Conclusions

The following conclusions may be drawn from the present experimental work

- The workability for recycled concrete aggregate is decreases when compared with normal aggregate concrete.
- The compressive, split tensile and bearing strengths were increases with the increase of recycled concrete aggregate up to 50% and for other dosage of RAC (75 and 100%) the strengths are decreased. The same behavior was observed for all mixes with incorporation of basalt fibers.
- For 25, 50% of recycled there is an increase in bearing strength by 9.36% and 5.72% respectively, over the natural aggregate concrete (NAC-0) for bearing area ratio of 10.
- For 25, 50% of recycled there is increase in bearing strength by 7.68% and 3.57% over the Natural aggregate concrete (NAC-0) for bearing area ratio of 15.
- The % of increase for 25 and 50% FRAC mixes is about 9 to 5% respectively when compared with FNAC-0 mix for both bearing ratios of 10 and 15.
- To estimate bearing strength for RAC mixes, regression model was proposed in the present article and its validity is tested.

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