International Journal of Advance Research, IJOAR .org
Volume 4, Issue 7, July 2016, Online: ISSN 2320-9100

STRUCTURAL PERFORMANCE OF REINFORCED CONCRETE BEAM WITH OMANI RECYCLED STONE SLURRY

Wadhah M. Tawfeeq[1], Asma Almaqbali[2], Ashwaq Alkhawaldi[2], Hanan Almaqbali[2], Amani Alessai[2]

[1]*Assistant Professor, Faculty of Engineering, Sohar University, Sohar, PC 311, Oman; email: WTawfeeq@soharuni.edu.om or wadhah78@yahoo.com*

[2]*Undergraduate student of Engineering, Sohar University, Sohar, PC 311, Oman*

ABSTRACT

Stone slurry is an industrial waste that causes environmental pollution. Approximately three quarters of volume of concrete mix is occupied by aggregate. The utilization of stone slurry as a fine aggregate in concrete would have a positive effect on the economy and reduce environmental pollution. In this project, an experimental investigation conducted to study the flexural behavior of concrete beams with stone slurry as a fine aggregate. General properties of aggregate were studied such as specific gravity, water absorption and water content. Six beams casted with different stone slurry replacement contents varying from 0%-50% by. All the beams are simply supported and subjected to one concentrated loads at mid-span of the beam, by using 600kN flexural and transverse frame. It has found that the plain cement concrete specimen has shown a typical crack propagation pattern which leaded into splitting of beam. But due to replacement of 5% stone slurry, cracks gets ceased which result into ductile behavior. The optimum percent of stone slurry to be used was found to be 5%. Also the compressive strength of concrete cubes is increased slightly by the replacement of 5% stone slurry. The load carrying capacity were compared with theoretical values calculated using BS8110 (Design Manual)

KeyWords

Beam, Behaviour, Compressive Strength, Physical Properties, Reinforced Concrete, Reycled, Stone Slurry.

Introduction

One of the significant problems now a day is the accumulation and management of construction waste. Due to extensive use of natural aggregate in construction, many countries throughout the world tried to find other of this material to use in construction, such as crushed tiles, construction… etc. The granite stone industry generates different types of waste. Solid waste and stone slurry, whereas solid waste is resultant from rejects at the time of cutting or at the processing unit. Stone slurry is a semi liquid substance consisting of particles originated from the sawing and polishing process and water used to cool and lubricate the sawing and polishing machines. The slurry is stored in tanks to transport and evaporated. Replacing the fine aggregate which will help in filling up the pores in the concrete which is otherwise porous this will increase the strength of the concrete. These wastes materials can be recycled to save money.

Almeida.N et. al.(2007) [1] found that large amounts of slurry in natural stone treatment plants with a significant impact on the environment and human. Through experiments and testing the feasibility of the production of high performance concrete was found as an alternative to fine aggregates. The test stone results show that this industrial by product is able to improve performance and enhance the toughness behavior of concrete and can be used in concrete mixtures.

Yu lee.M and Han Ko.C et. al.(2008) [2] presented research about recycled the glass and stone fragments as raw materials for making artificial stone slabs using vibratory compaction in a vacuum environment. This study shows both density and flexural strength of these materials increase with increasing compressive strength and the optimal compaction pressure obtained is 14.7 Mpa. Also, recycled the waste glass used as a substitute for sand stone used in asphalt paving. Recycled the waste glass and stone fragments into quality products of high unit price and generate great economic.

Alzboon.K and Mahasneh.K (2009) [3] show the use of sludge in the production of concrete, which claim to reduce the environmental impacts and costs of production of mud sludge. Use the cost of the impact of slurry sludge source of water in the production of concrete. Samples analysis also showed that 96% of clay sludge volume of water so it should be considered as important source of water. It can maintain the natural materials and solve environmental and economic problem resulting from the accumulation of sludge through this application.

