Comparative analysis of RCC and steel-concrete composite structure & expousre to engineering seismicity

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ABSTRACT

Reinforced concrete, which is used in the majority of building structures, is primarily designed and constructed in accordance with design codes, the availability of materials, and the level of skill required during construction. Due to their high dead load and dangerous formwork, R.C.C. is no longer economical. However, the concept of composite construction is new to the building industry. the use of modern composite technology, which makes it easier to quickly construct multi-story structural frames. According to reviews, composite structures are best suited for high-rise buildings when compared to steel and reinforced concrete constructions. Unfortunately, many of the nonlinear analytical tools are not directly applicable to other scenarios and are only suitable for simulating traditional steel or reinforced concrete structures.

1. INTRODUCTION

Recent trends Utilizing steel, reinforced concrete, and composite steel-concrete members—known as composite, mixed, or hybrid systems—has become a recent trend in the construction industry. In order to maximize the structural and economic benefits, these systems utilize each member type as efficiently as possible. Their superior fire resistance is another advantage that composite frames offer. Both Japan and the United States have employed composite RCS moment frame systems for the last 20 years. A lot of research is being done right now to learn more about how these frames behave. A significant portion of this research is focused on understanding the behavior of mixed assemblies and experimentally examining the properties of joints between steel and reinforced concrete members. Conversely, system behavior has received significantly less attention and is still poorly understood. However, the superior earthquake-resistant qualities of composite beam-columns have long been acknowledged in Japan, where they are now a widely used building material. Frame analysis is necessary given the increasing use and popularity of composite systems. Additionally, nonlinear analysis is a useful tool for better understanding how systems behave, particularly when dynamic excitation is applied. Sadly, many of the analysis programs that are currently available are only appropriate for modeling conventional steel or reinforced concrete systems; they are not directly applicable to composite frames. The goal of some of the work presented here is to comprehend the nonlinear behavior of composite frames using analysis tools ETAB-2018

Comparative inelastic analysis of RCC and steel-concrete composite frame.

2. OBJECTIVES

Following are the objectives of proposed work

1. Steel-concrete composite frames with rolled steel sections enclosed in concrete and steel sections filled with concrete undergo inelastic, or nonlinear static pushover analysis, using E-tab-2018
2. Examine how well the steel-concrete composite section performs in relation to various parameters, including bending moment, base shear, shear force, story drift, and story displacement.
3. To confirm the members' strong column weak beam behavior, examine the hinge formation during composite frame performance.

3. ELEMENTS OF COMPOSITE MULTISTORIED BUILDINGS

The primary structural components used in composite construction consists of

A. Composite deck slab

B. Composite beam

C. Composite column

D. Shear connector

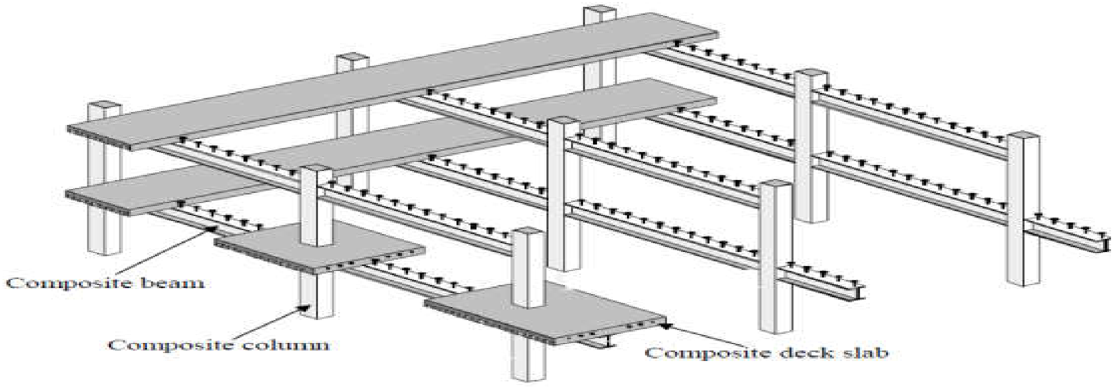

Fig .1. Typical Composite Frame

3.1. Composite deck slab

Profiled deck sheeting is becoming increasingly popular in western countries for composite floor construction. Composite deck slabs are better suited for situations where a concrete floor needs to be finished quickly and where steel work only needs a moderate amount of fire protection. Composite slabs with profiled decking, however, are inappropriate for structures like bridges that experience dynamic or high concentrated loads. Fig. 2 depicts a typical composite floor system that uses profiled sheets. As of right now, no Indian standard exists that addresses the design of composite floor systems that use profiled sheeting.

Fig. 2. Typical Composite Slab

Comparative inelastic analysis of RCC and steel-concrete composite frame.

3.2. Composite beam

In composite construction, concrete slabs are typically supported by beams and rest atop steel beams. In the absence of an interface connection, these elements function independently under loading conditions. As a result, both components function as a monolith when the interface connection is provided. In this instance, the steel beam and slab function as a "composite beam," acting similarly to a monolithic Tee beam. We can fully utilize each of these elements' advantages through the combined action of these two components. In Figure 3, a typical composite beam is displayed.

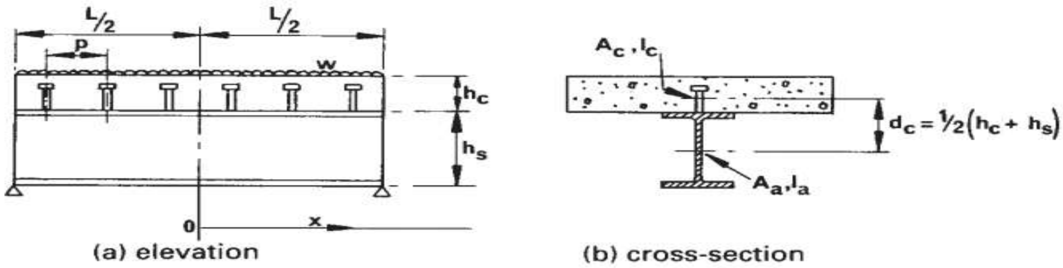

Fig. 3. Typical Beam Cross Sections

3.3.Column of composite

It is a compression member made of either hot rolled steel embedded in concrete or concrete encasing rolled steel. There is currently no Indian standard code that addresses composite column design. Euro Code 4, which offers the most recent research on composite construction, is largely followed in the design process. Regarding composite columns, IS 11384-1985 contains no special provisions. The European buckling curves for steel columns are used in this method as a foundation for column design.

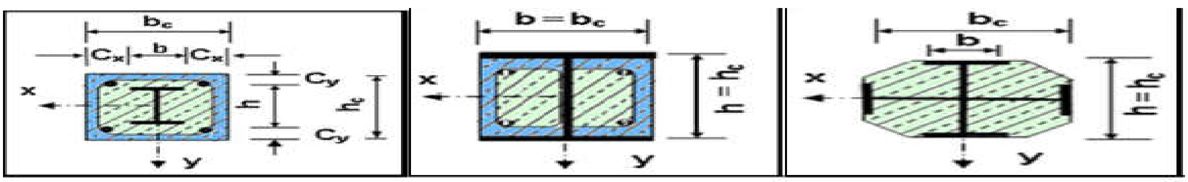

Fig.4 .Cross Section of Fully and Partially Concrete Encased Columns

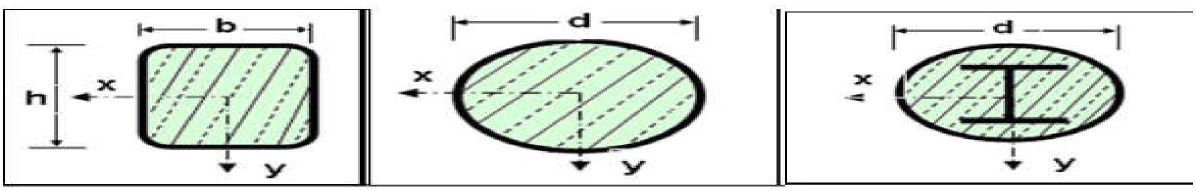

Fig.4. Typical column Cross Sections

3.3.1. The advantages of composite columns are- NO Need we are not publishing a book.

1) Enhanced strength for a specific cross-sectional area.
2) Reduced slenderness due to increased stiffness and buckling resistance.
3) In the case of an enclosed section, good fire resistance.
4) The encased section has good corrosion protection.
5) By altering the steel thickness, concrete grade, and reinforcement, identical cross sections with various load and moment resistances can be produced. This simplifies the building's construction and architectural details by maintaining a column's outer dimensions across several floors.
6) Reducing formwork because steel sections can withstand construction load and erection.

