Effect of Ferrocement In Beam Column Connection In Combined Bending And Shear

Krrishna Mahale[1], Pramod V. Kharmale[2]
[1]Dept of Civil
[2]Professor, Dept of Civil
[1, 2] G.H.Raisoni College of Engineering & management, Chas, Ahmednagar, Maharashtra,India

Abstract- *This paper aims to study the seismic performance of exterior beam-column joints in building frames strengthened by Ferrocement using nonlinear finite element analysis. Firstly, the proposed model was used to predict experimental results successfully. Secondly, a parametric study was carried out to assess the behavior of such joints with different additional variables. The studied variables were the level of axial loading on the column, compressive strength of specimens, percentage of longitudinal reinforcement in the beam, and orientation of expanded wire mesh in Ferrocement layer, for specimens strengthened by different number of Ferrocement layers. It was found that strengthening specimens by Ferrocement reduced the effect of axial loading level and longitudinal steel ratio in the beam on the ultimate load of studied specimens. In addition, changing the orientation angle of expanded wire mesh from 60° per Ferrocement layer to 45° has a minor effect on the ultimate load but it has a significant effect on the ductility of studied specimens. The effect of orientation angle became less significant on the ductility with increasing the number of Ferrocement layers used for strengthening. These findings would be helpful to the engineers to develop suitable, feasible and efficient upgrading technique for poorly designed building frame structural joints in seismic zones.*

Keywords- Ferrocement layers Orientation of expanded wire mesh Nonlinear finite element package “ANSYS 10.0” Beam-to-column joints

I. INTRODUCTION

Ferrocement is a term commonly used to describe a steel-and-mortar composite material. Essentially a form of reinforced concrete, it exhibits behavior so different from conventional reinforced concrete in performance, strength, and potential application that it must be classed as a completely separate material. It differs from conventional reinforced concrete in that its reinforcement consists of closely spaced, multiple layers of steel mesh completely impregnated with cement mortar. Ferrocement can be formed into sections less than 1 inch thick, with only a fraction of an inch of cover over the outermost mesh layer. Conventional concrete is cast into sections several inches thick with an inch or so of concrete cover over the outermost steel rods. Ferrocement reinforcing can be assembled over a light framework into the foal desired shape and mortared directly in place, even upside down, with a thick mortar paste. Conventional concrete must be cast into forms. These fairly simple differences lead to other, more remarkable differences. Thin panels of Ferrocement can be designed to levels of strain or deformation, with complete structural integrity and water tightness, far beyond limits that render conventional concrete useless. Ease of fabrication makes it possible to form compound shapes with simple techniques; with inexpensive materials; and, if necessary, unskilled (but supervised) labor.

1.2 History of Ferrocement:

The most extensively used building medium in the world today is concrete and steel combined to make reinforced concrete; familiar uses are in high-rise buildings, highway bridges, and roadways. Yet, the first known example of reinforced concrete was a Ferrocement boat. Joseph-Louis Limbos original French patents on wire-reinforced boats were issued in 1847 not long after the development of Portland cement. (See Figures 6, 7 .) This was the birth of reinforced concrete, but subsequent development differed from Lambton’s concept. The technology of the period could not accommodate the time and effort needed to make mesh of thousands of wires. Instead, large rods were used to make what is now called standard reinforced concrete, and the concept of Ferrocement was almost forgotten for a hundred years. Reinforced concrete developed as the material familiar today in fairly massive structures for which formwork to hold the fresh concrete in the wide gaps between reinforcing rods and a fairly thick cover over the rods nearest the surface are required. Reinforced concrete for boatbuilding reappeared briefly during the First World War, when a shortage of steel plates forced a search for other boatbuilding materials. The U.S. and U.K. governments, among others, commissioned shipbuilders to construct seagoing concrete ships and barges, some of which continued in use after the war. The same phenomenon occurred in the United States during the Second World War. However, the conventional use of large-diameter steel rods to reinforce the concrete required thick hulls, making the vessels less practical to operate than lighter wood or steel ships.

