Ferrocement Panels Under Impact Loading By Incorporating Basalt Fibers

Hupesh N. Patil, Darshan G. Gaidhankar, Mrudula S. Kulkarni

Abstract: Technology is growing rapidly day by day. In construction industry also, there are some techniques which helps to reduce the in-situ construction, Ferrocement is one of them. As thickness of ferrocement panels is relatively low, it easily tends to cracking failure. So, to reduce the chances of failure, use of fiber can be the better option. In this research, ferrocement panels with and without use of fiber are compared. In this research, Basalt fibers are used as a reinforcing material with wire mesh for ferrocement slabs. The main target of this study is comparative study of the behavior of plane Ferrocement panel and ferrocement panels with basalt fibres tested under low velocity impact with different drop heights as 0.5m and 1m. Panels used of size are 500mm×500mm with 15×15mm opening and varying thickness of 15mm, 20mm and 25mm with varying layers of mesh from 2 to 5. Comparison of ferrocement panels and basalt fibre reinforced ferrocement panels is studied out. Volume of basalt fibers was used as 0.5% of total volume of panel

Index Terms: Ferrocement, Galvanised steel mesh, Basalt fiber, Low velocity impact.

1 INTRODUCTION

Generally, buildings constructed with concrete are based on design considering static loads only. But these buildings may be intended by dynamic loads, blast loads, terrorist attacks, or chemical explosions. These sudden loads can produce shaking, vibrating and cracking effects on structures. If these loads are in high intensity it can affect in deep penetration in wall and may affect be injurious to people within the frame. Ferrocement slabs can be found most preventive to these suddenly occurring loads. Ferrocement is a material with a high tensile strength and good cracking behaviour compared to reinforced concrete. For the construction of roofs, walls, floors, underground water storage structures, retaining walls, use of ferrocement is the better choice. These ferrocement material can be modified with use of fibers. Throughout this research basalt fibres are used as additive material to ferrocement with mortar. Basalt fibers has better strength characteristics and it is highly resistant to alkaline, acidic and salt attack making it good for concrete, bridge and shoreline structures. It is easy to mixed with cement concrete and mortar. Basalt fibers has good corrosion resistance than other fibers.

2 LITERATURE REVIEW

Dr. Abdul kader Ismail Al-Hadithi, Dr. Khalil Ibrahim Aziz and Mohammed Tarrad Nawar Al-Dulaim (2015) [1], In their paper, 36 panels were constructed and tested under low velocity impact test. Panels size of 500×500×50mm are used for test and drop heights 0.83m, 1.2m, 2.5m are used. The polymer (SBR) is used which is replaced to cement by 3%, 5%, 10%. The number of blows required to the initial crack was recorded. The result shows that, increasing the polymer % and number of wire mesh layer, the number of blows required to first crack increase and as the height increase the no. of blows required to first crack was decreases. K. Mounika, A. Suchith Reddy, G. Latha (2015) [3], In their paper, the flexure and low impact velocity test are performed with layer of welded mesh and by varying the percentage of steel fibres. Panels used for low impact velocity test is 500×500×25mm and percentage of fibres used are 1%, 1.5%, 2%. The result shows that by increasing the percentage of steel fiber and by increasing the layer of mesh impact energy increases. By increasing the steel fiber central deflection of panel decreases and flexure strength increases. T. Subramani, R.Siva (2016) [2], the ferrocement panels with dimension 600×600×15mm were used and flexure and low velocity test were carried out on it. The PVC coated mesh is used and waste plastic fiber are used with 5% and 10%. The result shows that by addition of waste plastic fiber the number of blows increases for the first crack and ultimate failure. Also, by increasing the PVC coated wire mesh layers. P.B. Sakthivel[1], A. Ravichandran[2], and N. Alagumurthi[3], slab size 250×250×25mm were cast with steel mesh and polyolefin fibers with 0.25-2.5% of volume of specimen.the number of layers used are 3-5, the 3kg drop weight is used and drop from 0.6m. When the number of layer increases the energy absorption is also increases but when fibers wewre add energy absorption is two times of normal panel. Yash N. Patel, Darshan G. Gaidhankar, Mrudula S. Kulkarni (2019) [15], the panels of size 250×250mm are used with thickness 20mm, 30mm, 40mm. Corrugated fiber are used in ferrocement panel which is 1.5% of total volume of panel. The number of mesh layer used are 2 and 3. The drop height is 1m and grade of mortar used is M30 and M40. The result shows that by increasing the thickness and number of layers of mesh, deformation of panels, equivalent stress and normal stress reduces. By using welded mesh and corrugated fiber it gives good impact resistance. Zakaria Che Muda, et. Al (2016) [13], In their paper, the panels of size 300×3000mm are used which is subjected to low impact test. The drop weight of 1.236kg is used at drop height 150mm, 350mm, 500mm. The thickness and mesh spacing used is 20mm, 40mm and 50mm. The result shows that, the mesh with smaller opening provide more contribution to the impact resistance that that of slab thickness.

