NON-LINEAR TIME HISTORY ANALYSIS OF PRECAST AND RCC BEAM COLUMN

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Abstract: **The current study investigates the response of combined systems, RC frame pre-cast 3D wall sandwich panels in both linear and non-linear material properties. The seismic behavior of building constructed by 3D panels is studied in details, e.g. ductility evaluation in terms of load-displacement curves, energy loops and its dissipation during applied spectrum and material nonlinearities. The results are compared with regular bending RC frames and complete box type shotcrete sandwich panels system and present the differences of drifts and horizontal load distribution on floors.**

I. INTRODUCTION

1.1 History:

Ancient Roman builders made use of concrete and soon poured the material into moulds to build their complex network of aqueducts, culverts, and tunnels. Modern uses for pre-cast technology include a variety of architectural and structural applications — including individual parts, or even entire building systems.

In the US, precast concrete has evolved as two sub-industries, each represented by a major association. The precast concrete products industry focuses on utility, underground and other non-prestressed products, and is represented primarily by the National Precast Concrete Association (NPCA). The precast concrete structures industry focuses on prestressed concrete elements and on other precast concrete elements used in above-ground structures such as buildings, parking structures, and bridges. This industry is represented primarily by of the Precast/Prestressed Concrete Institute (PCI).

1.2 Introduction:

Precast concrete systems have many advantages like speed in construction, good quality due to factory production, economy in mass production. Despite many advantages of precast concrete, it is not widely used throughout the World, especially in regions of high seismic risk. The reason behind this is a lack of confidence and knowledge base about their performance in seismic regions as well as the absence of rational seismic design provisions in major model building codes (Priestley, 1991). High storey precast frame panel buildings performed poorly in the 1988 Spitak, Armenia earthquake due the lack of adequate seismic design considerations such as ductility in precast joints (Hadjian, 1993). The structural damage was due to insufficient connection detailing (Muguruma et al., 1995).

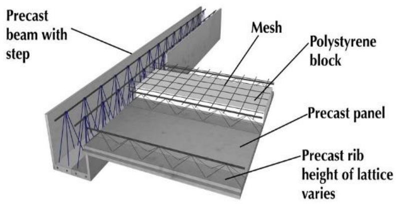


Fig 1.1: Precast beam

Rehabilitation and protection against seismic actions concerns a large number of buildings made of precast and prestressed concrete elements, basically for industrial-manufacturing purposes. These buildings are very common in many countries and especially in Italy, where a large number of constructions were built in the ‘50s, ‘60s and ‘70s, during the reconstruction after World War II and the consequent economic and social development [1]. At that time the buildings were characterized by innovative and even high performance materials and by complex structural solutions exploiting new material and design approaches. The latter however were not comparable with modern regulations and technical knowledge, so that assessment of present conditions needs specific studies on local and global behavior. This circumstance is more relevant if seismic risk is analyzed; in fact, many constructions are located in areas recognized to be exposed to seismic risk after erection, so that the original design takes into account only gravity loads, without any consideration of lateral loads due to earthquake.

1.3.1 Agricultural products:

Precast concrete products can withstand the most extreme weather conditions and will hold up for many decades of constant usage. Products include bunker silos, cattle feed bunks, cattle grid, agricultural fencing, H-bunks, J-bunks, livestock slats, livestock watering trough, feed troughs, concrete panels, slurry channels, and more. Prestressed concrete panels are widely used in the UK for a variety of applications including agricultural buildings, grain stores, silage clamps, slurry stores, livestock walling and general retaining walls. Panels can be used horizontally and placed either inside the webbings of RSJs (I-beam) or in front of them. Alternatively panels can be cast into a concrete foundation and used as a cantilever retaining wall.

1.3.2 Building and site amenities:

Fig1.2: Precast parking structure showing an interior column, girders, and double-tee structural floors. The two gray circles are covers to close the lifting anchor holes.

