COMPARATIVE STUDY ON VERTICAL IRREGULAR COMPOSITE STRUCTURE WITH RCC STRUCTURE

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Abstract - *RCC structures are more popular due to ease in construction but in developing countries there is a need for large number of medium and high rise structures to take care of growing urban population. For such high rise structures it was found that steel concrete composite structures are more beneficial than traditional RCC structures. In the present work, a simplified method of 30 story composite structure are modelled and analysed, where columns and slabs are of composite type and beam is of steel section. Equivalent static analysis and dynamic time history analysis is carried out as per IS 1893 (Part 1): 2016 specifications using ETABS Ver.15 software.*

Key Words: **Steel Concrete Composite Structures, Equivalent static analysis, dynamic time history analysis, earthquake intensity**

1. INTRODUCTION

In the past times, for designing a building, the choice was always between a concrete and a masonry structure. But the failure of various multi-storied level buildings and low-rise RC structures and masonry buildings due to the earthquake effect has forced the structural engineers to look forward for the alternative methods of construction. Use of composite and hybrid material in the members are of particular interest, due to this significant prospective in improvise the on the whole performance and rather changes in manufacturing and also constructional technologies. Formally the multi-level-story buildings in India were built with RC framed structure and Steel framed structure. However recently the trends in going towards the composite structure has been started and developing. In composite construction there are mainly two different Materials will be tied together by the shear studs at their interface which saves material cost considerably. Thermal expansion of both concrete and steel are nearly same. Therefore, there will be no induction of different thermal stresses in the section under variation in temperature.

1.1 Shear Connectors

Shear connections are one the essential for steel concrete bond construction as they integrate and increase the compression capacity of the supported concrete slab with the supporting steel beams to improve the load carrying capacity as well as overall rigidity. Though steel and concrete bond will help shear to transfer between the two up to certain extent, yet it will be neglected as per the codal provisions because of uncertainty. All codes will therefore specifies positive connectors at the interface between steel and concrete.

1.2 Composite. Slab

Composite floors using the GI profiled sheet decking have become the very popular in West for high rise buildings. Composite deck slabs are usually competitive in where the concrete floors have to be completed speedily and where the medium level of fire protection to steel job is sufficient. There is presently no IS Indian standard code for the design of composite floors system using profiled sheeting. In the composite floor system, the structural behaviour will be similar to a reinforced concrete RC slab, with the steel/ GI sheeting acting as tension reinforcement.

1.3 Composite Beam

A steel - concrete composite beam consisting of a steel beam, over which a RC slab is casted with shear connectors. The composite action will reduce the beam depth. If there is no any connection b/w concrete slab and the steel beam at interface, the relative slip occurs b/w the steel section and concrete slab upon the beam is loaded. Thus, each of components will act separately. With the help of a proper connection b/w concrete slab and steel beam the interface, the existing slip can be minimized or even eliminated altogether. If the slip at the interface is eliminate or significantly reduced, the slab upon the extent to which slip is prevented. The degree of interface depends mainly on the extent of shear connection used. Slip is zero at the mid-span and maximum at the support of a simply supported beam is subjected to UDL. Hence, shear is less in connectors located near centre and maximum in connectors located near supports.

1.4 Composite Column

Column is a conventionally compression member in which the structural steel is an main element. There are 3 main types of composite columns now used in practice, which are Concrete Encased, Battered Section, Concrete filled
Indian Standards IS for composite construction (IS: 11384-1985) will not make any specific reference to composite

columns. The provisions enclosed in IS: 456 – 2000 are often invoke for design of a composite structures

The concrete & steel is combining in such a way that the advantages of both materials are utilized effectively in composite type of column. There are many advantages related with the use of steel & concrete composite columns, small cross-sections, for an example, can be designed to withstand higher loads. Similarly, sections with different type of resistances, but identical external dimensions, can be produced by changeable steel area, concrete strength and additional reinforcement. Thus outer dimension of column can be held constant over a no. of floors in a buildings thus simplifying architectural detailing.

2. OBJECTIVES AND METHODOLOGY

The following objectives are considered in this work.

To model and analyse vertical irregular 30 story composite structure, where columns, beams and slabs are of composite type. Study is carried out for various earthquake zones of India and for soil type 2 and equivalent static analysis and dynamic time history analysis is carried out as per IS 1893 (Part 1): 2016 specifications using ETABS software. Vertical irregularity is considered in the form of double height at two locations. Conclusions are made base on the results obtained from the analysis of composite and RCC structure for different earthquake intensity.

