Behavior of Black Stone Marble Waste Aggregate Steel Fiber Concrete Beams Under Impact Loading

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ABSTRACT

Large amount of black stone marble waste is available in and around Tadipatri town in Anantapur district from granite industry. This paper presents Impact behavior of black stone marble waste aggregate steel fiber concrete beams, Total 45 number of beams cast and tested in which 15 beams are without steel fiber as control specimens and remaining 30 beams are with steel fiber with replacement of BSMWA with 0, 25, 50, 75 and 100% and in addition of fibber 0, 1 and 2%. All the beam specimens were tested under a drop weight of 50N with 100 mm diameter through a guiding barrel from a height of 450 mm. The results shown that the beams with steel fiber are having higher number of blows first crack, ultimate failure stage and energy absorptions. A comparative analysis of the experimental results of the black stone marble waste (BSMWA) aggregate concrete with natural aggregate concrete

Keywords: Natural coarse aggregate concrete, Black stone marble waste aggregate concrete, first crack, ultimate, energy absorption and steel fiber.

1. INTORDUCTION

From the past and present construction industrial sector it is known that, the growth urbanization increases in consumption on natural material and have lead to fast decline in available natural resources. On the other hand high volume of production has generated a considerable amount of waste materials which have adverse impact on the environment. Marble and granite aggregates, which are called as by-products from the marble and granite stone industries, Anantapur (Dist) and Kadapa (Dist) of Andhra Pradesh (state) are much potential for natural black stone layers. In these areas the layered stone are exploring from the quarry and making in to finished goods for flooring and ornamental purpose. During this stage, converting the finished goods the waste is generating and this is dumping in and around the stone industry and road side and it causing to inconvenience to the public who are residing near the industry and beside the road. In this connection a plan of research work has planned to utilize this waste in fibre reinforced concrete as low cost building material. Due to complexity of the dynamic response in concrete structures, the regular computational methods and design tools not be much help to understand the behavior of the materials and structural elements under impact loading. The deficiency has attracted many researchers in the past few years and investigations had been carried out to understand the behavior of the concrete under impact loading. Recent literature is presenting on utilization of waste material in concrete. Venkataramana et al.[1], studied the about stone waste aggregate and concluded that the utilization of waste aggregate can be used up to 50% replacement of natural aggregate in the concrete. Hanifi Binici et al, [2] studied the durability of concrete made with granite and marble as recycle aggregate and concluded that marble and waste aggregate can used to improved the mechanical properties, chemical resistance and workability of conventional concrete. SevilKofteci and NiyaziUgurKockal [3] presented the experimental results and showed that the use of 100% recycled marble aggregate as fine aggregate having the best marshal stability. Hanifi Binici et al, [4] studied the mechanical properties of concrete incorporation of marble dust and limestone dusts and concluded that these marble dust and limestone dust can be used for more durable concrete. Hebhoub [5] studied the waste marble aggregate in concrete and concluded that substation of natural aggregate by waste marble aggregate up to 75% is beneficial for the concrete resistance. Kamel et al, [6] studied the effects of using stone cutting waste on the compressive strength and slump characteristics and concluded that the slurry sludge generating from stone cutting may be used for concrete up to 25% of total volume of water required for producing the concrete. M.Chakradhara rao et al, [7] studied the behavior of recycled aggregate concrete impact load and concluded that 25% replacement does not influenced the strength of concrete. Jodilson et al, [8] studied the stress-strain behavior of steel fiber reinforced-recycled aggregate concrete and concluded the use of recycled aggregate in substitution of natural aggregate increased the compressive strength. Naresh kumar et al, [9] studied the performance of stone waste aggregate concrete slabs under impact loading and the results showed that the performance of stone waste aggregate concrete is lesser than the natural coarse aggregate concrete.

2. EXPERIMENTAL PROGRAM

The Experimental program comprises of casting and testing of total 45 beam specimens of size 100 x 100 x600 mm, in which 15 beams are without fiber as a control specimen and 30 beams are with 1% and 2% fiber. The beams were tested under 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 450mm. For experimental work the materials are used and methodology of casting and testing procedure are presented below.

2.1 Materials

2.1.1 Cement

Ordinary Portland cement of grade 43 confirming to IS 8112-1989 was used and specific gravity of cement were observed was 3.05. The setting time of cement initial and final were found 45 and 360 minutes respectively.

