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Behavior of Different Ferrocement Structural Elements under Different Condition of Loading: Review

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ABSTRACT

This study introduce a review on structural behavior of different structural elements such as beams, slabs, column….etc, under different type of loading. Through this review one can see the effectiveness of using ferrocement in casing slabs, beams subjecting to bending or impact load. Also the ferrocement make an essential role in strengthening of damage columns and beams.

1. Introduction

Ferrocement has been used in many structural application because its cheap, reliable and can be used as strengthening component for structural reinforced concrete elements in construction industry. It can be used as plate, panel or wall and also can be used in casing of beams. Because of closely distributed of reinforcement throughout the ferrocement element's cross sectional area, ferrocement shows a homogenous property. So many Experiments investigation should be done on strength of such type of concrete under different condition of loading like bending, shear, impact…..etc. Sasiekalaa and Malathy (2012) introduced a review about mechanical properties of ferrocement matrix.Yardim (2017) made a review about application of ferrocement in precast composite slabs.

Batra et al (2017) and Burakale et al (2020) introduced a review about application of ferrocement in engineering field. No a review was found dealing with structural behavior of different types of elements under different types of loading.

This work is review of about flexural and shear behavior of ferrocement elements. Also response of these element when subjected to impact load. Besides behavior of ferrocement as strengthened material have been reviewed.

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2. Flexural Behavior of Ferrocement Elements

Understanding of flexural behavior of different ferrocement element is so important and below a review about the existing research in this field.

Behavior of ferrocement elements in flexure influenced by many parameters; mesh type, matrix strength, mesh orientation and mesh properties. In general behavior in flexure can be categorized into three main stages: elastic, elastoplastic, and plastic stages (American Concrete Institute, 1982). Peak strength in flexural was proved to be affected by number of mesh layers, orientation of the reinforcing wire meshes and wire meshes types (Naaman, 2000 and Kong 1990).

Ashraf and Halhalli (2013) investigated the of behavior of self-compacted ferrocement concrete (SCFC) incorporating shaktiman steel fibers as slab panels under flexure. A total of eighteen 700 × 300 × 40 mm (length×width× thickness) panels have been casted and tested under flexural loading. The main parameters were ; number of welded mesh layers and percentage of shaktiman steel fibers (0.25% and 0.5%). The results showed that stiffness of panel with 1-layer reinforcing was lower than that of the panel with 2 layers, also a reduction in the number of cracks was notice with increasing in fiber content.

Service and ultimate behavior for roof slab panel made of ferrocement was studied by Hago et al (2005). Simply supported (S.S.) roof slab panels were made of ferrocement and influence of the panels shape was investigated. Results show that utilizing of monolithic shallow edge beam with the panel improved both service and the ultimate behavior of the panels.

Another researchers found that using skeletal steel in ferrocemect beam led to increase in flexural strength by 30 to 40% (2005). Others found that using of hybrid polypropylene fibers led to delay of crack's growth, reduce the width of crack's width and also noticed an increasing in numbers of cracks (Mhadeshwar et al, 2017).

Dharane and Architamalge (2014) investigated the behavior of two-way slabs that are made of ferrocement and conventional concrete under gradual load. They found that the crack numbers reinforced concrete slabs were less and wider than for ferrocement slabs .

Other researchers found that drop in flexural strength for hollow ferrocement beams compared to solid box-beams is less compared with decreasing in the weight of the beam. Also they found that moment-curvature response and post-ductility of hollow beam improved with increasing the number of mesh layers (Rao, 2012).

Sulaimani et al (1991) investigated the shear behavior of ferrocement box beam Test of their investigating showed that load at first crack and shear forces increased with increasing mesh layers in the web and with placing mesh in flanges, in additional to arrest tension cracks another factor that led to increase of load at first crack and shear forces decrease a /h ratio.

Mahmood and Majeed (2009) studied the flexural behavior of flat and folded ferrocement panels. For the same number of mesh layers capacity of folded panels were found to be 3.5 to 5 times of that for flat panels. The increasing of layers of reinforced mesh from one layers to two and three layers led to increase of flexural capacity of folded panels by by 37% and 90% , respectively.