Initially a 30-story rectangular in plan RCC moment resisting frame is considered, having overall dimension 32 m × 24 m in X and Y direction. Bay size is 4 m uniform along both the direction. Modeling and analysis is carried out using ETABS Ver. 2016. For the above dimensions a composite building with columns having structural steel encased by concrete and beams of only structural steel and composite slab is considered and modelled using ETABS Ver.2016. Vertical irregularity is considered at two locations as per IS 1893 Part 1: 2016 code specifications in the form of double height i.e., one location at bottom most levels and second at mid height of the building. Equivalent static analysis is carried out for the RCC and composite buildings for Zone 3 and 5 from the recommendations of IS 1893 2016. Also, dynamic time history analysis for ELCENTRO time history input is carried out. Analysis is carried out and key results, are extracted from ETABS ver. 2016.

Modeling of steel moment resisting frame is done using ETABS Ver. 2016, which is 3D modeling and analysis software package.

Following procedure is adopted for modeling of composite and RCC structures.

a. Development of grid system as per the plan and elevation requirements.

b. Defining the frame sections i.e., columns and beams, defining the deck section.

c. Defining the loads and load combinations as per IS 800 2007 steel code.

d. Defining the earthquake loads as per equivalent static and dynamic analysis procedure using IS 1893 – 2016 (Part 2).

e. Placing the structural elements in the respective position on grid systems which are developed at the beginning.

f. Assigning the floor loads and earthquake loads including mass source, followed by the analysis.

3. RESULTS AND DISCUSSION

In this chapter key results are extracted using ETABS 2016 for the responses obtained from lateral load analysis using equivalent static and time history dynamic inputs. Results are presented in the form of graphs, figures and tables along with the discussion followed by the conclusions. Two main structural systems are considered i.e., conventional RCC and composite structure. Modal analysis has been carried out to understand the dynamic vibration characteristics of the structural systems and corresponding time period results are extracted and presented. Results from time history analysis i.e., base force, peak displacement and peak accelerations are extracted and presented in the form of time history plots. All the results extracted are compared between two structural systems considered and based on the results and discussions, conclusions are drawn and presented.

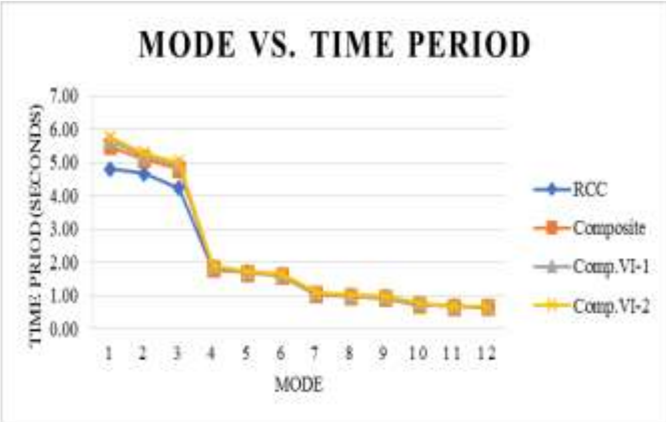

Chart -1: Mode V/s Mode (time) period

From the modal analysis it can be observed that, RC structure has least time period compared to composite structure. An increase of 19.5% in time period is observed in composite structure with vertical irregularity -2 where double height at two locations are adopted. Conversely frequency is found to be maximum in case of RC structure i.e., 0.21 Hz compared to all other composite structures with and without vertical irregularities.

3.1 Equivalent Static Analysis – Z5

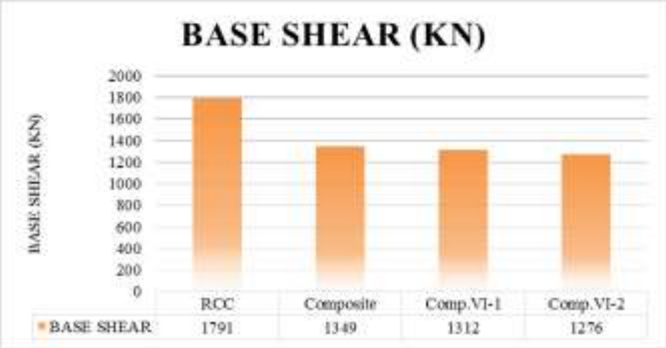

Chart -2: Maximum base force comparison

Chart -2 presents the maximum base force of all the structural systems, and it can be seen that RC structure has highest base force of 1791 kN and composite structure with vertical irregularities has least base force of 1276 kN, which is about 29% less.

