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Performance of Stone Waste Aggregate Concrete Slabs under Impact Loading

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Abstract:- This paper presents the behaviour of stone waste aggregate (SWA) concrete slabs under impact loading. The stone waste was obtained during extraction of layered stone (at mines) and at polishing stone industries. This stone waste is converted in useful aggregate and used in the concrete as coarse aggregate in the place of natural aggregate with replacement levels of 0, 25, 50, 75 and 100%. For each replacement level, three slab specimens were cast and tested. 0% replacement level consider as Natural Aggregate Concrete (NAC) slabs. The SWA slabs were compared with natural aggregate concrete (NAC) slabs. The results showed that the SWA slab performance is less than the natural aggregate concrete slabs. From experimental results, regression models were developed to estimate energy absorption at first and ultimate crack stages. In addition to the slab specimens cubes were cast and tested. The cube strength results were used during development of regression models.

Keywords:- Impact, stone waste aggregate, natural aggregate, failure loads, damage analysis, regression model.

I. INTRODUCTION

Prior to 1950, building and other structures were designed to resist general type of loading i.e., dead load, live load and wind load. But now days the designers are also focusing on impact loading. Sometimes concrete walls and slabs are struck by vehicles or subjected to accidently generated low speed objectives and it may leads to damage or destruction. Many research works are focused on this area. At present due to rapid urbanization there is a great demand for concrete composition materials, i.e. coarse aggregate and fine aggregate. The researchers are focusing to use recycle or waste materials instead of using natural available materials, this leads to preserving of natural available materials for future generation and at the same time to protect environment hazards. In this scenario Venkata Ramana et.al [1] were focused the stone waste utilization to construction industry. Based on their study it is observed that the stone waste is generated at mines and polishing industries and this waste is dumping in and around the town. In order to utilize the waste material some preliminary tests were conducted and they were thrown a ray of light to utilize this material for concrete works. In this concern the authors of this paper were studied the impact behaviour on concrete slabs, the concrete was made with stone waste aggregate at replacement levels of 0, 25,50,75 and 100%. In this connection a brief review of previous research work on impact loading was presented below.

II. REVIEW OF PREVIOUS RESEARCH

Wimal suaris et.al.[2] reported the behaviour of concrete with incorporation of steel, polypropylene and glass under impact loading. The results showed that energy absorption of fibre reinforced concrete is 100 times more than the unreinforced beams. Piti sukontaasukkul et.al. [3] studied the effect of confinement on plane and fibre reinforced concrete prisms subjected to uniaxial compressive impact. The investigation found that the material with confinement becomes more sensitive. Bibiana Maria Luccioni and Mariela Luege [4] presented the behaviour of concrete pavement slab under impact loading and for obtained results numerical analysis was performed. Katrin Habel and Paul Gauvreau [5] were conducted experimental and analytical study on ultra high performance fibre reinforced concrete (UHPFRC) under impact and static loading. The results of the study showed a significantly increased strength and fractured energy of the dynamically loaded compared with quasi-static loading.

Liu Haifeng and Ning Jianguo [6] studied the behaviour of concrete and reinforced concrete at high strain rates subjected to impact loading. Experimental results indicate that the load carrying capacities of concrete and reinforced concrete increases significantly with strain rate. F.J.Yang and W.J.Cantwell [7] were investigated on damage initiation threshold under impact loading for composite materials. M.Chakradhara Rao et.al. [8] were presented the behaviour of recycle aggregate concrete under impact loading.The effect of acceleration, strains and support reaction histories were studied in their investigation. Norman Jones [9] examined the behaviour of ductile rectangular plates under impact loading. The study focused on transverse displacement and response duration of plates having with different boundary conditions (simply supported and clamped). Hua Jiang et.al. [10] were conducted experimental work on reinforced concrete beams under impact loading and for test results numerical simulations were developed by using LS-DYNA finite element code.

