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No. COEP/Civil/Cons/ips/ 2019/ 1954 Date: 07.9.2019

To,

Moovers and Decorators
Sr. No. No. 44, Plot No. 2, Bhosale Industrial Estate
Nahre, Pune 411041

Sub : Certification of Mathematical modelling for Impact Load Analysis for Ferron Panel

Ref : 1. Your letter dated 03.09.2019

2. Letter and report by from Dr. Mrudula Kulkarni, from MIT, Pune

Respected Sir,

As per the references mentioned above, I received hard copy of FEM analysis report of panel manufactured from your side. The modelling of panel 600mm x 900 mm x 18 mm was done using ANSYS16.0 as per the material properties as specified in the report. The panel was compared with brickwall of 230 mm thick. The panels were tested for static and impact loading and it is observed that Ferron panels have shown better performance as compared to conventional brick wall panel.

Thanking you.

Yours faithfully,

7/9/19

Dr. I. P. Sonar

Dr. Ishwar P. Sonar
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Civil Engineering Deptt.
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Enclosed : 1. Report titled " Verification of Static and Dynamic impact Load of LGS sections and Ferron panels in comparison with 230 mm thick brick wall" prepared by Prof. Mrudula S. Kulkarni , Professor & Head of Civil Engineering Department, MIT Kothrud, Pune- 38

VERIFICATION OF STATIC AND IMPACT LOAD OF LGS SECTIONS AND FERRON PANELS IN COMPARISON WITH 230 MM BRICK WALL

Project details: Proposed modification in walling system of a building at Kabul.

INTRODUCTION

The proposed walling system consists of composite made of LGS channel sections along with Ferron panel. The composite system of LGS panel along with ferrocement panel known as **"Ferron"** propose good advantage over conventional material in terms of improved bending capacity and very large impact energy absorbing capacity. Ferron is ferrocement panel of cement mortar reinforced with two steel weld meshes sandwiched in cement mortar. This is factory made precast panel unit ,manufactured under strict quality control to get casting with good finish and dense ,light weight ,slender cross-section. The ferrocement panel being reinforced with steel exhibits better bending strength and elasticity.

Ferrocement use for architectural shapes has been in construction practice for more than 150 years. The major use was in constructing circular water tanks and also making canoes and ships upto 20 meter length. The Ferro cement section showed very large tensile capacity and excellent crack resistance. The material also exhibits large impact resistance due to closely spaced steel reinforcement in the form of steel weld mesh. These properties useful in the making of structural forms like slab panels, beam sections, hollow column sections. This project proposes use of ferrocement panels along with LGS channel section to make hollow wall panels to get advantage as thermal insulation, along with structural strength, high impact resistance.

The proposed Ferron sections were cast in steel molds with weld meshes of sizes and numbers as per recommendations of the ACI guidelines. The design stresses were taken from those obtained in the experimental work, Special mix design was made to get M-30 compressive strength of the mortar. The ferrcasting system refereed as "**Ferron**" has several advantages over conventional RCC construction. They are enumerated below.

a) Factory made elements.
b) High quality and structural performance
c) Light weight, leading to ease of handling in the casting yard, transportation etc.
d) Needs smaller capacity cranes for erection.
e) Reduction in Dead Load leading to structural cost reduction in all members.

MATERIALS AND PROPERTIES

Light gauge steel section when combined with Ferron panel of 25 mm thickness, acting as composite flange with LGS section.

The Ferron panel consists of two layers of steel mesh mild steel, 250 MPa yield strength. The cover to mesh is 2.5 mm. The two layers of weld mesh, 1.4 mm diameter, and 40 mm center to center on either side are encased in mortar of M33 grade.The thickness of steel weld mesh and mortar composite is 18 mm. This makes Ferron panel a light weight and sleek wall unit, easy to be fitted, reducing construction time. The Ferron panels are mostly maintenancefree but replacement is easy.