2.1.2 Coarse Aggregate

A. **Natural Coarse Aggregate:**

Crushed granite aggregate available from local source have been used. To obtain reasonably good grading 60% of the aggregate passing through 20mm and retained on 12.5 mm sieve was used the specific gravity of granite aggregate were observed as 2.75.

B. **Black Stone Marble Waste Aggregate:**

The raw material was obtained from stone polishing industry from Tadipatri town in Anantapuram district. To convert the waste material as a coarse aggregate collecting from the polishing industry and crushing was made for 20mm and 12.5mm aggregate. To obtain good grading 50% of the aggregate passing through 20 mm and retained on 12.5 mm sieve and rest of the 50% aggregate passing through 12.5mm and retained on 10mm sieve. The specific gravity of stone waste aggregate was observed as 2.68.

2.1.3 Fine Aggregate

River sand used as a fine aggregate collected from local source. The specific gravity of fine aggregate were observed as 2.70.

2.1.4 Water

Potable water, which is free from acids and organic substances, was used for preparing the concrete mix.

2.1.5 Fiber

The crimple fiber with aspect ratio of 50 has been used for the experimental work. The physical properties of rounded crimple fibers are shown in the below table 1 and the same fibers can be viewed in figure 1.

Table 1: Properties of rounded crimped steel fiber

S.No	Property	Values
1	Equivalent Diameter, mm	1.00
2	Unit weight (kg/m3)	7840
3	Tensile Strength, (Mpa)	345
4	Young’s Modulus. (Gpa)	200
5	Ultimate Elongation, %	10
6	Aspect Ratio	50

Figure 1: Crimped fiber

2.2 Casting

The Beams were cast in steel and timber moulds with inner dimensions of 100 x 100 x 600mm. All the materials were weighed as per mix design. The cement, coarse aggregate, sand, black stone marble waste aggregate and crimped fiber were mixed thoroughly till to reach uniformity to the concrete mix. While mixing care has to be taken to avoid balling effect.

All test specimens, moulds were kept on the table vibrator and the concrete was poured into the moulds in layers and compaction was adopted by mechanical vibrator. After twenty four hours the moulds were removed and the specimens were demoulded and were exposed to water bath for 28 days in curing pond. The specimens were taken out from curing pond and kept under shade to allow drying.

2.3 Test Setup

The Impact test has been carried out by using impact test machine. 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 beam 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 is shown in Figure 2. Two sides of beam are fixed using the clams with bolt and nut arrangement as shown in Figure 3. 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 of 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.

Figure 2: Pulley arrangement and impact testing machine

Figure 3: Testing of the beam specimen

2.4 Analysis of results

The results of the experimental investigation are presented in table 2, 3 and 4. 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 BSMWAC concrete beams under impact loading.

2.4.1 Number of Blows Attained For Failure.

The number of blows required for beam with out fiber is presented in table 2 and figure 4. From table 2 and figure 4 we can observe that the numbers of blows required at first crack stage for NAC-0-0 are 130 and for BSMWAC-25-0, BSMWAC-50-0, BSMWAC-75-0 and BSMWAC-100-0 are 115, 95, 80 and 55 respectively.

For ultimate stage number of blows required for NAC-0-0 are 260 and for BSMWAC-25-0, BSMWAC-50-0, BSMWAC-75-0 and BSMWAC-100-0 are 230, 200, 155 and 101 respectively.

The percentage decrease with respect to the first crack stage NAC-0-0 is 11.53, 26.92, 38.46 and 57.69% for BSMWAC-25-0, BSMWAC-50-0, BSMWAC-75-0 and BSMWAC-100-0 respectively.

The percentage decrease with respect to the ultimate stage NAC-0-0 is 11.53, 23.07, 40.38 and 61.15% for BSMWAC-25-0, BSMWAC-50-0, BSMWAC-75-0 and BSMWAC-100-0 respectively.

From table 2 and figure 4, it can be conclude that as the percentage of BSMWA increases the number of blows decreased.