3.4. Shear connectors

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About eight times the total load supported by the steel beam is the total shear force at the interface between the concrete slab and the beam. Consequently, at the steel-concrete interface, mechanical shear connectors are needed. The purpose of these connectors is to (a) transfer longitudinal shear along the interface and (b) keep the concrete slab and steel beam from separating at the interface.

3.4.1. Types of shear connectors:**-**

Type that is Rigid

Due to their extreme stiffness, these connectors resist shear force with only minor deformation. They fail as a result of concrete crushing, and they get their resistance from applying pressure to the concrete. Because they combine the compression capacity of a supported concrete slab with supporting steel beams to increase load carrying capacity and overall rigidity, shear connectors are crucial for steel concrete composite construction.

Type that is flexible

This group includes channels and headed studs. The steel beam's flange is where these connectors are welded. Bending gives them their stress resistance, and they experience significant deformation prior to failure. Stud connectors of this kind are widely used. While the head resists uplift, the shank and the weld collar next to the steel beam resist shear loads.

Type of bond or anchorage:

Through bond action, it resists horizontal shear and keeps the girder from separating from the concrete slab at the interface. These connectors used bonding and anchoring action to overcome the resistance.

4. LITERATURE REVIEWS

Sherif El-Tawil,1 Member, ASCE, and Gregory G. Deierlein,2 Fellow (2001) The formulation for a distributed beam-column element based on plasticity is presented in this paper. This element can be used for seismic analysis of three-dimensional mixed frame structures made of composite, reinforced concrete, and steel components. The suggested formulation, which employs the flexibility method to derive the element stiffness equation, is essentially a trade-off between the more sophisticated but computationally costly fiber element formulation and the approximate but computationally efficient concentrated plastic hinge model.

According to the literature review above, a significant amount of research is conducted in the field of composite construction in western nations such as the United States, Japan, Germany, and others. Research has been done on the experimental design and analysis of composite elements, such as filled or encased sections, taking into account both linear and nonlinear structural behavior. The steel-concrete composite element's FE formulation is also being used in relevant fields. However, very few studies have looked at software-based analysis of steel-concrete frames. As a result, there is scope for analyzing the steel-concrete composite frame with soft materials. Therefore, using software, inelastic analysis (pushover analysis) is being conducted for various steel-concrete frame types as part of the dissertation. (E-tab 9.7).

Keh-Chyuan TSAI, Yuan-Tao WENG, Sheng-Lin LIN, and Subhash GOEL (2004) A full-scale, three-story, three-bay CFT buckling restrained braced frame (CFT/BRB) specimen that was built and tested in a structural laboratory is described in this paper. According to pre-test nonlinear dynamic analyses, after applying the 2/50 design earthquake to the frame specimen, the peak story drift is probably going to reach 0.025 radians. Because of the moderate rotational demand, CFT columns that hinge at the base are expected but shouldn't fail. The experimental peak shears were very accurately predicted by the PISA3D and OpenSees analyses, according to tests. The experimental peak inter-story drifts of 0.019 and 0.023 radians were also found to be in good agreement with the target design limits of 0.02 and 0.025 radians that were specified for the 10/50 and 2/50 events, respectively.

Eiichi Inai, Akiyoshi Mukai, Makoto Kai, Hiroyoshi Tokinoya, Toshiyuki Fukumoto, and Koji Mori (2004) This study examined the experimental behavior of concrete-filled circular and square steel tubular (CFT) beam columns made of various material strengths. To elucidate the impact of the test parameters on the behavior, the interior beam-column models were tested under cyclic horizontal load and constant axial compression with gradually increasing lateral deformation. According to the test results, the overall behavior of the beam column is improved by thicker and stronger steel tubes, whereas the behavior is negatively impacted by stronger concrete.

Comparative inelastic analysis of RCC and steel-concrete composite frame.

Radomir Folic, **Vlastimir Radonjanin**, **Mirjana Malesev;(2005)**The current state of the art in design and analysis is presented in this paper. Steel beams and concrete slabs, their connections, and the results of their interaction are the main topics of discussion. The benefits of using a hollow core slab include lowering the weight of the concrete, lowering the amount of concrete needed, minimizing the effects of creep and shrinkage on the concrete slab, and cutting down on erection time by using precast elements joined together on site.

A. Zona, M. Barbato & J. P. Conte The study offers a better understanding of how different modeling assumptions affect the nonlinear seismic response behavior of SCC frame structures. The findings demonstrate that the SCC frame structures exhibit inelastic partial composite action. The deformability of the shear connection has a major impact on the global seismic response, causing interstory shear demand to decrease and floor displacements and interstory drifts to increase.

J.M. Castro, A.Y. Elghazouli and B.A. Izzuddin (2008) A sophisticated analysis program that takes material and geometric nonlinearities into account is used to conduct a number of sensitivity and parametric studies. The inelastic seismic performance of moment-resisting frames made of composite steel and concrete is evaluated in this paper. The parametric study demonstrates that a number of variables and presumptions can directly affect the composite frames' inelastic behavior as measured by the plastic hinge patterns, inter-story drift distribution, and overall lateral response. Additionally, the behavior is significantly influenced by a number of geometric parameters related to the structural configuration, such as beam span and structural height.

S. Gramblicka, S. Matiasko (2009) The experimental results of the tested columns and a non-linear analysis using Atena software were compared with the theoretical analysis conducted in this work in relation to the current applicable European standards. The experimental results can be utilized for additional research on composite steel-concrete columns. The values of the non-linear analysis of the composite columns using the actual measured material properties show a very good match with the tested columns.

5. METHODOLOGY

Encased and unfilled RCC and steel-concrete composite models are made. Models are made of FTS (concrete-filled tube) columns with RC beams, EIS (encased I-section) columns with RC beams, and ETS (encased tube section) columns with RC beams. Additionally, the software program ETAB-2018 is used to perform inelastic analysis, or nonlinear static pushover analysis, of both RCC and steel-concrete composite frames. Shear force, bending moment, story drift, story displacement, and performance points of both RCC and composite frames are among the many parameters that are discussed. Examine the hinge formation in both frames to confirm the structure's capacity-based design.