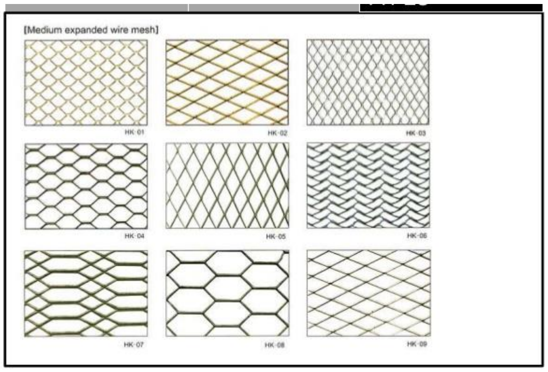


Fig1.1 Types of ferrocement

In the early 1940's, Pier Luigi Nervi resurrected the original Ferrocement concept when he observed that reinforcing concrete with layers of wire mesh produced a material possessing the mechanical characteristics of an approximately homogenous material and capable of resisting high impact. Thin slabs of concrete reinforced in this manner proved to be flexible, elastic, and exceptionally strong. After the Second World War, Nervi demonstrated the utility of Ferrocement as a boatbuilding material. His firm built the 165-ton motor sailor Irene with a Ferrocement hull 1.4 inches (3.6 ems) thick, weighing 5 percent less than a comparable wood hull, and costing 40 percent less. The Irene proved entirely seaworthy, surviving two serious accidents. Other than simple replastering necessitated by the accidents, the hull required little maintenance. Despite this evidence that Ferrocement was an adequate and economical boatbuilding material, it gained wide acceptance only in the early 1960's in the United Kingdom, New Zealand, and Australia. In 1965, an American owned Ferrocement yacht built in New Zealand, the 53-foot A wash nee, circumnavigated the world without serious mishap, although it encountered 70- knot gales, collided with an iceberg, and was rammed by a steel-hulled yacht. Other Ferrocement boats have shown similar practicality, and their number is steadily increasing.

Fig1.2: Built in 1887, this Dutch Ferrocement boat was still afloat, in 1967, at the Amsterdam Zoo. (Cement, Amsterdam, The Netherlands)

The recent emphasis on the use of Ferrocement for boatbuilding has obscured Nervi's noteworthy applications to buildings, begun in 1947. After building a small storage building in his own construction yard to demonstrate its versatility and strength, he covered the swimming pool at the Italian Naval Academy with a SO-foot vault and followed this with the famous Turin Exhibition Hall-a structure spanning 300 feet. He subsequently built several other long-span structures of Ferrocement...) Nervi's work and subsequent applications presage an application of Ferrocement on land that may overshadow the fresh-water applications.

1.3 Characteristics of Ferrocement:

Ferrocement is a high-quality structural material whose simple constituents and formation make it usable for many construction purposes in even the most underdeveloped societies. In no way an inferior product specifically for cheap uses, it is in some respects more sophisticated than prestressed concrete. Ferrocement usually uses a freestanding frame of wire mesh that is mortared in place on site. The wire mesh is formed into the desired shape {domes, simple curves, or compound curves). Supporting framework used to outline the shape can be wood, precast concrete, or a simple jig made from steel rods or pipes. These supports are usually very rudimentary and serve only to outline the shape for the layers of wire mesh to be added next. They can eventually be removed or left in place to become part of the final structure. The economy of Ferrocement construction, compared with steel, wood, or glass-fiber reinforced plastic (FRP), depends greatly on the product being built, but Ferrocement is almost always competitive, particularly in tropical developing countries where steel is expensive, frequently drains foreign exchange reserves, and requires sophisticated facilities and skilled operators. FRP is much more costly, creates a free hazard, requires advanced technology, sophisticated materials, and skilled labor; and its ingredients are sensitive to tropical temperatures. Wood is almost nonexistent in many arid or deltaic countries. Even heavily forested countries such as Indonesia, the Philippines, and Thailand foresee serious shortages due to growing demands of an increasing world population. Furthermore, in the tropics wood is subject to rot, insects, and toreros. The relatively low unit cost of materials may be the greatest virtue of Ferrocement. Worldwide, the costs of sand, cement, and wire mesh vary somewhat; but the greatest variable in construction costs is the unit cost of labor. In countries with high-cost labor, the economics of Ferrocement often make it noncompetitive. But, according to UNIDO,

Fig1.3: Ferrocement-roofed warehouse in Tortona, Italy, for storing salt, designed and built by Nervi, 1950-51.