The section of Ferron panel is as shown in figure.1

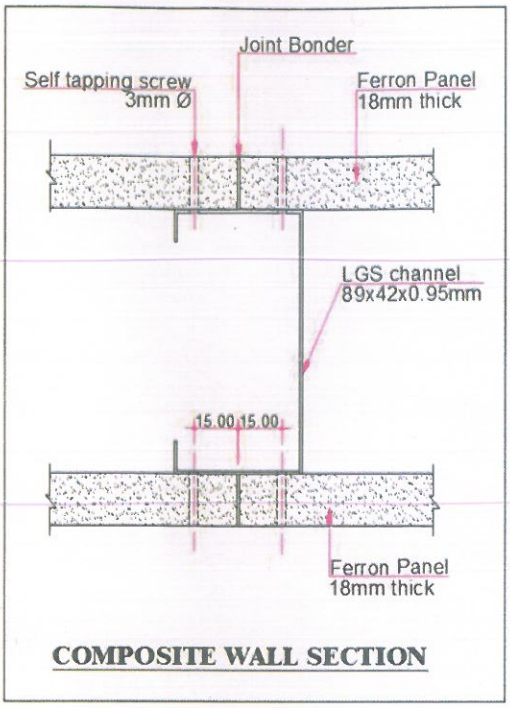

Fig 1: Cross section of LGS channel and Ferron panel mounted on either side

METHODS

1. Finite Element Analysis

The models analyzed are as following cases .

1. 600 mm by 900 mm burnt brick of 9 inch by 4 inch by 4 inch thick, constructed as single brick wall. Total wall thickness used as façade to interior structure is 230 mm. Density 1800 kg/m3.
2. Light gauge steel channels fitted with Ferron panel of 18 mm thickness at one side of LGS. Total wall thickness 107 mm.
3. Light gauge steel channels fitted with Ferron panel 18 mm thickness on either side of LGS section to make composite hollow wall unit of 125 mm thickness.as shown in fig 1.

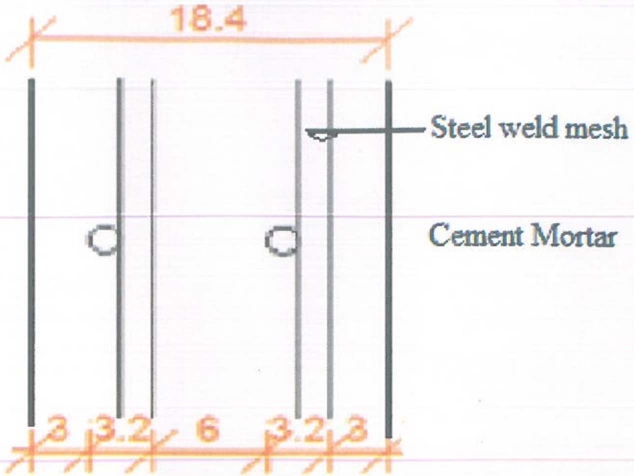

Fig2: Ferron panel section

For FEM analysis using **ANSYS 16.0**, the modeling is done for LGS sections and Ferron panel fixed on LGS section with help of self-tapping screws and Polymer Glue. The element type used for LGS section and Ferron panel is **SHELL 181** which is available with in ANSYS library, which allows out of plane bending. It has six degrees of freedom, three translations and three rotations. The shell element is modelled as layers of mortar and steel weld mesh, with input of material properties of mortar and steel weld mesh. This panel is considered as simply supported at two sides which are supported by LGS panel.

Table No 1: Material properties.

Material ID	Material	Density Kg/m^3	Modulus of Elasticity MPa	Poison`s Ration	Yield Strength MPa	Allowable flexural tensile strength MPa
1	Mortar	2000	4000	0.22	33	0.2
4	Burnt brick wet condition	1800	4500	0.20	1.4	0.2-0.5
2	Light Gauge Steel strength	7800	200000	0.29	250	165
3	Ferron Panel 25 mm thick(5 layer properties)	2400	Orthotropic composite property	0.23	35	25

Case1: Brick wall with mortar joints. 600 mm * 900 mm *230 mm thick wall.