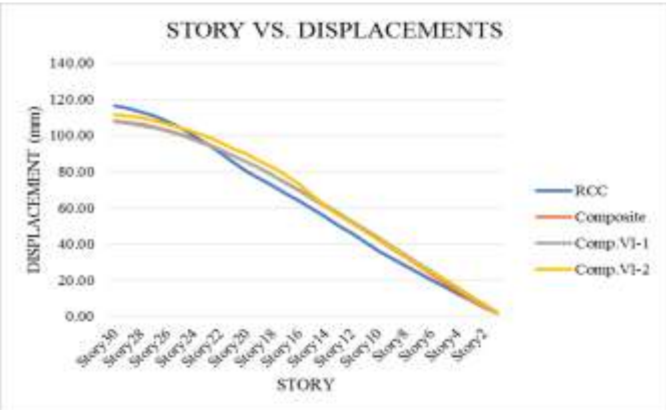

Chart -3: Z3 - Story vs Displacements – X Dir.

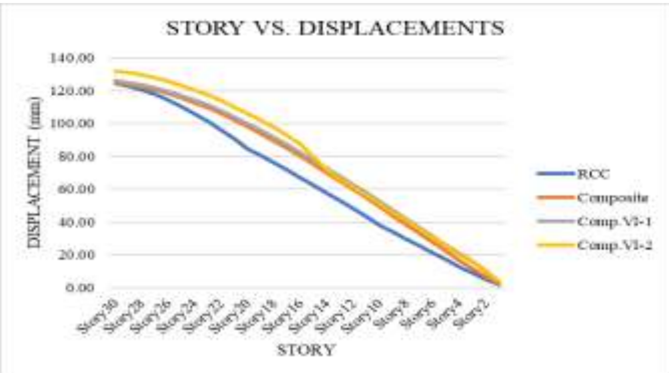

Chart -4: Z3 - Story vs Displacements – Y Dir.

Story displacements along X direction varies between 116.27 mm in RCC structure to minimum of 107.64 mm. In case of composite structure with double height at the base of the structure, which is found to be 7.4% less. Story displacements are found to be more in Y direction than X direction about 7%. In this case due to vertical irregularities, story displacements are found to increase around 6% only.

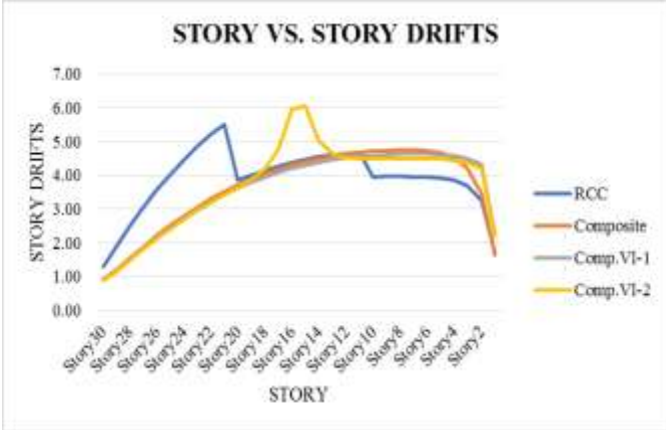

Chart -5: Z3 - Story vs drifts – X Dir.

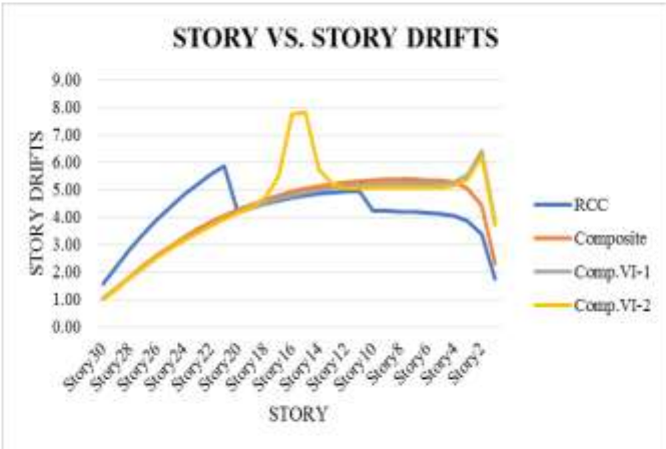

Chart -6: Z3 - Story vs drifts – Y Dir.

Story drifts are found to increase sharply at mid-level in X direction, and both at mid-level and story 1 along Y direction as shown in Ch. 5 and 6 which is found to be 35% along X direction and 64% along Y direction.

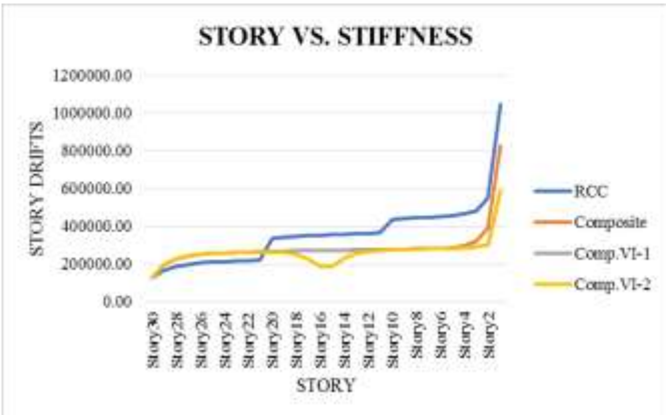

Chart -7: Z3 - Story vs Stiffness – X Dir.