Table no 1- Particulars of Project Work

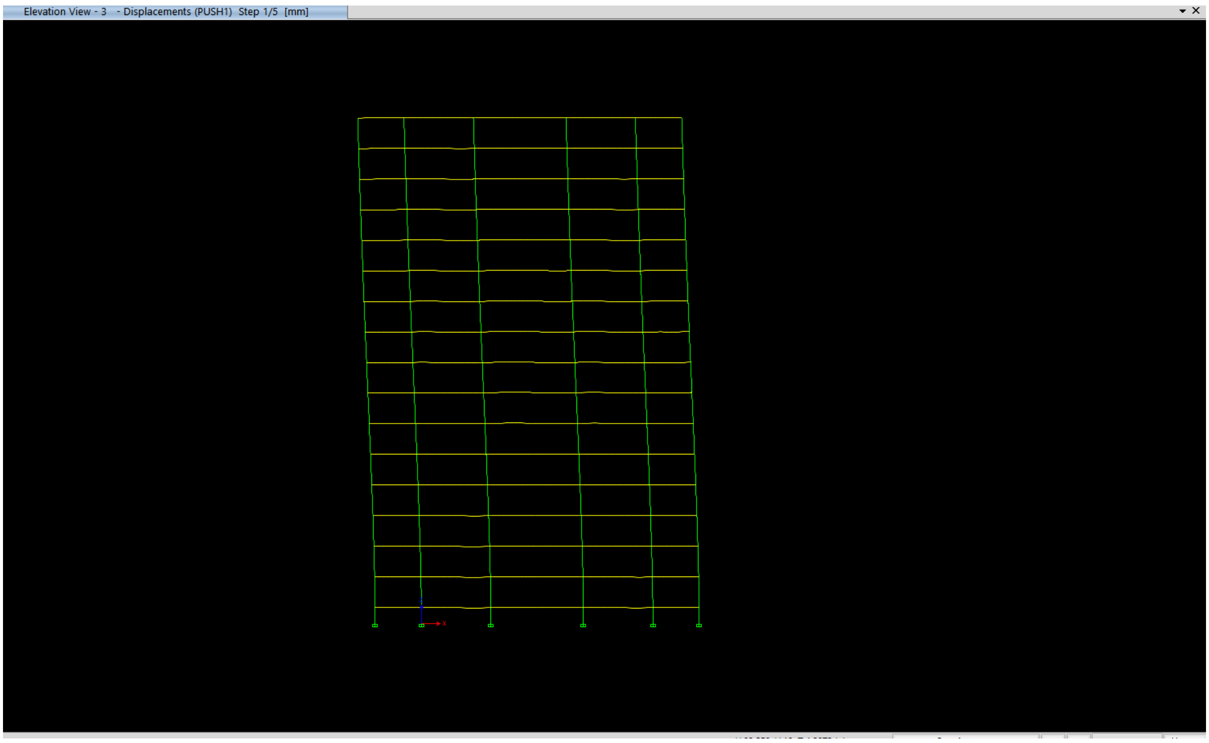
Particulars	RCC structure	Composite structure
Plan dimension	42mx48m	42mx48m
No of story	17	17
Height of each story	3.97m	3.97m
Total height	65.52m	65.52m
Depth of footing	2m	2m
Size of beam	300x750	300x750
Size of column	600mmx600mm 750mmx750mm 900mmx900mm	Encased I section (SRC)
Slab thickness	150	150
Dead load	2kn/m2	2kn/m2

Live load	4kn/m2	4kn/m2
Seismic zone	III	III
Soil condition	Medium	Medium
Response reduction factor	5	5
Importance factor	1	1
Zone factor	0.16	0.16
Grade of concrete	M30	M30
Grade of reinforcing steel	Fe500	Fe500
Grade of structural steel	-----	Fe250
Density of concrete	25 kn/m3	25 kn/m3
Density of brick masonry	20 kn/m3	20 kn/m3
Damping ratio	5%	5%

6. RESULTS AND DISCUSSION

Comparative inelastic analysis of both RCC & Composite frame building is carried out using E-tab-2018 The outcome from the analysis is described in this chapter and comparative analysis is discussed.

5.1. Results showing pushover analysis for RCC Model in E-tab-2018



Comparative inelastic analysis of RCC and steel-concrete composite frame.

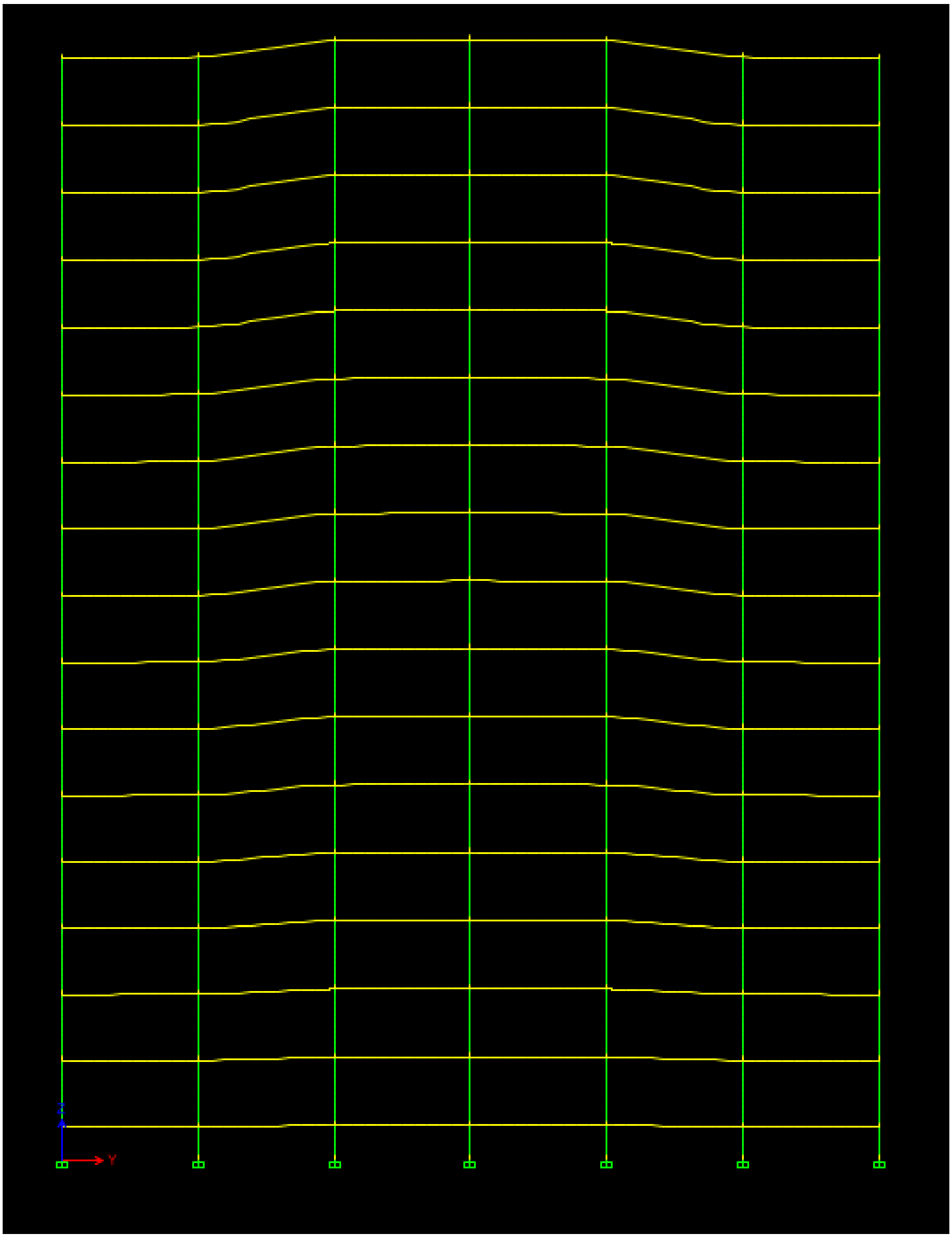


Fig.5. Hinge formation during deformation of RCC frame within elastic limit

5.1.1. Performance point or capacity curve of existing RCC building.

Comparative inelastic analysis of RCC and steel-concrete composite frame.