The force transverse load capacity of brick wall panel with no pre compression, the flexural capacity is 0.023N/m2.That accounts for 0.023*600*900= 12720 N, 12.7 KN , 1.2 tonesstatic force.

Case 2: LGS section with One Ferro Panel attached as wall unit. The Ferron panel resting on LGS section is treated as simply supported on two sides . Dimensions 600 mm * 900mm. Thickness of panel 18 mm.

The ultimate flexural stress in Ferron panel is 25 MPa , where cracking is initiated, and material starts showing elastic plastic behavior. The bond between mortar and steel is assumed to break at 25 MPa flexural stress. The flexural capacity is found to be 35 KN, 3.5 Tones

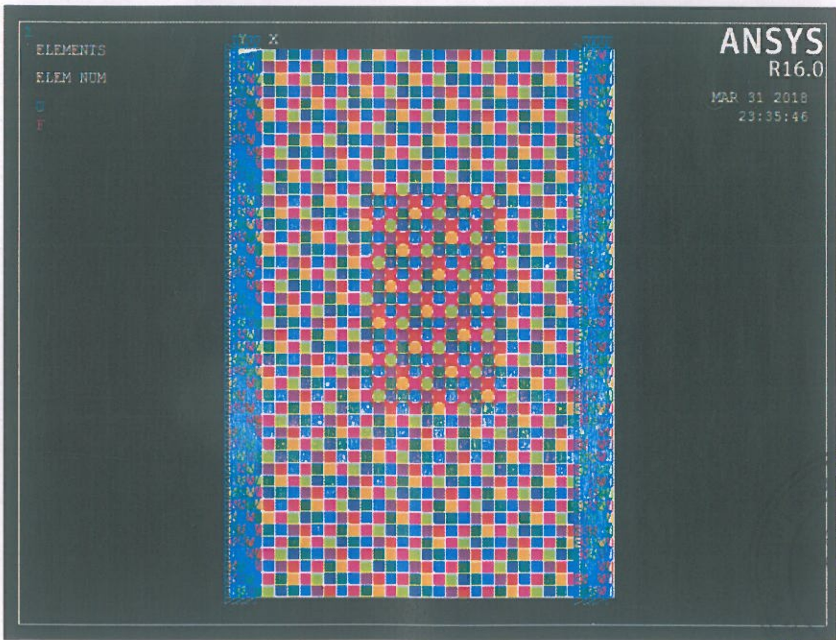

Fig 3: Meshed FEM Model showing nodes on which load is applied.