- *Hupesh Patil, is currently pursuing Master's degree program in Structural Engineering in MIT World Peace University, Pune-India, Email: patilhupesh@gmail.com*
- *Prof. Darshan G. Gaidhankar, is currently Associate Professor in School of Civil Engineering, MIT World Peace University, Pune-India, Email: darshan.gaidhankar@mitwpu.edu.in*
- *Prof. Dr. Mrudula S. Kulkarni, is currently Professor in School of Civil Engineering, MIT World Peace University, Pune-India.*

By increasing the thickness, the number of blows required for first and ultimate crack is also increases.

3 OBJECTIVES

1. To study effect of height drop height on deformation, equivalent stress and normal stress of the ferrocement panel.
2. To study effect of panel thickness deformation, equivalent stress and normal stress of the ferrocement panel.
3. To study effect of different layers of mesh on deformation, equivalent stress and normal stress of the ferrocement panel.
4. To study effect of basalt fiber on deformation, equivalent stress and normal stress of the ferrocement panel.

4 ANALYTICAL WORK

For analytical study ANSYS 16.0 is used. To determine the response of the ferrocement panels under impact load, the panels are modelled and analyzed in explicit dynamics analysis. The ferrocement panels with and without fiber are modelled in ANSYS workbench. The sizes of panels are 500x500mm with varying thickness of 15mm, 20mm and 25mm with 53 grade mortar. The panels are reinforced with welded wire mesh with diameter of 1.2mm and opening of 15mm x15mm. Tensile yield strength of mesh is 450 MPa. The hammer of weight 3.5kg is dropped on panels with height of 0.5m and 1m. This analysis is carried out in explicit dynamics. The properties adopted for modelling are shown in table below.

***Table 1**: Material Properties*

Material	Properties	
Mortar	Compressive Strength	53 MPa
	Poisson's Ratio	0.18
	Young's Modulus of Mortar	20 GPa
	Density	2000 kg/m^3
Mesh	Tensile Yield Strength	450MPa
	Poisson's Ratio	0.3
	Density	7850 kg/m^3
Drop Hammer	Weight	3.5 kg

Dimensions of drop hammer are shown below:

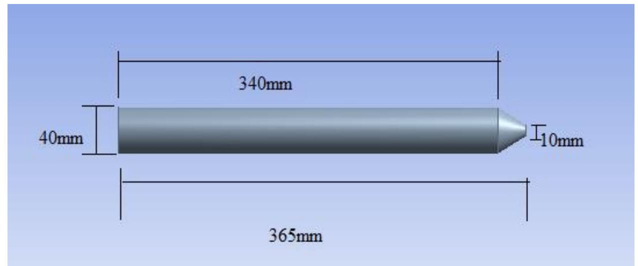

***Fig.**1 Dimensions of drop hammer*

***Table 2:** Properties of Fibers (adopted for Panel Modelling)*

Properties of Basalt Fibers	
Compressive Strength(with morter)	58 MPa
Percentage of Fiber Used	0.5%
Diameter of Fiber	15 µm
Length of Fiber	6 mm
Density	2.67g/cm^3