Chih chang.F et. al.(2010) [4] found the waste stone sludge and waste silt were recycled into artificial aggregate by used vibratory compaction method. The results show the ratio of compacted the stone sludge is 35% with 50% of waste silt and the compressive strength is 29.4 Mpa compacted packing its more valuable recycling product. Also, the ratio of compacted packing is one of the influential factors that impact compressive strength which differs from the pertaining cement concrete and the fine compacted structure has lower absorption only 0.08% it's quite different from effect of cement concrete hydration. The waste stone sludge and waste silt recycling for artificial aggregate not only substitute for sand and stone, but also an ecological alternative.

Shirazi E.(2011) [5] show that artificial stone industry generates large volume of stone slurry as waste with environmental impacts. To solve the problems stone west could be used in different industrial activities as ceramics industry, plastics, polymers, glass and paper.

Divakar. Y.(2012) [6] made experimentally to investigate the Strength Behavior of Concrete with the use of Granite Fines. Stone slurry is a semi liquid substance consisting of particles originated from the sawing and polishing process and water used to cool and lubricate the sawing and polishing machines. Granite rocks arecutting to produce the power. The slurry is stored in tanks for evaporation. granite fine dust remained is transported and disposed in landfills. Concrete is mixed with granite fines and replacement of fine aggregate in 5%, 15%, 25%, 35% and 50% used compressive strength test, Split tensile strength test and Flexural strength test. The value found from tests compared with the conventional concrete without granite fines. The results have been tabulated in table.

AL-joulani N.(2014) [7] descried that in Palestine a huge amount of stone slurry waste generated from stone cutting industry is utilized as construction materials. The materials used Portland cement and two types of commercial cement with three different percentages (15%,20%,30%) and three compaction pressure (4MPa,8MPa,12MPa).The results indicated that the compressive strength of the artificial stones is affected by the cement to stone powder percent ,compaction pressure and curing time. The maximum compressive strength was checked after 28 days at 30% Portland cement and compaction pressure of 30KN.the tests results indicated that the compressive strength increased with cement ratio, level of compaction pressure and curing time. The natural absorption increased at low compaction pressure and cement ratio.

Masoud T. (2015) [8] made research to investigate effect of using stone cutting slurry waste (Al-Khamkha) in Jordan on the unit weight and moisture content on the compaction characteristics of Jerash cohesive soil which is the local name of the stone cutting slurry waste. It is produced during the cutting operation which cut either into tiles or slabs. This study describes the use of crushed tiles waste as fine aggregate in concrete products. Many of these concrete products routinely are included in industrial business through manufacturing products.

Methodology

In this project natural sand from local crusher in Salan was used, and the cement quantity for all mixes was 400kg. Also the gravel from local crusher in Salan. The different replacement ratios were used for stone slurry (5%, 7%, 10%, 25% & 50% replacement). The (gravel/sand) ratio was used (1.1). The (cement/water) ratio was used (0.5). The water was adjusted to keep the slump between 100-180 mm. Before mixing, the characterizations of aggregates such as the grading, water absorption, water content, and clay percent tests were measured.

Experimental Materials

Natural sand from local crusher in Salan is used. The grading of the fine aggregate and the limits of aggregate as the British specification BS 882: 1992 [9]. Stone slurry is getting from Gulf stone company. Natural gravel from local crusher in Salan region is used. The grading of this aggregate conforms to the British Specification BS 882:1992[9]. The cement used in this study is Fujairah cement industries O.P.C. according to British Standard Specification BS EN 197-1:2000[10]. Potable water was used in concrete trial mixes and in curing.

Concrete Trail Mix

Mixing stone waste with concrete will have different properties. Stone slurry defined as a semi-liquid substance composed of particles, arises from the sawing and polishing processes. In this procedure, water is used to cool down and lubricate the machines which saw and polish the stone slabs. Generally in artificial stone plants, the procedure slurry is sent to a sedimentation tank for precipitation. Stone powder can reduce the porosity and permeability of topsoil and causing blocks in water penetration. Stone waste can be used in concrete to improve its strength and other durability factors. Stone waste can be used as a partial replacement of fine aggregates and as supplementary addition to achieve different properties of concrete. The adopted mix proportion will be: cement: sand: gravel / water. 400:835.2:904.8/200. With expected 28 days compression strength is 30-35 MPa and the workability (slump) between 100-180.

