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Design and Testing of Precast Structures for Seismic Forces

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Abstract **– In the recent years, the construction industry is slowly shifting its focus from conventional method of construction to prefabricated construction. Faster rate of construction, affordability, eco-friendly nature, joint flexibility are some of the qualities due to which prefabrication is obtaining rapid recognition in this industry. People prefer the faster rate of construction which is provided by the prefabricated construction compared to the long and tedious work of the masonry construction. Large-scale projects now undertaken have a need to be completed in the shortest span of time, hence the concept of prefabrication will be a huge hit in the coming years. In this paper, an attempt has been made to analyze the load carrying capacity of the prefabricated structure against the seismic forces. This paper shows the time history analysis results of a single degree freedom system and the multi-degree freedom system. A framed structure is designed using the codal provisions of IS456:2000. A comparative study has been made for a rigid building and precast building where the joint stiffness is reduced due to the introduction of precast joints. It has been observed that the precast joints are more flexible than the rigid joints; provided the precast joints are designed properly otherwise these joints will become vulnerable to seismic loads.**

Keywords**: Multi degree freedom, prefabricated construction, Seismic Forces, Time History Analysis.**

I. INTRODUCTION

India now is slowly shifting its center from the conventional method of construction to the prefabricated method of construction. Prefabricated structures are those whose various building components are cast-in the factory and later transported and assembled at the construction site. People nowadays need faster results in the shortest possible duration of time and because of this reason prefabricated structures will be a huge hit in the future. Earthquakes can destroy the whole structure if the structure is not designed accurately. In this paper the prefabricated joint is being analyzed to study its load carrying capacity against the seismic forces.

II. DESIGN AND ANALYSIS OF STRUCTURE

1) DESIGN OF THE STRUCTURE

A multi storied building was designed with the help of the codal provisions in the IS456:2000. The building is a G+2 structure with 3 bays on both the axis. The reinforcements of slab beam and column are shown in Fig. 1(a), Fig. 1(b) and Fig. 1(c). Analysis of the building was done using STAADPro.

a) Design of Slab

The slab designed is a 2 way interior slab of length and breadth 4m and depth of 0.175m.

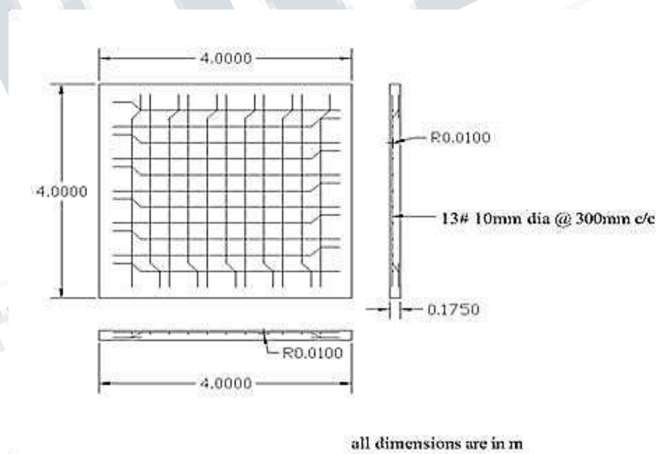

Fig. 1(a) Slab Reinforcement

b) Design of Beam

A rectangular beam of span 4m, width 0.3m and depth of 0.35m is designed

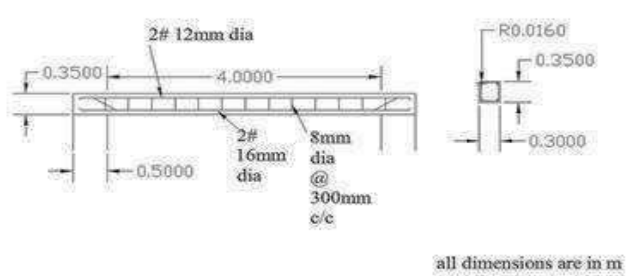

Fig. 1(b) Beam Reinforcement

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c) Design of Column

An axially loaded column of span 3m and of length and breadth 0.5m is designed.