MODELLING OF FERROCEMENT PANELS IN ANSYS:

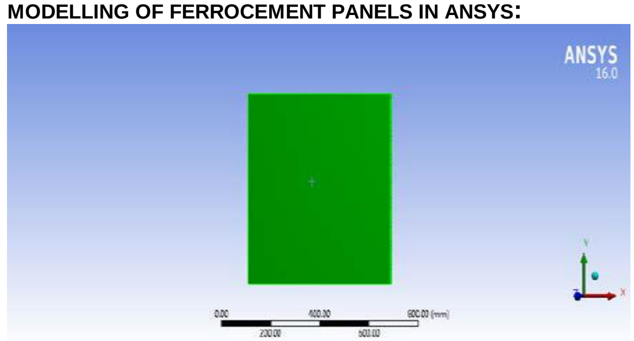

***Fig.** 2 Slab*

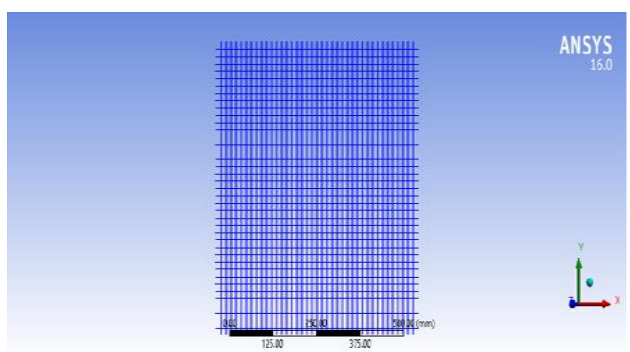

***Fig. 3** Mesh*

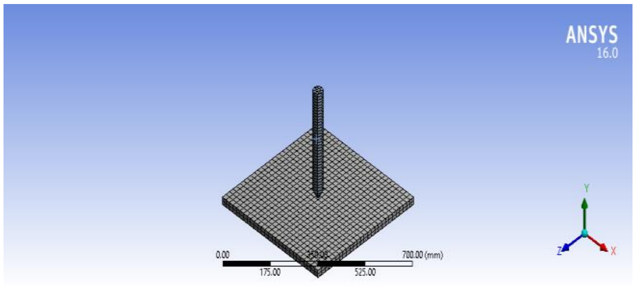

Fig. 4 *Meshing*

Meshing: Meshing is the process in which your geometry is spatially discretized into elements and nodes.

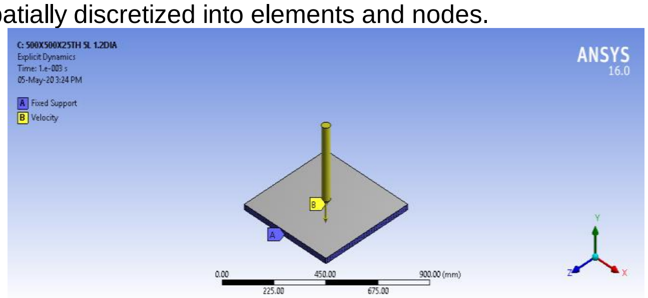

Fig. 5*. Modelling of hammer and panel*

5 RESULT AND DISCUSSION

The Explicit analysis was carried out for ferrocement panels with and without basalt fibers. The panel size of 500x500mm with varying thickness of 15mm, 20mm, and 25mm with different drop heights of hammer. The results are shown below.

