Analytical Studies on the Behaviour of 3D RC Frame With Ferrocement Panel as Infill

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ABSTRACT *Masonry is a major infill material which is used in RC frames throughout the world; we have accepted that the masonry increases the stiffness of structure. The vertical live load and dead loads due to masonry do not pose much of problems to the RC frame in the absence of lateral forces of wind or earthquake, but concentrated masses of masonry accelerates the lateral forces during the affect of wind forces and earthquake forces. The frame exhibits diagonal crack failure at brick infill at a relatively slow rate of increase before they started to break down. After collapse of masonry infill, the infill frame shall act as a soft story so that the infill didn't take any load after collapse. In the present study Ferrocement panel is used as infill in place of masonry, because of its major advantages such as light weight, thin section, easy of construction, economy of materials total mass is less than masonry per length, better utilization of human resources and architectural flexibility in addition to these advantage it also create monolithic action. RC frame of four story, single bay, with Ferrocement panel as infill is generated using ETAB software. Assigned material properties, sectional properties, boundary conditions, dead load and lateral force in terms acceleration to the model, displacement controlled pushover analysis is carried out, the seismic performance of a buildings are evaluated in terms of i) Pushover curve, ii) Performance point and Capacity-Demand spectrum, iii) Plastic hinge formation etc.*

INTRODUCTION.

The RC frames filled with brick or concrete block masonry subjected to Seismic force, develop beam and column hinges near beam- column interfaces before they reached their maximum story shear, exhibiting successive strength drops. The first cracks shall be developing in the interface between the beam and the infill, because of low shear resisting capacity of the inner face joint. The frame exhibits diagonal crack failure at brick infill at a relatively slow rate of increase before they started to break down. After collapse of masonry infill, the infill frame shall act as a soft story so that the infill didn't take any load after collapse. The contribution of masonry infill was significant up to breaking. Major failures will be occurred by the hinge formation in the column-beam joints. It also observed that much of horizontal forces develop at floor levels due to heavy mass concentration at floor levels, it is one of the major reasons for beam and column hinges near beam-column interfaces.

Ferrocement has been recognized as a well suited material for building construction due to its light weight, easy of construction, economy of materials, better utilization of human resources and architectural flexibility. Ferrocement elements are thin walled structures, due to their strength and rigidity they can be formed in to any shape. Ferrocement is relatively cheap, strong and durable, and the basic technique is easily acquired. Ferrocement has a great strength and economy. It is fireproof, earthquake safe and does not rust.

To overcome above said problems due to wind and earthquake forces and an advantage properties of Ferrocement, we made an effort to use ferrocement components as infill to RC frame, the analysis has been carried out to study the behavior of 3D frame with Ferrocement infill, subjected to lateral forces.

2. FEM modeling of 3D infill frame.

The following steps are followed to generate 3D FE model.

ETAB offers different option for modeling, some of them are 2D plane and space frames, 3D plane and space frames etc, depending upon the user's convenience and problem definition, selection can be made, 3D plane frame is suit to our problem. A three dimensional RC frame with Ferrocement infill model is of four story single bay is generated using ETAB as shown in fig (1).

2.1 Geometric Modeling

First step of RC 3D modeling using SAP or ETAB is the generation of grid lines using Cartesian coordination system. The grid line pattern parameters are, number of grid lines in X direction, Y direction, and Z directions, grid spacing parameters are spacing of grid lines in X direction, Y direction, and Z directions, First Grid line position in X direction, Y direction, and Z directions are entered, for each floor levels, if plan is symmetric, duplicate in other directions (Z) can be transferred. The details are shown in fig (1)

Material properties

M20 concrete and Fe-415 steel materials are used for beams, columns and slabs, 50 mm thick Ferrocement panels are used for walls, all the three materials such as M20 concrete, Fe-415 steel, and Ferrocement panels are considered as isotropic materials. Table (1) shows the details of material properties.

Table (1) the details of material properties.