Design of Simply Supported Beam

Accordomg to BS8110-1997[11], the ultimate moment of resistance of singly-reinforced rectangular beams can be determined in terms of concrete capacity and the steel capacity. The maximum compressive force which can be resisted by the concrete corresponds to the maximum depth permitted for the neutral axis. If the maximum neutral axis depth is limited to 0.5d the steel stress will reach its design strength of 0.95fy. The maximum ultimate moment of resistance of a singly-reinforced beam in which the dimensions b and d and the area of reinforcing steel A_s are known is given by the lesser of the following equations:

$\boldsymbol{M_{ult}}$**, concrete = 0.156$bd^2 f_{cu}$** based on the concrete strength

$\boldsymbol{M_{ult}}$**, steel = 0.95$f_y A_s z$** based on the steel strength where $z = 0.775d$

In this project 12 mm bar diameter was used, the concrete cover is equal to 25mm, height of mold (H)=300 mm and breadth (b) of the mould=200mm. as shown in Figures 1 & 2.

Figure 1. Beam Steel Reinforcement

Figure 2. Beam Mould

Casting of Specimens

The materials were weighed accurately using a digital weighing instrument. For plain concrete, fine aggregates, coarse aggregate, cement, water were added to mixture machine and mixed thoroughly. Stone slurry was manually sprinkled inside the mixture machine after thorough mixing of the ingredients of concrete. For preparing the specimen for compressive, tensile, and flexure strength permanent steel moulds were used. Before mixing the concrete the moulds were kept ready. The sides and the bottom of the all the mould were properly oiled for easy demolding. We casted six beams and with each beam three cubes has been casted as shown in Table 1.

Table 1: Casting of Specimens

Beams Designation	Cement kg	Sand Kg	Gravel kg	Water kg	Stone slurry kg
B0	400	835.2	904.8	200	0
B1	400	835.15	904.8	200	41.76
B3	400	835.13	904.8	200	58.464
B2	400	835.1	904.8	200	83.53
B4	400	834.95	904.8	200	208.8
B5	400	834.7	904.8	200	417.6

Test Results and Discussion

In this paragraph, the experimental test results are presented and discussed. The discussion is based on ultimate capacity, and concrete crushing strength. The design calculation of and ultimate load are also conducted and discussed in compared to the experimental results. Pressing machine with 150 Ton capacity, load cell with 600kN Max capacity, and Electronic Dial gauge with 25.4mm capacity where used. Tables 2 & 3 summarize the test results obtained from the experimental work done.

Table 2: Summarizes of Experimental Test Results

Beam	Compressive Strength [f_{cu}]	Failure Load [$P_{Max\ Test}$]	Compressive Strength Changing Percentage %	Failure Mode
B0 (0%)	30.22	180.3	0	Combined (Flexural bending + Concrete Crushing)
B1 (5%)	33.41	180.3	-10.5%	Combined (Flexural bending + Concrete Crushing)
B3 (7%)	34.90	180.3	-15.4%	Combined (Flexural bending + Concrete Crushing)
B2 (10%)	27.91	180.3	7.6%	Combined (Flexural bending + Concrete Crushing)
B4 (25%)	28.46	180.3	5.8%	Combined (Flexural bending + Concrete Crushing)
B5 (50%)	19.47	180.3	35.5%	Combined (Flexural bending + Concrete Crushing)
P_{Max}: Maximum load Compressive Strength percentage: (-) increase , (+) decrease				

Table 3: Design Data

Beam	P_{conc}	P_{steel}	P_{Max}
B0 (0%)	171.27	53.3	180.3
B1 (5%)	189.3	53.3	180.3
B3 (7%)	158.16	53.3	180.3
B2 (10%)	197.8	53.3	180.3
B4 (25%)	161.3	53.3	180.3

B5 (50%)	110.3	53.3	180.3

Reference Beam with 0% Stone Slurry Replacement [B0]