III. EXPERIMENTAL PROGRAM

The experimental program comprises of casting and testing of twelve Stone Waste Aggregate (SWA) concrete slabs (size of slab: 600x600x50 mm) and three Natural Aggregate Concrete (NAC) slabs. All the slabs were cast with M20 grade concrete and as per IS mix design the proportion was arrived as 1:1.91:3.17. The SWA used in the slabs as coarse aggregate and this was used in the mix in the proportion of 0,25,50,75 and 100% with replacement of natural granite aggregate. All the slabs were cured for 28 days and later the slabs were white painted for better vision of crack pattern while testing. The Impact test has been performed on all the slab specimens by drop weight of ball and the slab was fixed with platform using nut and bolts, which simulates all edges fixed condition. The impact machine was locally fabricated with the specification of weight of ball as 50N, fall of ball height is 450mm.The ball was dropped over the slab through guiding barrel and which was fixed to slab specimen. The detailed procedure of casting and testing is discussed in the coming text.

IV. EXPERIMENTAL MATERIALS USED IN THE INVESTIGATION

Cement: Portland Pozzolana cements conforming to IS 8112: 1989was used. The specific gravity of the cement is 3.05. The initial and final setting times were found as 90 minutes and 340 minutes respectively.

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

Fine Aggregate: Locally available river sand passing through 4.75 mm I.S .Sieve is used. The specific gravity of the sand is found to be 2.75.

Granite coarse aggregate: Crushed granite aggregate available from local sources has been used. To obtain a reasonably good grading, 60% of the aggregate passing through 20 mm I.S. sieve and retained on 12.5mm I.S. Sieve and 40% of the aggregate passing through 12.5mm I.S. Sieve and retained on 10 mm I.S. Sieve is used in the present experimental work. The specific gravity of the combined aggregate is 2.70.

Stone waste aggregate: The raw material of stone waste was obtained from stone polishing industries. The generated waste material was unable to use as it is, as coarse aggregate in the concrete. To convert the waste as useful coarse aggregate, the waste material was transported to crusher unit (figure.1) and made as 20 and 12.5 mm aggregate. Two different sizes (20 and 12.5mm) were obtained from the waste material, so as to use the material effectively (figure.1). 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 as 2.56.

Figure 1: Stone Waste Aggregate

V. CASTING OF TEST SPECIMENS

Steel moulds were used to cast the slab specimens of required size i.e. 600 x 600 x 50 mm. Initially the steel mould is coated with waste oil so that the slab specimens can be removed easily from the moulds. Then the 8mm diameter HYSD rods at 105mm center to center are placed in both directions by maintaining a clear cover of 10mm. Then the prepared green concrete is poured into the mould and compacted with table vibrator. The whole process can be viewed in figure.2. The cast specimens were later de-moulded and kept in curing pond for a period of 28 days. After completion of curing period all the specimens are taken out from the curing pond, allowed to dry under shade for a while and then they are coated with white paint on both sides, to achieve clear visibility of cracks during testing.

Figure 2: Slab mould with reinforcement and View of cast slab specimens

VI. LOADING ARRANGEMENT AND TESTING

The impact test has been carried out by using an in-house manufactured impact testing machine. The impact test machine was fabricated in accordance to the drop weight test, which was already reported by earlier researchers Balaguru et.al [11]. 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 slab specimen through a guiding barrel from a height of 450mm. 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. All the four edges of the slab are fixed using the with nut and bolt arrangement. The loading platform consists of four welded steel beams of ISMB 150 in square shape and it is supported by masonry wall. The impact machine was connected with the power, so that the machine would give blows on the top of slab. The functioning of to and fro motion ball gives the impact on top of slab. The activity was continued till the slab was failure, meanwhile the impact process the blows were noted to cause the first and ultimate failure. The test setup for slab specimen can be viewed in figure 3.

Figure 3: Test setup for slab specimen

VII. ANALYSIS OF TEST RESULTS

The results of the experimental investigation are presented in Table 1. The values presented here in represent the average number of blows obtained for three specimens.