Chart -8: Z3 - Story vs Stiffness – Y Dir.

From the Ch. 7 and 8 it can be observed that, maximum stiffness is found in RC structure whereas due to vertical irregularities, stiffness has reduced significantly in composite structure with vertical irregularities at two locations along both X and Y direction.

3.2 Equivalent Static Analysis – Z5

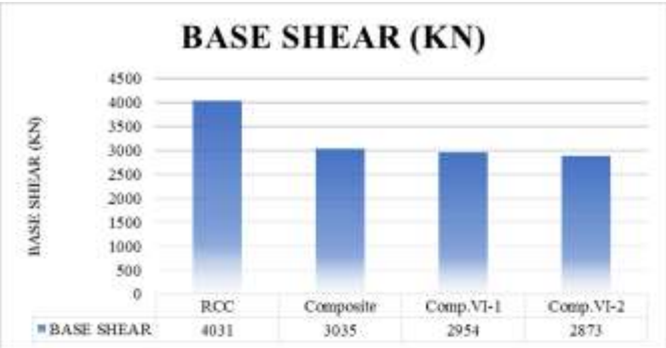

Chart -9: Z5 - Maximum Base shear

From Ch. 9 due to change in the zone from zone 3 to zone 5, base force has increased 125% in RC structure. And like Z3 in Z5 also, composite structures have less base force compared to RC structure.

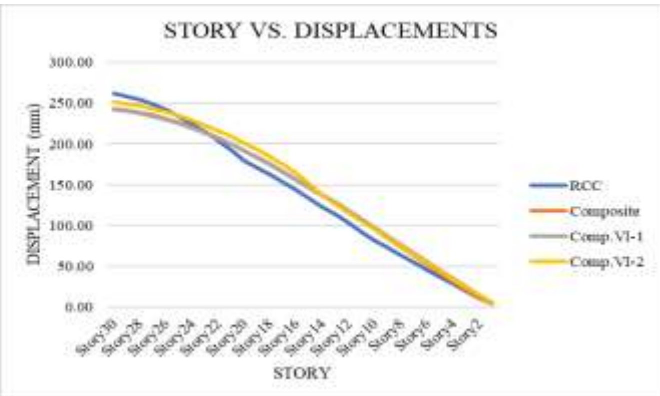

Chart -10: Z5 - Story vs Displacements – X Dir.

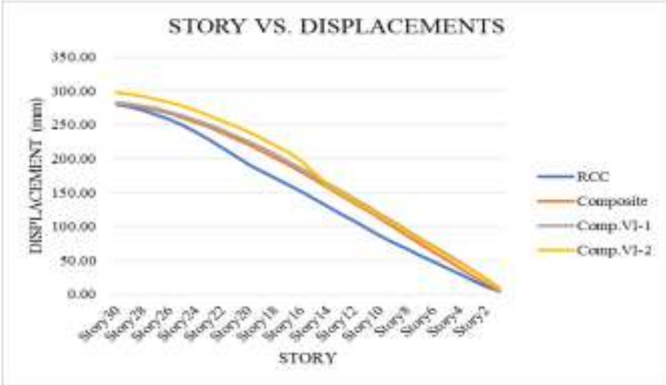

Chart -11: Z5 - Story vs Displacements – Y Dir.

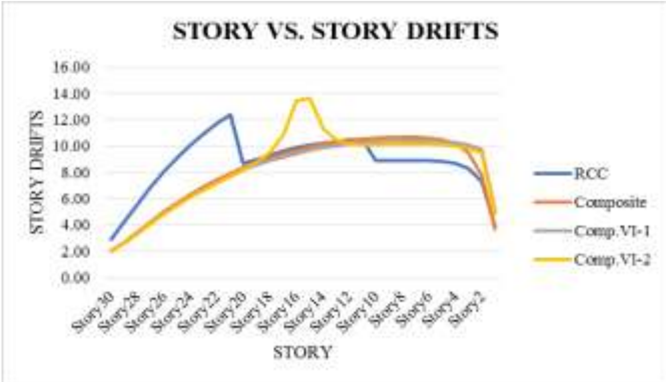

Chart -12: Z5 - Story vs drifts – X Dir.