Ferrocement has been used for high-priced domes and enormous roofs over stadiums, opera houses, restaurants, etc., but this specialized application is less relevant to the urgent needs of most developing countries. (Studio Nervi, Rome) experience has shown that where unskilled, low-cost labor is available and can be trained, and as long as a standard type of construction is adhered to, the efficiency of the labor will improve considerably, resulting in a reduced unit cost. Under these conditions, Ferrocement compares more than favorably with other materials used in boat· building, such as timber, steel, aluminum or fiberglass, all of which have a higher unit material cost and require greater inputs of skilled labor.

1.4 Suitability of developing countries:

Although the increased interest in Ferrocement for water and land use is fairly recent, successful examples of innovative applications, within a wide range of construction techniques and sophistication, already promise a major impact on developing countries for the following reasons:

1. Ferrocement may be fabricated into almost any conceivable form to meet the particular requirements of the user. This is particularly pertinent where acceptance of new materials may be dependent on their ability to reproduce traditional designs.
2. The basic raw materials for the construction of Ferrocement-sand, cement, and reinforcing mesh-are readily available in most countries. Sand and cement are used in building and road construction, and mesh is used in agriculture (chicken netting) and housing construction (plastering lath).
3. Except for highly stressed or critical structures such as deep-water vessels, adequate Ferrocement construction does not demand stringent specifications. A wide range of meshes can be used; both hexagonal and square meshes have produced successful structures. The cement is of standard quality used in building construction. Special grades are unnecessary.
4. Little new training is required for the laborers, providing a skilled supervisor is on hand. Cement construction techniques are widely known in developing countries, and indigenous construction workers often show a good aptitude for plastering.
5. Transportation, logistics, and materials-handling are serious problems in developing countries, and Ferrocement construction simplifies each one. Sand and water can usually be obtained in the region of the building site; and the quantity of cement normally required can be easily transported. Only the wire mesh may require transportation from distant production centers~ Under extremely difficult conditions (such as in the road less highlands of Nepal), wire mesh may be hand loomed on site from reels of straight wire, a technique apparently already in use in rural areas of the People's Republic of China.

Fig1.4: A paste of mortar is forced into the layers of mesh by hand . . . (Smith Kam· pempool, Applied Scientific Research Corporation of Thailand)

1.5 AIM AND OBJECTIVE

Experimental investigation of Ferrocement beam for shear strength

OBJECTIVES

- Performance analysis of Ferrocement in RCC beam for increasing its shear strength
- To perform experimental analysis for RCC beam for 7 days,14 days,28 days for percentage from 0 to 40
- Validation of experimental results in ANSYS software
- To compare design parameter such as shear stress, principal stress, normal stress after analysis

II. LITRATURE REVIEW

2.1Arif, M., Akhtar, S., Masood, A., Garg, M. and Basit'F'lexuralBehaviour of Fly Ash Mortar Ferrocement Panels for Low Cost Housing' Journal of Ferrocement, Vol. 31, No. 2, 125-135, F. (2001):

Providing low cost housing especially to middle and low income group both in rural and urban areas is a serious national problem. The magnitude and acuteness of the problems is obviously more pronounced in urban areas. Also the conventional construction materials are becoming excessively costly day by day. Innovative and low cost construction materials and techniques thereby become urgent need. Ferrocement may serve as one such alternative. It has proven itself as an excellent material for low cost housing. It has high degree of ductility and energy absorbing capacity and has been increasingly used both in terrestrial and marine environments as a structural grade material system, which competes favorably with reinforced concrete and other building materials (Hermosura, and Austriaco, 1994; Ramli and Wahab, 1994; Arif et al.1994; Naaman, 2006).Investigations on the use of pre-cast Ferrocement elements in low cost housing have proved the effectiveness of the material system under static conditions. The prefabricated Ferrocement elements have also been used successfully in both residential and industrial buildings. It has been established in the studies reported that the Ferrocement has performed well under almost all the loading conditions, whether it is tension, compression, flexure, shear, torsion, fatigue, impact or the dynamic loading. A large number of experimental and analytical studies dealing with Ferrocement structural elements, having various shapes and sizes, subjected to different loading conditions are reported in literature. These studies have established the material worthiness for use in diversified applications and prove it to be a strong alternative to conventional construction material.