Precast concrete building components and site amenities are used architecturally as fireplace mantels, cladding, trim products, accessories and curtain walls. Structural applications of precast concrete include foundations, beams, floors, walls and other structural components. Multi-storey car parks are commonly constructed using precast concrete. The constructions involve putting together precast parking parts which are multi-storey structural wall panels, interior and exterior columns, structural floors, girders, wall panels, stairs, and slabs. These parts can be large; for example, double-tee structural floor modules need to be lifted into place with the help of precast concrete lifting anchor systems.

1.3.3 Retaining walls:

Fig1.3: precast concrete retaining wall.

Precast concrete provides manufacturers with the ability to produce a wide range of engineered earth retaining systems. Products include: commercial retaining walls, residential walls, sea walls, mechanically stabilized earth (MSE) panels, modular block systems, segmental retaining walls, etc. Retaining walls have five different types which include: gravity retaining wall, semi gravity retaining wall, cantilever retaining wall, counter fort retaining wall, and buttress retaining wall.

1.3.4 Sanitary and storm water:

Sanitary and storm water management products are structures designed for underground installation that have been specifically engineered for the treatment and removal of pollutants from sanitary and storm water run-off. These precast concrete products include storm water detention vaults, catch basins, and manholes.

1.3.5 Utility structures:

For communications, electrical, gas or steam systems, precast concrete utility structures protect the vital connections and controls for utility distribution. Precast concrete is nontoxic and environmentally safe. Products include: hand holes, hollow core products, light pole bases, meter boxes, panel vaults, pull boxes, telecommunications structures, transformer pads, transformer vaults, trenches, utility buildings, utility vaults, utility poles, controlled environment vaults (CEVs), and other utility structures.

1.3.6 Water and wastewater products:

Precast water and wastewater products hold or contain water, oil or other liquids for the purpose of further processing into non-contaminating liquids and soil products. Products include: aeration systems, distribution boxes, dosing tanks, dry wells, grease interceptors, leaching pits, sand-oil/oil-water interceptors, septic tanks, water/sewage storage tanks, wet wells, fire cisterns, and other water and wastewater products.

1.4 OBJECTIVE:

- To study precast element and compare its aspect with RCC.
- To study and collect data of specified ground motion for time history analysis.
- To check and compare parameters like bending stress, shear stress and principal stress for linear and non-linear analysis.

II. LITERATURE REVIEW

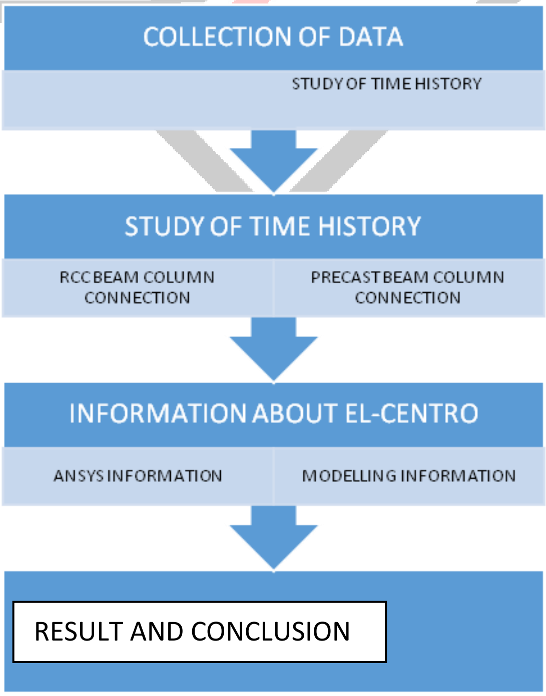
Hopkins, (2015) Precast insulated concrete sandwich panels have been used with proven success in commercial building application as wall elements to provide both vertical and lateral strength and thermal and environmental protection. Various configurations and materials have been used to provide certain degrees of strength, thermal resistance and composite action. The mechanics of the sandwich panel rely on the transfer of compressive and tensile forces due to flexure via shear through the web connectors. These web connectors have varied from steel wire trusses to carbon fiber composite grid trusses to solid concrete zones.