SL No	Properties	M20 concrete	Fe415 Steel	Ferrocement panel
1	Mass per unit volume	2.5	7.8275	2.553
	Weight per unit volume	25	76.819	25.53
2	Modulus of Elasticity	22360000	2100000	26700000
3	Passions ratio	0.2	0.3	0.18
4	Shear modulus	9316666.7	76884615	11313559.3
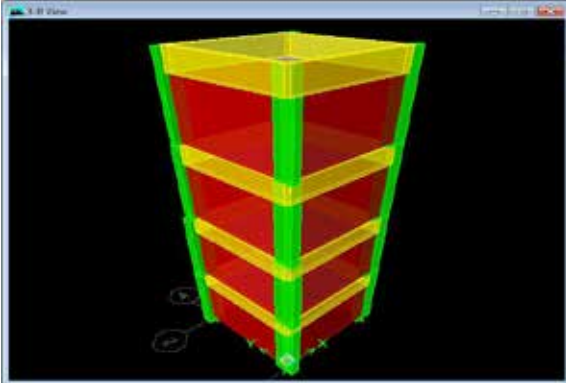
Figure 1. 3D model of infill frame

2.3. Structural modeling

The analytical model is created in such a way that the different structural components represent as accurately as possible, the characteristics like mass, strength, stiffness and deformability of the structure. The various primary structural components that were modeled are as follows:

(a) Beams and columns:
Beams and columns are modeled as 3D frame elements. The   members were represented through the assignment of properties like cross sectional area, reinforcement details and the type of material used.

(b) Beam-column joints:
The beam-column joints were assumed to be rigid and were modeled by giving end-offsets to the frame elements. This was intended to get the bending moments at the face of the beams and columns. A rigid zone factor of 1 was considered to ensure rigid connections of the beams and columns.

(C) Slab Modeling:
Slab is modeled as a rigid diaphragm. In rigid diaphragm case all the joints in the slab moves together as a single unit. ETAB offers features such that slab can be modeled as rigid diaphragm as well as shell element but in present case slab is modeled as rigid diaphragm. Being a rectangular slab meshing was done by dividing the area into smaller rectangular segments. Meshing improves the results but increases the computational time by a large extent.

(d) Foundation modeling:
The foundation was modeled based on the degree of fixity. The effect of soil structure interaction was ignored in the analysis. In the model, fixed support was assumed at the column ends.

e) Wall modeling:
Ferrocement panels are used as infill wall panels, the properties of Poisons ratio, modulus of elasticity, and coefficient of thermal expansion, shear modulus, and are obtained from experimental investigation conducted in laboratories as shown in table (1). Being it taken as rectangular slab meshing was done by dividing the area into smaller rectangular segments.

f) Plastic Hinge:
When a concrete element undergoes large deformations in the post-yield stage, it is assumed that the entire deformation takes place at a point called "plastic hinge". The hinges represent concentrated post yield behavior in one or more degree of freedoms. Each plastic hinge is modeled as a discrete point hinge. Hinges can only be introduced in frame elements at any location. ETABS implements the plastic hinge properties described in FEMA-356 (or ATC-40).ETAB also gives the choice for uncoupled moment (M), torsion (T), axial force (P) and shear (V) hinges and coupled P-M3, P-M2 and P-M2-M3 hinges(CSI Analysis reference manual), which yields based on the interaction of axial force and bending moments at the hinge location. More than one type of hinge can exist at the same location, for example, both M3 (moment) and V2 (shear) hinge can be assigned to the same end of a frame element.

Figure 2. Ferrocement elements testing for properties

3. Pushover Analysis :

The following steps are included in the pushover analysis.

1. Using the graphical interface of   ETAB generate 3D model of RC frame with Ferrocement panel as infill.
2. Assign the corresponding sectional properties to the beam, column, slabs, and Ferrocement panels.
3. For column PMM Plastic hinge properties are to be assigned and for beam M3 hinge property shall be assigned. These points will have pre-defined properties as per FEME-356.
4. Define the pushover load cases as shown in figure 3. Typically the first pushover load case is used to apply gravity load and then subsequent lateral pushover load cases are specified to start from the final conditions of the gravity pushover, some of the Pushover values for displacement controlled pushover analysis are acceleration in X direction, Displacement value, load case type as static nonlinear,   P-Delta as geometric nonlinear are to be added.
5. Analysis has is carried out for both gravity and earthquake loads.
6 Design has been carried out using ETAB 9.7 itself, as per IS:456-2000 provision
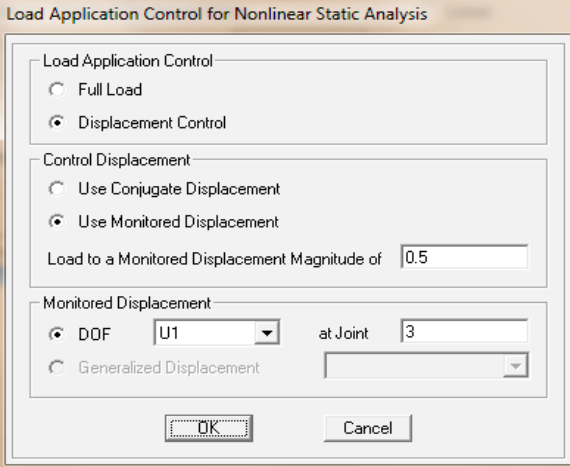7. Run the static non-linear analysis to get pushover curve shown in figure 4.