Test specimen B0 had no powder (slurry stone) identical dimensions as that of all other test specimens and had characteristic strength are fy=460N/mm^2 for the reinforcement and f_{cu}=30.22N/mm^2 for concrete. The failure load, failure mode, load-displacement behavior were observed in the test as shown in Figure 3. By the starting of the loading, specimen behaved linearly until the first crack was observed, which occurred at approximately 14.4kN of the maximum load. After that, the deflection increased significantly and the cracks were widened until complete failure occurred. The cracks were observed under the loading position and extended through the beam depth and were concentrated in the region of maximum bending moment. It should be noted that steel plates were used under the loading position to avoid local failure of the slurry stone reinforced concrete beam. The failure mode predicted at the end of the test is shown in the Figure 4 the failure mode was mainly by Flexural Bending and reinforcement bars were raptured at the maximum stressed region between the middle loading positions where the maximum bending moment is concentrated. However by continuing loading combined flexural bending and concrete crushing occurred. The maximum failure load measured in the test was 180.3 kN. Figure 5 shows the load deflection curve of the reference beam (B0) that presents a typical bending failure mode started by steel yielding followed by a concrete crushing at an ultimate applied load of 180.3kN. It can be seen that the steel yielded at a load of about 120.55 kN with a maximum measured displacement of 8.41mm. The load-deflection curve had three stages. The first part (0 to 14.4kN) represents the behavior of the beam with its gross inertia before concrete cracking which started at a load of about 14.4kN. The second part (14.4 to 120kN) shows the behavior after cracking until steel yielding, whereas the third part (120 to 180.3kN) presents the behavior of the beam after steel yielding until final collapse of the beam due to concrete crushing at a load 180.3kN.

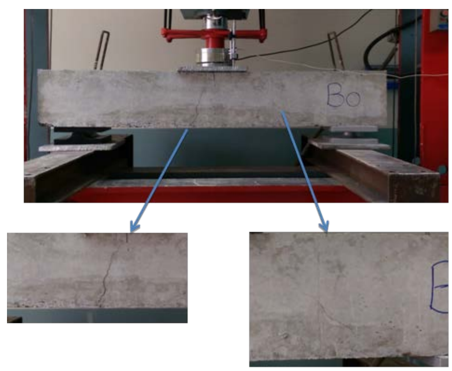

Figure 3: Cracks for Beam B0

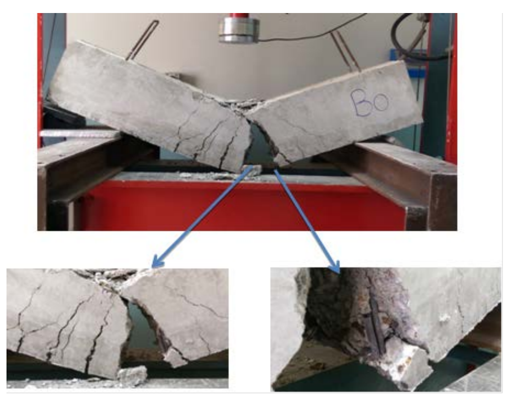

Figure 4: The Beam B0 after Failure

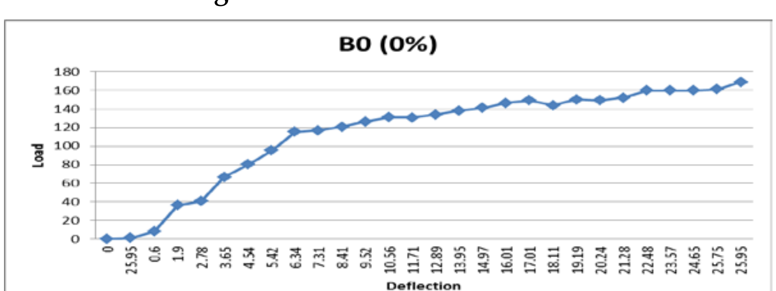

Figure 5: Load deflection curve for beam B0

Beam with 5% Stone Slurry Replacement [B1]