Tatsa (1991) found that the reduction in modulus of elasticity of ferrocement mortar is about 20% compared convention concrete for similar cylinder or cube strength. And he stated that a two-way action may be found in ferrocement members due to the wire mesh distributed.

In step to get a lightweight ferrocement beams, Desayi and Reddy (1991) replaced sand by foamed blast furnace slag from 0 to 100% replacement in steps of 20%. density and compressive strength of mortar decreased linearly with increasing replacement of foamed blast furnace slag. Also the stress in extreme tension fibers of lightweight beams linearly varied with strength and density of mortars.

Another study investigated behavior of ferrocement deep beam subjected to central point load. Results demonstrated that diagonal cracks increased with decreasing of l/d ratio, amount of mesh reinforcement and increased of morters strengths (Hussain et al, 2013).

Kadhum (2013) produced a new type of ferrocement of polystyrene concrete, which has several advantages compared to ordinary reinforced concrete plates, such as lower density, abrasion resistance, compressive strength and flexural strength.

Ali et al (2020) incorporating two type of fibers alone in ferrocement matrix; steel and aluminum fibers and studied their effect on flexural strength of one-way slabs. They font that steel fibers more effective in case of improvement the flexural strength of slabs. But both types of fibers improved the ductility of tested slabs.

3. Impact resistance of ferrocement elements

Impact can be defined as the process of collision of two bodies in a very short period of time causing impact load, in which depends on mass , velocity, shape and elastic and plastic properties of the collided bodies. In this section, a review of lectures about effect of impact loads on ferrocement elements are presented as follow;

Ferrocement two-way panels incorporating waste plastic fibers (WPF) were tested by Al-Hadithi and Al-Obaidi (2015) , which have dimensions of (500×500×50 mm) under low velocity impact load. They found that WPF increased the number of falling blows that required to cause first crack and that needed to cause failure of the panel. experimental work was made by Al-Hadithi et al (2014) to investigate the influence of utilizing polymer in ferrocement panel on its impact resistance [17]. Results showed that number of falling blows that required to cause the first invisible crack and that for failure, increased with increasing of polymer content and number of mesh layers, see Fig 1 and Table 1.

Polyolefin fibers with steel mesh PVC coated were used in ferrocement slab panel which were tested under low-velocity impact load. Energy capacity absorption for fiber reinforced ferrocement slabs was higher than that of ferrocement slabs without fibers (but both were casted with PVC mesh). Also energy absorption increased with increasing in number of layers of welded mesh, and with increase in percentage of fibers from 0.5% to 2.5% (Sakthivel and Jagannathan, 2012).

Gaylan (2008) enhanced mechanical properties and impact resistance of ferrocement by adding different types of fibers .