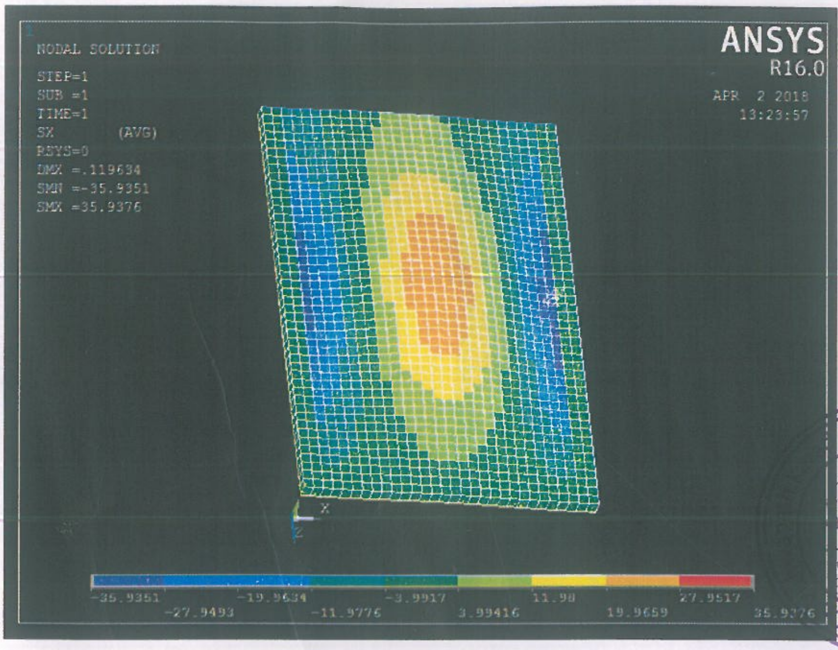

Fig 4: Single Ferron panel with LGS section, flexural stresses

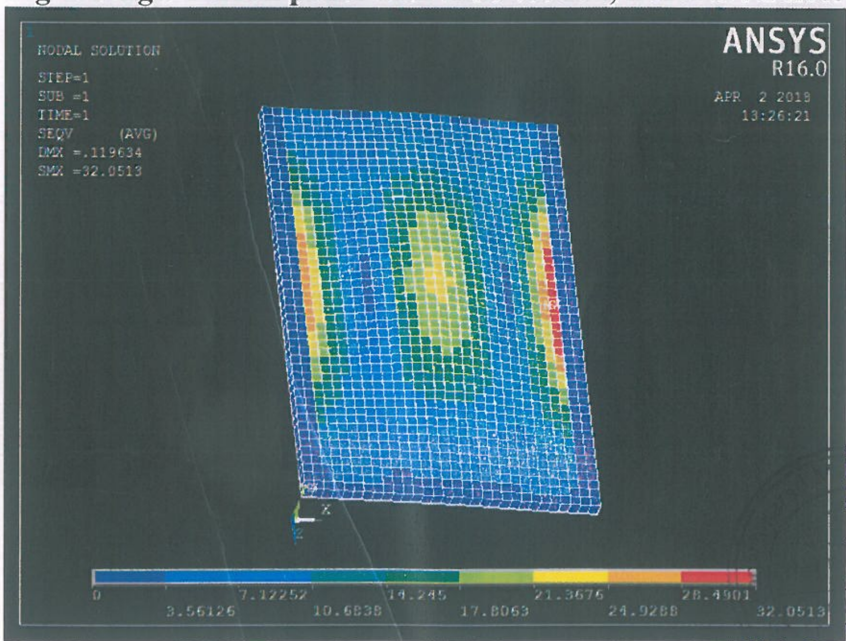

Fig 5: single Ferron panel with LGS , vonmises failure stress.

Case 3: LGS section with Two Ferron panels on either side of channel.

The load is applied on one panel as transverse load to object hitting the panel. The flexural capacity is found to be 140KN = 14 Tonnes. The capacity calculation is based on the fact that cracking starts due to flexure at 25 MPa. There after Ferron is no longer linearly elastic .There after the mortar starts cracking, and steel mesh starts taking major load.