Hawileh, (et. al.) (2009) In this work, a detailed three-dimensional (3D) nonlinear finite element model is developed to study the response and predict the behavior of precast hybrid beam–column connection subjected to cyclic loads that was tested at the National Institute of Standards and Technology (NIST) laboratory. The precast joint is modeled using 3D solid elements and surface-to-surface contact elements between the beam/column faces and interface grout in the vicinity of the connection. The model takes into account the pre-tension effect in the post-tensioning strand and the nonlinear material behavior of concrete. The model response is compared with experimental test results and yielded good agreement at all stages of loading. Fracture of the mild-steel bars resulted in the failure of the connection.

Farsangi, (2010) This paper presents a finite element analysis on 4 types of precast connections which are pinned, rigid, semi rigid and a new proposed connection. The stiffness of the new connection is obtained from the slope of the total load versus deflection graph in the elastic range. Then the seismic loading from El Centro earthquake modified with 0.15g and 0.5g were applied to the whole structure. From the analysis results, new connection has sufficient stiffness, strength and also higher ductility.

Preetha.V This study deals with the finite element analysis of the monotonic behavior of reinforced concrete beams, slabs and beam-column joint sub assemblages. It is assumed that the behavior of these members can be described by a plane stress field. Concrete and reinforcing steel are represented by separate material models which are combined together with a model of the interaction between reinforcing steel and concrete through bond-slip to describe the behavior of the composite reinforced concrete material.

III. METHODOLOGY



3.1 GROUND MOTIONS AND LINEAR TIME HISTORY ANALYSIS

Dynamic analysis using the time history analysis calculates the building responses at discrete time steps using discredited record of synthetic time history as base motion. If three or more time history analyses are performed, only the maximum responses of the parameter of interest are selected.
In linear dynamic method, the structure is modeled as a multi degree of freedom (MDOF) system with a linear elastic stiffness matrix and an equivalent viscous damping matrix. The seismic input is modeled utilizing time history analysis, the displacements and internal forces are found using linear elastic analysis. The playing point of linear dynamic procedure as for linear static procedure is that higher modes could be taken into account.

In order to study the seismic behavior of structures subjected to low, intermediate, and high-frequency content ground motions, dynamic analysis is required. The STAAD Pro [1] software is used to perform linear time history analysis.

3.1.1 Ground Motion Records

Buildings are subjected to ground motions. The ground motion has dynamic characteristics, which are peak ground acceleration (PGA), peak ground velocity (PGV), peak ground displacement (PGD), frequency content, and duration. These dynamic characteristics play predominant rule in studying the behavior of RC buildings under seismic loads. The structure stability depends on the structure slenderness, as well as the ground motion amplitude, frequency and duration. Based on the frequency content, which is the ratio of PGA/PGV the ground motion records are classified into three categories:
1) High-frequency content PGA/PGV > 1.2
2) Intermediate-frequency content 0.8< PGA/PGV< 1.2
3) Low-frequency content PGA/PGV < 0.8

The ratio of peak ground acceleration in terms of acceleration of gravity (g) to peak ground velocity in unit of (m/s) is defined as the frequency content of the ground

3.1.2 Load Balancing Concept:

It is possible to select cable profile in a prestressed concrete member such that the transverse component of the cable force balances the given type of external loads. This can be readily illustrated by considering the free body of concrete beam. The various type of reaction of a cable upon a concrete member depend upon the shape of cable profile. Straight portion of the cable do not induce any reactions except at the end, while curved cables result in uniformly distributed loads.

Sharp angles in cable induce concentrated loads. The concept of load balancing is useful in selecting the tendon profile. If the beam supports uniformly distributed loads, the corresponding tendon should follow a parabolic profile. In short, the external bending moment counteracts with internal bending moment.

Figure 3.1 c shows the variation of 1979 Imperial Valley-06 (Holtville Post Office) H-HVP225 component ground acceleration versus time with -0.253 g PGA. The second curve is the ground velocity, obtained by integrating the acceleration-time function. The PGV is -0.488 m/s. Integration of ground velocity gives the ground displacement, displayed as the lowest trace. The peak ground displacement is 0.316 m. In the same manner, Figure shows the variation of ground acceleration versus time with PGA, ground velocity versus time with PGV, and ground displacement versus time with PGD for corresponding ground motions. Then from the acceleration and velocity curves of the ground motion, frequency content, which is the ratio of PGA/PGV, can be obtained.

