World Wide Journal of Multidisciplinary Research and Development (August-2022)

WWJMRD 2022;8(08):118-123
www.wwjmrd.com
International Journal
Peer Reviewed Journal
Refereed Journal
Indexed Journal
Impact Factor SJIF 2017: 5.182 2018: 5.51, (ISI) 2020-2021: 1.361
E-ISSN: 2454-6615

An Analytical Investigation on Two-Dimensional Two Bay Two Storey RC Frame with RC Pre-Fabricated Infill Wall Panel

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Abstract

The seismic behaviour of a two bay two storey RC Frame with prefabricated reinforced wall panel subjected to lateral cyclic loading is investigated experimentally and analytically using ETABS (Extended Three-Dimensional Analysis of Building System). The frame is scaled down to 1:3 for this purpose. The experimental values are used to calculate seismic parameters such as load deflection, P-Delta analysis, the maximum load carrying capacity of the frame, stiffness degradation and ductility and cumulative ductility, energy dissipation and cumulative energy dissipation capacity. This research will make recommendations for prefabricated RC wall panels and encourage the development of prefabricated concrete frame structures.

Keywords: Prefabricated RC wall panel, cyclic loading, load-deflection, P-Delta analysis strength, stiffness, analytical modelling.

1. Introduction

Engineers learn more from their failures rather than their successes and failure is vital to the design evolution in structural engineering. During an earthquake, buildings are prone to deform laterally from their original position with an eccentricity. When the construction of structures is subjected to seismic loads, causing the structure to deform, the eccentricity resulting from the total gravity load due to inclined axes of the structure causes the structure to deform. P-Δ effect reduces lateral resistance of a system, which under strong excitation may cause partial or total loss of load carrying capacity. Precast reinforced concrete (RC) structures have attracted a lot of attention in comparison to traditional cast-in-site constructions because of their numerous advantages, such as better-controlled environment, improved construction quality, faster construction speed, and reduced pollution, among others. As a result, precast PC structures have seen a significant increase in market share in recent years. Because of its higher stiffness and greater lateral-load resistance during earthquakes, precast RC wall panel structure has rapidly developed as a common type of precast RC structure. In this research work, A two-bay, two-storey structure with a reinforced cement concrete prefabricated wall panel is being investigated. The modelling and analysis have been done using ETABS

Sina Farahani et.al [1] studied that factors that influence progressive collapse resistance of RC frame structures, such as adjacent structural elements, beam dimensions, top and bottom reinforcement ratios, seismic design and detailing, column removal position, and presence of slabs and transverse beams Finally, knowledge gaps in the current state of the art about progressive collapse of RC frame structures are accentuated in order to promote related research in the future.

Xin Wang et.al [8] conducted a research based on cyclic loading test, the seismic behaviours of four prefabricated and cast-in-situ joints were investigated in terms of failure modes, strength, ductility, stiffness degradation, hysteretic curve and energy dissipation

Qing-feng Liu et.al [6] experimentally investigated that influence of progressive collapse

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resistance of RC frame structures, such as adjacent structural elements, beam dimensions, top and bottom reinforcement ratios, seismic design and detailing, column removal position, and presence of slabs and transverse beams.an energy absorption index (ΔE) is proposed for evaluating the progressive collapse resistance of RC beam-column and beam-slab substructures

Neha Tirkey et.al [7] analyzed the case study on diagonal perimeter often known as the diagrid structure using software ETABS (Extended Three-Dimensional Analysis of Building System). The diagrid structure has emerged into an innovative method in the recent construction field and has led to the advancement of tall buildings and high-rise structures not only in the engineering field but also in the architectural field. It has also made the structure stiffer and lighter when compared to the normal conventional buildings. The diagrid structure is designed, analyzed and is compared with the conventional building using ETABS software mainly focusing on seismic and wind analysis parameters.

1.2 Scope and Objective

An Analysis of the Two-Dimensional Two Bay Two Storey RC Frame with RC Pre-Fabricated Infill Wall Panel is carried out by ETABS.This study's conclusions will support the adoption of a novel method for manufacturing prefabricated wall components for industrialized building systems, thereby fostering the development of cutting-edge construction techniques and higher standards in the building sector.