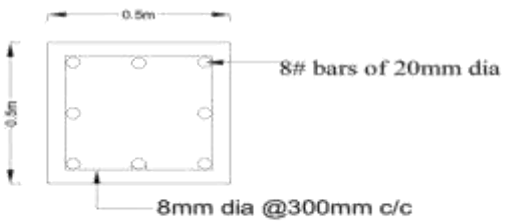

Fig. 1(c) Column Reinforcement

2) LUMPED MASS SYSTEM

The mass at the floor levels was calculated and using lumped mass system concept the mass matrix, stiffness matrix and damping matrix in the different floor levels of the building was found out. A rigid building and a flexible building were designed. In the rigid building the stiffness of the column was considered as 12EI/l3 and in the flexible building the stiffness of the column was considered as 3EI/l3. In the rigid structure the beam column joints are rigid whereas in the flexible structure the joints are allowed to rotate as the stiffness of the column is reduced.

III. TIME HISTORY ANALYSIS

1) DYNAMIC ANALYSIS

The Dynamic Analysis of a structure can be done with two methods; Response Spectrum Method and the Time History Method. This paper follows the time history analysis method using Newmarks Linear Method. The steps followed for linear method are-

1.0 *Initial calculations*

1.1 $\ddot{u}_0 = \dfrac{p_0 - c\dot{u}_0 - ku_0}{m}$.

1.2 Select Δt.

1.3 $\hat{k} = k + \dfrac{\gamma}{\beta \Delta t}c + \dfrac{1}{\beta(\Delta t)^2}m$.

1.4 $a = \dfrac{1}{\beta \Delta t}m + \dfrac{\gamma}{\beta}c$; and $b = \dfrac{1}{2\beta}m + \Delta t\left(\dfrac{\gamma}{2\beta} - 1\right)c$.

2.0 *Calculations for each time step, i*

2.1 $\Delta\hat{p}_i = \Delta p_i + a\dot{u}_i + b\ddot{u}_i$.

2.2 $\Delta u_i = \dfrac{\Delta\hat{p}_i}{\hat{k}}$.

2.3 $\Delta\dot{u}_i = \dfrac{\gamma}{\beta \Delta t}\Delta u_i - \dfrac{\gamma}{\beta}\dot{u}_i + \Delta t\left(1 - \dfrac{\gamma}{2\beta}\right)\ddot{u}_i$.

2.4 $\Delta\ddot{u}_i = \dfrac{1}{\beta(\Delta t)^2}\Delta u_i - \dfrac{1}{\beta \Delta t}\dot{u}_i - \dfrac{1}{2\beta}\ddot{u}_i$.

2.5 $u_{i+1} = u_i + \Delta u_i$, $\dot{u}_{i+1} = \dot{u}_i + \Delta\dot{u}_i$, $\ddot{u}_{i+1} = \ddot{u}_i + \Delta\ddot{u}_i$.

3.0 *Repetition for the next time step.* Replace i by $i+1$ and implement steps 2.1 to 2.5 for the next time step.

A program was developed using MATLAB for time history analysis considering Newmarks linear for the rigid and flexible building. The building has been analyzed for the different conditions listed below and a comparative graph has been plotted for each of them;

1. Rigid joints in all the floor (m1)
2. Flexible joints in all the floors (m2)
3. Flexible joints in ground floor alone (m3)
4. Flexible joints in first floor alone (m4)
5. Flexible joints in second floor alone (m5)

2) EL CENTRO DATA

On 18th May 1940, an earthquake hit the Imperial Valley of the international borders of USA and Mexico. The earthquake was a strike slip fault with a depth of 16km. The magnitude of this earthquake was 6.9 and on the Mercalli Intensity scale it was X which is considered as extreme. At the Imperial area around 80% of the buildings were ruined. It caused widespread damage to the irrigation systems and also led to a death of 9 people and left 20 people injured. The accelerogram which recorded the acceleration of the earth during the earthquake was attached to the El Centro Terminal Substation Building's concrete floor. The soil-structure interaction of the massive foundation with that of the adjacent soft soil may have under characterized the high frequency motions of the ground. In this paper the Time (seconds) and Loading (N) values were taken from the Time History Data File for North-South Component.