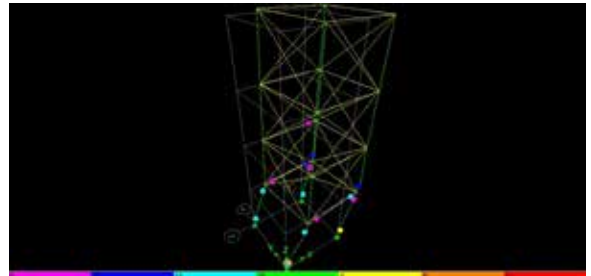**Figure 3. Details of displacement controlled analysis**

Figure 5. hinge level of 4 storey frame with Ferrocement panel infill
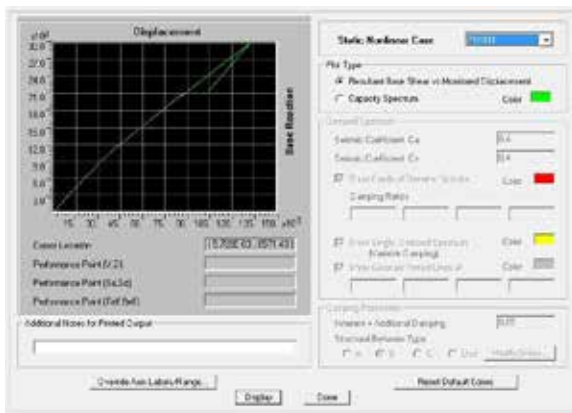

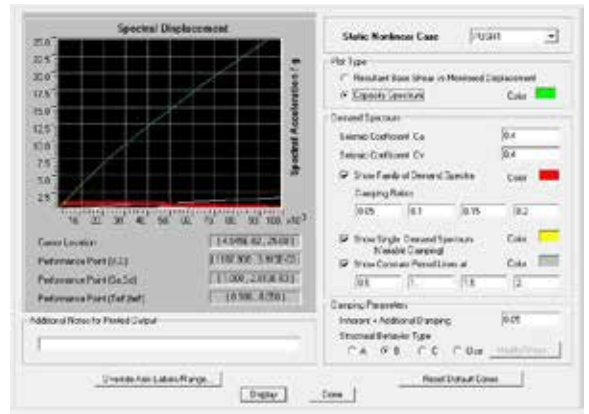**Figure 4. pushover curve for 4 storey frame with ferrocement panel infill**

Figure 6. capacity-demand spectrum for 4 storey frame with Ferrocement panel infill

Conclusions.

It is observed that the use of brick or concrete block masonry as an infill to RC frame subjected to Seismic force, develop beam and column hinges near beam- column interfaces before they reached their maximum story shear, exhibiting successive strength drops. The first cracks shall be developing in the interface between the beam and the infill, because of low shear resisting capacity of the inner face joint. The frame exhibits diagonal crack failure at brick infill at a relatively slow rate of increase before they started to break down. After collapse of masonry infill, the infill frame shall act as a soft story so that the infill didn't take any load after collapse. But use of ferrocement panel as an infill to RC frame, significant changes in RC frame behavior under seismic force can be observed because of its less weight, durability, ductility in compare with Masonry, monolithic action,   RC frame under goes a lesser deformation, and Stiffness of the frame increases considerably.

Results

The models are pushed in monotonic increasing order in a particular direction till the collapse of the structure. The global response of structure at each displacement level is obtained in terms of the base shear, which is presented by pushover curve shown in figure 4 . Pushover curve is a base shear force versus roof displacement curve, which tells about the shear force developed at the base of the structure at any push level. The peak of this curve represents the maximum base shear, i.e. maximum load carrying capacity of the structure; the initial stiffness of the structure is obtained from the tangent at pushover curve at the load level of 10% that of the ultimate load and the maximum roof displacement of structures is taken that deflection beyond which collapse of structure takes place.

The seismic performance of a building can be evaluated in terms of

1.   Pushover curve as shown in figure 3,
2.   Plastic hinge formation shown in figure 5.
3.   Performance point and Capacity-Demand spectrum shown in figure 6,
4.   Diaphragm CM Displacement
5.   Diaphragm Drift
6.   Maximum Storey Displacement
7.   Maximum Storey Drift
8.   Story Shears
9.   Storey overturning Moments.

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