For 0.5m drop height, Without Fibres

Table 3: *Results for 0.5m drop height, Without Fibres*

Panel Size	Mesh Layers	Total Deformation in mm	Equivalent Stress in MPa	Normal Stress in MPa
500x500x15	2	3.3812	38.828	35.079
	3	3.1716	36.444	33.021
500x500x20	2	2.6913	33.368	30.333
	3	2..4422	31.573	28.754
	4	2.1912	30.561	27.843
500x500x25	3	1.5349	28.858	26.305
	4	1.284	27.935	25.456
	5	1.0647	26.068	23.656

For 0.5m drop height, With Fibres

Table 4: *Results for 0.5m drop height, With Fibres*

Panel Size	Mesh Layers	Total Deformation in mm	Equivalent Stress in MPa	Normal Stress in MPa
500x500x15	2	2.5042	32.32	29.409
	3	2.2547	31.573	28.754
500x500x20	2	1.6907	29.389	26.789
	3	1.4815	28.124	25.721
	4	1.346	26.482	24.089
500x500x25	3	0.8772	25.037	22.889
	4	0.7517	24.467	22.135
	5	0.56424	22.504	21.007

For 1m drop height, Without Fibres

Table 5: *Results for 1m drop height, Without Fibres*

Panel Size	Mesh Layers	Total Deformation in mm	Equivalent Stress in MPa	Normal Stress in MPa
500x500x15	2	6.2607	54.867	48.771
	3	5.994	51.478	45.897
500x500x20	2	5.0716	48.667	43.5
	3	4.7889	45.421	40.736
	4	4.5076	43.658	39.224
500x500x25	3	3.2557	39.96	36.055
	4	3.0682	38.224	34.65
	5	2.8806	35.668	34.342

For 1m drop height, With Fibres

Table 6: *Results for 1m drop height, With Fibres*

Panel Size	Mesh Layers	Total Deformation in mm	Equivalent Stress in MPa	Normal Stress in MPa
500x500x 15	2	5.0868	49.086	43.862
	3	4.8524	45.777	41.042
500x500x 20	2	3.7259	42.142	38.924
	3	3.4432	39.46	35.643
	4	3.1619	37.755	34.157
500x500x 25	3	2.348	34.785	31.579
	4	2.1292	32.841	29.959
	5	1.8782	31.052	28.556