Test specimen B1 had 5% powder (slurry stone) identical dimensions as that of all other test specimens and had characteristic strength are fy=460 N/mm^2 for the reinforcement and f_{cu}=33.41 N/mm^2 for concrete. Figure 6 shows the load deflection curve of the beam (B1) that presents a typical bending failure mode started by steel yielding followed by a concrete crushing at an ultimate applied load of 180.3kN. it can be seen that the steel yielded at a load of about 146.89 KN with a maximum measured displacement of 14.13mm. The load-deflection curve had three stages. The first part (0 to 14.4kN) represents the behavior of the beam with its gross inertia before concrete cracking which started at a load of about 14.4kN. The second part (14.4 to 146.89 kN) shows the behavior after cracking until steel yielding, whereas the third part (146.89 to 180.3kN) presents the behavior of the beam after steel yielding until final collapse of the beam due to concrete crushing at a load 180.3kN. The first crack in the reference beam was observed at the load 14.4kN. After that formation of the first crack, the crack width increased sharply until a load of about 146.89 kN, followed by a slight increase until failure due to the formation of other cracks beside the first crack. As the applied load increased, the number and depth of cracks increased.

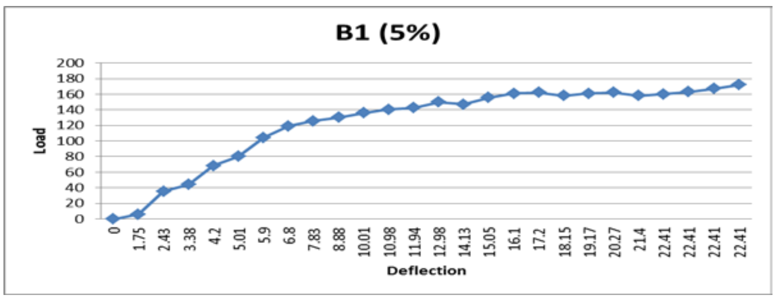

Figure 6: Load deflection curve for Beam B1

Beam with 7% Stone Slurry Replacement [B3]

Test specimen B3 had 7% powder (slurry stone) identical dimensions as that of all other test specimens and had characteristic strength are fy=460 N/mm^2 for the reinforcement and f_{cu}=34.90 N/mm^2 for concrete. Figure 7 shows the load deflection curve of the beam (B3) that presents a typical bending failure mode started by steel yielding followed by a concrete crushing at an ultimate applied load of 180.3kN. It can be seen that the steel yielded at a load of about 135.45 KN with a maximum measured displacement of 10.48mm. The load-deflection curve had three stages. The first part (0 to 14.4KN) represents the behavior of the beam with its gross inertia before concrete cracking which started at a load of about 14.4kN. The second part (14.4 to 135.45kN) shows the behavior after cracking until steel yielding, whereas the third part (146.89 to 180.3kN) presents the behavior of the beam after steel yielding until final collapse of the beam due to concrete crushing at a load 180.3kN. The first crack in the reference beam was observed at the load 14.4kN. After that formation of the first crack, the crack width increased sharply until a load of about 135.45kN, followed by a slight increase until failure due to the formation of other cracks beside the first crack. As the applied load increased, the number and depth of cracks increased.

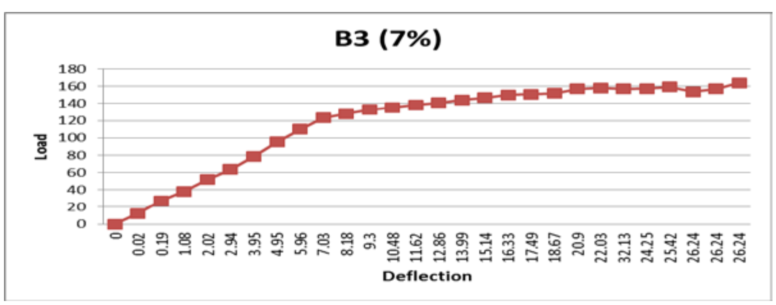

Figure 7: Load deflection curve for Beam B3

Beam with 10% Stone Slurry Replacement [B2]