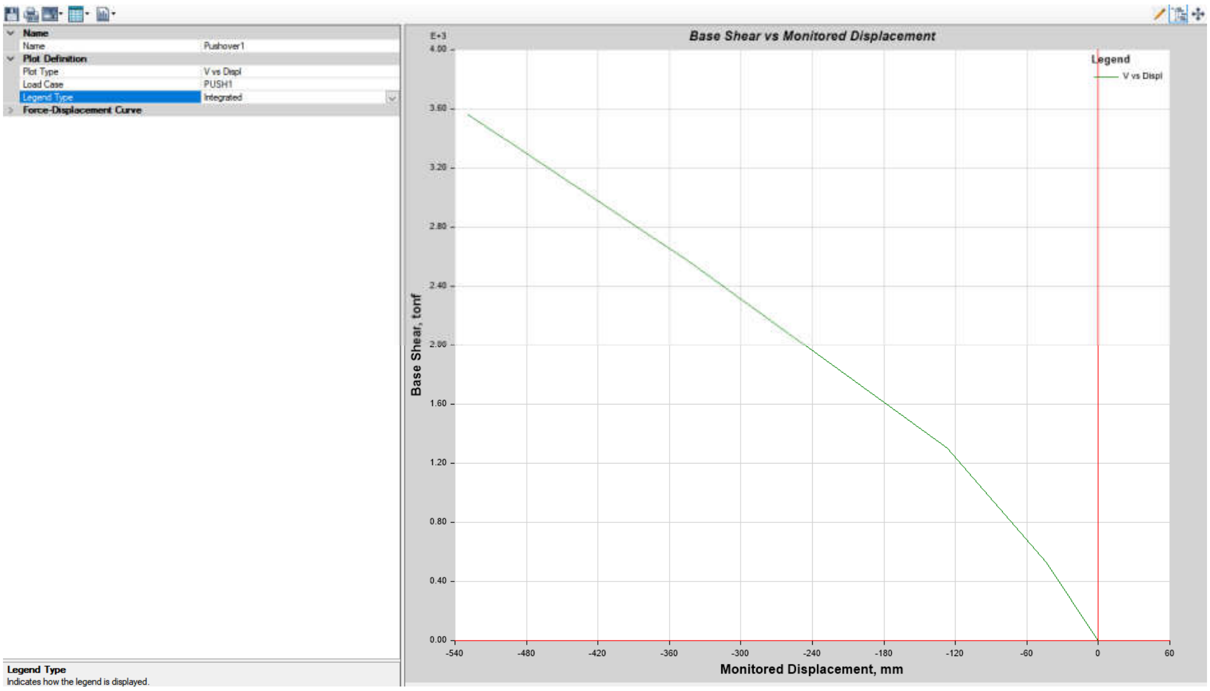


Fig.6. Performance Point of RCC frame model

5.2. Results showing (EIS-RC, ETS-RC, FTS-RC) composite frame.

5.2.1. Results of EIS-RC (Encased I-Section column with RC beam) composite frame

5.2.1.1. Pushover analysis of EIS-RC composite frame

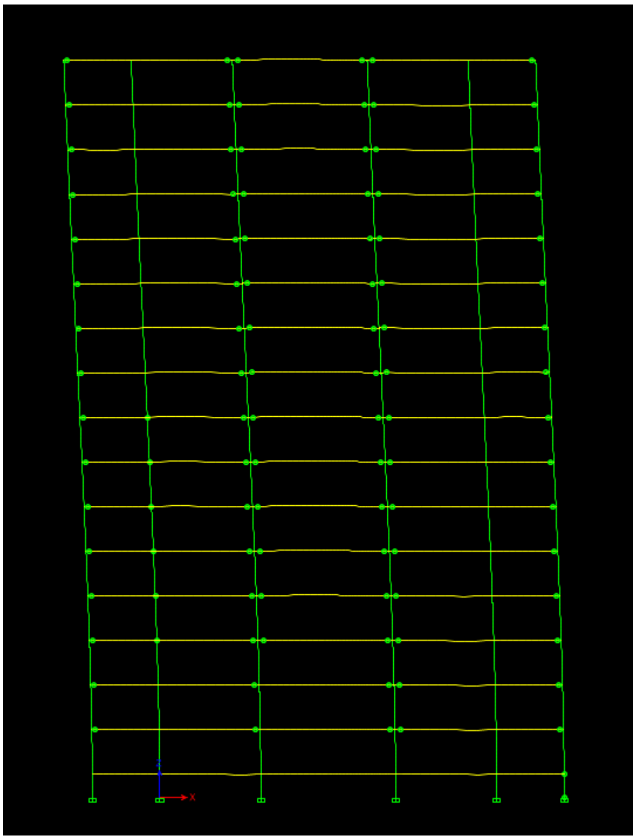


Fig.7.Hinge formation of EIS-RC frame at elastic limit

Comparative inelastic analysis of RCC and steel-concrete composite frame.

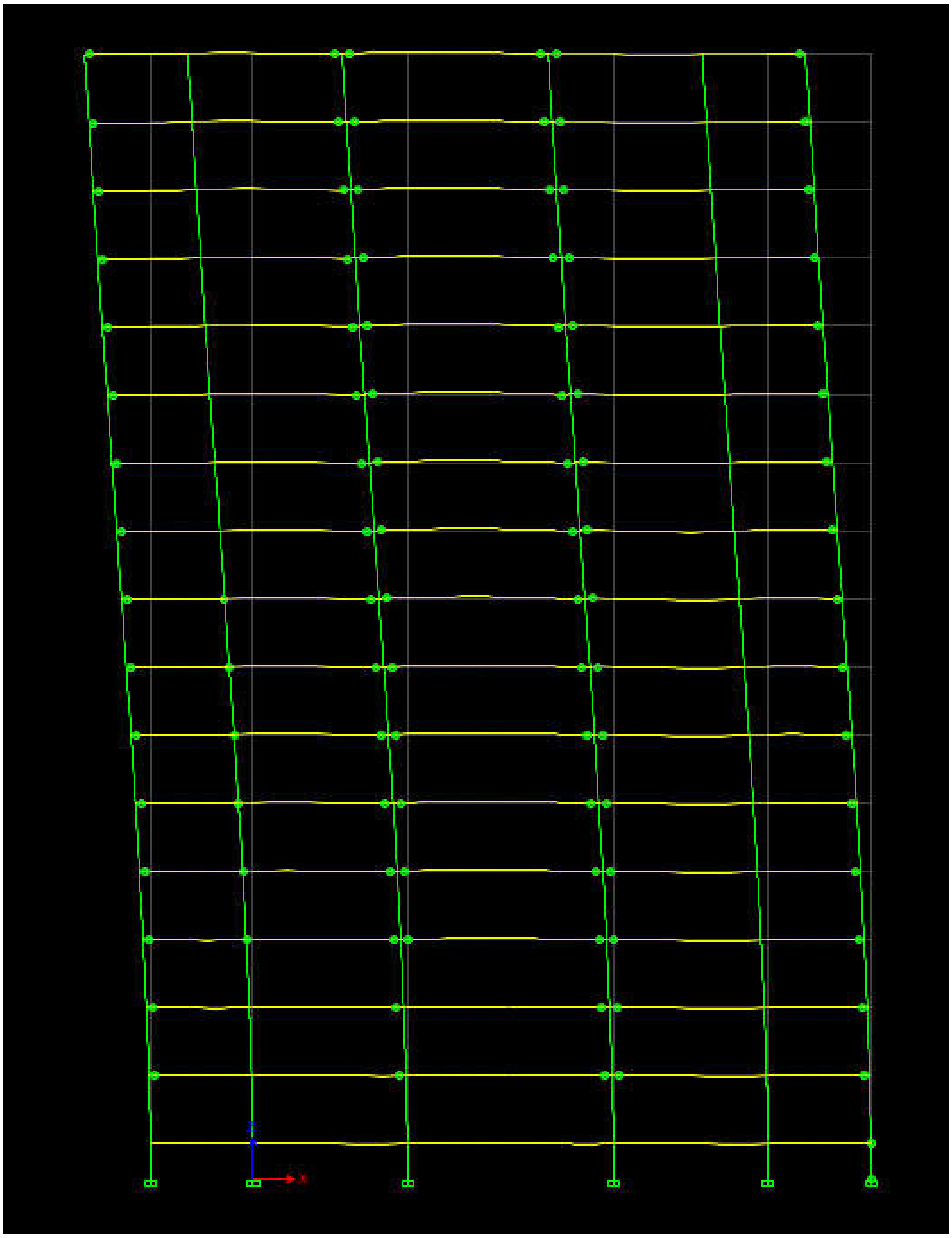


Fig.8. Hinge formation of EIS-RC frame at yield point

5.2.1.2. Capacity spectrum curve or performance point of EIS-RC composite frame

Comparative inelastic analysis of RCC and steel-concrete composite frame.