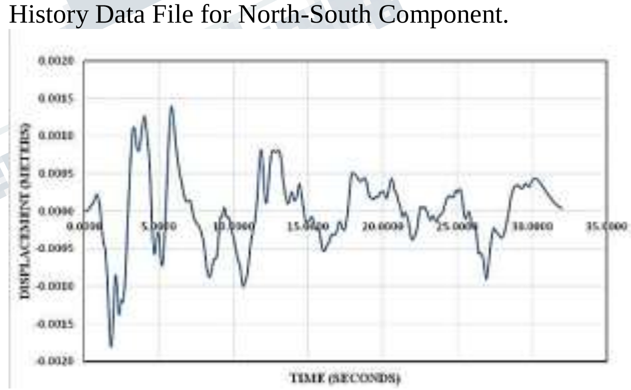

Fig. 2 Roof top displacement for m1- Linear

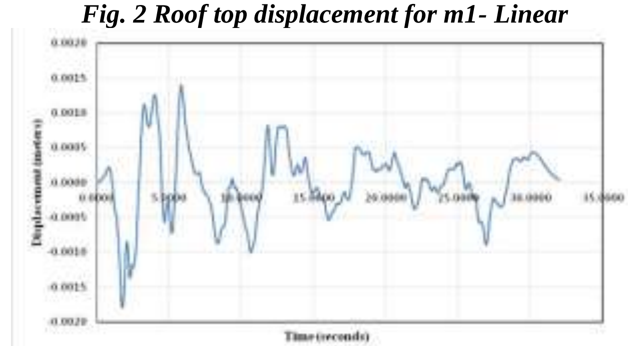

Fig. 3 Roof top displacement for m2- Linear

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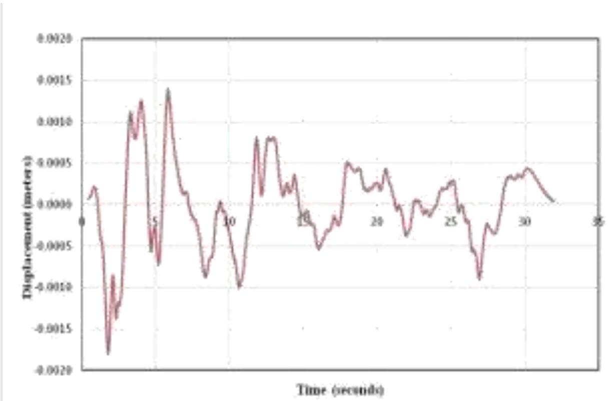

Fig. 4 Roof top displacement for m3- Linear

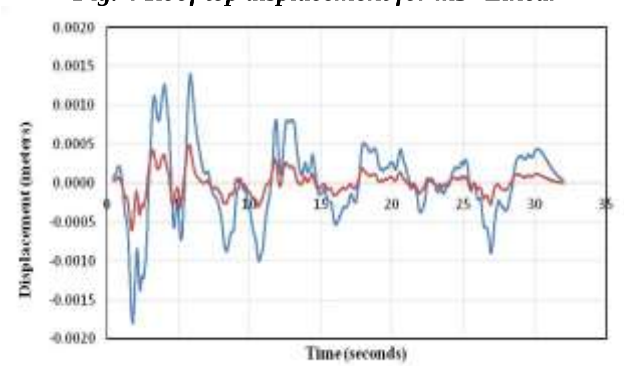

Fig. 5 Roof top displacement for m4- Linear

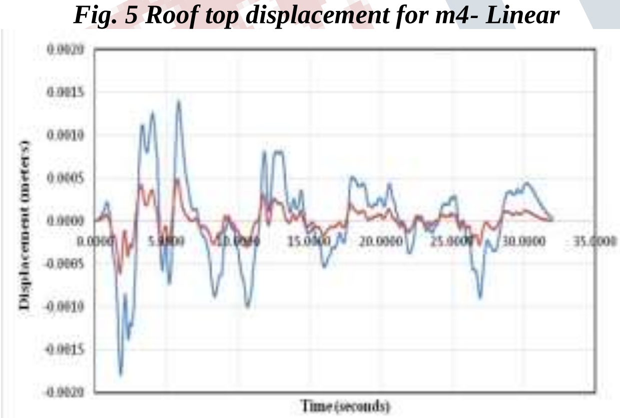

Fig. 6 Roof top displacement for m5- Linear

IV. RESULTS AND DISCUSSION

1. The increase in displacement of model m3 compared with m1 (linear) is 7.14%.

2. The increase in displacement of model m4 compared with m1 (linear) is 64.28%.

3. The increase in displacement of model m5 compared with m1 (linear) is 89.28%.

V. CONCLUSION

1. The second floor flexible linear building (m5) has the highest increase of displacement in percentage compared to that of the other building.

2. Though the displacement is the values are within the permissible drift level as given in IS1893 (PART 1):2002.

3. Making the joints flexible by reducing the movements may be advantageous for better seismic resistance of structures.

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