2.2 D. G. Gaidhankar1,M. S. Kulkarni2, Abhay R. Jaiswal 'FERROCEMENT COMPOSITE BEAMS UNDER FLEXURE':

Ferrocement is a type of thin wall reinforced concrete constructed of hydraulic cement mortar reinforced with closely spaced layers of continuous and relatively small size wire mesh". Mesh may be made of metallic or other suitable materials. The matrix may contain discontinuous fibers. This definition ignores as important type of reinforcement currently in use in Ferrocement i.e. the combination of steel rods and wire mesh**.** India has been identified as a developing economy which tends to give rise to a lot of infrastructure developments especially the building projects. RCC is most widely used in all over world because of its high load carrying capacity but the cost of cement and steel is increasing day-by-day. So, we require a substitute to concrete which gives the strength as that of RCC with low cost. In Ferrocement, hydraulic cement mortar with closely spaced small diameter wire meshes is used. To improve certain characteristics of Ferrocement various materials such as admixtures, silica fumes, fly ash and fibers are used. Generally, the thickness of Ferrocement ranges from 20 – 50 mm. Ferrocement is a wire mesh reinforcement impregnated with mortar to produce elements of small thickness, high durability and resilience and, when properly shaped, high strength and rigidity. To bypass these problems and directly determine the response of Ferrocement in unconventional applications, numerical simulations exploiting the Finite Element Method (FEM) have yielded important results in recent years.

2.3S.Dharanidharan 'FLEXURAL BEHAVIOUR OF FERROCEMENT COMPOSITE SLAB'October, 2016:

A large number of civil structures everywhere the world are in a state of thoughtful deterioration today due to carbonation, chloride attack, etc. Moreover numerous civil constructions are no longer considered safe due to increase load specifications in the design codes or due to overloading or due to under design of existing structures or due to lack of quality control. In order to maintain efficient serviceability, older structures must be repaired or strengthened so that they meet the same requirements demanded of the structures built today and in future. These leads to the development of Ferro cement structures. Ferro cement is a type of thin-wall reinforcement concrete commonly constructed of hydraulic cement mortar, reinforced with closely spaced layers of continuous and relatively small diameter mesh. The strength properties

2.4Hamid Eskandari , Amirhossein Madadi 'INVESTIGATION OF FERROCEMENT CHANNELS USING EXPERIMENTAL AND FINITE ELEMENT ANALYSIS'19 June 2015:

Ferrocement, also called reinforced concrete, is obtained by mixing cement with sand mortar and applying the mixture over some layers of woven or welded steel mesh with small-diameter holes. It is widely used in shipbuilding, water and food storage tanks, water transport tubing, silos, roofs, urban and rural houses, and structure repair. Ferrocement is especially popular because its raw materials are available, it is easy to prepare and shape, and it is fire resistant. It is also known to promote the seismic resistance of masonry structures. Research has indicated the use of additives such as fibers, silica, fly ash, and resin to increase the strength of mortar in Ferrocement. Although the need for experimental research to provide the basis for design equations continues but by applying the FEM, can reduce the time and cost of otherwise expensive experimental tests, and may better simulate the loading and support conditions of the actual structure. So to this end the FEM is used by Nassif and Najm to investigate the behavior of Ferrocement composite beams under a two-point loading system.

2.5Y. B. I. Shaheen, B. Eltaly and M. Kameel'Experimental And Analytical Investigation Of Ferrocement Water Pipe'11 April, 2013:

Ferrocement is type of reinforcement concrete. It commonly composed of hydraulic cement mortar reinforced with closely spaced layers of continuous and relatively small size wire mesh. The mesh may be made of metallic or other suitable materials (Blake, 2001). It is low cost, durable, weather-resistance, lightweight and particularly its versatility comparing to the reinforced concrete (Ali, 1995).Their test results indicated that using the Ferrocement jacket increases the axial load capacity and the axial stiffness of repairing reinforced concrete column compared to the control columns. Kaish et al. (2011) and Xiong (2004) investigated the possibility of using Ferrocement jacket in strengthening of square reinforced concrete short column.

2.6Shamir Sakira, S.N. Ramana, A.B.M.A. Kaisha, A.A. Mutalib 'Self-flowing mortar for Ferrocement instrengthening applications'4 June 2014:

Ferrocement is a thin-shell mortar system reinforced with single or multiple layers of wire mesh (Kaish et al., 2012, 2016). In most cases of Ferrocement construction, mortars placed by hand-toweling, which makes standardized placement a challenge. Another method is by plastering the wire mesh with cement mortar manually in several stages that makes it labour intensive. Therefore, the quality of the end product becomes non-uniform and at the same time it become both time and labour consuming. Self-flowing mortar (SFM) can easily eliminate these problems. Another advantage of SFM is that the time and manpower required to place large sections is considerably reduced.