- To determine the ultimate load carrying capacity of an RC frame.
- To examine the load vs deflection variation of two bay two storey frame with RC wall panel
- To determine the stiffness of two bay two storey frame with RC wall panel.
- To determine the cumulative ductility of an RC frame.
- To calculate the RC Frame's energy dissipation capacity and cumulative energy dissipation capacity

2.Experimental Investigation

2.1Materials

Ordinary Portland Cement (OPC) purchased from Dalmia Cement was used in this study. The cement used was found to meet various IS: 1489 (Part 1) 1991 specifications. Crushed granite angular aggregate of 12 mm and 20 mm nominal size at 40% and 60% nominal size as coarse aggregate with specific gravity of 2.64 and 2.67, respectively. As fine aggregate, manufactured sand (M-Sand) with a specific gravity of 2.71 was used. Locally available potable water that met IS 456 standards was used. IS 10262 [2009] was used to design the mix for M20 concrete. Conbextra GP2 is a special mortar used for precision grouting where static and dynamic loads must be withstood. It complies with ASTM C1107. Steel rebar of grade Fe 550 D was used in various sizes, including 8, 10, and 12mm.

2.2 Details of the Frame Model

Table -1: Dimensions of the frame model.

Details	Size (mm)
All floor Columns	100×130×1000
All floor Beams	100×130×925
All Wall Panels	905×980×100
Foundation	600×2620×150

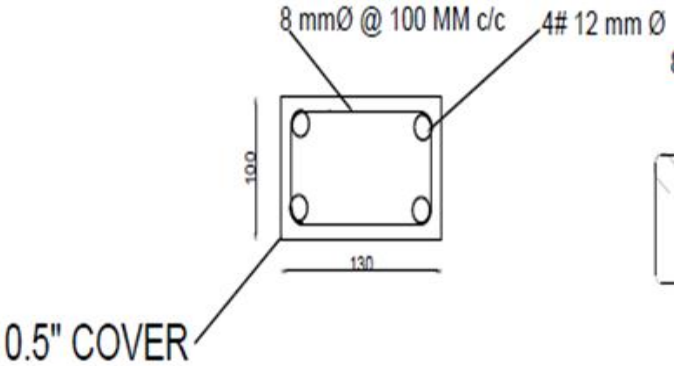


Fig -1: Cross-section of column.

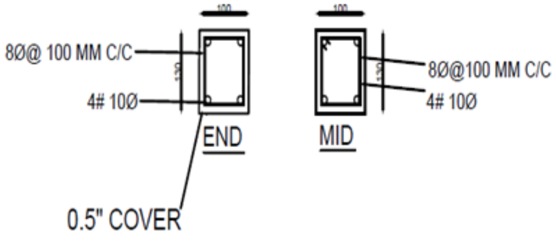


Fig -2: Cross-section of beam.

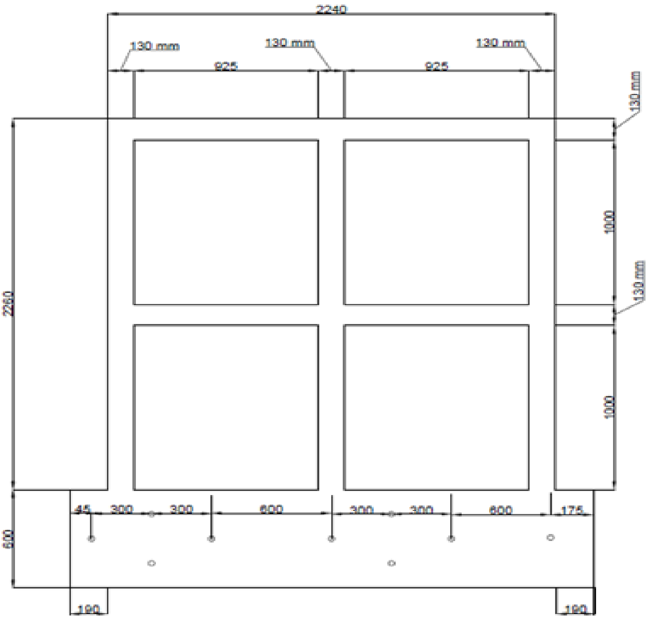


Fig -3: Dimensions of Frame.

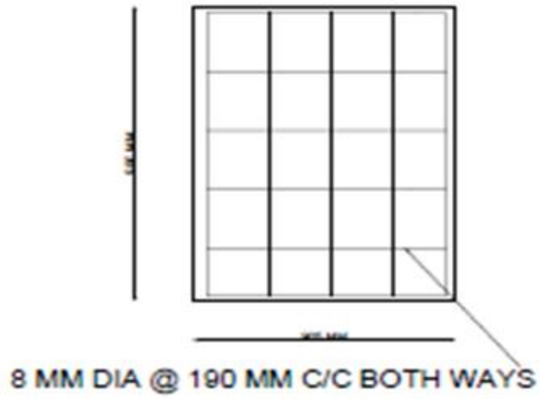


Fig -4: Prefabricated wall panel.