Number of blows to cause Failure

The number of blows required to cause the first crack is presented in Table 1. From this table, it can be observed that the number of blows decreased with increase in the stone waste aggregate in slabs. The blows decrement in SWA slabs for 25 to 100% replacement is in the range of 12.96 to 52.70% when compared with NAC. The number of blows required to cause the ultimate failure is also presented in Table.1. The SWA slab specimens required lower number of blows than the NAC slab specimens for ultimate failure. The SWA slabs for 25 to 100% replacement, the decrement of blows % is in the range of 18.55 to 52.23%, when compared with NAC slab specimens.

Thus it can be observed that the SWA slabs are inferior to NAC slabs under impact loading both at first crack stage and ultimate stage. This decreased performance under impact may be due to bond between mortar and coarse aggregate. The crushed waste lime stone material show the relatively lesser frictional surface when compared with granite aggregate i.e., surface texture of aggregate.

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Table.1: Blows required for first crack and ultimate failure.

S.No	Type of slab	Number of blows to cause First crack	% Decrease w.r.t NAC	Number of blows to cause Ultimate Failure	% Decrease w.r.t NAC
1	NAC	1296	--	2776	--
2	SWA-25	1128	12.96	2261	18.55
3	SWA-50	981	24.30	2104	24.20
4	SWA-75	722	44.29	1763	36.49
5	SWA-100	613	52.70	1326	52.23

Energy absorption

Total energy absorption capacities of slab specimens at first crack and at ultimate failure are presented in Table 2 and figure 4. The energy absorption capacity is obtained 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 (50N) and the fall of height (450mm) are maintained constant throughout the experimentation. From Table 2 and Figure 4, it can be observed that SWA slab specimens possess lower amount of energy absorbing capacity than NAC slab specimens. At first crack, the SWA slab specimens show energy absorption capacities of about 13.79 kJ to 25.38 kJ. The higher energy absorption (29.16kJ) is obtained for NAC slab specimens. Among the SWA slab, the energy absorption capacity decreases with increase in the stone waste aggregate percentage. The energy absorption capacity at first crack stage for SWA slabs is about 12.96 to 57.20% lower when compared with the NAC slab specimens.

From the same table and figure, it can be observed that SWA slab specimens acquired lower amount of energy absorbing capacity than NAC slab specimens for ultimate failure. At ultimate failure the SWA slab specimens show energy absorption capacities of about 29.83 kJ to 50.90 kJ. Among SWA slabs specimens, the higher energy absorption is obtained for SWA-25. Once again the SWA specimens show lower energy absorption capacity with increase in the SWA percentage. The NAC slab specimens recorded energy absorption capacities of 62.46 kJ. The energy absorption capacity of SWA slabs is about 18.55 to 52.23% lower when compared with the NAC slab specimens.

Table.2: Energy Absorption.

S.No	Type of slab	Average Number of Blows First Crack	First Crack Energy Absorption (KJ)	Average Number of Blows at ultimate stage	ultimate stage Energy Absorption (KJ)
1.	NAC	1296	29.16	2776	62.46
2.	SWA-25	1128	25.38	2261	50.90
3.	SWA-50	981	22.07	2104	47.34
4.	SWA-75	722	16.24	1763	39.66
5.	SWA-100	613	13.79	1326	29.83