Particle homogeneity are required for the adequate fluid-it of fresh mix. Using super plasticizer and addition of some specific filler materials improves the flow ability but often decrease strength properties. An optimization between fluidity and strength is required. This study discusses Ferrocement strengthening mechanism and applicability of SFM in Ferrocement for strengthening applications. The study also focuses about the principle, raw materials, preparation techniques and recent developments of SFM, which are compatible with Ferrocement technology.

III. METHODOLOGY

Material modeling

The definition of the proposed numerical model was made by using finite elements available in the ANSYS code default library. SOLID186 is a higher order 3-D 20-node solid element that exhibits quadratic displacement behavior. The element is defined by 20 nodes having three degrees of freedom per node: translations in the nodal x, y, and z directions. The element supports plasticity, hyper elasticity, creep, stress stiffening, large deflection, and large strain capabilities. It also has mixed formulation capability for simulating deformations of nearly incompressible elastoplastic materials, and fully incompressible hyper elastic materials. The geometrical representation of is show in SOLID186 fig 22.

This SOLID186 3-D 20-node homogenous/layered structural solid were adopted to discredit the concrete slab, which are also able to simulate cracking behavior of the concrete under tension (in three orthogonal directions) and crushing in compression, to evaluate the material non-linearity and also to enable the inclusion of reinforcement (reinforcement bars scattered in the concrete region). The element SHELL43 is defined by four nodes having six degrees of freedom at each node. The deformation shapes are linear in both in-plane directions. The element allows for plasticity, creep, stress stiffening, large deflections, and large strain capabilities the representation of the steel section was made by the SHELL 43 elements, which allow for the consideration of non-linearity of the material and show linear deformation on the plane in which it is present. The modeling of the shear connectors was done by the BEAM 189 elements, which allow for the configuration of the cross section, enable consideration of the non-linearity of the material and include bending stresses as shown in fig 3.5. CONTA174 is used to represent contact and sliding between 3-D "target" surfaces (TARGE170) and a deformable surface, defined by this element. The element is applicable to 3-D structural and coupled field contact analyses. The geometrical representation of CONTA174 is show in fig 3.2. Contact pairs couple general axisymmetric elements with standard 3-D elements. A node-to-surface contact element represents contact between two surfaces by specifying one surface as a group of nodes. The geometrical representation of is show in TARGET 170 fig 19.

The TARGET 170 and C0NTA 174 elements were used to represent the contact slab-beam interface. These elements are able to simulate the existence of pressure between them when there is contact, and separation between them when there is not. The two material contacts also take into account friction and cohesion between the parties.