The number of blows required for beam with 1% fiber is presented in table 3 and figure 5. From table 3 and figure 5 we can observe that the numbers of blows required at first crack stage for NAC-0-1 are 150 and for BSMWAC-25-1, BSMWAC-50-1, BSMWAC-75-1 and BSMWAC-100-1 are 131, 115, 88 and 60 respectively.

For ultimate stage number of blows required for NAC-0-1 are 300 and for BSMWAC-25-1, BSMWAC-50-1, BSMWAC-75-1 and BSMWAC-100-1 are 260, 231, 178 and 125 respectively.

The percentage decreases with respect to the first crack stage NAC-0-1 are 12.70, 23.30, 41.30 and 60.00% for BSMWAC-25-1, BSMWAC-50-1, BSMWAC-75-1 and BSMWAC-100-1 respectively.

The percentage decreases with respect to the ultimate stage NAC-0-1 are 13.30, 23.00, 40.70 and 58.30 % for BSMWAC-25-1, BSMWAC-50-1, BSMWAC-75-1 and BSMWAC-100-1 respectively.

From table 3 and figure 5, it can be conclude that as the percentage of BSMWAC increases the number of blows decreased.

The number of blows required for beam with 2% fiber is presented in table 4 and figure 6. From table 4 and figure 6 we can observe that the number of blows required at first crack stage for NAC-0-2 are 180 and for BSMWAC-25-2, BSMWAC-50-2, BSMWAC-75-2 and BSMWAC-100-2 are 155, 141, 115 and 76 respectively.

For ultimate stage number of blows required for NAC-0-2 are 360 and for BSMWAC-25-2, BSMWAC-50-2, BSMWAC-75-2 and BSMWAC-100-2 are 308, 285, 234 and 168 respectively.

The percentage decrease with respect to the first crack stage NAC-0-2 are 13.90, 21.70, 36.10 and 57.80 % for BSMWAC-25-2, BSMWAC-50-2, BSMWAC-75-2 and BSMWAC-100-2 respectively and are shown in table 4 and figure 6.

The percentage decreases with respect to the ultimate stage NAC-0-2 are 14.40, 20.80, 35.00 and 53.30 % for BSMWAC-25-2, BSMWAC-50-2, BSMWAC-75-2 and BSMWAC-100-2 respectively.

From table 4 and figure 6, it can be conclude that as the percentage of BSMWA increases the number of blows decreased.

Thus it can be observed that the BSMWAC specimens showed lesser performance under impact when compared with NAC at ultimate stage. This may be due to weak bond between mortar and coarse aggregate. The crushed black stone marble waste aggregate material show the relatively lesser frictional surface when compared with granite aggregate. Better results are obtained on incorporation of 2% fiber.

Table 2: No of blows attained for impact on beams at first crack stage with 0% fiber for 28days

S.No	Nomenclature	No of blows		% decrease	
		First crack Stage	Ultimate stage	First crack Stage	Ultimate stage
1	NAC-0-0	130	260	-	-
2	BSMWAC-25-0	115	230	11.53	11.53
3	BSMWAC-50-0	95	200	26.92	23.07
4	BSMWAC-75-0	80	155	38.46	40.38