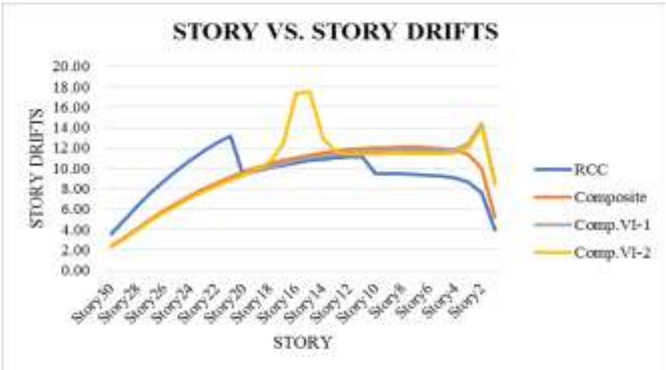

Chart -13: Z5 - Story vs drifts – Y Dir.

Chart -14: Z5 - Story vs Stiffness – X Dir.

Chart -15: Z5 - Story vs Stiffness – Y Dir.

Due to change from Z3 to Z5 the overall responses of the structures like, displacements, story drifts have been increased along both X and Y direction. And like Z3 composite structure with vertical irregularities at two locations (Comp.VI-2) has maximum displacements and drifts and least stiffness along both X and Y direction.

3.3 Time History Analysis

Dynamic time history analysis has been done in for Bhuj earthquake and results are summarized in Table 1.

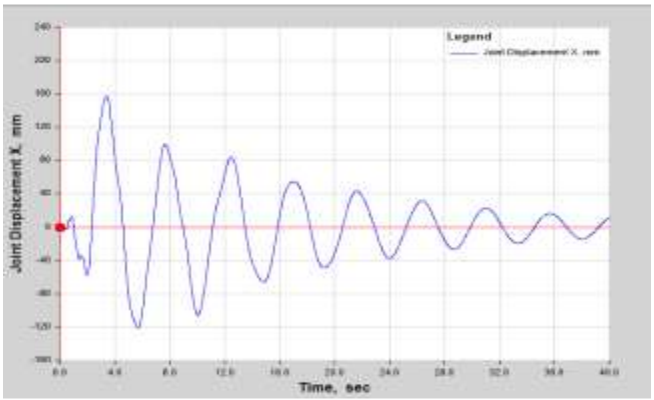

Chart -16: Peak displacements – RCC – X Dir.

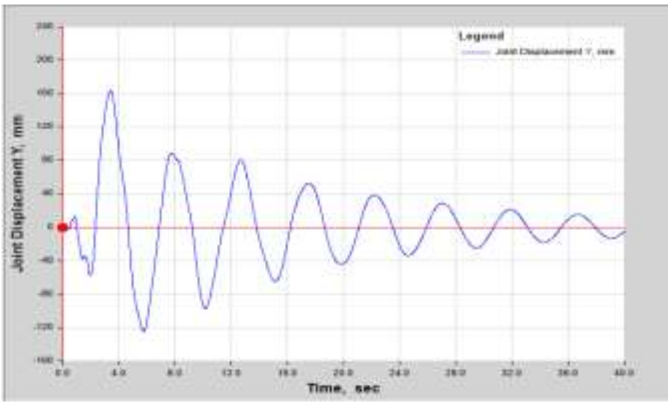

Chart -17: Peak displacements – RCC – Y Dir.

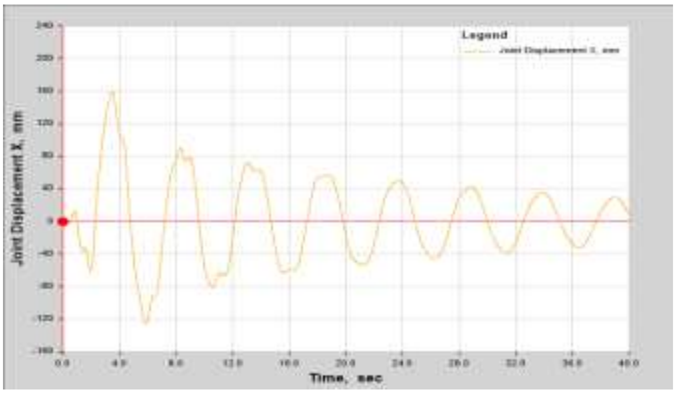

Chart -18: Peak displacements – Composite – X Dir.

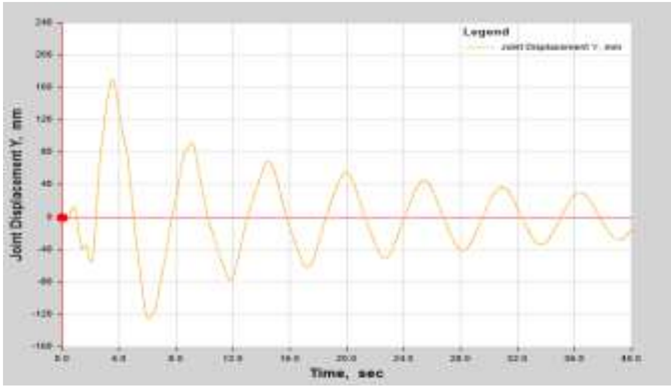

Chart -19: Peak displacements – Composite – Y Dir.