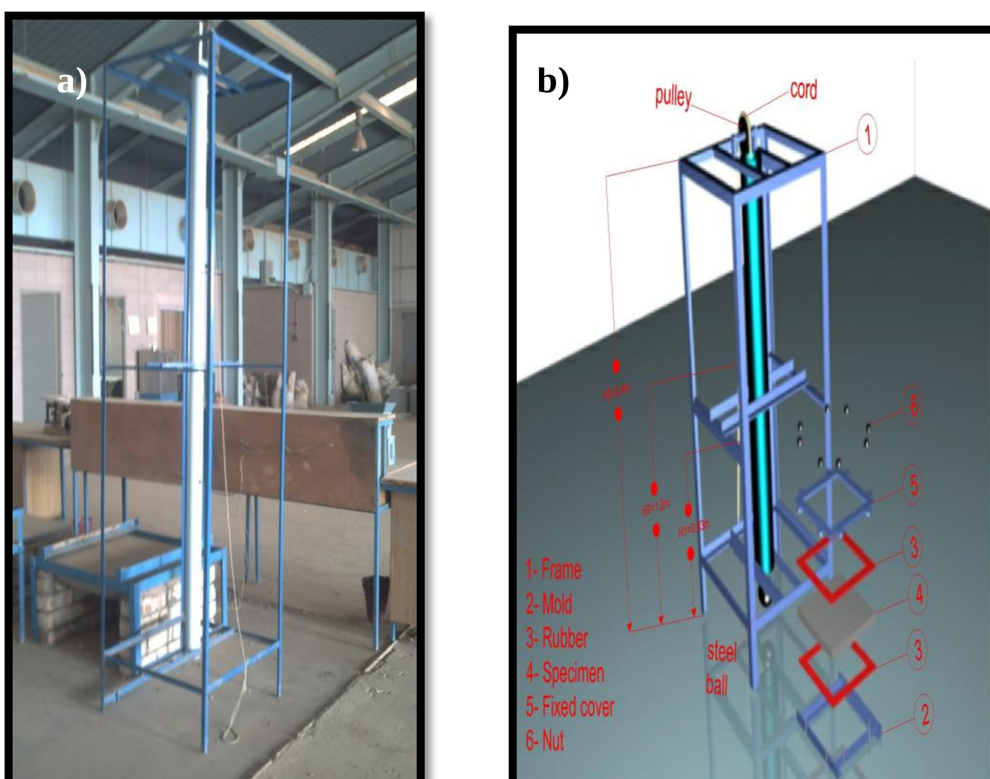

Fig. 1 Test Rig Used for Low Velocity Impact Test b) Detail of the Rig Used for Low Velocity Impact (Al-Hadithi and Al-Obaidi, 2015)

Table 1 – No. of Blows that Caused First Crack and Ultimate Failure of Various Concrete Slab Specimens for 2.4 m High Falling Mass (Al-Hadithi and Al-Obaidi, 2015) .

No. of Blows	Number of Reinforcement Layers	(vol. of fiber within mix) %			
		0%	0.5%	1.0%	1.5%
Number of Blows to Cause a First Crack by Falling Mass	0	4	16	25	18
	1	10	25	44	34
	2	16	29	72	58
	3	20	37	84	78
% Increase No. of Blows over Reference Mix	0	0	300	525	350
	1	0	150	340	240
	2	0	62.5	350	262.5
	3	0	85	320	290
Number of Blows to Cause Ultimate Failure by Falling Mass	0	6	28	34	22
	1	13	32	50	41
	2	20	37	81	67
	3	25	44	99	90
% Increase No. of Blows over Reference Mix	0	0	367	467	266
	1	0	146	285	215
	2	0	76	305	235
	3	0	76	296	260

4. Strengthening using ferrocement

Structural element are often partially damaged during its service life under different type of loading , which led to the need of strengthen of that element. There are many type of strengthened one of them is using ferrocement. Razvi and Saatcioglu (1989) made a small scale of reinforced concrete column to investigate its behavior when Welded Wire Fabric (WWF) was used as lateral reinforcement in order to confine column's core. A different combinations of Welded Wire Fabric with tie reinforcement was used as a confinement reinforcement. Results showed that using of Welded Wire Fabric as confinement reinforcement led to an improvement in column strength also the ductility was significantly improved.

Kaushik et al. (1990) used ferrocement to encase short square and circular columns with reinforced and unreinforced cores. Also they found an improvement in strength and ductility of tested column that ferrocement encasement.

Another interesting research work made by Ahmad et al. (1990), who investigated about possibility of utilizing of ferrocement as a retrofit material using for masonry column. They found that using of ferrocement improved cracking resistance.

A series of square section R.C. columns were casted and tested by Mourad and Shannag (2012). The columns have been preloaded under axial compression load about 0%, 60%, 80%, and 100% of column's ultimate load. Columns were repaired by utilizing ferrocement jackets with two layers of welded mesh encapsulated in high strength mortar. Retested was made to repaired columns until failure. Results of tests indicated that using jacketing R.C. square columns led to increase in axial load capacity of column by 33% and 26% compared to control columns. Fang et al (2017) utilized alkali-activated slag ferrocement in order to strengthen corroded R.C. columns. Results showed that the corroded columns lose capacity of loading about 21 to 30 % due to corrosion as compared to control column. AAS ferrocement strengthening can improved capacity of corroded damaged columns by about 37–72 %.