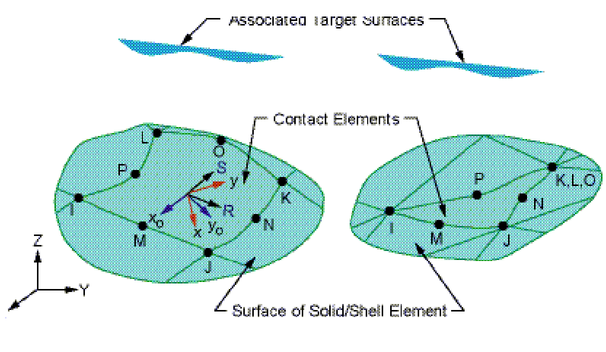


Fig.no1.5: CONTA 174

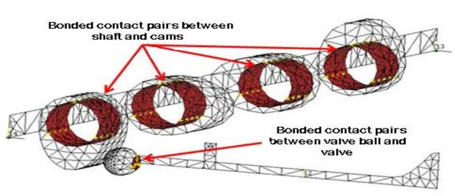


Fig.no.1.6: TARGET 170

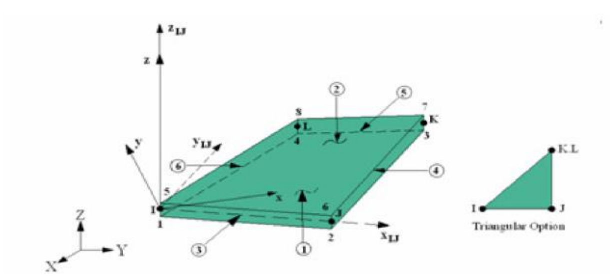


Fig.no.1.7: Shell 43

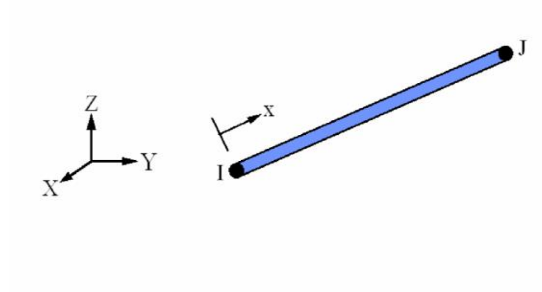


Fig.no.1.8: Beam 189

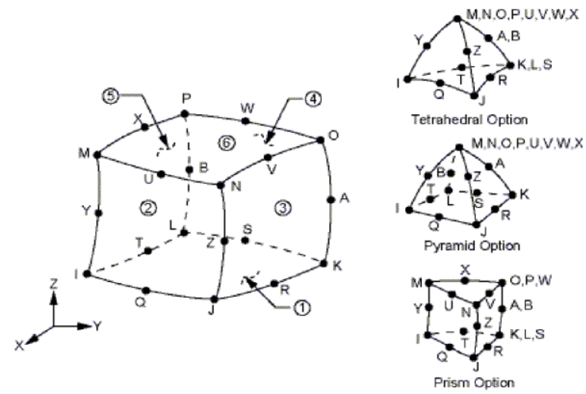


Fig no1.9: Solid 186

3.2 Material properties

Sr.No.	Material	Property	Value
1	Structural steel	Yield stress f_y (MPa)	265
		Ultimate strength f_u (MPa)	410
		Young's modulus Es(MPa)	205×10^3
		Poisson's ratio μ	0.3
		Ultimate tensile strain e_t	0.25
2	Reinforcing bar	Yield stress f_y (MPa)	250
		Ultimate strength f_u (MPa)	350
		Young's modulus Es(MPa)	200×10^3
		Poisson's ratio μ	0.3
		Ultimate tensile strain e_t	0.25
3	Concrete	Compressive strength f_{c}(MPa)	42.5
		Tensile strength f_t(MPa)	3.553
		Young's modulus E_c(MPa)	32920
		Poisson's ratio μ	0.15
		Ultimate compressive strain e_u	0.045
4	Duplex steel	Yield stress f_y (MPa)	435
		Tensile strength f_u (MPa)	530
		Young's modulus E_s(MPa)	200×10^3
		Poisson's ratio μ	0.31
		density	7.8

Table1.1: Material properties

3.3Numerical Modeling

Constitutive model of the material

3.3.1 Constitutive model of concrete

Due to the complexity of concrete, the constitutive relations of it differ from the different load case. In this case, several different constitutive models of concrete were proposed. The elastoplastic constitutive model based on the increment

Theory is used to describe the constitutive relations of concrete. This model uses Wiliam-Warnke's five-parameter yield criterion, uniform strength criterion and associated flow criterion[7].Because of the special structure style of the steel-concrete composite beam to concrete-filled steel tubular column joints, the behavior differs in the different place of concrete. The concrete in the core area of concrete-filled steel tubular restrained by the steel tubular is under triaxial load cases. According to the numerical analysis and experimental results, the Han-linhai's model is reasonable and reliable by using the confinement index to define the concrete restrained by the steel tubular. Because of the insufficient research on the dynamic property, experiments of the stress-strain hysteretic models of concrete in the core area are not reported. The skeleton curves of stress-strain hysteretic relationship of concrete under cyclic load are basically close to the stress-strain curves under monotonic load[9]. So many researchers approximate skeleton curves of the stress-strain relationship under monotonic load as the stress-strain relationship under cyclic load.

The common constitutive models is used in the composite beam[10]. The MISO method is used to describe the stress strain relationship of concrete in the procedure of analysis, shown in Figs 1 and 2.