Table -2: Reinforcement of the frame model

Details	Flexural reinforcement	Shear reinforcement
All floor Columns	4 Nos. of 12 mm ϕ - 2 Nos. on either side.	Ties 8 mm ϕ @ 75 mm c/c 8 mm ϕ @ 100mm c/c
All floor Beams	Top - 2 Nos. of 10 mm ϕ Bottom-2 Nos. of 10 mm ϕ	Stirrups 8 mm ϕ @ 75 mm c/c 8 mm ϕ @ 100mm c/c
Wall Panel	Top face - 8 mm ϕ @ 100 mm c/c Bottom face - 8 mm ϕ @ 100 mm c/c	Stirrups 8 mm ϕ @ 180 mm c/c
Foundation	Top face - 10 mm ϕ @ 150 mm c/c Bottom face - 10 mm ϕ @ 150 mm c/c	Stirrups 8 mm ϕ @ 150mm c/c

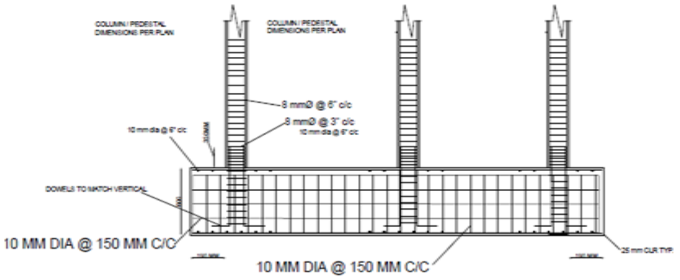


Fig -4: Reinforcement Details of the frame.

3. Modelling and Designing

ETABS: Extended Three-Dimensional Analysis of Building System.

A structure's computer model is a compromise between the genuine structure and its mathematical representation. Understanding these models, their underlying assumptions, and analysis techniques is critical for structural design in order to arrive at an adequate and efficient design solution. The application of inelastic computer modelling and nonlinear analysis has risen dramatically in recent years, thanks to the introduction of performance-based seismic design methods. This document summarizes the fundamental ideas of inelastic computer modelling and nonlinear building structure analysis. ETABS 2018 has been used in this project.

3.1 Plan Details

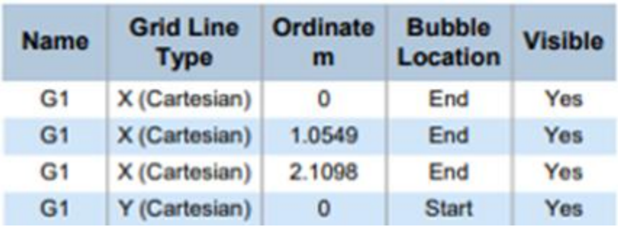
A 2.240m in X direction and 2.260m in Y direction and a 2-storey building with 2 bay is modelled using ETABS Software. The height of each story is kept as 1 m in the structure with the total height of the structure as 2.260 m. Analysis and design of the structure is done and then the result generated by this software is compared manually and a conclusion is drawn from them.

Table-3: Storey data.

Tower	Name	Height m	Master Story	Similar To	Splice Story	Color
T1	Story2	1.1299	Yes	None	No	Yellow
T1	Story1	1.1299	No	Story2	No	Gray8Dark

Table-4: Grid systems.

Tower	Name	Type	Ux m	Uy m	Rz deg	Story Range	Bubble Size m	Color
T1	G1	Cartesian	0	0	0	Default	1.524	Gray6



Name	Grid Line Type	Ordinate m	Bubble Location	Visible
G1	X (Cartesian)	0	End	Yes
G1	X (Cartesian)	1.0549	End	Yes
G1	X (Cartesian)	2.1098	End	Yes
G1	Y (Cartesian)	0	Start	Yes

IS 1893:2016 Seismic Load Calculation

Lateral seismic loads according to IS 1893:2016, as calculated by ETABS
Direction and Eccentricity Direction = X

Structural Period
Period Calculation Method = Program Calculated

Factors and Coefficients
Seismic Zone Factor, Z [IS Table 3]Z = 0.36
Response Reduction Factor, R [IS Table 9] R = 5
Importance Factor, I [IS Table 8]I = 1
Site Type [IS Table 1] = II

Seismic Response
Spectral Acceleration Coefficient, Sa /g [IS 6.4.2]
Sa g = 1.36 T Sa g = 2.396565

Equivalent Lateral Forces Seismic Coefficient, Ah [IS 6.4.2]Ah = Z I Sa g 2 R

Table 5: Calculated Base Shear.