Other researchers utilized polymer-modified ferrocement with 15% styrene-butadiene-rubber latex polymer to strengthen damaged beams. Ductility and cracking pattern of strengthened beams were remarkably improved (Ghai, 2018).

5. Conclusions

1. Behavior of ferrocement elements in flexure can be categorized into three main stages: elastic, elastoplastic, and plastic stages
2. Behavior of ferrocement elements in flexure influenced by many parameters; mesh type, matrix strength, mesh orientation and mesh properties.
3. Stiffness and flexural strength of frerrocement elements increase with increasing of number of reinforcing layers
4. For deep beams made of ferrocement, diagonal cracks increased with decreasing of l/d ratio, amount of mesh reinforcement and increased of mortars strengths
5. Ferrocement of polystyrene concrete has several advantages compared to ordinary reinforced concrete plates, such as lower density, abrasion resistance, compressive strength and flexural strength
6. Using of WPF (waste plastic fibers) increases the number of falling blows that required to cause first crack and that needed to cause failure of the panel subjecting to impact load.
7. Number of falling blows that required to cause the first invisible crack and failure, increased with increasing of number of mesh layers.
8. Using of welded wire fabric ferrocement as confinement reinforcement for strengthen of damage column led to an improvement in column strength also the ductility was significantly improved
9. Using jacketing by ferrocement for R.C. square columns led to increase in axial load capacity of column by 33% and 26% compared to control columns**.**
10. Utilize of polymer-modified ferrocement with 15% styrene-butadiene-rubber latex polymer to strengthen damged beams led to remarkably improve in Ductility and cracking pattern of strengthened beams.

References

Ahmed T, Ali S, Choudhury J. (1990). Experimental study of ferrocement as a retrofit material for masonary columns. In: Nedwell, Swamy, editors. *Proceedings of the fifth international symposium on ferrocement*; 1990. 269 – 76.

Ali Z. M., Hama S. M., Mohana M. H. (2020). Flexural behavior of one-way ferrocement slabs with fibrous cementitious matrices. *Periodicals of Engineering and Natural Sciences*. 8(3).1614-1624.

A1-Sulaimani G. J., I. A. Basunbul and E. A. Mousselhy. Shear Behavior of Ferrocement Box Beams. *Cement &Concrete Composites* 13 (1991) 29-36

Al-Hadithi A. I. and Al-Obaidi Z.A. (2015). Behavior of Ferrocement Slabs Containing Waste Plastic Fibers under Impact Loadings. *Ciência e Técnica Vitivinícola* 30(5):205-219.

Al-Hadithi A. I., Aziz K. I. and Al-Dulaim M. T. N. (). Behavior of Ferro-Cement Slabs Modified By Polymer Under Low Velocity Impact. *Advanced Materials Research*. 925 (2014). 3-7. doi:10.4028/www.scientific.net/AMR.925.3

American Concrete Institute. State-of-The-art Report on Ferrocement. Concrete International. 1982. 13-38.

Ashraf M., Halhalli V. (2013). Flexural Behavior of SCC Ferrocement Slabs Incorporating Steel Fibers. *International Journal of Engineering Research & Technology (IJERT)*. 2 (10),. 557-561

Batra A., Ghangas S. , Kumar L. and Saxena H. (2017). A Review study of Application of Ferro-Cement. *International Research Journal of Engineering and Technology (IRJET)* 04(06).

Burakale A.S. , Attarde P.M. and Patil M.D. (2020). Ferrocement Construction Technology and its Applications – A Review. *International Research Journal of Engineering and Technology (IRJET)* 07 (07), July 2020.

Desayi P. and Reddy V. (1991). Strength of Lightweight Ferrocement in Flexure. *Cement & Concrete Composites* 13. 13-20

Dharane S. and Architamalge (2014). Experimental Performance of Flexural Behavior of Ferrocement Slab under Gradual Loading. *International Journal of Civil, Structural, Environmental and Infrastructure Engineering Research and Development (IJCSEIERD)*. 4(2). 97-102.