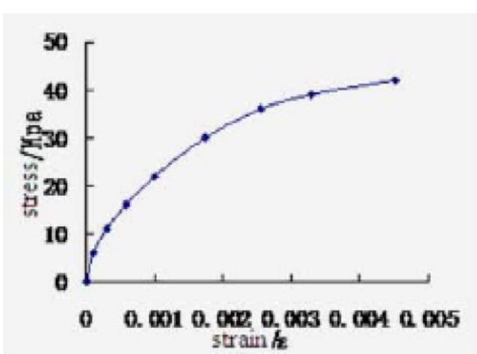


Figure 1.10

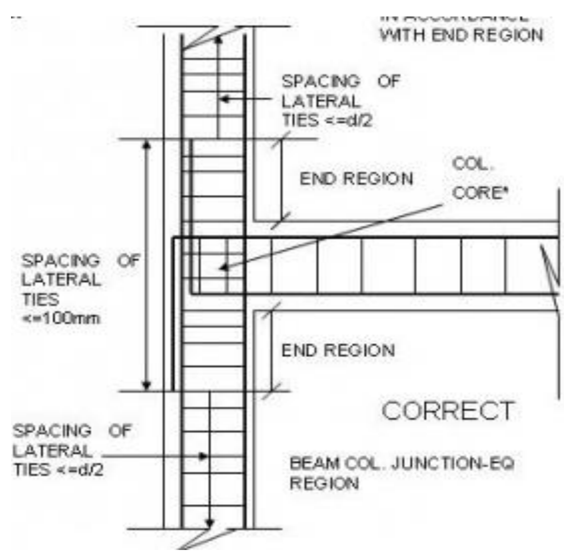
PROBLEM STATEMENT

A G+9 RCC Commercial building is considered.out of which one beam column member is selected

Plan dimensions:12 m x 12 m
Location considered: Zone-IV
Soil Type considered: Hard Strata.
General Data of Building:

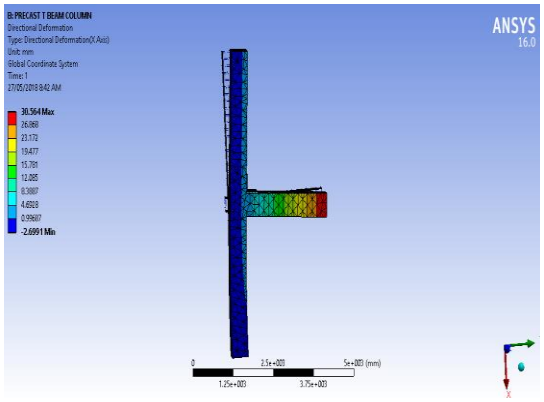
- Grade of concrete: M 25
- Grade of steel considered: Fe 250, Fe 500
- Live load on roof: 2 KN/m2 (Nil for earthquake)
- Live load on floors: 4 KN/m2
- Roof finish: 1.0 KN/m2
- Floor finish: 1.0 KN/m2
- Brick wall in longitudinal direction: 240 mm thick
- Brick wall in transverse direction: 140 mm thick
- Beam in longitudinal direction: 230X350 mm
- Beam in transverse direction: 230X350 mm
- Column size: 300X750 mm
- Density of concrete: 25 KN/m3
- Density of brick wall including plaster: 20 KN/m3
- Plinth beam (PB1): 350X270 mm
- Plinth beam (PB2): 270X300 mm

Beam column joint detail
Span of beam: 3m
Main bar: 4# 12mm
Stirrup: 8 @mm 200mmc/c
Span of column : 3.5m
Main bar:4# 16mm
Stirrup: 8 @mm 300mmc/c