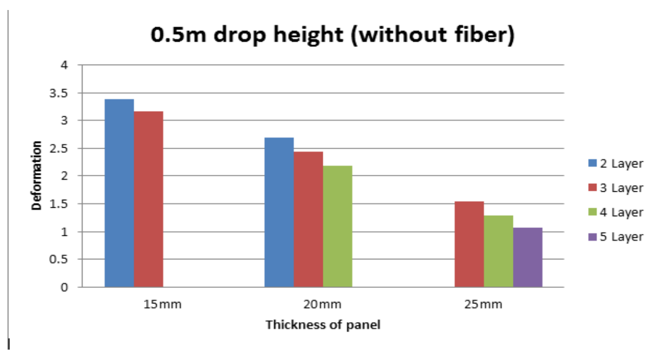

Fig 6: *Deformation for 0.5m drop height, Without Fibres*

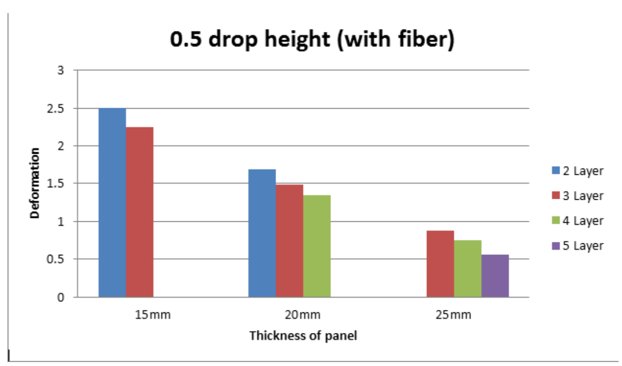

Fig 7: *Deformation for 0.5m drop height, With Fibres*

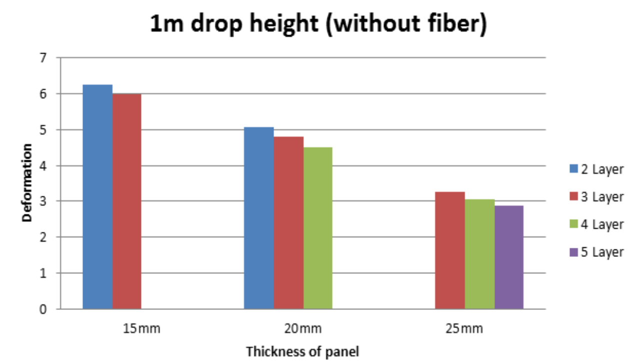

Fig 8: *Deformation for 1m drop height, Without Fibres*

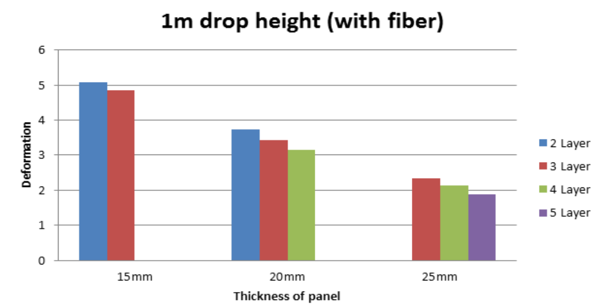

Fig 9: *Deformation for 1m drop height, With Fibres*

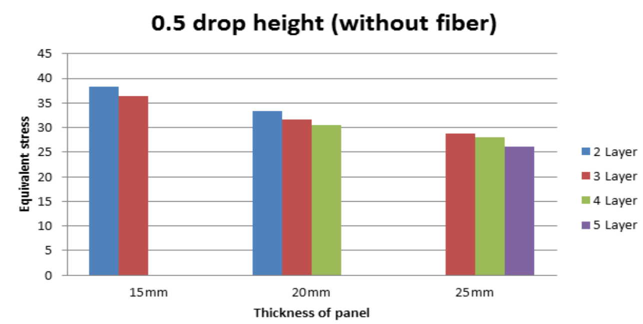

Fig 10: *Equivalent Stress for 0.5m drop height, Without Fibres*

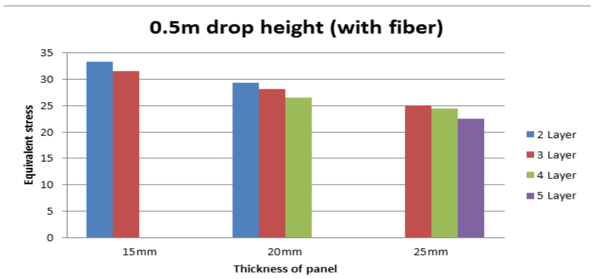

Fig 11: *Equivalent Stress for 0.5m drop height, With Fibres*

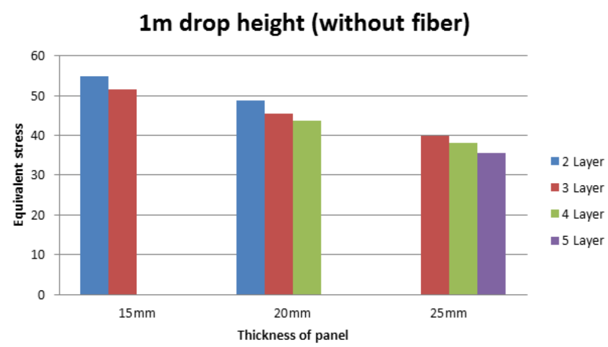

Fig 12: *Equivalent Stress for 1m drop height, Without Fibres*

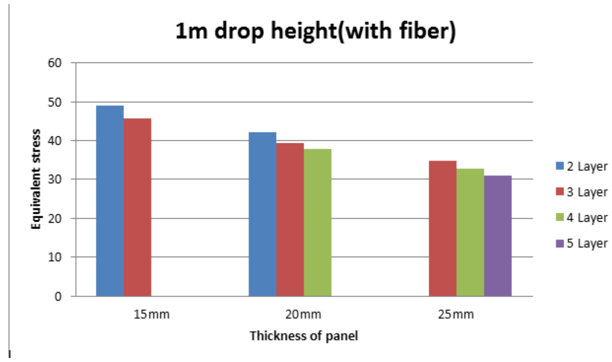

Fig 13: *Equivalent Stress for 1m drop height, With Fibres*

From the above result it is show that,

1) Average Deformation for 1m drop height is 2.33 times greater than Average deformation of 0.5m drop height for without fibres and 2.32 times for with fibres, Average Equivalent Stress for 1m drop height is 1.41 times greater than Average Equivalent Stress of 0.5m drop height for without fibres and 1.42 times for with fibres panels, Average Equivalent Stress for 1m drop height is 1.40 times greater than Average Equivalent Stress of 0.5m drop height for without fibres and 1.41 times for with fibres panels.
2) Average Deformation for 15mm thickness panel is 2.16 times greater than Average deformation of 25mm thickness and 1.31 times greater than Average deformation of 20 mm thickness for panels without fibres,
3) Average Deformation for 15mm thickness panel is 2.18 times greater than Average deformation of 25mm thickness and 1.48 times greater than Average deformation of 20 mm thickness for panels with fibres.
4) Average Equivalent Stress for 15mm thickness panel is 1.38 times greater than Average Equivalent Stress of 25mm thickness and 1.16 times greater than Average Equivalent Stress of 20 mm thickness for panels without fibres, Average Equivalent Stress for 15mm thickness panel is 1.39 times greater than Average Equivalent Stress of 25mm thickness and 1.17 times greater than Average Equivalent Stress of 20 mm thickness for panels with fibres.
