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Impact Resistance of Steel Fiber Reinforced Recycle Aggregate Concrete Beams

N. Venkata Ramana[1], Y. Venkata Subbareddy[2], and C.Sashidhar[3]
[1]Associate Professor, UBDT College of Engineering Davangere, Karnataka,
[2]Research Scholar, JNTUA, Anantapur, A.P, India, PIN: 515002
[3]Professor, JNTUA College of Engineering, Anantapur, A.P, India, PIN: 515002

Abstract: This paper presented the behavior of Recycle aggregate concrete with and without addition of steel fibers under impact loading. For this, experimental investigation 60 cubes and 60 beams were cast and tested. The concrete mix was designed as per ACI code. Total twenty mixes were taken for this study, in the mixes natural aggregate was replaced with the recycle aggregate in the proportion of 0,25,50,75 and 100% and the fiber was varied in the mix as 0, 1, 1.5 and 2% by volume of the cast specimen. The drop weight test was adopted to evaluate the impact performance. Few specimens are also cast without fibers and these results were taken for comparison purpose. The results indicated that the mix with higher content of Recycle aggregate the impact performance was decreased and also noticed that incorporation of steel fibers for the mixes increases the impact energy. Few regression models are developed to estimate the compressive and impact strengths and the models were tested for the experimental data.

Keyword: Compressive strength, Impact energy, Natural aggregate concrete (NAC), Recycle aggregate concrete (RAC), Steel fibers damage analysis and regression models.

I. INTRODUCTION

The characteristics of the impact load are a high loading rate and very short period that cause high strain rate in the structure. This implies that the statically determined properties of concrete meanwhile, the mechanical properties of materials were different under impact loading compared with the static loading. Due to the complexity of the dynamic response of concrete structures, the traditional computational methods and design tools may not be much help to understand the behavior of materials and structural elements under impact loading. This deficiency has been paid attention by many researchers in the past few years and investigations have been carried out to understand the behavior of concrete and concrete based composites under impact loading. Here in few studies are mentioned to know the status of work progressed in the impact area. M. Chakra dhara Rao et.al.,[1] studied the behavior of recycle aggregate concrete under impact load with incorporation of recycle aggregate concrete at various proportions of 0,25,50,75 and 100%. Feng Liu et.al [2] did the impact study on rubber reinforced concrete. Jianzhuang Xiao et.al [3] presented the over view on Recycle aggregated concrete. Dora Foti and Francesco Paparella [4] studied the impact behavior of concrete with addition of PET grids. Ahmed Tareq Noaman et.al [5] found the impact energy of concrete with the combination of hooked steel and crumb rubber fibers. Chao-Lung Hwang et.al [6] studied the effect of short coconut fibers in concrete for impact behavior. J. Trejbal et.al.,[7] presented the impact performance of PET fiber reinforced in cementations composites. A.S.Shakir et.al.,[8] studied the lateral impact response of the concrete strengthen with an without Carbon fiber reinforced polymer [CFRP]. M. Mastali et.al.,[9] conducted the experimental work on self compacting concrete to evaluate impact resistance.M.Mastali et.al.,[10] presented the impact resistance of self compacting concrete with recycled carbon fiber reinforced polymer pieces. Md Iftekharul Alam et.al [11] aimed the work to evaluate the performance of concrete subjected to lateral impact. Hossein Mohammadhosseini et.al.,[12] investigated the impact resistance an mechanical properties of concrete reinforced with polypropylene carpet fibers.The recent past literature survey revealed that very little work has been carried out on Recycle Aggregate concrete (RAC) under impact loading with low strength steel fibers. Hence, there is need to conduct experimentation to understand the behavior of RAC beam specimens under impact loading. This article presents details of investigation carried out on RAC beam specimens under impact loading. Natural aggregate concrete (NAC) beam specimens are also cast and tested under impact loading for comparison. The details of this study are presented in the following sections. It has been well established that RAC can be used for all structural elements in civil engineering [3]. Based on review of literature it is clear that no research was carried out so far on the impact behavior of RAC concrete beams with low strength steel fibers. Accordingly, the present investigation aims to study the impact behavior of RAC with and without steel fibers. In the present experimental work, low strength steel fiber dosage provided as 0, 1, 1.5 and 2% by volume of cast specimen and the aspect ratio of 50 kept as constant for fibers.