5	BSMWAC-100-0	55	101	57.69	61.15

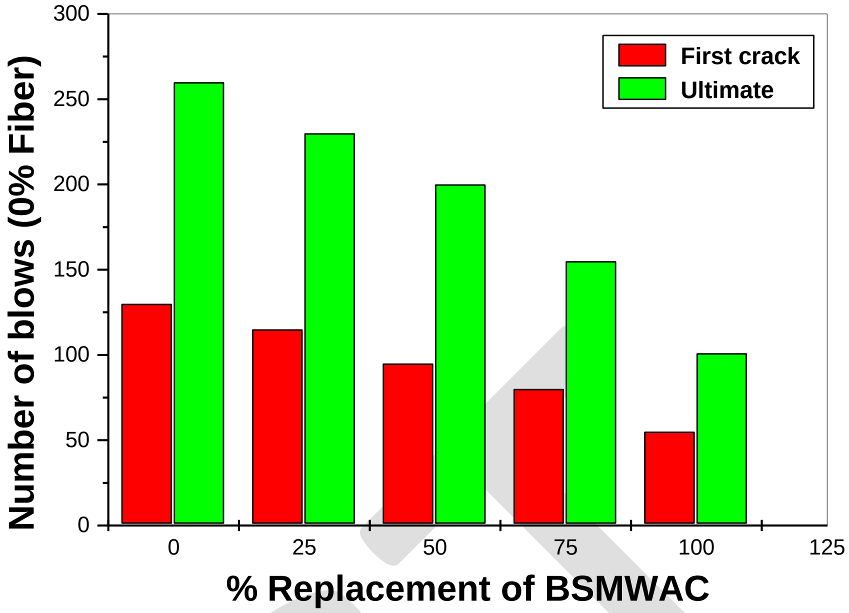

Fig. 4: No of blows (0% Fiber) Vs % Replacement of BSMWAC

Table 3: No of blows attained for impact on beams at first crack and ultimate stage with 1% fiber for 28 days

S.No	Nomenclature	No of blows		% decrease	
		First crack Stage	Ultimate stage	First crack Stage	Ultimate stage
1	NAC-0-1	150	300	-	-
2	BSMWAC-25-1	131	260	12.70	13.30
3	BSMWAC-50-1	115	231	23.30	23.00
4	BSMWAC-75-1	88	178	41.30	40.70
5	BSMWAC-100-1	60	125	60.00	58.30

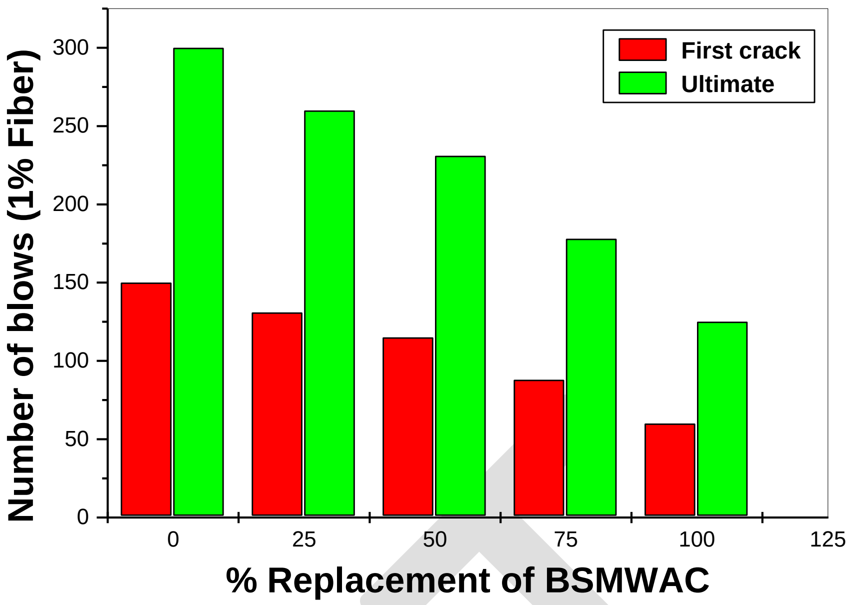

Fig. 5: No of blows (1% Fiber) Vs % Replacement of BSMWAC

Table 4: No of blows attained for impact on beams at first crack and ultimate stage with 2% fiber for 28 days

S.No	Nomenclature	No of blows		% decrease	
		First crack Stage	Ultimate stage	First crack Stage	Ultimate stage
1	NAC-0-2	180	360	-	-
2	BSMWAC-25-2	155	308	13.90	14.40
3	BSMWAC-50-2	141	285	21.70	20.80
4	BSMWAC-75-2	115	234	36.10	35.00
5	BSMWAC-100-2	76	168	57.80	53.30