5) Average Normal Stress for 15mm thickness panel is 1.35 times greater than Average Normal Stress of

25mm thickness and 1.16 times greater than Average Normal Stress of 20 mm thickness for panels without fibres.

6) Average Normal Stress for 15mm thickness panel is 1.72 times greater than Average Normal Stress of 25mm thickness and 1.45 times greater than Average Normal Stress of 20 mm thickness for panels with fibers.
7) Average Deformation for 2 Layered mesh panel is 2.38 times greater than Average deformation of 5 Layered mesh panel and 1.64 times greater than Average deformation of 4 Layered mesh panel and 1.25 times greater than Average deformation of 3 Layered mesh panel.
8) Average Equivalent Stress for 2 Layered mesh panel is 1.42 times greater than Average Equivalent Stress of 5 Layered mesh panel and 1.25 times greater than Average Equivalent Stress of 4 Layered mesh panel and 1.12 times greater than Average Equivalent Stress of 3 Layered mesh panel.
9) Average Normal Stress for 2 Layered mesh panel is 1.37 times greater than Average Normal Stress of 5 Layered mesh panel and 1.24 times greater than Average Normal Stress of 4 Layered mesh panel and 1.12 times greater than Average Normal Stress of 3 Layered mesh panel.
10) Average Deformation, Average Equivalent Stress and Average Normal Stress of without fiber panels are 1.35, 1.15, 1.15 times greater than panels with fibers respectively.

CONCLUSION

1) When the thickness of ferrocement panel increased from 15mm to 25mm then the deformation, equivalent stress and normal stress is decreased.
2) The average deformation of panel with basalt fiber is decreased by 24% compared to ferrocement panel without fiber.
3) The average equivalent stress of panel with basalt fiber is decreased by 13% compared to ferrocement panel without fiber.
4) Average reduction in deflection of panel found to be 5% with addition of each steel layer mesh of both with and without fiber.
5) When drop height is change from 0.5m to 1m deflection of panel is increased by 45% for panel with and without basalt fiber.