II. TEST PROGRAMME

The experimental program consists of a total of 60 cubes and 60 beams. The standard cubes were cast and tested in the compressive testing machine to know the compressive strengths for different mixes. Among 60 beams, 15 beams are without fiber and remaining 15 beams are with 1% fiber, 15 beams are with 1.5% fiber and 15 beams are with 2% fiber. All the 60 beams are fully restrained by nut and bolt system on all edges. The experimental program is planned for only fully restrained beams. The impact test is not conducted for simply supported beams as the beams are laterally displaced under the blows of the drop weight and it requires special arrangements. Hence, it was planned to investigate the impact behavior of RAC and NAC beams with all edges fixed conditions only. All the beam specimens are prepared with dimensions of 100x100x600 mm and tested under a centrally applied impact loading on the beam specimens. The concrete was designed for M20 grade concrete as per ACI 211 code. The mix proportions are presented in Table 1. The low strength steel fibers (yield strength of wire is 390 MPa) are obtained from binding wire, which was cut by shear cutter with aspect ratio as 5 (the diameter of wire is 1.0mm and length is 50mm).In the Table1, the nomenclature can understand as the first three letters indicated as type of concrete, next two letters indicated as % of replacement of natural aggregate by the recycle aggregate and the next digits are represented as % of fiber incorporation in the mix.(RAC-25-0 can be noticed as the concrete mix having the recycle aggregate 25% and 0 indicate the % of fiber). The same nomenclature is used in the forth coming test and in the Table 2 also.

Table 1: Mix proportions of concrete (Kg/m3)

Type of Mix	Recycle Aggregate in percentage	Water/ Cement	Cement (kg)	Fine aggregate (kg)	NCA (kg)	RCA (kg)	Mixing water (Lit)
NAC-0	0	0.55	364	823	942	-	200
RAC-25	25	0.55	364	836	754	169	200
RAC-50	50	0.55	364	842	565	337	200
RAC-75	75	0.55	364	845	377	506	200
RAC-100	100	0.55	364	875	-	843	200

III. PREPARATION OF TEST SPECIMEN

The cubes and beams were cast in steel moulds with inner dimensions of 150x150x150 and 100 x 100 x 600mm respectively. All the materials are weighed as per mix design and kept a side separately. The cement, sand, coarse aggregate, fibers and recycle aggregate were mixed thoroughly till to reach uniformity to the concrete mix. For all test specimens, moulds were kept on table vibrator and the concrete was poured into the moulds and the compaction was adopted by mechanical vibrator. The moulds were removed after twenty four hours and the specimens were de-moulded 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 allow drying under shade. Three cubes and beams were cast for each mix.

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IV. TEST SET UP AND TESTING

The cubes were tested in the compressive testing machine to evaluate cube compressive strengths for various mixes. The capacity of the CTM is 2000kN with a least count of 1kN. The test was conducted as per IS standards. The obtained results are presented in the next section. The impact test has been carried out by using an in-house manufactured impact testing machine. The impact test machine has been planned and fabricated in accordance to the drop weight test, which was already reported by earlier researchers Balaguru and shah [13]. The details of test setup used for conducting impact test on beams are presented below. To perform the impact test, a drop weight load is applied through an iron ball of diameter 100mm and weight of 50 N (Including hook arrangements), falling on the center of the beam specimen through a guiding barrel from a height of 450 mm. This guiding barrel is connected to the loading frame to guide the ball so that it falls exactly at the specified location (center) for all blows. The iron ball is connected to by a flexible rope of 5mm diameter with pulley arrangement is shown in Figure 1. Two sides of beam are fixed using the clams with bolt and nut arrangement as shown in Figure 2. The loading platform consists of four welded steel beams of ISMB 150 in square shape and it is supported on six columns of ISMB 150 placed at four corners. The impact machine was connected with the power, so that the machine would give blows on the top of beam. The functioning of to and fro motion ball gives the impact on top face of the beam. The activity was continued till the beam was failure, meanwhile the impact process the blows were noted to cause the first and ultimate failure. The tested specimens are staked aside of testing machine and this can be viewed in Figure.3. From this observation the impact energy absorption is calculated and these results are presented in the analysis of test results.