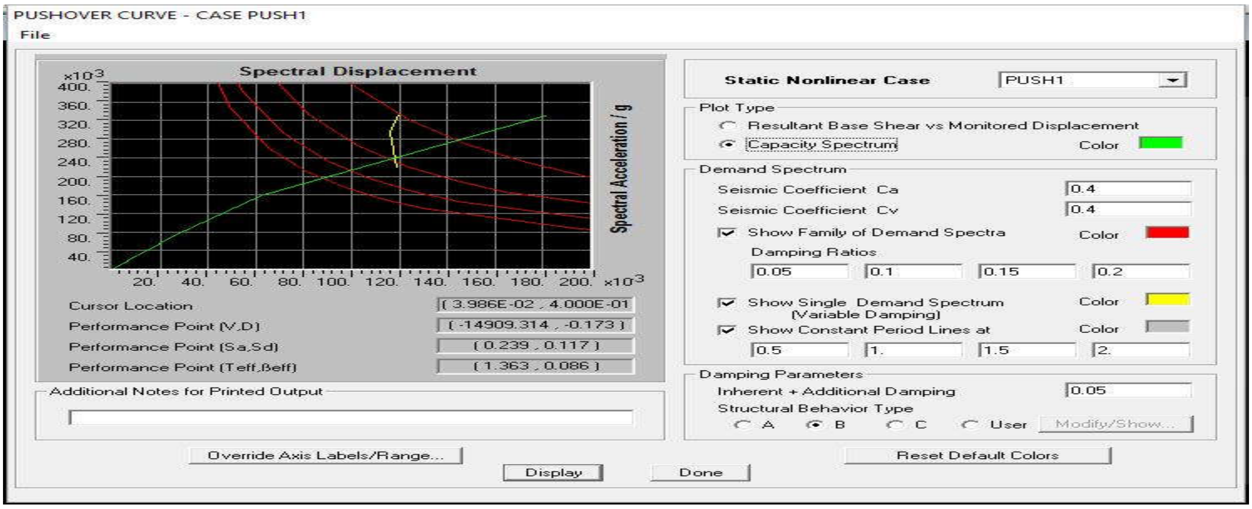


Fig.9. capacity curve for EIS-RC frame

5.2.1.3. 3-D model of EIS-RC composite frame in E-tab-2018

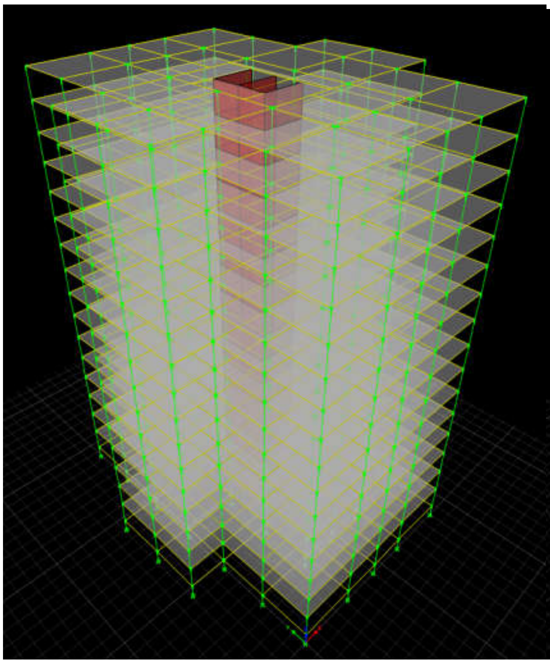


Fig.10. EIS-RC frame at elastic limit

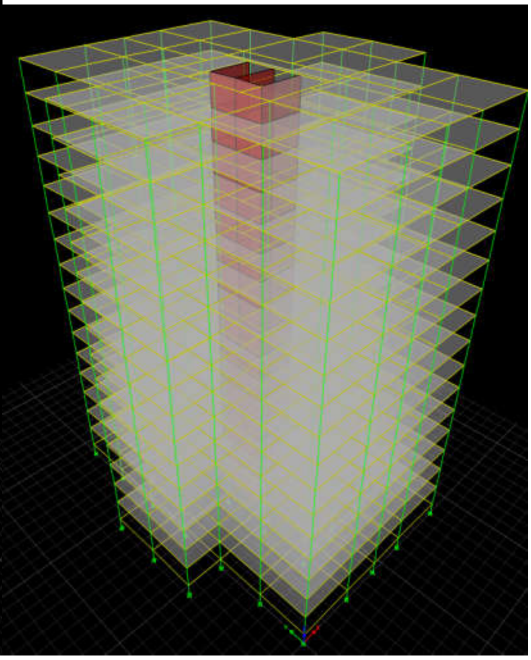


Fig.11. EIS-RC frame at yield point

5.3. Results for ETS-RC (Encased Tube Section column with RC beam) composite frame

5.3.1. Pushover analysis of ETS-RC frame.

Comparative inelastic analysis of RCC and steel-concrete composite frame.

Story	Elevation m	Location	X-Dir	Y-Dir
STORY17	65.519994944	Top	0.00197806458416984	5.91795154036552E-05
STORY16	61.549995264	Top	0.0020187725515172	3.74572169784266E-06
STORY15	57.579995584	Top	0.002134097124587	6.67306282415493E-06
STORY14	53.609995904	Top	0.00226178193977776	8.84808868247006E-06
STORY13	49.639996224	Top	0.00237051414830941	2.03491384626076E-10
STORY12	45.669996544	Top	0.00250157233881759	2.51942923666371E-10
STORY11	41.699996864	Top	0.00262256630218864	3.02108176731248E-10
STORY10	37.729997184	Top	0.00272175567345682	3.52792804586634E-10
STORY9	33.759997504	Top	0.00278794458201994	4.03589854607823E-10
STORY8	29.789997824	Top	0.00280870716307914	4.5392382313711E-10
STORY7	25.819998144	Top	0.00277017972116946	5.02609558027174E-10
STORY6	21.849998464	Top	0.00265653281323683	5.47103411183096E-10
STORY5	17.879998784	Top	0.00244953690204059	5.81966200335399E-10
STORY4	13.909999104	Top	0.00212730310043825	5.95568223610296E-10
STORY3	9.939999424	Top	0.00166649992891754	5.62867168752289E-10
STORY2	5.969999744	Top	0.00106410714905482	6.70499756395196E-05
STORY1	2.000000064	Top	0.000477127641531767	0.000133094159221066
BASE	0	Top	0	0

Fig.12. ETS-RC frame at elastic limit

5.3.2. Capacity curve or pushover point of ETS-RC frame

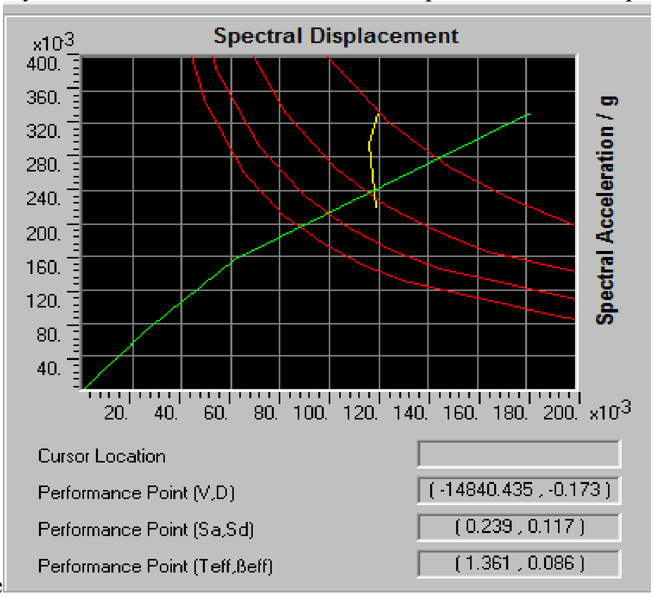


Fig.13. Capacity curve of ETS-RC frame

5.3.3. 3-D model of ETS-RC frame

Comparative inelastic analysis of RCC and steel-concrete composite frame.