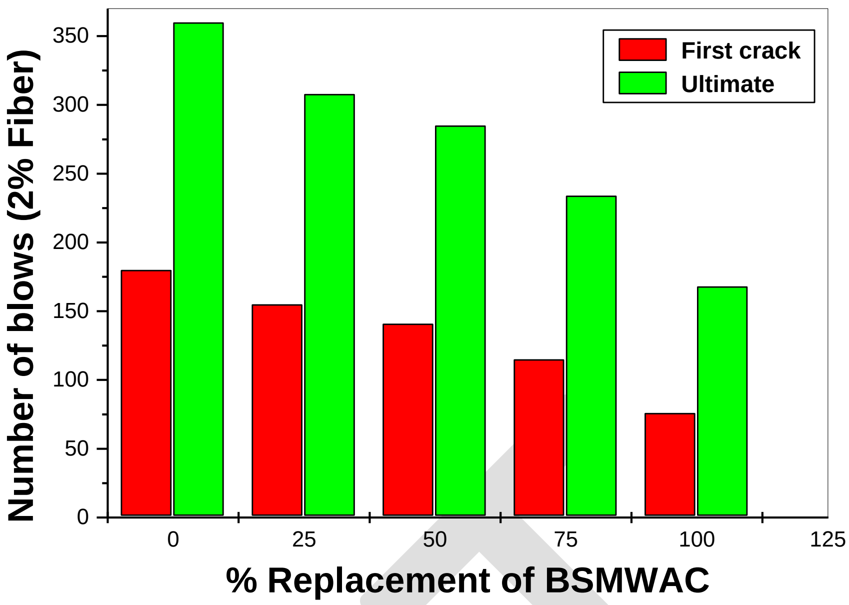

Fig. 6: No of blows (2% Fiber) Vs % Replacement of BSMWAC

2.5.2 Energy Absorption.

Total energy absorption capacities of different beams specimens at first crack and at ultimate failure are presented in table 5 and table 6. The first and ultimate stages failures are depicted in figure 7 and figure 8. In both tables 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 (50 N) and the fall of height (450mm) are maintained constant throughout the experimentation.

From table 5 and figure 7, it can be observed that BSMWAC beam specimens possess lower amount of energy absorbing capacity than NAC beam specimens. At first crack, the BSMWAC beam specimens show energy absorption capacities are 2.925, 3.587, 2.137, 1.80 and 1.237 kJ for NAC-0-0, BSMWAC-25-0, BSMWAC-50-0, BSMWAC-75-0 and BSMWAC-100-0 respectively. For 1% fiber the energy absorption capacities are 3.375, 2.95, 2.59, 1.98 and 1.35 kJ, for NAC-0-1, BSMWAC-25-1, BSMWAC-50-1, BSMWAC-75-1 and BSMWAC-100-1 respectively. Those are lesser than NAC-0-1. And for 2% fiber the energy absorption are 4.05, 3.48, 3.17, 2.58 and 1.71 kJ for NAC-0-2, BSMWAC-25-2, BSMWAC-50-2, BSMWAC-75-2 and BSMWAC-100-2.The higher energy absorption is obtained for NAC-0-2 beam specimens. Among the BSMWA concrete beams, the energy absorption capacity decreases with increase in the black stone marble waste aggregate percentage.

From the table 6 and figure 8, it can be observed that BSMWAC beam specimens required lower amount of energy absorbing capacity than NAC beam specimens at ultimate stage.

The energy absorption at ultimate stage are 5.85 kJ for NAC-0-0 and 5.175, 4.50, 3.487 and 2.272 kJ for BSMWAC-25-0, BSMWAC-50-0, BSMWAC-75-0 and BSMWAC-100-0 respectively for 0% fiber.

For 1% fiber energy absorption capacities are 6.75 kJ for NAC-0-1 and 5.85, 5.197, 4.005 and 2.812 kJ for BSMWAC-25-1, BSMWAC-50-1, BSMWAC-75-1 and BSMWAC-100-1respectively.

For 2% fiber energy absorption capacities are 8.10 kJ for NAC-0-2 and 6.930, 6.412, 5.265 and 3.78 kJ for BSMWAC-25-2, BSMWAC-50-2, BSMWAC-75-2 and BSMWAC-100-2 respectively.

Table 5: Energy absorption at first crack stage

S.No	Type of beam	Average Number of Blows	Energy Absorption (KJ)	% of decrease /increase w.r.t NAC-0-0
1	NAC-0-0	130	2.925	
2	BSMWAC-25-0	115	3.587	-11.55
3	BSMWAC-50-0	95	2.137	-26.94
4	BSMWAC-75-0	82	1.800	-38.46
5	BSMWAC-100-0	55	1.237	-57.71
6	NAC-0-1	150	3.375	15.38
7	BSMWAC-25-1	131	2.950	0.85