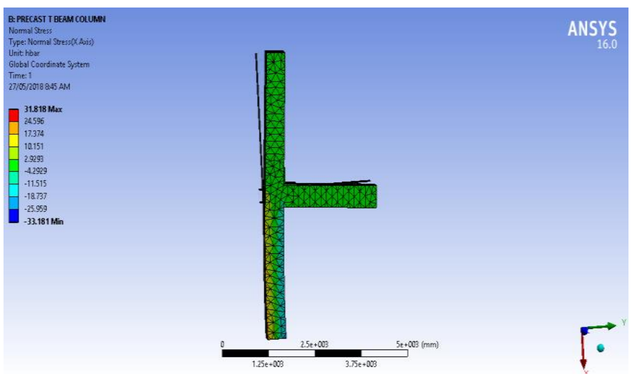


Detailing of Beam Column Joint

IV. RESULTS AND DISCUSSION

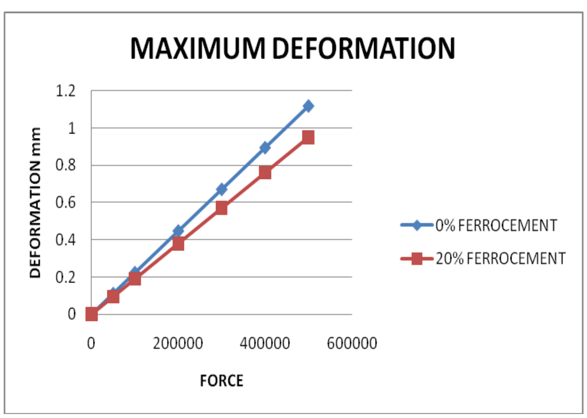


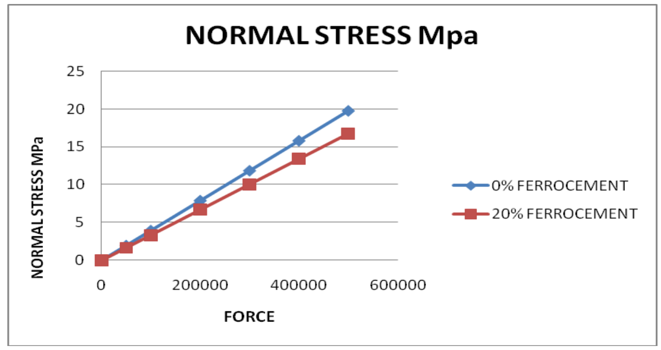
MAXIMUM EQUIVALENT STRESS

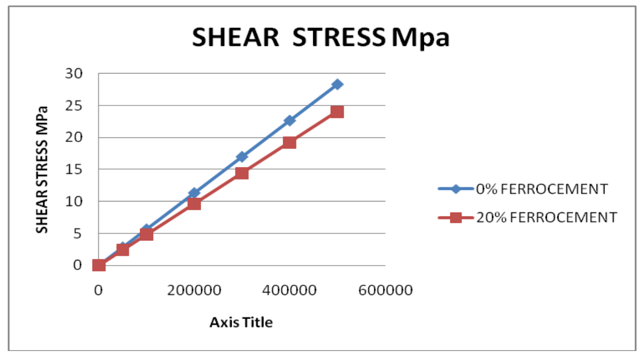


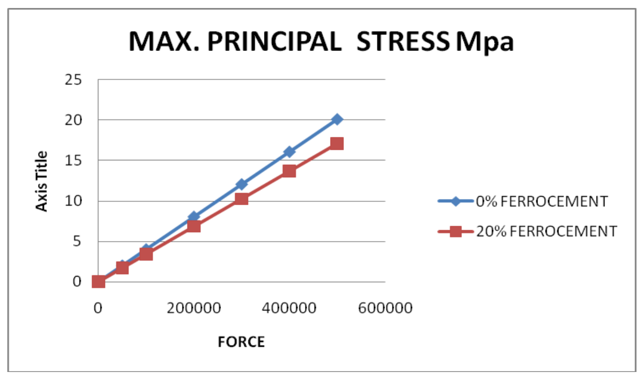
NORMAL STRESS

MODEL NO.1	BEAM COLUMN RCC
MODEL NO.2	BEAM COLUMN WITH 20% REPLACEMENT OF FERROCEMENT









V. CONCLUSION

The numerical results obtained by ANSYS model were verified using experimental results obtained by the first author [22]. A

Parametric study was carried out using this model to investigate the effect of additional variables on the behavior of exterior beam column
joints in building frames strengthened by Ferrocement layers. The main conclusions can be drawn from this study as follows:

1. The application of non-linear finite elements model presented in this study yielded satisfactory prediction of load-carrying capacity and load-deflection response for experimentally tested specimens strengthened by Ferrocement layers. Crack patterns, load displacement hysteresis loops, and stress distribution results for

theoretically studied specimens were simulated accurately using ANSYS package.

2. The level of applied axial load to the column, longitudinal steel ratio in the beam and compressive strength of the studied specimens had a significant effect on their ultimate load, ultimate displacement and stiffness degradation before strengthening, to different degrees. Applying the strengthening scheme reduced the effect of these parameters. Increasing the number of Ferrocement layers in such strengthening scheme led to a further improvement in resisting higher levels of axial loads applied to the column, in the beam-column joints.
3. The results of this research indicates that accurate simulation of beam-column joints before and after strengthening using Ferrocement Can help engineers to successful upgrading of the joints in existing buildings, saving time, money and lives in seismic Zones.
4. The maximum displacement ,principal stress,shear stress is reduced by 15-20 % in to precast beam column connections as compared to rcc beam column connections

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