Fig 1:Impact testing mechine

Fig 2:Testing of the beam

V.ANALYSIS OF TEST RESULTS

A. Compressive Strength

The 28 days compressive strength values are presented in Table 2. From this it is noticed that, for plane mixes, as % of RA content increases in the mixes the compressive strengths are decreasing. The strengths are varying 33 to 29 MPa. This trend is similar to for RAC mixes with addition of fibres. But the variations of strengths are noticed between the RAC mixes with addition of fibres. Among fibre mixes, the mix with 2% fibre showed high strength values than others. From this it is observed that as the fibre content increases in the mixes the compressive strengths are increased. This may be due to effect of fibre and these fibres may act as energy observers and also crack arresters. Here in, the authors would like to develop a model in order to suit the experimental data. In this connection a simple regression model had been developed from the results of present experimental investigation and the same is presented below. The compressive strength values obtained from the regression model are presented in Table 2 and in the same table the ratio of experimental to regression model strengths are also presented. From this it observed that the results are varying about 5%, this shows as the proposed equation is well suited for the experimental data.

f_{ck} = 32.92 - 0.043 (% RAC) + 4.22V_f
Where: f_{ck}= 28 days cube compressive strength in N/mm^2
RAC = Percentage of replacement of recycle aggregate, and Vf= Percentage Volume of fibers

Table 2: Compressive strength (MPa)

S.No	Nomenclature	Experimental (Exp) Compressive Stress(N/mm^2)	Compressive stress (N/mm^2) predicted by Regression Model (RM)	Exp value/predicted by RM
1	NAC-0-0	33.33	32.92	1.01
2	RAC-25-0	32.40	31.85	1.02
3	RAC-50-0	31.68	30.77	1.03
4	RAC-75-0	30.80	29.70	1.04
5	RAC-100-0	29.30	28.62	1.02
6	NAC-0-1	35.68	37.14	0.96
7	RAC-25-1	34.80	36.07	0.96
8	RAC-50-1	33.80	34.99	0.97
9	RAC-75-1	33.02	33.92	0.97
10	RAC-100-1	31.42	32.84	0.96
11	NAC-0-1.5	38.67	39.25	0.99
12	RAC-25-1.5	37.68	38.18	0.99
13	RAC-50-1.5	36.57	37.10	0.99
14	RAC-75-1.5	35.77	36.03	0.99
15	RAC-100-1.5	34.04	34.95	0.97
16	NAC-0-2	42.43	41.36	1.03
17	RAC-25-2	41.46	40.29	1.03
18	RAC-50-2	40.40	39.21	1.03
19	RAC-75-2	39.33	38.14	1.03
20	RAC-100-2	37.42	37.06	1.01

B. Number of Blows Required For Failure

The results of the experimental investigation are presented in Table 3. The values presented here represent the average number of blows obtained for three specimens. Based on the results obtained from the experimentation, the following section presents an analysis and gives insights in to the behavior of RAC concrete beams under impact loading. The number of blows required for beam without fiber is presented in Table 3, from this Table it can observe that the number of blows required at first crack stage for NAC-0-0 is 160 and for RAC-25-0, RAC-50-0, RAC-75-0 and RAC-100-0 are 140, 120, 95 and 75 respectively. For ultimate stage number of blows required for NAC-0-0 are 300 and for RAC-25-0, RAC-50-0, RAC-75-0 and RAC-100-0 are 260, 230, 175 and 135 respectively. The percentage decrease with respect to the first crack stage NAC-0-0 is 12.50, 25.00, 40.63 and 53.13% for RAC-25-0, RAC-50-0, RAC-75-0 and RAC-100-0 respectively. The percentage decrease with respect to the ultimate stage NAC-0-

0 is 13.33, 21.67, 41.67 and 55.00% for RAC-25-0, RAC-50-0, RAC-75-0 and RAC-100-0 respectively. From Table 3 and Figure 3 we can conclude that as the percentage of RAC increases the number of blows decreased.