8	BSMWAC-50-1	115	2.590	-11.45
9	BSMWAC-75-1	88	1.980	-32.30
10	BSMWAC-100-1	60	1.350	-53.84
11	NAC-0-2	180	4.050	38.46
12	BSMWAC-25-2	155	3.48	18.97
13	BSMWAC-50-2	141	3.17	8.37
14	BSMWAC-75-2	115	2.58	-11.79
15	BSMWAC-100-2	76	1.71	-41.53

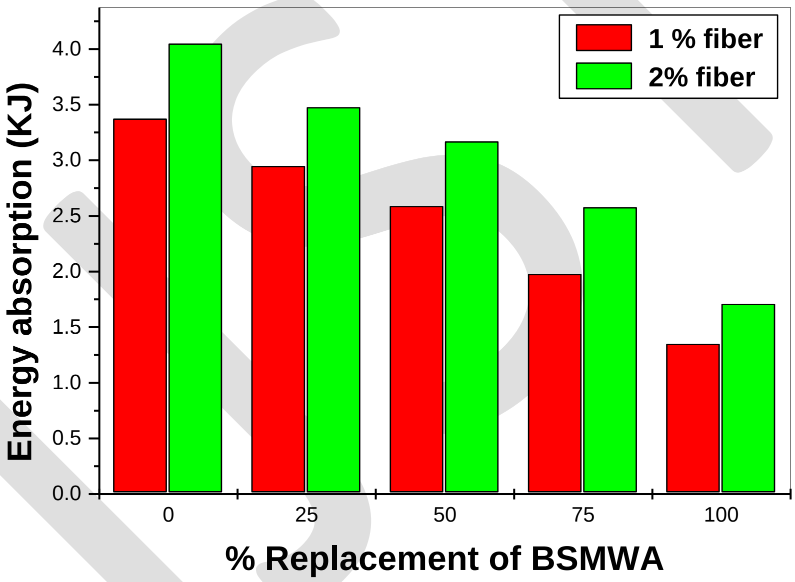

Figure 7: Energy absorption at first crack stage

Table 6: Energy absorption of beams at ultimate stage

S.No	Type of Beam	Average Number of Blows	Energy Absorption(KJ)	% of increase or decrease w.r.t NAC-0-0
1.	NAC-0-0	260	5.850	--
2.	BSMWAC-25-0	230	5.175	-11.53
3.	BSMWAC-50-0	200	4.500	-23.07

4.	BSMWAC-75-0	155	3.487	-40.38
5.	BSMWAC-100-0	101	2.272	-61.15
6.	NAC-0-1	300	6.750	15.38
7.	BSMWC-25-1	260	5.850	0.00
8.	BSMWC-50-1	231	5.197	-11.15
9.	BSMWC-75-1	178	4.005	-31.53
10.	BSMWC-100-1	125	2.812	-51.92
11.	NAC-0-2	360	8.100	38.46
12.	BSMWC-25-2	308	6.930	18.46
13.	BSMWC-50-2	285	6.412	9.61
14.	BSMWC-75-2	234	5.265	0.00
15.	BSMWC-100-2	168	3.780	-35.38