And (2) the procedure chosen to introduce the missing baseline in the record. [35]

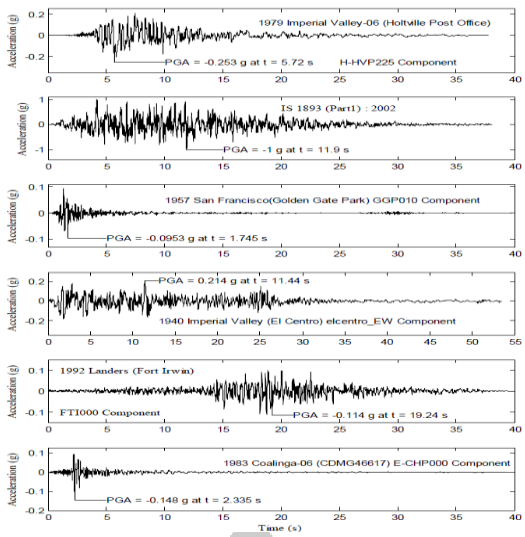


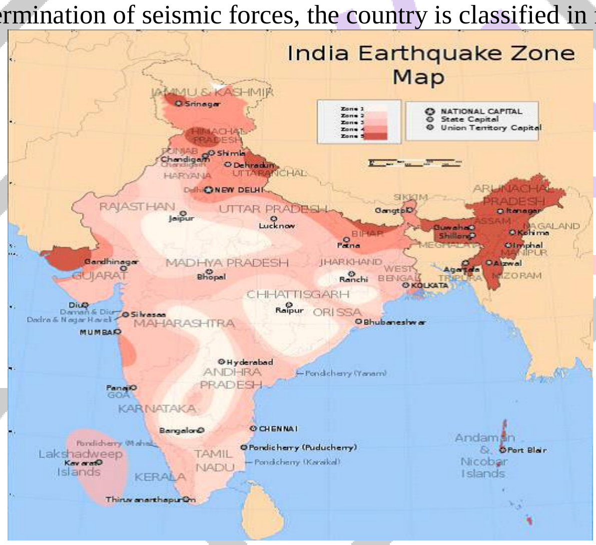
Figure 3.1: Ground motion acceleration versus time with PGA value of 1979 Imperial Valley-06 (Holtville Post Office) H-HVP225 component, IS 1893 (Part1) : 2002, 1957 San Francisco (Golden Gate Park) GGP010 component, 1940 Imperial Valley (El Centro) elcentro_EW component, 1992 Landers (Fort Irwin) FTI000 component, and 1983 Coalinga-06 (CDMG46617) E-CHP000 component

3.2 Design Criteria

Following are the major steps in determining the seismic forces:

3.2.1 Determination of base shear:

For the determination of seismic forces, the country is classified in four seismic



The total design lateral force or design base shear along any principal direction shall be determined by this expression

$V_b = A_h * W$……………………………………….... (B)

Where,

Ah = design horizontal seismic coefficient for a structure

W= seismic weight of building

The design horizontal seismic coefficient for a structure Ah is given by

Z is the zone factor given in Table 2 of IS 1893:2002 (part 1) for the maximum considered earthquake (MCE) and service life of a structure in a zone. The factor 2 is to reduce the MCE to the factor for design base earthquake (DBE)

It is the importance factor, depending upon the functional use of the structure, characterized by hazardous consequences of its failure, post-earthquake functional needs, historical or economic importance. The minimum values of importance factor are given in table 6 of IS 1893:2002 R is the response reduction factor, depending on the perceived seismic damage performance of the structure, characterized by ductile or brittle deformations. The need for introducing R in base shear formula

Sa/g is the average response acceleration coefficient for rock and soil sites as given in IS 1893:2002 (part 1). The values are given for 5 % of damping of the structure.