Gaylan , A. A.(2008) Behavior of fiber reinforced ferrocement slabs under static and cyclic loadings. Ph.D. Thesis, *Building and Construction Eng. Dept., University. of Technology*, Baghdad, Iraq . January, 2008.

Ghai R. , Bansal P. P., and Kumar M. (2018). Strengthening of RCC Beams in Shear by Using SBR Polymer-Modified Ferrocement Jacketing Technique. *Advances in Civil Engineering*. 16 pages. https://doi.org/10.1155/2018/4028186

Hussain M. I. , Halhalli V., Nanduri P.M.B. (2013). Shear and Flexural Behavior of Ferro Cement Deep Beams. *International Journal of Research in Engineering and Technology*. IC-RICE Conference Issue, Nov-2013.

Kaushik S, Prakash A, Singh A. (1990) Inelastic buckling of ferrocement encased columns. In: Nedwell, Swamy editor. *Proceedings of the fifth international symposium on ferrocement*; 1990. 327 – 41.

Kong F.K. Reinforced Concrete Deep Beams: *Taylor & Francis Group*. 1990.

Hago A.W., Al-Jabri K.S., Alnuaimi A.S. , Al-Moqbalia H., Al-Kubaisy M.A. (2005). Ultimate and service behavior of ferrocement roof slab panels. *Construction and Building Materials* .19 (2005) 31–37

Mansour K. M. (2013). Experimental studies to investigate the properties of polystyrene concrete ferrocement plates," *Babylon University Journal-Engineering Sciences*, 20(4), 2013.1015-1032.

Mhadeshwar S. N., Naik A. M. (2017). Experimental Performance, mathematical modelling and development of Stress Block Parameter of Ferrocement Beams with Rectangular Trough Shaped Skeletal Steel. *International Research Journal of Engineering and Technology (IRJET).* 04 (06) .

Mohamad N. Mahmood Sura A. Majeed. Flexural Behavior Of Flat And Folded Ferrocement Panels. *Al-Rafidain Engineering*. 17 (4).

Mourad S.M., Shannag M.J.(2012). Repair and strengthening of reinforced concrete square columns using ferrocement jackets. *Cement & Concrete Composites* 34 (2012). 288 – 294

Naaman A.E.(2000) Ferrocement and laminated cementitious composites. Ann Arbor, Michigan, USA: Techno Press 300. 2000.

Rao T., Rao.D.G., RamanaRao N.V., Rambabu Ch. (2012). An Experimental Study on Ferrocement Box-Beams under Flexural Loading. *International Journal of Emerging Technology and Advanced Engineering*. 2(9).

Razvi S, Saatcioglu M. (1989). Confinement of reinforced concrete columns with welded wire fabric. *ACI Struct J* 1989;86:615 – 23.

Shri S. D. and Thenmozhi R.(2012). An Experimental Investigation on The Flexural Behavior of SCC Ferrocement Slabs Incorporating Fibers. *International Journal of Engineering Science and Technology (IJEST)*. 4 (05) May 2012.

Sakthivel P.B. and Jagannathan A.(2012). Fibrous ferrocement composite with PVC-coated weld mesh and bar-chip polyolefin fibers. *International Journal of Geomate*. 3(2). 381-388.

Sasiekalaa K. and Malathy R. (2012). A Review Report On Mechanical Properties Of
Ferrocement With Cementitious Materials. *International Journal of Engineering Research & Technology (IJERT)*. 1 (9).

Shuai Fang Eddie Siu-Shu Lam and Wing-Ying Wong. (2017). Using alkali-activated slag ferrocement to strengthen corroded reinforced concrete columns. *Materials and Structures* (2017) 50:35. DOI 10.1617/s11527-016-0915-4

Tatsa E. Z. (1991). Limit States Design of Ferrocement Components in Bending. *Cement & Concrete Composites* 13 (1991) 49-59

Yardim Y. (2017). Review of Research on the Application of Ferrocement in Composite Precast Slabs. *Periodica Polytechnica Civil Engineering*. 62(4), pp. 1030–1038, 2018. https://doi.org/10.3311/PPci.11737