Direction	Period used	W (kN)	Vb (kN)
X	0.567	18.89	21

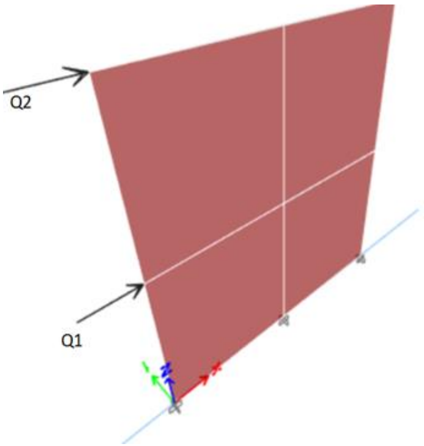


Fig -5: ETABS modelling of the frame.

4.Analysis Result

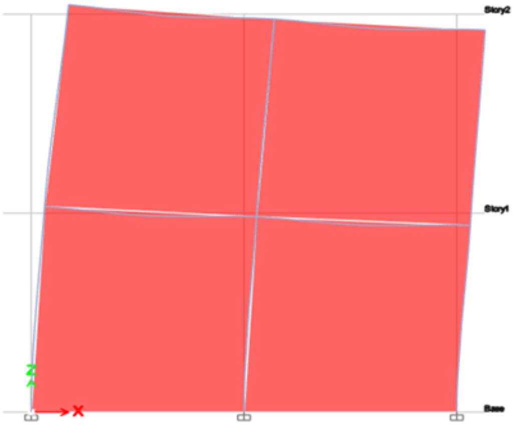


Fig -6: Deformed Shape of the frame.

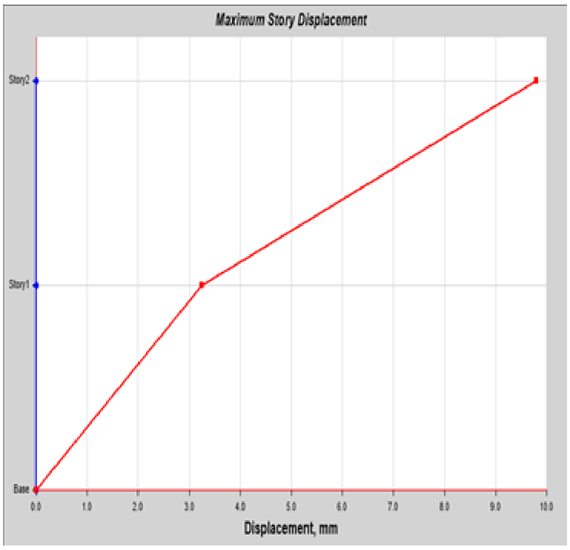


Fig 7: Maximum Story Displacement.

4.1 Analysis of P-Δ effect

P Delta analysis is a very common type of force follower analysis. It is also known as "Geometric Nonlinearity" because when the deflection grows, the additional forces generated by P-delta effects must be tested again. A force follower analysis is one in which, as a member loses its stability, the force follows the deformed member and soon produces additional instability. A P-Delta analysis is not as straightforward as it sounds, and ignoring it might have serious consequences. These impacts will be more severe in soft lateral force resisting systems, such as moment frames, than in stiff systems, such as core wall systems and braced frames. When discussing P-Delta, P delta is a phrase derived from the letter P, which stands for load.

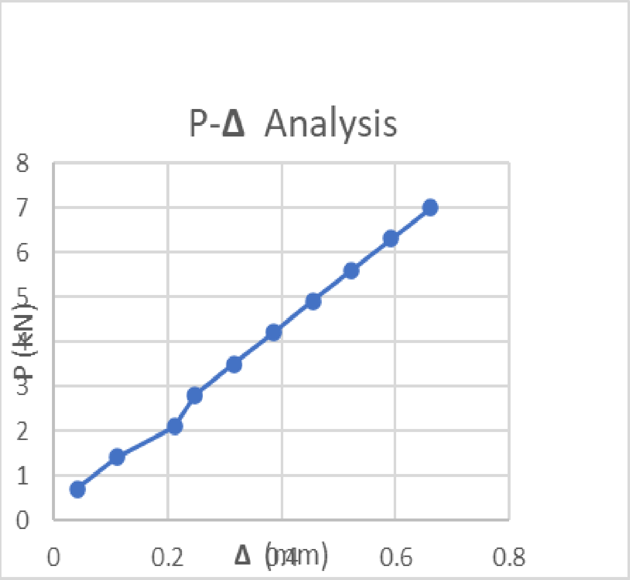


Chart1:P-delta Analysis.