The number of blows required for beam with 1% fiber is presented in Table 3 and Figure 4, from Table 3 and Figure 4 it can observed that the number of blows required at first crack stage for NAC-0-1 are 190 and for RAC-25-1, RAC-50-1, RAC-75-1 and RAC-100-1 are 170, 155, 120 and 90 respectively. For ultimate stage number of blows required for NAC-0-1 are 345 and for RAC-25-1, RAC-50-1, RAC-75-1 and RAC-100-1 are 305, 270, 225 and 175 respectively. The percentage decrease with respect to the first crack stage NAC-0-1 is 10.53, 18.42, 36.84 and 52.63% for RAC-25-1, RAC-50-1, RAC-75-1 and RAC-100-1 respectively. The percentage decrease with respect to the ultimate stage NAC-0-1 is 11.59, 21.74, 34.78 and 49.28% for RAC-25-1, RAC-50-1, RAC-75-1 and RAC-100-1 respectively. From the results it can conclude that as the percentage of RAC increases the number of blows decreased. This type of observations has been observed by the M.Chakradhra Rao et.al.,[1].

The number of blows required for beam with 1.5% fiber is presented in Table 3 and Figure 5, from these it can observed that the number of blows required at first crack stage for NAC-0-1.5 are 210 and for RAC-25-1.5, RAC-50-1.5, RAC-75-1.5 and RAC-100-1.5 are 190, 170, 140 and 115 respectively. For ultimate stage number of blows required for NAC-0-1.5 are 380 and for RAC-25-1.5, RAC-50-1.5, RAC-75-1.5 and RAC-100-1.5 are 335, 300, 255 and 210 respectively. The percentage decrease with respect to the first crack stage NAC-0-1.5 is 9.50, 19.05, 33.33 and 45.24% for RAC-25-1.5, RAC-50-1.5, RAC-75-1.5 and RAC-100-1.5 respectively. The percentage decrease with respect to the ultimate stage NAC-0-1.5 is 11.84, 21.05, 32.89 and 44.74% for RAC-25-1.5, RAC-50-1.5, RAC-75-1.5 and RAC-100-1.5 respectively.

The number of blows required for beam with 2% fiber is presented in Table 3 and Figure 6, from them it can observed that the number of blows required at first crack stage for NAC-0-2 are 225 and for RAC-25-2, RAC-50-2, RAC-75-2 and RAC-100-2 are 205, 185, 165 and 135 respectively. For ultimate stage number of blows required for NAC-0-2 are 420 and for RAC-25-2, RAC-50-2, RAC-75-2 and RAC-100-2 are 370, 340, 285 and 240 respectively. The percentage of decrease with respect to the first crack stage NAC-0-2 is 8.89, 17.78, 26.67 and 40.00 % for RAC-25-2, RAC-50-2, RAC-75-2 and RAC-100-2 respectively. The percentage decrease with respect to the ultimate stage NAC-0-2 is 11.90, 19.05, 32.14 and 42.86 % for RAC-25-2, RAC-50-2, RAC-75-2 and RAC-100-2 respectively. From Table 2 and Figure 8 we can conclude that as the percentage of RAC increases the number of blows decreased.

Thus from the above results, it can be observed that, at ultimate stage RAC specimens showed lesser performance under impact when compared with NAC. This may be due to weak bond between mortar and coarse aggregate. The crushed recycle aggregate material show the relatively lesser frictional surface when compared with granite aggregate. But with incorporation of fibers up to 2% better results are obtained in the present study and also noticed that 2% fiber volume fraction is effective compared to other volume fraction (1 and 1.5) of fibers. Ahmed Tareq Noaman et.al.,[5] has noticed this type of observations for the concrete beam reinforced with crumb rubber and steel fibers.

C. Energy Absorptio

Total energy absorption capacities of different beams specimens at first crack and at ultimate failure are presented in Table 3. The first and ultimate stages failures are depicted in Figure 7 to 9. From the obtained results the energy absorption capacity is calculated by using the following formula.