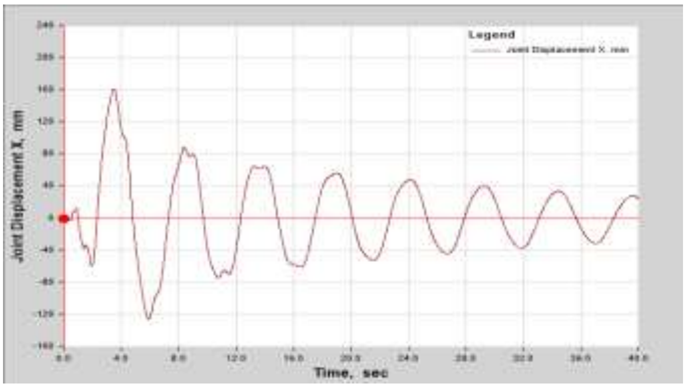

Chart -20: Peak displacements – Comp. VI-1 – X Dir.

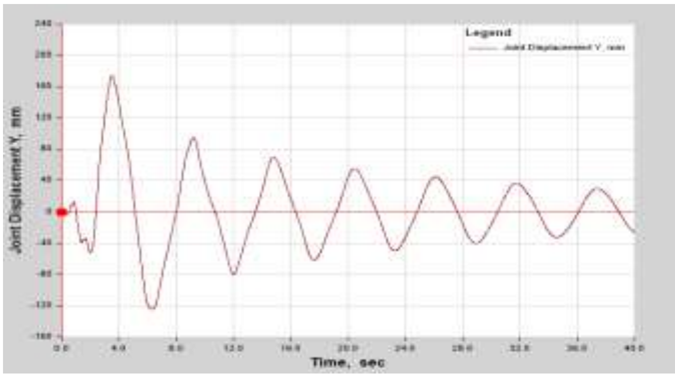

Chart -21: Peak displacements – Comp. VI-1 – Y Dir.

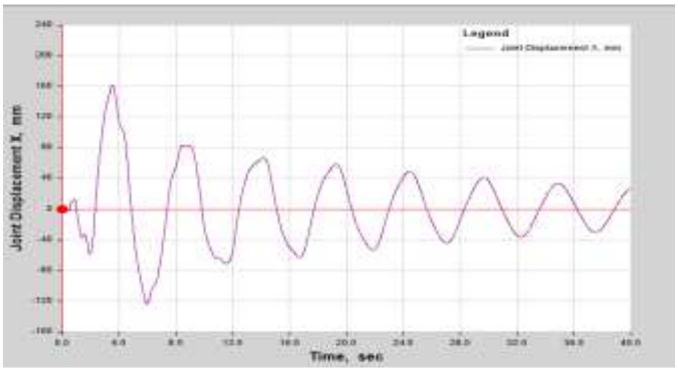

Chart -22: Peak displacements – Comp. VI-2 – X Dir.

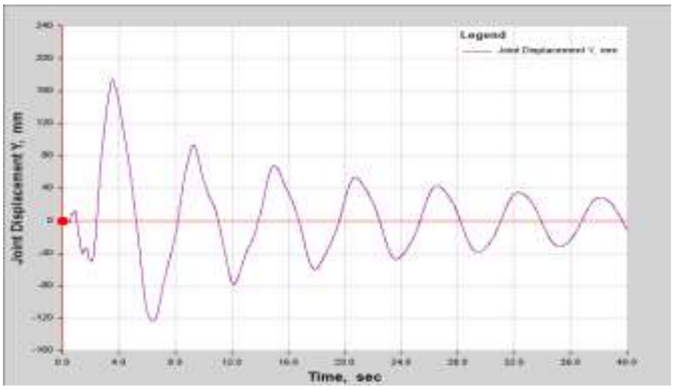

Chart -23: Peak displacements – Comp. VI-2 – Y Dir.