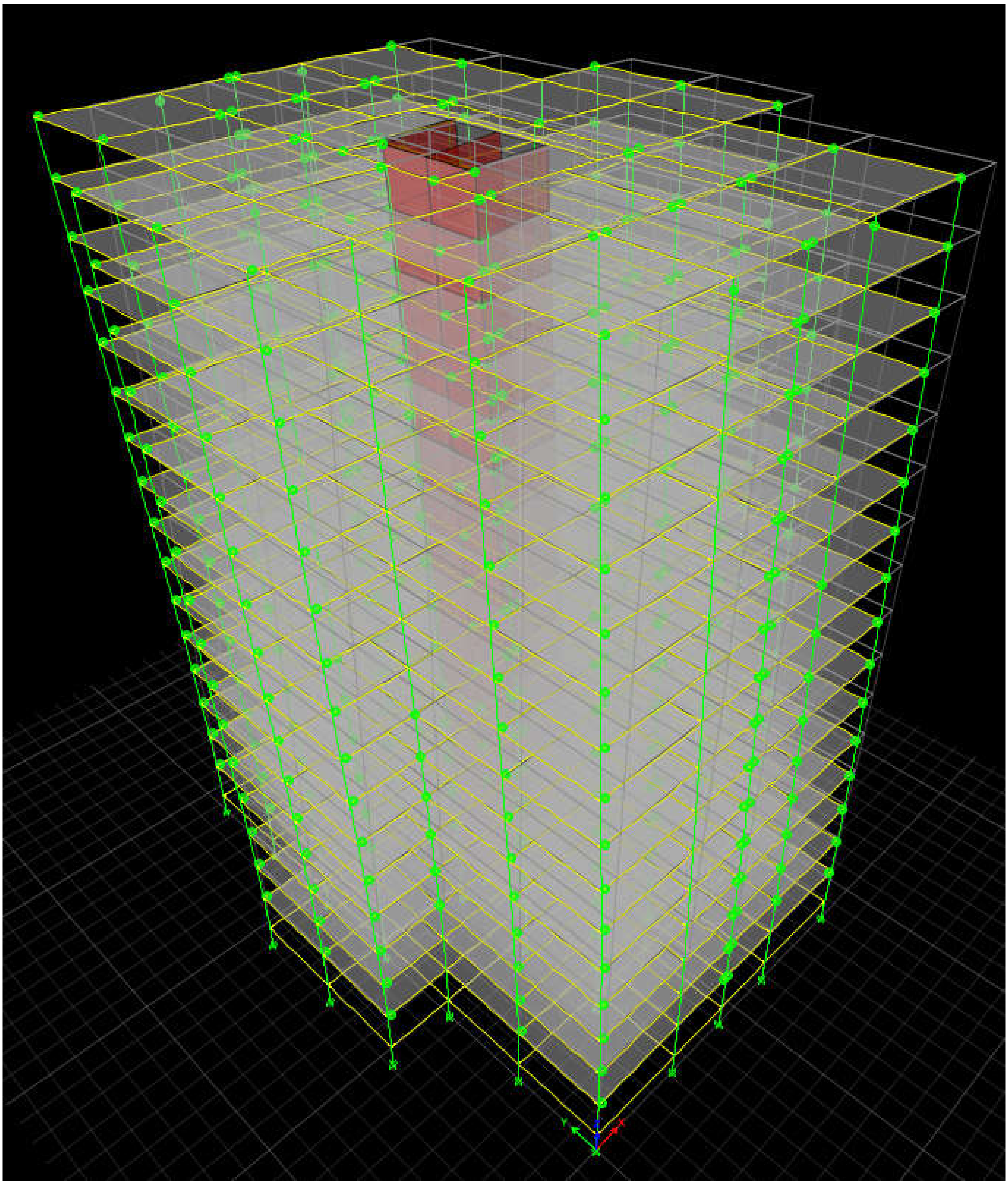


Fig.14. ETS-RC frame at elastic limit

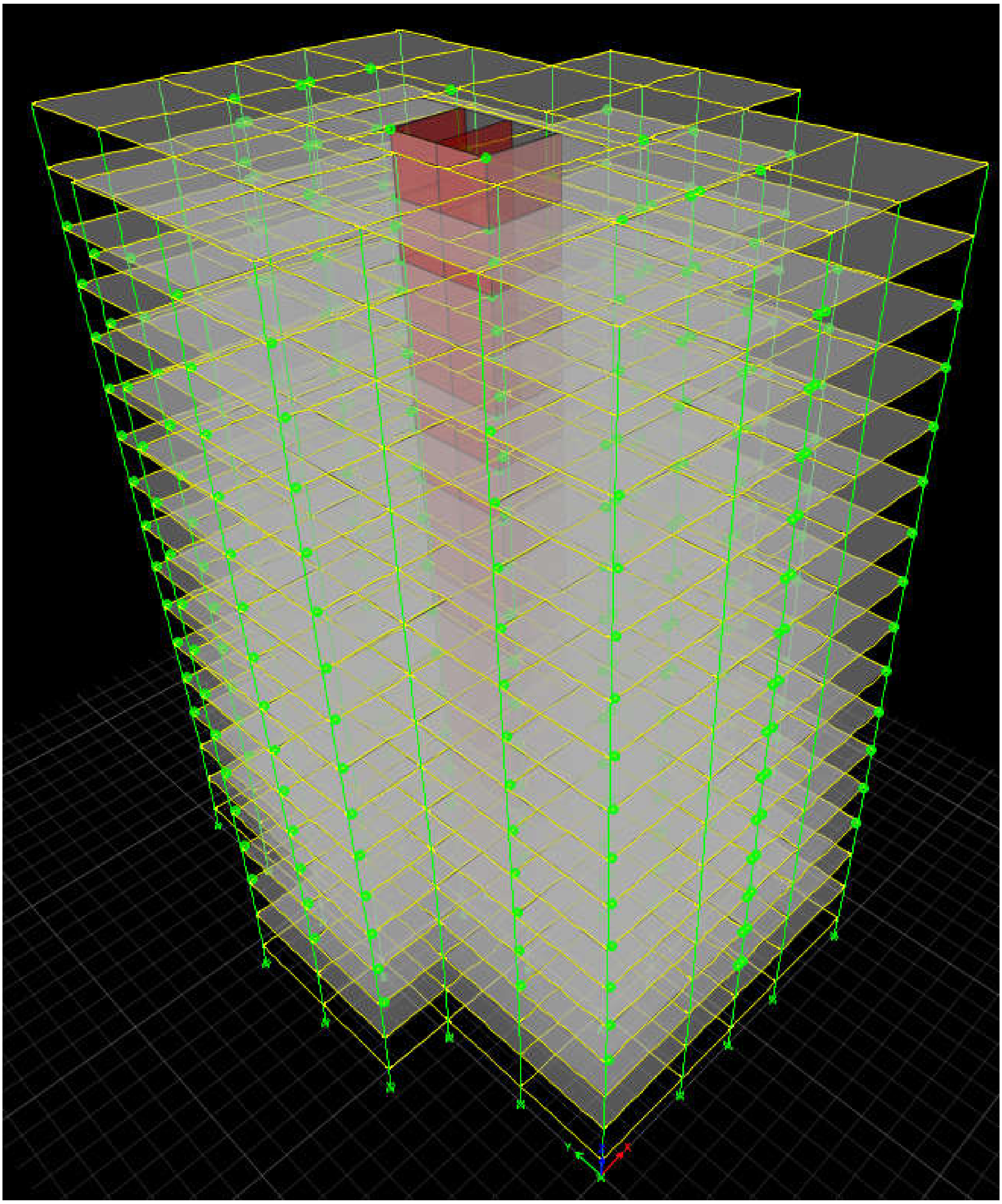


Fig.15. ETS-RC at yield point

5.4. Results for FTS-RC (Concrete Filled Tube Section with RC beam) composite frame

5.4.1. Pushover analysis of FTS-RC frame

Comparative inelastic analysis of RCC and steel-concrete composite frame.