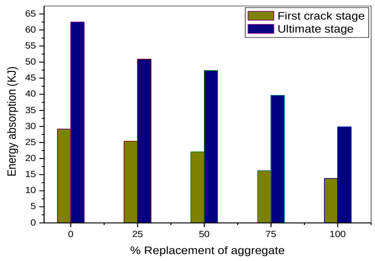

Figure 4: Energy Absorption at First Crack and Ultimate stage

Damage analysis

The damage of different slab specimens under impact loading is presented in Figure 5. From this it can be observed that the SWA slab specimens show more damage compared to the NAC slab specimens. Among the SWA slab specimens, the slab SWA-25 show lesser damage compared to other three slab specimens of SWA-50, SWA-75 and SWA-100. The disturbance increases with the increase in the lime stone aggregate percentage in slab specimens. Less number of blows is recorded to cause ultimate failure observed in 100% stone waste aggregate concrete slabs, this may be due to the interface bond development between aggregate and cement mortar. Obviously the smoother texture surface shows less bond effect when compared with rough surface texture surface. The granite aggregate showed the rough texture surface whereas the stone waste aggregate showed somewhat inferior texture surface. During the experimentation process it was observed that the slab specimens showed the propagation of first crack exactly beneath the slab specimen, where the ball strikes the specimen. In the subsequent stages the concrete converted in to powder due to hitting of impact ball on the slab specimen. Just before ultimate failure of specimen, the mass of concrete in slab specimen likely to peel form the integrity of concrete.

NAC - 0 SWA - 25 SWA – 50 SWA –75 SWA – 100

Figure.5: Tested slab specimens

VIII. REGRESSION MODEL FOR ENERGY ABSORPTION CAPACITY OF SWA SLABS

A simple regression model has been developed from the test results. The energy absorption capacities up to first crack and ultimate stages are correlated with28 days cube compressive strength (f_{ck}). Thus the proposed equations for energy absorption capacities are as given below:

The energy absorption up to first crack stage

$E = 1.31(f_{ck})-11.57$ -------------- (1)

The energy absorption up to ultimate failure

$E = 3.70(f_{ck})-35.60$-------------- (2)

Where,

E = Energy absorption in kJ

f_{ck} =28 days cube compressive strength in N/mm^2

The performance of the regression model is presented in the Table 3 and Figure.6. Form those it is observed that at first crack and ultimate stages, the developed regression models are able to predict the energy absorption quite satisfactorily. The ratio of experimental energy absorption capacities to the predicted value by regression model is in the rage of 0.91 to 1.06. The variation is about 6 to 8%. The authors felt that the proposed modes made good compatibility with the experimental data.

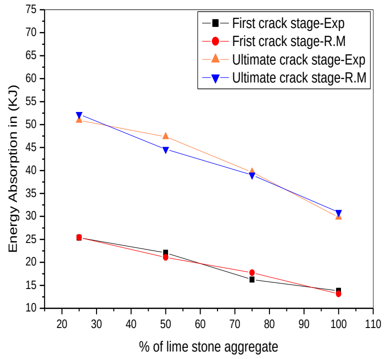

Figure 6: Performance of regression models

Table 3: Performance of regression models

S. No	Type of slab	28 th day Cube compressive strength (MPa)	Energy absorption at first crack stage (kJ)		Exp value/ Predicted value	Energy absorption at ultimate stage (kJ)		Exp value/ Predicted value
			Exp value	Predicted by Regression model		Exp value	Predicted by Regression model	
1.	SWA 25	28.23	25.38	25.41	1.03	50.90	52.22	0.97
2.	SWA 50	24.93	22.07	21.08	1.04	47.34	44.63	1.06
3.	SWA 75	22.39	16.24	17.76	0.91	39.66	39.02	1.01
4.	SWA 100	18.88	13.79	13.16	1.04	29.83	30.91	0.96

IX. CONCLUSIONS

1. The Impact strength of the SWA slabs is lower than the NAC slab specimens.
2. The decrease in Impact strength of SWA slabs over NAC slabs is in the range of 12.96 to 52.70%. at first crack stage
3. The decrease in ultimate Impact strength of SWA slabs over NAC slab is in the range of 18.55 to 52.23%.
4. The Energy Absorption of SWA slabs are in the order of lower magnitude than that of NAC slabs at first crack stage and ultimate failure stage.
5. The energy absorption capacity of SWA slabs at first crack and ultimate stages is about 12.96 to 52.70 % and 18.55 to 52.33% lower when compared to NAC slabs.
6. The Proposed regression models to estimate the energy absorption models are made with good agreement with the experimental data.

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