4.2 Load Cycle vs Strain Measurement:

Reinforced concrete frames designed as ductile moment-resisting space frames may, depending on the intensity of the earthquake, be subjected to several post-elastic cycles throughout its duration. With each cycle, the accumulation of damage in the failure region means a degradation in stiffness, and since ductility is determined by the ratio of deflection at ultimate to the deflection at first yield (Δu/Δy), this loss of stiffness tends to increase the apparent ductility of. the structure. However, the ability for energy absorption, as indicated by the area under the load-deflection curve, is generally not enhanced due to a loss in load-resisting capacity. Conventional theories based on maintaining the ultimate strength of the structure cannot, therefore, be forgotten in the need to satisfy ductility requirements**.** Since energy absorption in reinforced concrete is best achieved by yielding of the flexural reinforcement, care must be taken to ensure that other stress requirements are not underestimated. If a "brittle failure occurs - that is, one due primarily to bond, shear or compression - little or no ductility is available for post-elastic deformations and collapse of the structure is a likely outcome. The beam-column joint is a region where shear and bond stresses are critical, and since the strength. and ductility of the members cannot be achieved without an adequate connecting detail, the performance of this region can be a decisive factor in determining the overall behaviour of the structure.

4.3 Analysis of Moment curvature

Moment curvature analysis is a method for precisely determining the load-deformation behaviour of a concrete segment utilizing nonlinear material stress-strain relationships Consider the strain in the extreme fiber, assuming the strain is distributed linearly across the depth of the section, compute the stress based on the stress strain relationship for the material(s), and then estimate the location of the neutral axis to satisfy equilibrium. The moment of resistance is then the pair produced by the compressive and tensile stress resultants. Curvature is the angle in radians formed by the cross section's final location based on the estimated extreme fibre strain and the beam or column's axis. These processes are repeated for various severe fibre strain values. Some fibres reach yield as the extreme strain exceeds the yield strain

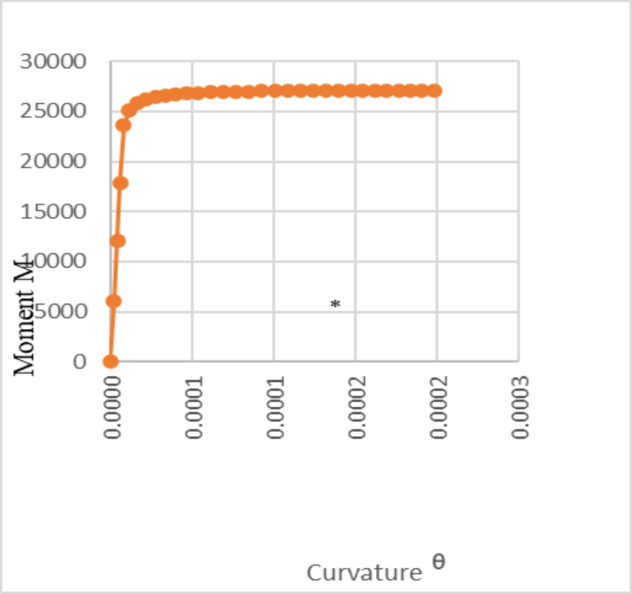


Chart 3 – Moment curvature Curve.

5.Conclusion

Analysis was done on the Two bay Two Storey RC frame with a prefabricated RC wall panel done by using the software ETABS, to study the seismic behaviour of the structure subjected to lateral cyclic loading. Lateral load resisting system is better in resisting the gravity loads of the structural system. The ETABS software is used to design and analyze the results such as load-displacement behaviour, P-Delta analysis, the maximum load carrying capacity of the frame, stiffness degradation and ductility, energy dissipation and cumulative energy dissipation capacity was studied. At 40kN the column beam junction failure occurs a maximum displacement of 1.72mm is observed. Hence strengthening of the junction is to be adopted further. Minor cracks were developed in the pre-fabricated RC infill wall. From detailed investigation it has been concluded that introduction of pre-fabricated RC wall panel in frame increases the stiffness and stability of the structure. Thus, in seismic zone, RC frames with wall panel exhibits increased strength.

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