ACKNOWLEDGMENT

I earnestly wish to express my heartfelt thanks and a School of Civil Engineering, MITWPU, Pune and “Mr. D. G. Gaidhankar”, Professor, School of Civil Engineering, School of engineering, MITWPU, Pune, for his valuable guidance and constant inspiration in preparing this report. Frequent interactions with his in all aspects of the report writing have been a great learning experience

REFERENCES

[1] G Abdul Kader Ismail, A. Al-Hadithi, Khalil Ibrahim Aziz, Mohammed Tarrad Nawar Al-Dulaimi, “Behaviour of Ferro-cement slabs containing SBR under impact loads”, International Journal of Sustainable and Green Energy 2015; 34-50

[2] T.Subramani, R.Siva. “Experimental Study On Flexural And Impact Behavior Of Ferro-cement Slabs”, International Journal of Application or Innovation in Engineering & Management (IJAIEM), Volume 5, Issue 5, May 2016

[3] K.Mounika, A.Suchith Reddy, G.Latha, “Experimental Investigation On Performance of Fibrous Ferrocement”, International Journal of Innovative Research in Science, Engineering and Technology, Vol. 4, Issue 8, August 2015

[4] Hajare M, Varma MB. Flexural Behaviour of Ferro Cement Panels with Different Types of Meshes.

[5] Al-Hadithi AI, Aziz KI, Al-Dulaimi MT. Behavior of Ferro-Cement Slabs Modified by Polymer under Low Velocity Impact. InAdvanced Materials Research 2014 (Vol. 925, pp. 3-7). Trans Tech Publications.

[6] B. Sivakrishna, K. Madhan gopal, G. Sreenivasulu Flexural performance of ferrocement containing metakolin and fly ash reinforced with chicken mesh IJATES 2016

[7] Subramani T, Siva R. Experimental study on flexural and impact behavior of ferrocement slabs. International Journal of Application or Innovation in Engineering & Management (IJAIEM). 2016;5(5):228-38

[8] Chaohua Jiang, Ke Fan, Fei Wu and Da Chen (2014), Experimental study on the mechanical properties and microstructure of chopped basalt fibre reinforced concrete, Journal of Materials and Design, Vol. 58, pp 187-193.

[9] Marianne Inman, Eythor Rafn Thorhallsson and Kamal Azrague (2017), A mechanical and environmental assessment and comparison of basalt fibre reinforced polymer (BFRP) rebar and steel rebar in concrete beams, Journal of Concrete and Energy Procedia, Vol. 111, pp 31-40.

[10] Marek Urbanski, Andrzej Lapko and Andrzej Garbacz (2013), Investigation on concrete beams reinforced with basalt rebars as an effective alternative of conventional RC structures, Journal of Concrete and Procedia Engineering, Vol. 57, pp 1183-1191.

[11] Zakaria Che Muda, Agusril Syamsir, Kamal Nasharuddin Mustapha, Sorefan Sulleman, Salmia Beddu , Sivadass Thiruchelvam , Firas B. Ismail5, Fathoni Usman1, Nur Liyana Mohd Kamal, Md Ashraful Alam, Ahmed H Birima, Zarina Itam, O S Zaroog, “The Effect of Mortar Grade and Thickness on The Impact Resistance of Ferrocement Slab”, International Conference on Advances in Renewable Energy and Technologies, 2016

[12] Darshan G. Gaidhankar, Mrudula S. Kulkarni, Abhizer Akhtar (2018) “Behaviour of ferrocement panels under impact loading.” International Refereed Journal of Engineering and Science (IRJES) ISSN 2319-1821 Volume 7, Issue 7 Ver. I (October 2018)

[13] Yash N. Patel, Darshan G. Gaidhankar, Mrudula S. Kulkarni (2019) “Effect of mortar strength on the behaviour of ferrocement panel under low velocity impact.” In International Journal of Innovative Technology and Exploring Engineering (IJITEE), ISSN: 2278-3075, Volume-8 Issue-12, October 2019