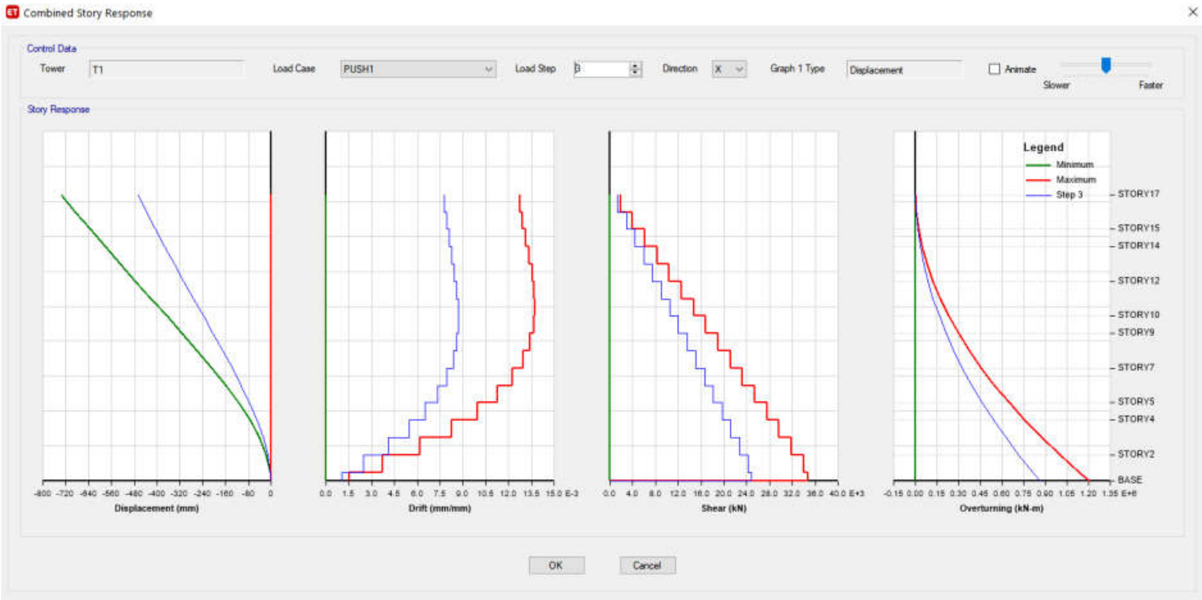
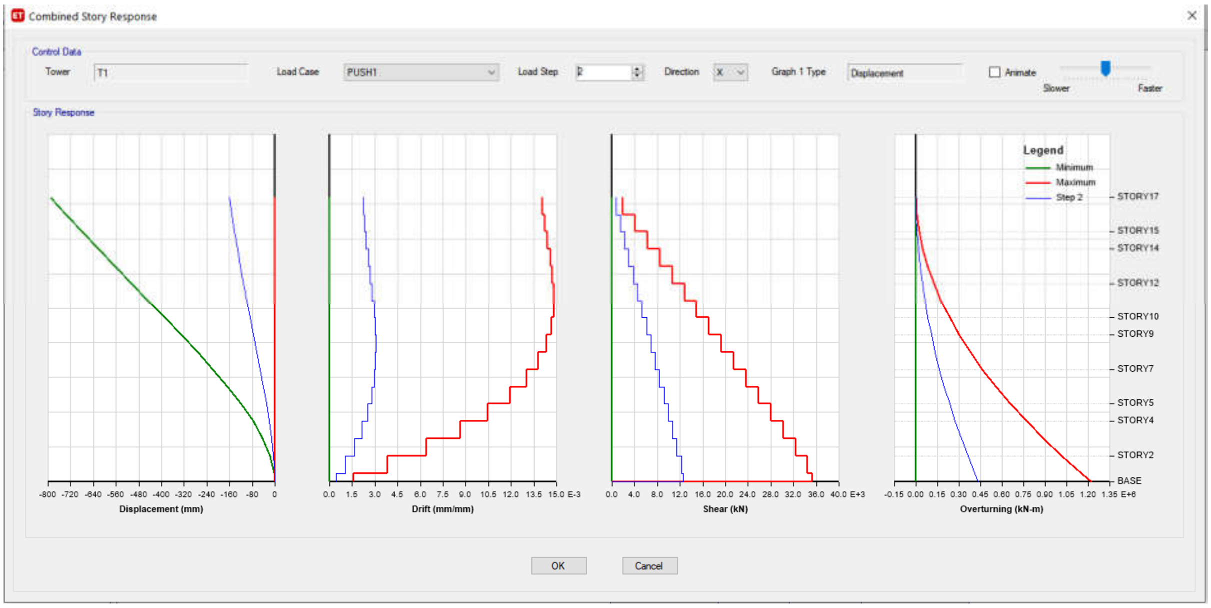


Fig.16. Combined story Response-RC Building



Fog.17. Combined story Response-Composite

5.4.2. 3-D model of CFT-RC frame

Comparative inelastic analysis of RCC and steel-concrete composite frame.

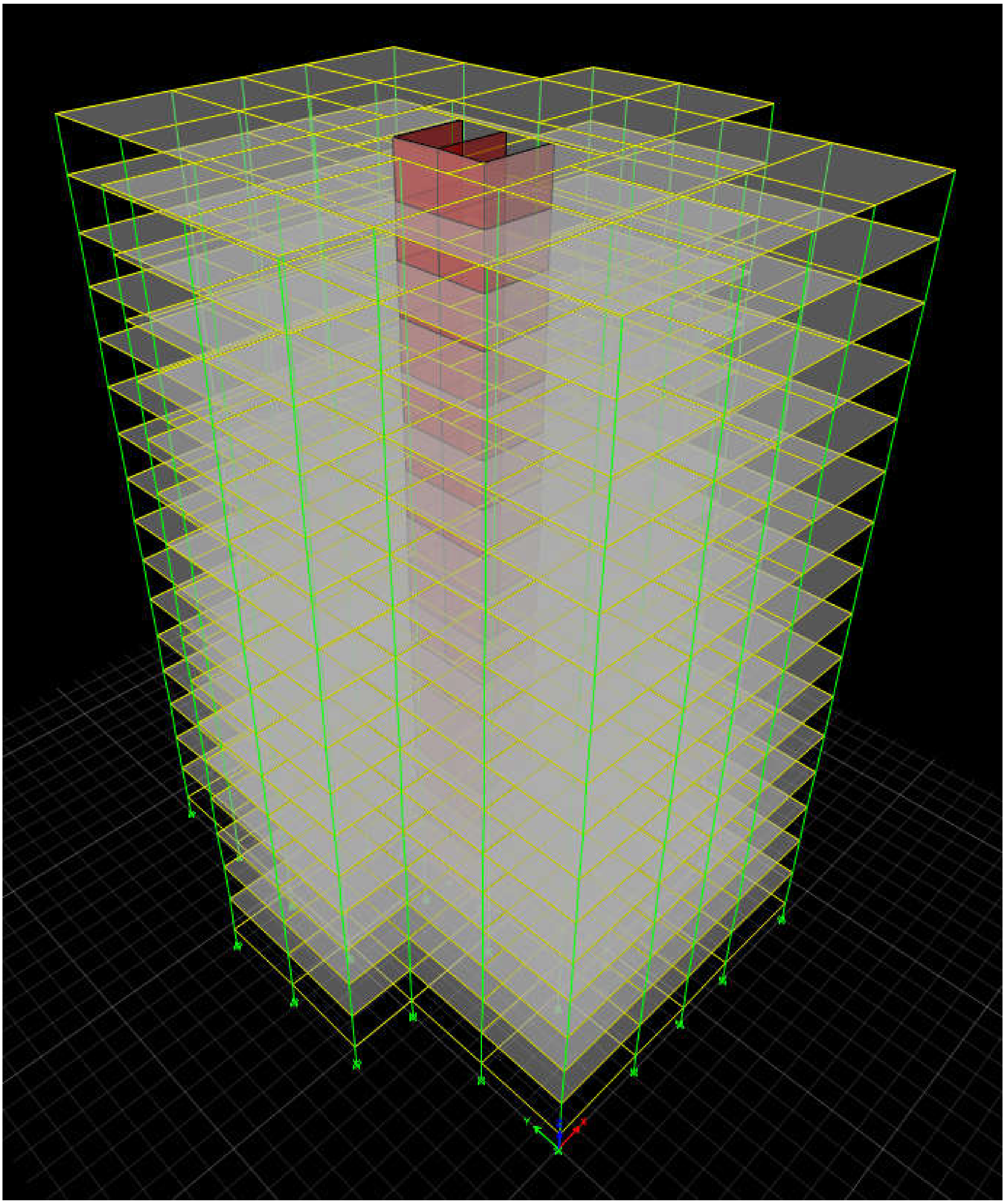


Fig.18. FTS-RC at elastic limit

Comparative inelastic analysis of RCC and steel-concrete composite frame.