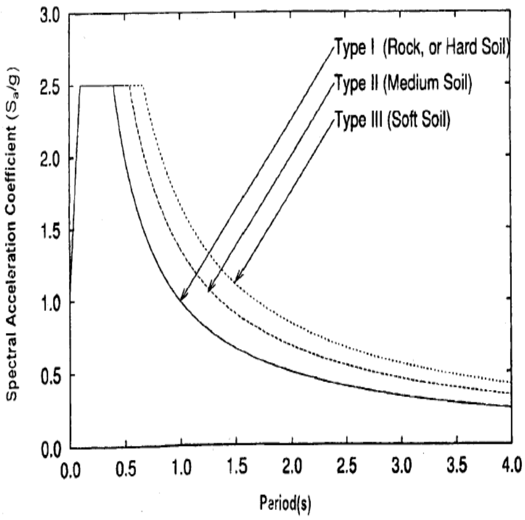


Figure no.3.2 IS code spectra from IS 1893:2002 (Part I)

Response Spectrum Method

Response spectrum analysis is a procedure for computing the statistical maximum response of a structure to a base excitation. Each of the vibration modes that are considered may be assumed to respond independently as a single-degree-of-freedom system. Spectra which determine the base acceleration applied to each mode according to its period (the number of seconds required for a cycle of vibration).

Response spectrum analysis produces a set of results for each earthquake load case which is really in the nature of an envelope. It is apparent from the calculation, that all results will be absolute values - they are all positive. Each value represents the maximum absolute value of displacement, moment, shear, etc. that is likely to occur during the event which corresponds to the input response spectrum.

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.

This SOLID186 3-D 20-node homogenous/layered structural solid were adopted to discrete 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 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 Contact pairs couple general ax symmetric 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. 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.