Energy absorption = Weight of ball x fall of height x Number of blows

In the above equation, the weight of ball (50 N) and the fall of height (450mm) are maintained constant throughout the experimentation. From Table 3 and Figure 7, it can be observed that RAC beam specimens possess lower amount of energy absorbing capacity than NAC beam specimens. At first crack, the RAC beam specimens show energy absorption capacities is about 3.60, 3.15, 2.70, 2.138 and 1.688 kJ, for NAC-0-0, RAC-25-0, RAC-50-0, RAC-75-0 and RAC-100-0 respectively. For 1% fiber the energy absorption capacities are 4.275, 3.825, 3.488, 2.70 and 2.025 kJ, for NAC-0-1, RAC-25-1, RAC-50-1, RAC-75-1 and RAC-100-1 respectively. For 1.5% fiber the energy absorption capacities are 4.725, 4.275, 3.825, 3.15 and 2.588 kJ, for NAC-0-1.5, RAC-25-1.5, RAC-50-1.5, RAC-75-1.5 and RAC-100-1.5 respectively and for 2% fiber the energy absorption are 5.063, 4.613, 4.163, 3.713 and 3.038 kJ for NAC-0-2, RAC-25-2, RAC-50-2, RAC-75-2 and RAC-100-2.The higher energy absorption is obtained for NAC-0-2 beam specimens. Among the recycle aggregate concrete beams (without fibers addition), the energy absorption capacity decreases with increase in the recycle aggregate percentage.

From the Table 3 and Figure 8, it can be observed that RAC beam specimens required lower amount of energy absorbing capacity than NAC beam specimens at ultimate stage. The energy absorption at ultimate stage are 6.75 kJ for NAC-0-0 and 5.85, 5.288, 3.938 and 3.038 kJ for RAC-25-0, RAC-50-0, RAC-75-0 and RAC-100-0 respectively for 0% fiber. For 1% fiber energy absorption capacities are 7.763 kJ for NAC-0-1 and 6.863, 6.075, 5.063 and 3.938 kJ for RAC-25-1, RAC-50-1, RAC-75-1 and RAC-100-1respectively. For 1.5% fiber energy absorption capacities are 8.55 kJ for NAC-0-1 and 7.538, 6.750, 5.738 and 4.725 kJ for RAC-25-1.5, RAC-50-1.5, RAC-75-1.5 and RAC-100-1.5 respectively. For 2% fiber energy absorption capacities are 9.45 kJ for NAC-0-2 and 8.325, 7.65, 6.413 and 5.40 kJ for RAC-25-2, RAC-50-2, RAC-75-2 and RAC-100-2 respectively.

From the Table 3, it can conclude that the percentage of RAC increases the energy absorption decreases but with incorporation of steel fibers the energy absorption is increasing, this may be due to effective bond action between concrete and fibers. Ahmed Tareq Noaman et.al.,[5] and Hossein Mohammadhosseini et.al.,[12] has been shown this type of enhancement of energy absorption for their studies.

Table 3: Impact Test Results

Sl.No	Type of Beam	First Crack Stage		Ultimate stage	
		Average Number of Blows	Energy Absorption (KJ)	Average Number of Blows	Energy Absorption (KJ)
1	NAC-0-0	160	3.600	300	6.750
2	RAC-25-0	140	3.150	260	5.850
3	RAC-50-0	120	2.700	235	5.288
4.	RAC-75-0	95	2.138	175	3.938
5	RAC-100-0	75	1.688	135	3.038
6	NAC-0-1	190	4.275	345	7.763
7	RAC-25-1	170	3.825	305	6.863
8	RAC-50-1	155	3.488	270	6.075
9	RAC-75-1	120	2.700	225	5.063
10	RAC-100-1	90	2.025	175	3.938
11	NAC-0-1.5	210	4.725	380	8.550
12	RAC-25-1.5	190	4.275	335	7.538
13	RAC-50-1.5	170	3.825	300	6.750
14	RAC-75-1.5	140	3.150	255	5.738
15	RAC-100-1.5	115	2.588	210	4.725
16	NAC-0-2	225	5.063	420	9.450
17	RAC-25-2	205	4.613	370	8.325
18	RAC-50-2	185	4.163	340	7.650
19	RAC-75-2	165	3.713	285	6.413
20	RAC-100-2	135	3.038	240	5.400