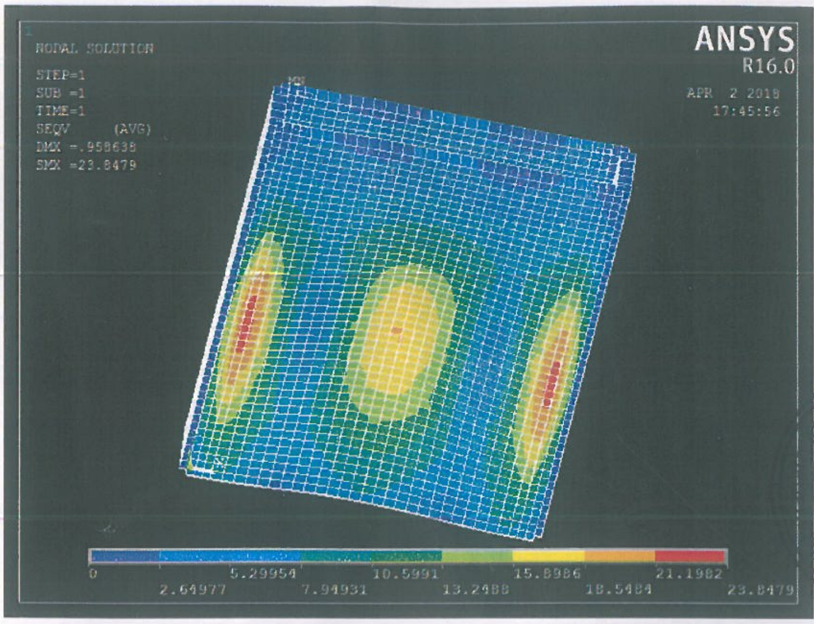

Fig 6: Double Ferron panel flexural stresses

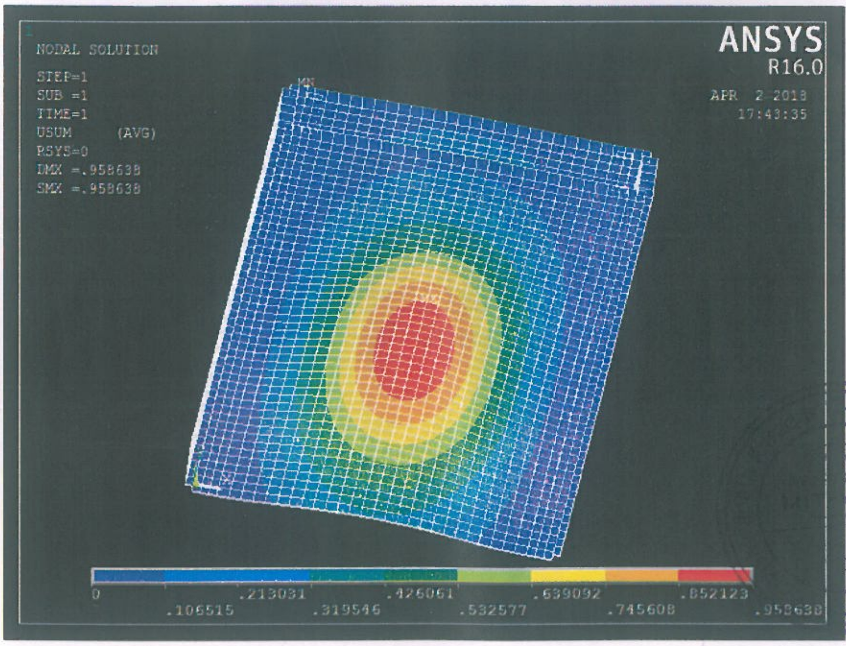

Fig 7 : Double Ferron panel, flexural deflection (out of plane bending)

Table No 2: Flexural load capacity

Case No	Material	Maximum Flexural load capacity	Equivalent impact load(striking velocity)
1	Brick wall	12.72 KN	2843 N (20KMPH)
			1562 N (50KMPH)
2	LGS with one Ferron panel	35 KN	8293 (20KMPH)
			4557 (50KMPH)
3	LGS with two Ferron panels	140 KN	33175 (20KMPH)
			18229 (50KMPH)

2. Empirical analysis for Impact load capacity

For idealization of equivalent static load for expected impact load, the theory presented by Prof.J.E.Akin of Rice University USA , is used. For calculation of load capacity of brick wall empirical relation as presented by Dr.KSN Rao, IISC Banglore, is used. This relation gives fairly correct value of flexural capacity of brick masonry wall along with mortar joints.

The bending force is considered on contact area on which impact due to object hitting the wall unit is assumed.

1. Static load Defelction **=δ_{static} =(W L ^{3}) / (48 EI)**
2. Striking velocity of object assumed to be lowest 20 Kmph highest 50 Kmph.
3. Impact load conversion factor as per prof. Akin , University of Rice ,as below.

$$Impact\ factor = \sqrt{(v^2/(g.\delta_{static})}$$

P_{max} : Impact load = Impact factor * mg.

v : striking velocity of object.