Test specimen B2 had 10% powder (slurry stone) identical dimensions as that of all other test specimens and had characteristic strength are fy = 460 N/mm^2 for the reinforcement and fcu=27.91 N/mm^2 for concrete. Figure 8 shows the load deflection curve of the beam (B2) that presents a typical bending failure mode started by steel yielding followed by a concrete crushing at an ultimate applied load of 180.3kN. It can be seen that the steel yielded at a load of about 149.82 KN with a maximum measured displacement of 12.17mm. The load-deflection curve had three stages. The first part (0 to 14.4KN) represents the behavior of the beam with its gross inertia before concrete cracking which started at a load of about 14.4kN. The second part (14.4 to 149.82 kN) shows the behavior after cracking until steel yielding, whereas the third part (149.82 to 180.3kN) presents the behavior of the beam after steel yielding until final collapse of the beam due to concrete crushing at a load 180.3kN. The first crack in the reference beam was observed at the load 14.4kN. After that formation of the first crack, the crack width increased sharply until a load of about 149.82 kN, followed by a slight increase until failure due to the formation of other cracks beside the first crack. As the applied load increased, the number and depth of cracks increased.

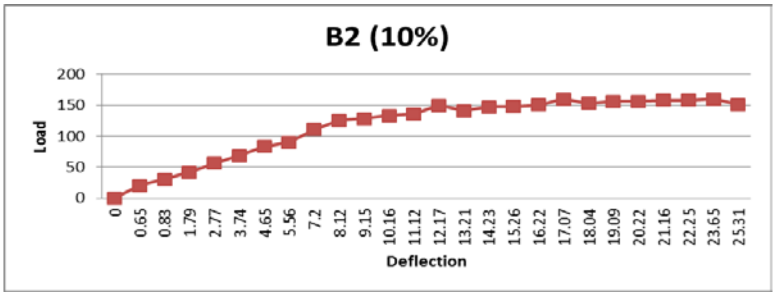

Figure 8: Load deflection curve for Beam B2

Beam with 25% Stone Slurry Replacement [B4]

Test specimen B4 had 25% powder (slurry stone) identical dimensions as that of all other test specimens and had characteristic strength are fy=460N/mm^2 for the reinforcement and f_{cu}=28.46N/mm^2 for concrete. Figure 9 shows the load deflection curve of the beam (B4) that presents a typical bending failure mode started by steel yielding followed by a concrete crushing at an ultimate applied load of 180.3kN. it can be seen that the steel yielded at a load of about 149.94 KN with a maximum measured displacement of 10.07mm. The load-deflection curve had three stages. The first part (0 to 14.4KN) represents the behavior of the beam with its gross inertia before concrete cracking which started at a load of about 14.4kN. The second part (14.4 to 149.94 kN) shows the behavior after cracking until steel yielding, whereas the third part (149.94 to 180.3kN) presents the behavior of the beam after steel yielding until final collapse of the beam due to concrete crushing at a load 180.3kN. The first crack in the reference beam was observed at the load 14.4kN. After that formation of the first crack, the crack width increased sharply until a load of about 149.94 kN, followed by a slight increase until failure due to the formation of other cracks beside the first crack. As the applied load increased, the number and depth of cracks increased.

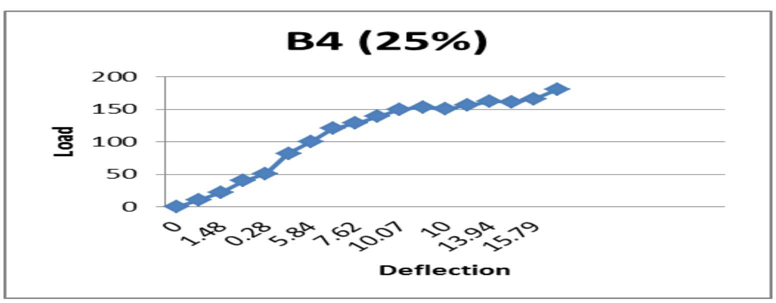

Figure 9: Load deflection curve for Beam B4

Beam with 50% Stone Slurry Replacement [B5]