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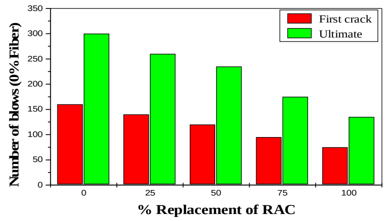

Fig 3:No of blows(0% Fibre) vs % replacement of RAC

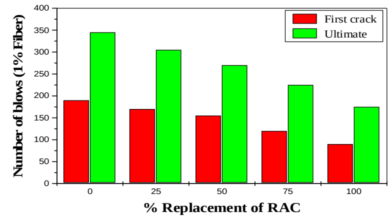

Fig 4:No of blows(1% Fibre) vs % replacement of RAC

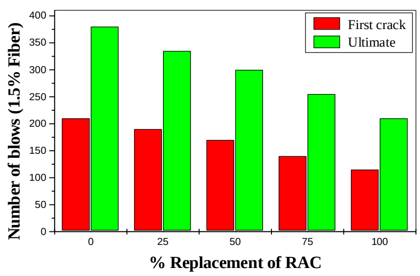

Fig 5:No of blows(1.5% Fibre) vs % replacement of RAC

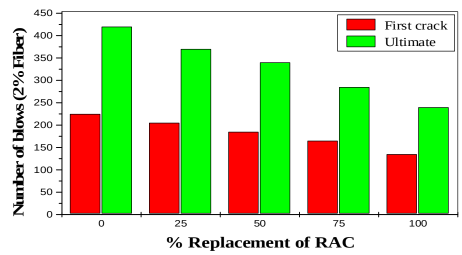

Fig 6:No of blows(2% Fibre) vs % replacement of RAC

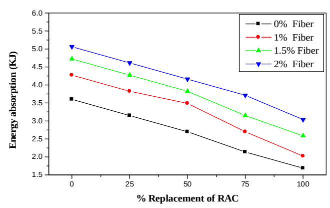

Fig 7:Energy absorption at first crack stage

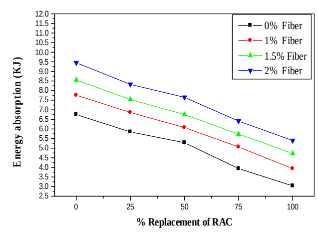

Fig 8:Energy absorption at Ultimate stage

D. Damage Analysis

The damage of different beam specimens under impact loading is presented in Figure 9 and 10. From those figures, it can be observed that the RAC-100-0 beam specimens show more damage compared to the NAC-0-0 beam specimens. Among the RAC beam specimens, the beam RAC-25 show lesser damage compared to other three beam specimens, i.e. RAC-50, RAC-75 and RAC-100. Less number of blows is recorded to cause ultimate failure observed in 100% recycle aggregate concrete beams this may due to the weak interface bond between aggregate and cement mortar. Obsessively the inferior texture surface shows less bond effect when compared with rough surface texture surface. The granite aggregate showed the rough texture surface whereas the recycle aggregate showed somewhat inferior texture surface. During the experimentation process it was observed that the beam specimens showed the propagation of first crack exactly beneath the beam specimen, where the ball strikes the specimen. The concrete beam specimen with addition of fibers showed the ductile failure instead of breaking into two pieces but in the case beams without fibers broken into two pieces. So the authors felt that, the incorporation of fibers is more beneficial to recycle aggregate concrete to enhance the energy capacities.

Fig 9:Stacking of tested beams

Fig 10: Tested SFRAC Beam

E. Regression Modal

To evaluate the energy absorption in terms of compressive strength, a regression model was developed. The equation showed the regression coefficient as 0.74 with a standard deviation of 0.88. The developed equation is presented below.