δ_{static} : static deflection of panel

The striking velocity of object is assumed as approximately from 20 Kmph(5.5 m/s) and 50 (10m/s) Kmph.

Table No 2: Comparison of Impact resistance of wall panel

Case	Wall Description	Static Flexural load capacity N	Static flexural strength of LGS+Ferron panel w.r.t, Brick masonry	Dynamic factor ή	striking velocity of object	Equivalent Dynamic load N	Impact Strength of LGS+Ferron w.r.t Brick masonry
1	Brick wall 600 mm * 900 mm 230 mm thick	3500 N	--	ή = 28.35 velocity	20 KMPH striking velocity	123.46 N	---
			--	ή= 51.52 for	50 KMPH striking velocity	61.94 N	----
2	LGS channel with one Ferron panel	35000 N	10 times	ή=3.51	for 20 KMPH striking	9971.5 N	80.76 times
				ή=6.391	50 KMPH striking velocity	5476.45 N	88.41 times
3	LGS channel section with two Ferron panels , each attached to channel flange.	142000 N	40 times	ή=2.483	for 20 KMPH striking	56383 N	456.69 times
				ή=4.5152	50 KMPH striking velocity	31006.38 N	500.58 Times.

CONCLUSION:

Ferron panel along with LGS section, is much stronger to resist static as well as impact loading.

For static loading

1.Single Ferron panel is 3 times stronger than brick wall.

2. Double Ferron panel makes hollow section of 89 mm external thickness, is 11 times stronger than brick wall.The lateral load resistance is eleven times more than brick wall. Also note that because of reinforced nature of Ferron panel, the failure of panel with bending or impact will not create debris. At failure multiple cracking on surface will be seen but mortar will remain entangled with steel mesh. This poses better solution with respect to rescue operation and prevention of loss of life in case of failure of structure.

For Impact load

3. LGS channel with single Ferron panel is 80 times stronger than brick wall for instantaneous impact load.

4. LGS channel section with Ferron panel on either side of channel creates section that can be treated as LGS web and Ferron flanges. This improves sectional modulus of wall panel, imparting great enhancement in bending capacity. The close spacing of steel reinforcement in ferrocement panel imparts impact energy absorption making it impermeable ductile material that absorbs impact energy without crushing failure that is exhibited by brick masonry wall. It is therefore a better alternative to a conventional brick wall.

5.Thus LGS channel section ,to which Ferron panels are bolted by self-tapping screws and also glued by polymer bonder, makes a very strong wall panel to resist static as well as transverse Impact loads due to horizontal objects hitting the panel with large striking velocity. This can be simulated condition for construction in area where military activities are observed.

6.It should be noted that Ferron panel mounted on LGS section gives light weight, fast construction. Small capacity crane is sufficient for lifting the panels. Transportation is easy. Replacement of panels is easy, if in case required.

7. Factory manufactured product with better quality control. Saving in construction time. Overall cost effective construction.

The detail calculations and simulation files are available with undersigned. If required, will be made available.

Design Verification done and submitted by :

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REFERENCES:

1. Impact load factors for conversion of static analysis, Prof.J.E.Akin, Rice University. USA
2. Experimental determination of design stresses for Ferro cast elements, Indian Society of Structural Engineering`s Journal of Structural Engineering,2016-06-01 | journal-article URL: http://www.isse.org.in/index.php/publications/quarterly-journals#
3. Structural Investigation of steel fiber reinforced concrete subjected to impact loading International Journal of Science and Research,2016-06-01 | journal-article URL: https://www.ijsr.net/archive/v5i6/NOV164510.pdf
4. Structural Investigation of steel fiber reinforced concrete subjected to impact loading .International Journal of Science and Research2016 | journal-article
5. Use of Ferro casting for high volume Building construction, Indian Society of Structural Engineering.2015-10-30 | journal-article
6. Confinement of Concrete with Ferro cement Jacket, ACI Technical Discussion meeting, Washington Bulletin ACI, 2015-07-19 | magazine-articleURL: **http://www.ACI.com**
7. Analysis of tensile fabric structure using thin concrete doubly curved shell International Journal of Research in Advent Technology,2014-04-18 | journal-article. Part of ISSN: E-ISSN: 2321–9637 (Online) URL: http://citeseerx.ist.Psu.edu/viewdoc
8. Experimental study of Ferrocement Channel Units Under flexure International Journal of Research in Technological studies, 2014-02-08 | journal-article Part of ISSN: ISSN [ONLINE]:- 2348 – 1439
9. Behavior of Columns with Ferro cement and Steel Tube Confinement under Axial Compression

10. Prof. D G Gaidhankar, Rohit T S Netravalkar, Dr. M. S. Kulkarni,International Journal of Engineering Research and Management,(An ISO 9001:2008 Certified Online Journal),https://www.ijerm.com/vol/Volume-03-Issue-08.
11. Analysis and Design of Ferrocement Panels an Experimental Study, Nagesh Kulkarni, D.G.Gaidhankar,M.S.Kulkarni International Journal of Inventive Engineering and Sciences (IJIES) ISSN: 2319 9598, Volume-1, Issue-5, April 2013, https://www.scribd.com/document/324945642/Analysis-and-Design-of-Ferrocement-Panels-an-Experimental-Study.
12. Behavior of Ferrocement Composite in Direct Tension by using Welded square mesh, P.S.Parande, DG Gaidhankar, M.S.Kulkarni International Journal of Research In Advent Technology 2 (07), 40-45, 2014
13. FERROCEMENT COMPOSITE BEAMS UNDER FLEXURE,DG Gaidhankar, MS Kulkarni, AR Jaiswal,2017Analysis and Design of Composite Power House Sub-Structure, D.G.Gaidhankar, International Journal of Current Engineering and Technology 6 (05), 1722-1727,2016
14. Behavior of Columns with Ferro cement and Steel Tube Confinement under Axial Compression, DG Gaidhankar, International Journal of Engineering Research and Management 3 (08), 14-17,2016.
15. Ferrocast Structural Elements For Mass Housing For Low Income Group In India, Arun N. Purandare, Mrudula Kulkarni,3rd Residential Building Design & Construction Conference - March 2-3, 2016 at Penn State, University Park,PHRC.psu.edu **www.phrc.psu.edu/assets/docs/Publications/.../Purandare-2016-RBDCC.pdf**
16. EXPERIMENTAL STUDY ON FERROCEMENT CHANNEL UNITS under Flexure, M.S. Kulkarni, Kawaljeet Singh Chhabra,Constro2014 , www.constro2014.blogspot.com/2014/02/experimental-study-on-ferrocement.
17. Experimental determination of design stresses for Ferro cast elements, Arun Purandare, Mrudula Kulkarni Indian Society of Structural Engineering`s Journal of Structural Engineering 2016-06-01 | journal-article **URL: http://www.isse.org.in/index.php/publications/quarterly-journals.**
18. Structural Investigation of steel fiber reinforced concrete subjected to impact loading .D.G.Gaidhankar, M.S.Kulkarni, International Journal of Science and Research,2016-06-01 | journal-article URL: https://www.ijsr.net/archive/v5i6/NOV164510.pdf
19. Confinement of Concrete with Ferro cement Jacket, Arun Purandare, Mrudula Kulkarni ACI Technical Discussion meeting, **Washington Bulletin ACI, 2015-07-19| magazine-article ,URL: http://www.ACI.com**

20. Experimental study of Ferrocement Channel Units Under flexure International Journal of Research in Technological studies, 2014-02-08 | journal-article Part of ISSN: ISSN [ONLINE]:- 2348 – 1439