Test specimen B5 had 50% powder (slurry stone) identical dimensions as that of all other test specimens and had characteristic strength are fy=460N/mm^2 for the reinforcement and f_{cu}=19.47N/mm^2 for concrete. Figure 10 shows the load deflection curve of the beam (B5) that presents a typical bending failure mode started by steel yielding followed by a concrete crushing at an ultimate applied load of 180.3kN. It can be seen that the steel yielded at a load of about 144.5 KN with a maximum measured displacement of 13.92mm. The load-deflection curve had three stages. The first part (0 to 14.4KN) represents the behavior of the beam with its gross inertia before concrete cracking which started at a load of about 14.4kN. The second part (14.4 to 144.5 kN) shows the behavior after cracking until steel yielding, whereas the third part (144.5 to \180.3kN) presents the behavior of the beam after steel yielding until final collapse of the beam due to concrete crushing at a load 180.3kN. The first crack in the reference beam was observed at the load 14.4kN. After that formation of the first crack, the crack width increased sharply until a load of about 144.5 kN, followed by a slight increase until failure due to the formation of other cracks beside the first crack. As the applied load increased, the number and depth of cracks increased.

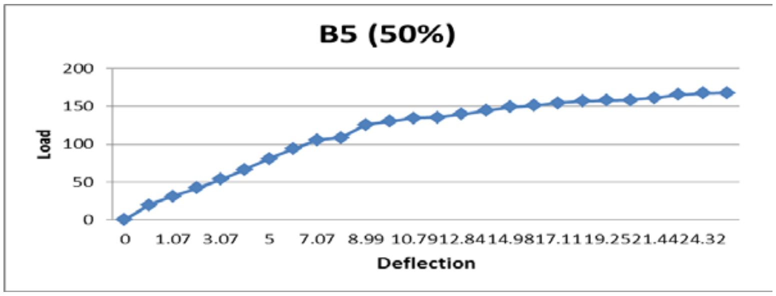

Figure 10: Load deflection curve for Beam B5

Conclusion

This study investigated experimentally and theoretically the flexural strength of stone slurry reinforced concrete beams. Six tests were conducted under one point loading bending, which is complied with BS 8110[13]. Material tests were conducted to measure the compressive strength of concrete and the properties of them. Design strength were conducted according to BS 8110[13] compared against the test failure loads.

1. The flexural strength for the beams is approximately different considerably by the addition of stone slurry.
2. The optimum stone slurry concrete beam percent to be used was found to be 7%.
3. With 5% of adding stone slurry provided better enhancement for the flexural strength, it had load of 119.34kN compared with 80.32kN of B0.
4. For all the beams we identical the experimental maximum load of failure are 180.3KN.

Acknowledgment

The authors wish to thank Sohar University for the supports during this study.

References

[1]- Almeida.N and Branco.F et.al(2007) "High-performance concrete with recycled stone slurry", Technical University of Lisbon .

[2]- Yu lee.M et. al.(2008)" Artificial stone slab production using waste glass, stone fragments and vacuum vibratory compaction " Cheng Shiu University, Taiwan.

[3]- Alzboon.K and Mahasneh.K.(2009)" Effect of Using Stone Cutting Waste on the Compression Strength and Slump Characteristics of Concrete" International Journal of Civil and Environmental Engineering 1:4.

[4]- Chih chang.F and Dong Lin.J et. al. "Artificial aggregate made from waste stone sludge and waste silt", Journal of Environmental Management, P.P 2289e2294,(2010).

[5]- Shirazi E.(2011)" Reusing of stone waste in various industrial activities" Islamic Azad University, Tehran in Iran, vol.4.

[6]- Divakar. Y.(2012)" Experimental Investigation On Behaviour Of Concrete With The Use Of Granite Fines" International Journal of Advanced Engineering Research and Studies E-ISSN2249–8974.

[7]- AL-joulani N.(2014)" The Stone Slurry in Palestine from Environmental Burden to Economic Opportunities—Feasibility Analysis" Palestine Polytechnic University, Hebron, Palestine.

[8]- Masoud T. (2015)" Effect of Using Stone Cutting Slurry Waste (Al-Khamkha) on the Compaction Characteristics of Jerash Cohesive Soil" Jerash University, Jerash, Jordan.

[9]- BS882:1992,"Aggregates from Natural Sources for Concrete"1992.

[10]- BS EN 197-1:2000. (2000). Cement. Composition, specifications and conformity criteria for common cements. British Standard.

[11]- BS 8110-1997 "Structural use of concrete. Code of practice for design and construction"