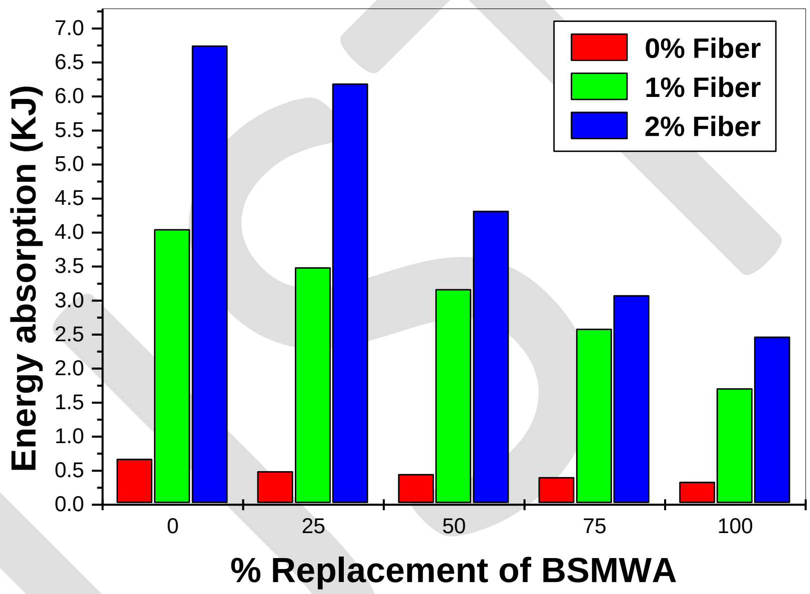

Figure 8: Energy absorption at ultimate stage

CONCLUSIONS

1. The impact strength of the BSMWAC-25 to BSMWAC-100 is lower than the NAC concrete.
2. The number of blows to cause first crack stage for 0% fiber for NAC-0-0 to BSMWA-25-0, BSMWA-50-0, BSMWA-75-0 and BSMWA-100-0 are 130, 115, 95,

80 and 55 and that of 1% fiber are 150, 131, 115, 80 and 60 and 2% fiber are 180, 155, 141, 115 and 76

3. The number of blows to cause ultimate stage for 0% fiber for NAC-0-1 to BSMWA-25-1, BSMWA-50-1, BSMWA-75-1 and BSMWA-100-1 are 130, 115, 95, 80 and 55 for 1% fiber are 300, 260, 231, 178 and 125 for 2% fiber 360, 308, 285, 234 and 168.
4. Energy absorption at first crack stage with 0% fiber are in the range 1.23 to 2.925 kJ and for 1% fiber are in the range 1.35 to 3.375 kJ and for 2% fiber varies are in the range 1.71 to 4.05 kJ.
5. Energy absorption at ultimate stage with 0% fiber are in the range 2.272 to 5.850 kJ and for 1% fiber are in the range 2.812 to 6.750 kJ and for 2% fiber varies are in the range 3.78 to 8.10 kJ.

References

[1] N.Venkata Ramana, G.Reddy Babu, U.Raghu Babu, Bearing Strength of Steel Fibre Reinforced Balck marble Stone Waste Aggregate Concrete, International Conference on Processing of Materials, Minerals and Energy (July 29th – 30th) 2016, Ongole, Andhra Pradesh, India.

[2] Hanifi Binici, tahir Shas, Orhan Aksogam, Hadan Kaplan, Durability of Concrete made with granite and marble as recycle aggregates, Journal of Material Processing Technology, Vol. 208, no. 1-3, pp. 299-308, 2008.

[3] SevilKofteci and NiyaziUgurKockal, Using Marble Wastes as Fine Aggregate in Hot Mix Asphalt Production, Proc. of the Intl. Conf. on Advances In Civil, Structural And Construction Engineering . pp. 117-121, 2014.

[4] Hanifi Binici, Hasan Kaplan and Salih Yilmaz, Influence of marble and lime stone dusts as additives on some mechanical properties of concrete, Scientific Research and Essay Vol. 2(9), pp. 372-379, 2007.

[5] Hebhoub, H.Aoun, M.Belachia, H. Houari, E. Ghorbel, Use of waste marble aggregates in concrete, Construction and Building Materials, Vol. 25, pp.1167-1171, 2011.

[6] Kamel K. Alzboon, Khalid N. Mahasneh, Effect of Using Stone Cutting Waste on the Compression Strength and Slump Characteristics of Concrete, International Journal of Environmental, Chemical, Ecological, Geological and Geophysical Engineering Vol:3, No:3, pp. 83-88, 2009.

[7] M.Chakradhara Rao, S.K. Bhattacharyya, S.V. Baral, Behavior of recycled aggregate concrete under drop weight impact load, Construction and Building Materials, Vol. 25 Issue 1, pp. 69-80. 2011.

[8] Jodilson Amorim Carneiro, Paulo Roberto Lopes Lima, Monica Batista Leite, Romildo Dias Toledo Filho, Compressive stress–strain behavior of steel fiber reinforced-recycled aggregate concrete, Cement & Concrete Composites, Vol. 46, pp. 65–72, 2014.

[9] T. Naresh Kumar, N.Venkata Ramana , E. Arunakanthi , C. Sashidhar, Performance of Stone Waste Aggregate Concrete Slabs under Impact Loading, International Journal of Engineering Research and Development, Vol. 8, Issue 7, pp. 75-80, 2013.