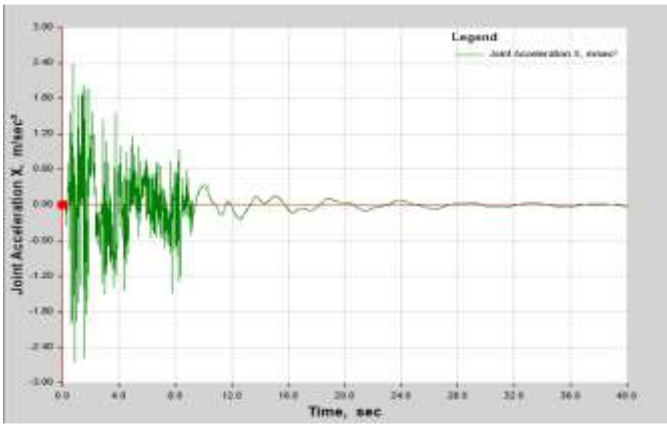

Chart -24: Peak accelerations – RCC – X Dir.

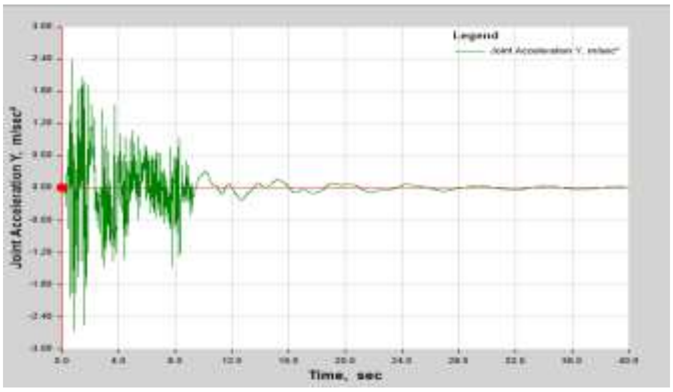

Chart -25: Peak accelerations – RCC – Y Dir.

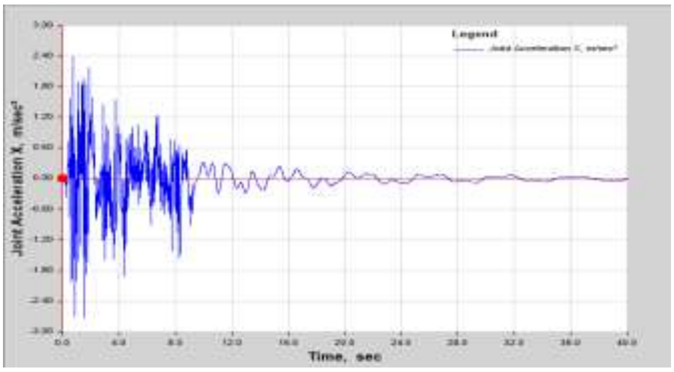

Chart -26: Peak accelerations – Composite – X Dir.

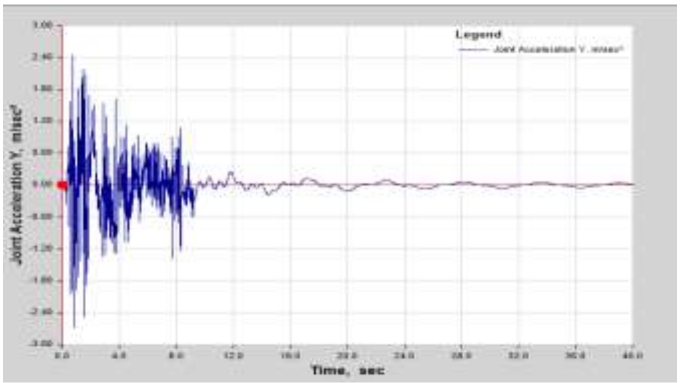

Chart -27: Peak accelerations – Composite – Y Dir.

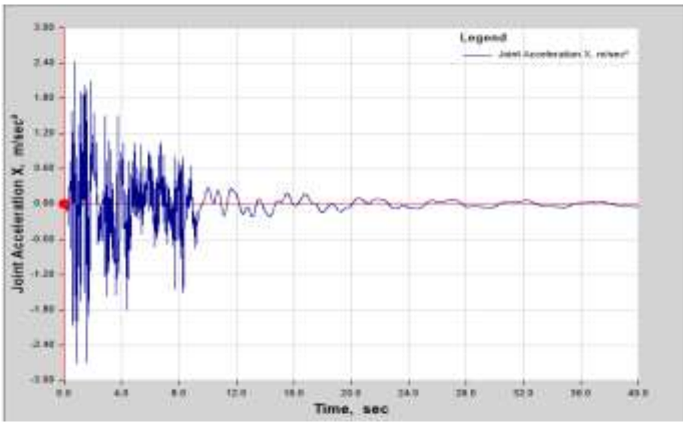

Chart -28: Peak accelerations – Comp. VI-1 – X Dir.