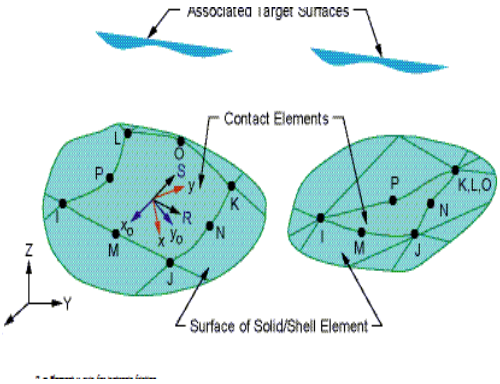


Fig.no.3.3 CONTA 174

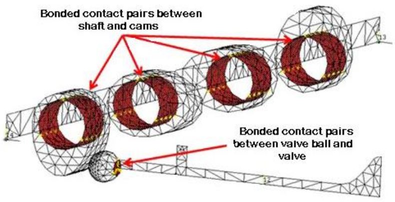


Fig.no.3.4 TARGET 170

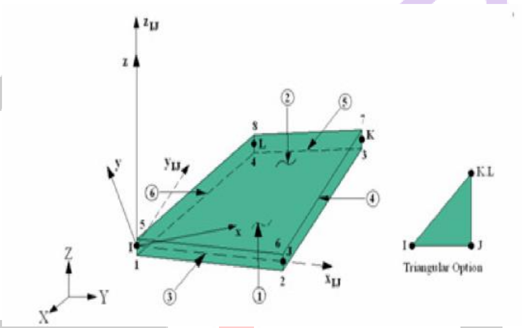


Fig.no.3.5 Shell

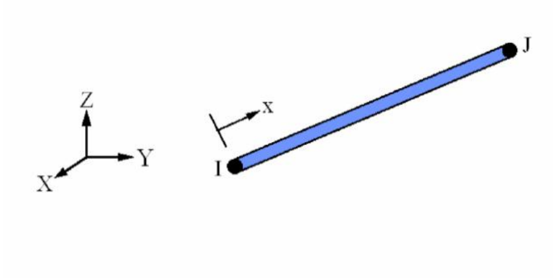


Fig.no.3.6 Beam

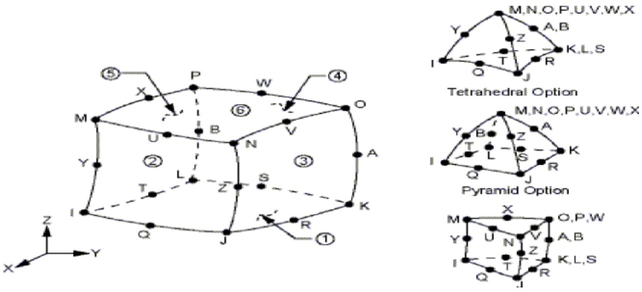


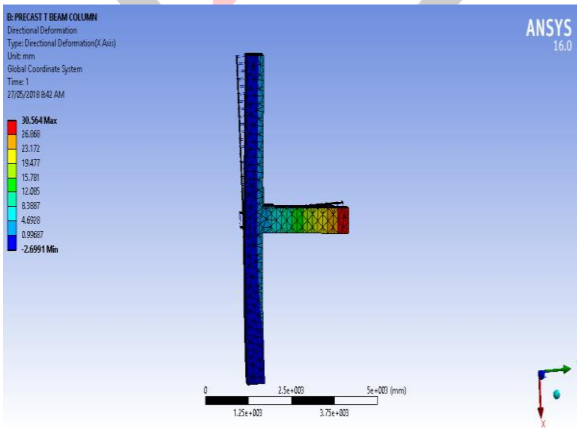
Fig.3.7 Solid 186

Material properties

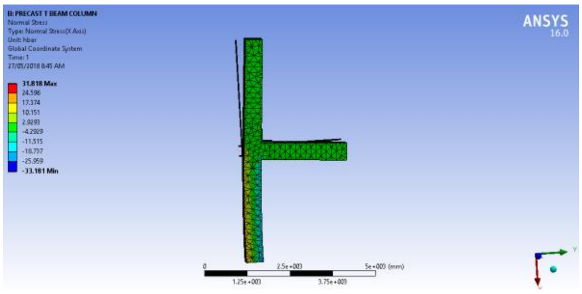
Sr.No.	Material	Property	Value
1	Structural steel	Yield stress f_{sy}(MPa)	250
		Ultimate strength f_{su}(MPa)	500
		Young's modulus Es(MPa)	210×10^3
		Poisson's ratio µ	0.3
		Ultimate tensile strain e_t	0.25
2	Reinforcing bar	Yield stress f_{sy}(MPa)	250
		Ultimate strength f_{su} (MPa)	500
		Young's modulus Es(MPa)	200×10^3
		Poisson's ratio µ	0.3
		Ultimate tensile strain et	0.25
3	Concrete	Compressive strength f_{sc}(MPa)	30
		Tensile strength f_{sy}(MPa)	3.553
		Young's modulus E_c(MPa)	$5000\sqrt{f_{ck}}$
		Poisson's ratio µ	0.15