Energy absorption = $1.98\ (f_{ck})^{2/3} - 14.5$

Where

$f_{ck} = 32.92 - 0.043\ (\%\ RA) + 4.22V_f$

where:f_{ck}= 28 days cube compressive strength in MPa, RA= Recycle aggregate concrete, V_f= Volume of fraction of fibre

After submitting the concerned values, the obtained results are presented in the Table 4.The experimental Energy absorption values are also presented in the same table. The ratio of experimental to regression modal energy absorption values can be noticed in the table. From this it is noticed, that the ratio is varying from 0.7 to 1.16, it inferences the values are varied from 15 to 30%. The more deviation value is observed for 100% replacement of RAC, irrespective of the dosage of steel fiber.

Table 4: Performance of Regression Modal

Sl.No	Type of Beam	Average Number of Blows	Energy Absorption (KJ)	Energy Absorption RM (KJ)	Exp/RM
1	NAC-0-0	300	6.750	5.84	1.16
2	RAC-25-0	260	5.850	5.39	1.08
3	RAC-50-0	235	5.288	4.94	1.07
4	RAC-75-0	175	3.938	4.49	0.88
5	RAC-100-0	135	3.038	4.03	0.75
6	NAC-0-1	345	7.763	7.54	1.03
7	RAC-25-1	305	6.863	7.11	0.96
8	RAC-50-1	270	6.075	6.68	0.91
9	RAC-75-1	225	5.063	6.25	0.81
10	RAC-100-1	175	3.938	5.80	0.68
11	NAC-0-1.5	380	8.550	8.37	1.02
12	RAC-25-1.5	335	7.538	7.95	0.95
13	RAC-50-1.5	300	6.750	7.52	0.90
14	RAC-75-1.5	255	5.738	7.10	0.81
15	RAC-100-1.5	210	4.725	6.67	0.71
16	NAC-0-2	420	9.450	9.18	1.03
17	RAC-25-2	370	8.325	8.77	0.95
18	RAC-50-2	340	7.650	8.35	0.92
19	RAC-75-2	285	6.413	7.93	0.81
20	RAC-100-2	240	5.400	7.51	0.72

VI.CONCLUSIONS

Form the experimental work the following conclusions are noticed.

A. The compressive strengths are decreasing as the %of RA content increases in the plane mix. For mixes with steel fiber incorporation the strengths are increasing when compared with plane mix.

B. Among the different % of steel fiber mixes, the mix with 2% shown higher strengths.

C. The impact strength of the RAC-25 to RAC-100 is lower than the NAC concrete. The addition of fibers for the concrete mixes showed improvement in the impact strengths and also to enhance impact energy capacities.

D. The number of blows to cause first crack stage for 0% fiber for NAC-0-0 to RAC-25-0, RAC-50-0, RAC-75-0 and RAC-100-0 are 160, 140, 120, 95 and 75, and that of 1% fiber are 190, 170, 155, 120 and 90 and that of 1.5% fiber are 210, 190, 170, 140 and 115, and 2% fiber are 225, 205, 185, 165 and 135.

E. The number of blows to cause ultimate stage for 0% fiber for NAC-0 to RAC-25-0, RAC-50-0, RAC-75-0 and RAC-100-0 are 300, 260, 230, 175 and 135, and that of 1% fiber are 345, 305, 270, 225 and 175, and for 1.5% fiber are 380, 335, 300, 225 and 210, and for 2% fiber 420, 370, 340, 285 and 240.

F. Energy absorption at first crack stage with 0% fiber are in the range 1.688 to 3.6 kJ and for 1% fiber are in the range 2.025 to 4.275 kJ and for 1.5% fiber are in the range 2.588 to 4.725KJ and for 2% fiber varies are in the range 3.038 to 5.063 kJ.

G. Energy absorption at ultimate stage with 0% fiber are in the range 3.038 to 6.75 kJ and for 1% fiber are in the range 3.938 to 7.763 kJ and for1.5% fiber are in range 4.725 to 8.55 KJ and for 2% fiber varies are in the range 6.413 to 9.45kJ.

H. Regression models are developed to estimate the compressive and impact energy for the obtained experimental values and the proposed models are suited well within the limitations.

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