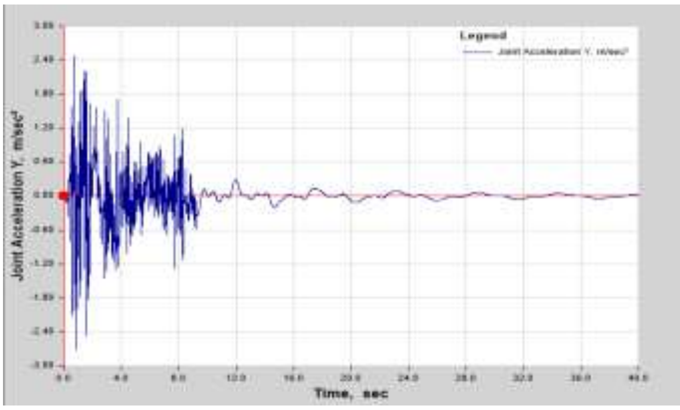

Chart -29: Peak accelerations – Comp. VI-1 – Y Dir.

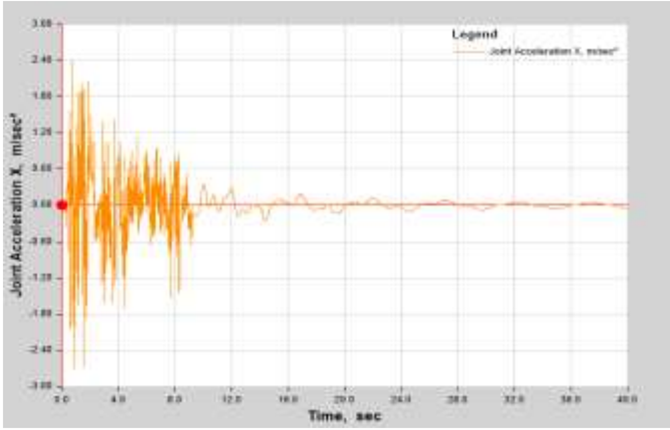

Chart -30: Peak accelerations – Comp. VI-2 – X Dir.

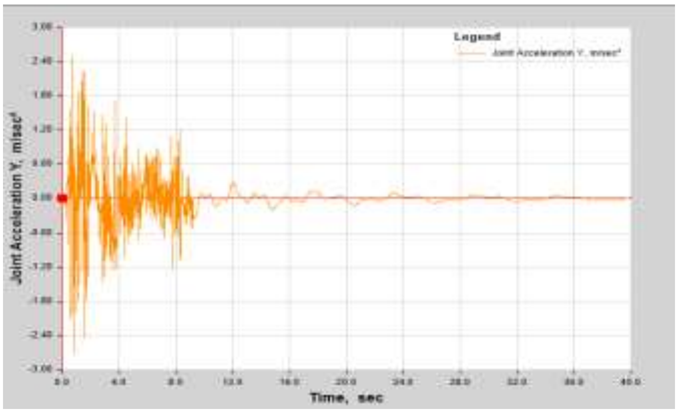

Chart -31: Peak accelerations – Comp. VI-2 – Y Dir.

Table -1: Time History Response Summary Chart

Time History Response Summary Table						
Model Type	Base Force (kN)		Peak Acceleration (m/s2)		Peak Displacements (mm)	
	X Dir.	Y Dir.	X Dir.	Y Dir.	X Dir.	Y Dir.
RCC Structure	4155	3769	2.66	2.65	157.31	163.78
Composite Structure	3791	2741	2.72	2.68	159.24	169.88
Composite VI – 1	3513	2383	2.71	2.71	161.28	174.01
Composite VI – 2	3213	2244	2.70	2.71	161.77	173.73

From the time history analysis, it can be observed that, maximum base force is found to be in RC structure along both X and Y direction. i.e., 4155 KN and 3769 KN respectively. Peak acceleration is found to be almost same for all type of composite structures with only 2% higher than the RC structure. And finally, composite structure with vertical irregularities are found to be 7% higher than RC structure.

4. CONCLUSIONS AND SCOPE OF FUTURE WORK

Following conclusions are made from modal, equivalent static and dynamic time history analysis.

From modal analysis it can be concluded that, composite structures are more flexible in nature due to larger time period and due the presence of vertical irregularities increases the time period. Composite structure with vertical irregularities at two locations i.e., at base and at mid height is subjected to larger deformation and drifts compared to all other structural systems. The drifts and displacements of composite structure with vertical irregularities at two locations are found to be within permissible limits as specified by the code (H/300 = 300 mm and h/250 = 12 mm). Hence these structures can be proposed in high seismic zone also, up to 30 stories. Vertical irregularities lower the overall stiffness of the composite structure, hence certain additional bracing systems can be adopted at these locations. From the dynamic time history analysis, it can be concluded that, vertical irregular steel structure does not induce additional acceleration but slight increase in displacement can be seen.The present work can be extended with utilization of bracings at double height column location. Damper can be adopted for the present work and results are compared without dampers.

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