IV. RESULTS AND DISCUSSION

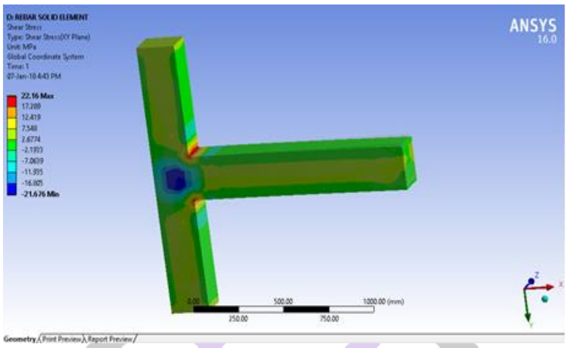
MODEL NO.1	BEAM COLUMN RCC
MODEL NO.2	BEAM COLUMN WITH PRECAST



MAXIMUM EQUIVALENT STRESSES

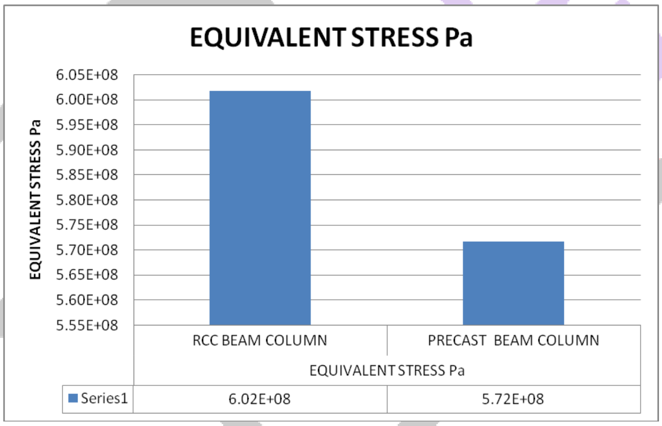


NORMAL STRESSES

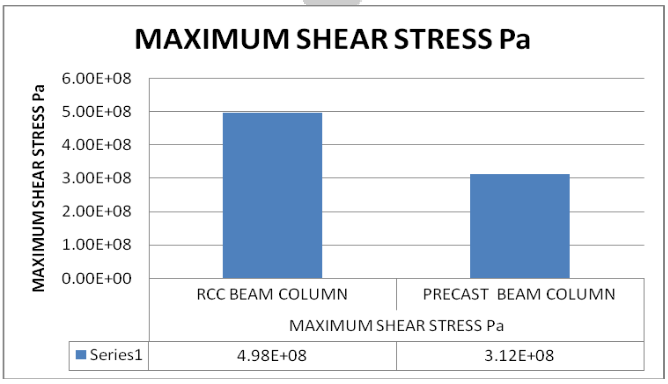


SHEAR STRESSES

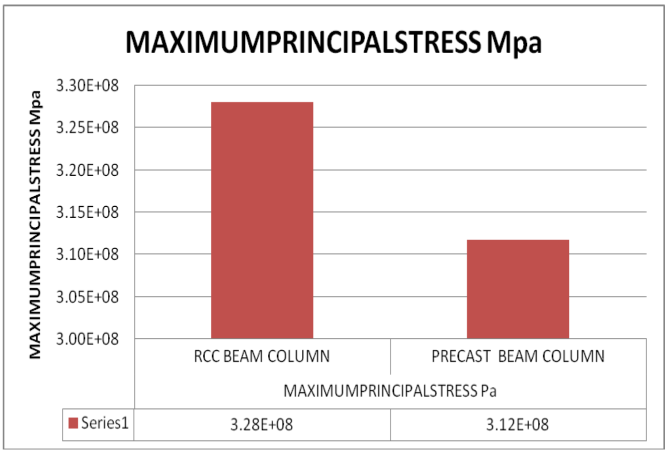
In earthquake resistance structure, while detailing of beam-column connection, the spacing of stirrups is less. Hence during exact work at site it is hard to execute. In precast joint the stirrup spacing will be more for strengthening of beam column connection, hence there should be provision of bolting and prestressing.



Graph 4.1: Equivalent Stresses of RCC Beam-Column and Precast Column



Graph 4.2: Shear Stresses of RCC Beam-Column and Precast Column



Graph 4.3: Maximum Principle Stresses of RCC Beam-Column and Precast Column

V. CONCLUSION

In this project the comparative analysis is made for RCC and PRECAST beam column connections and following conclusions are observed that

1. The maximum deformation, stress parameters are reduced by 15-20 % in to Precast beam column connections as compared to RCC beam column connections.

2. From the analytical study of the different shape of the beam column connection has been shown that the precast system is more as compared to RCC.

3. Deformation (Total and Directional) of precast connection system is more than RCC.

For dynamic results the El Centro data is used after analysis by using ANSYS following conclusion are made

- The total deformation In precast beam columns observed 15 to 20 % less as compared to rcc beam column
- Equivalent Stress In precast beam column is observed 5 to 10 % less as compared to rcc beam column
- Shear Stress In precast beam column is observed 10 to 15 % less as compared to rcc beam column

FUTURE SCOPE

On this project the various precast members are studied subjected to static load and dynamic load. It's observed that precast members are more effective than RCC members for both static load and dynamic load. However same comparison can be made for vibration analysis.

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