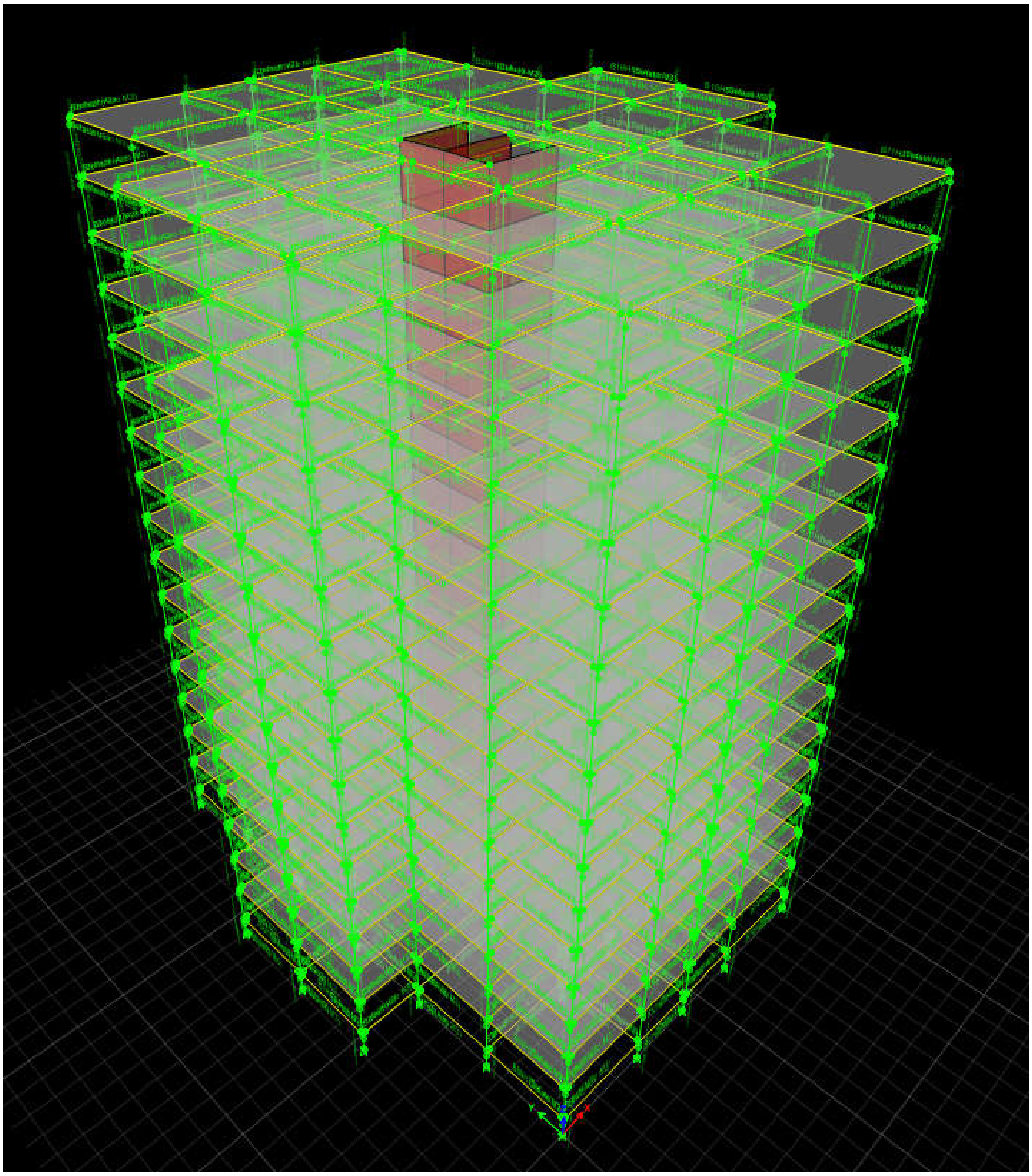


Fig.19. FTS-RC frame at yield point

Comparative inelastic analysis of RCC and steel-concrete composite frame.

5.5. Comparative assessment of performance point and displacement for EIS-RC, ETS-RC, CFT-RC composite frame with RCC frame.

Table 2- Assessment of performance of composite frame with RCC model

TYPES OF MODELS	PERFORMANCE POINT	DISPLACEMENT
RCC	16866.465	0.216
EIS-RC	17612.565	0.192
FTS-RC	19234.165	0.1806
ETS-RC	16946.54	0.1883

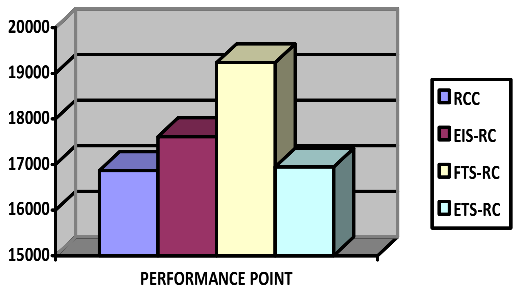


Fig.20. Performance Point of composite & RC frame

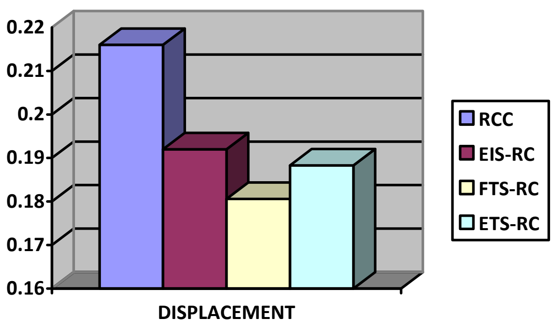


Fig.21 Performance Point (displacement) of composite & RC frame

5.6. Result showing the comparison between self-weight, base shear in X & Y direction of RCC-reinforced concrete section, EIS-RC, ETS-RC, CFT-RC frame.

Comparative inelastic analysis of RCC and steel-concrete composite frame.

7. DISCUSSIONS

1) The composite frame's self-weight is observed to be up to 30% lower than that of the RCC frame.

2) In contrast to RCC frames, the composite frame's base shear can only be 20–50%.

3According to pushover analysis, the composite frame's story displacement is 15% to 20% less than that of the RCC frame.

4) In addition, story drift in composite frames was significantly lower than in RCC frames, by as much as 5–10%.

5) According to the performance point curve, composite frames outperform RCC frames by up to 15% to 20%.

6) The displacement of composite frames is less than that of RCC frames, according to performance metrics.

Conclusion

1)The steel-concrete composite frame has a greater lateral load capacity than an RCC frame, according to the results and discussion above.
2) Compared to RCC frames, steel-concrete composite frames have less lateral displacement.
3) Because hinges are formed in the beam element rather than the column element, the steel-concrete composite frame exhibits strong column weak beam behavior.

Acknowledgements

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