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COMPARATIVE PUSHOVER ANALYSIS OF RCC, STEEL AND COMPOSITE HIGH RISE BUILDING FRAME (G+11) BY USING ETABS

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ABSTRACT*- The majority of building structures are designed and constructed in reinforced concrete which is mainly depends upon availability of the constituent materials and the level of skill required in construction, as well as the practicality of design codes. R.C.C is no longer economical because of their increased dead load, hazardous formwork. However composite construction is a new concept for construction industry. The use of modern composite systems, allowing the erection of multi-story structural frames to proceed at pace, can make it economically prohibitive to delay the construction of each floor while concrete columns are cast. In Japan, however, the superior earthquake resistant properties of composite beam-columns have been long recognized and have become a commonly used for construction in that region. It was therefore necessary to develop seismic design criteria for typically used Indian structural systems, to advance the use of this efficient type of mixed construction. This Project shows comparison of various aspects of building.*

In this project a residential of G+11 multi-story building is studied for Pushover Analysis using ETABS, assuming that material property linear, static and dynamic analysis is performed. These non-linear analysis are carried out and different parameters like displacement, storey drift, Performance point, base shear are plotted. Now it is the demand of time that every structure must be analyzed and designed for lateral forces such as earthquake and wind forces. But generally it is found that the cross sectional area of RCC structural member comes out very heavy with large amount of constituent material such as steel & concrete, which takes large space in construction of multistory building. Under such circumstances composite structure is one of the best options, which not only takes care for earthquake forces but also gives less cross sectional area of structural member and provides large space for utilization in economical way.

KEYWORDS*- Pushover, ETABS, Performance Point, Non-linear*

I. INTRODUCTION

1.1 Introduction to project work

The majority of building frames are designed and constructed in reinforced concrete structures, depending upon the availability of constituent materials and the workmanship required in construction industry along with practicality of the existing design codes. Now a day to fulfill the demand of increasing population there is need of high rise building construction and today in India RC construction is popular to fulfill demand of construction industry. But since from last two decades construction industry experiences drastic changes due to increasing population demand, market condition, and availability of resources (men, money & material) etc. which results new techniques of construction are introduces in industry by inventors which give alternative solution to conventional construction. These are mix type or hybrid construction called as a composite construction, which are make efficient use of constituent material which can be most effective than conventional RC construction. The composite structures is the structures in which sections are made up of building different types of materials such as steel and concrete which are used for construction of beams, columns, slabs etc. Numbers of the studies are carried out on composite construction techniques by different researchers in different parts of the world and found it to be better earthquake resistant and more economical as compared to RCC construction.

In composite or hybrid construction different types of sections are utilized as a encased or in filled sections.

1.2 Alternative construction Techniques-

There are various techniques are used for the fulfillment of demand of construction industry. Some of them are popular due to availability of men, material & money, some of them are popular due to their practicality of design.

There are mainly three types of Construction techniques used for the high rise buildings construction and these are:

- RCC Construction

- Steel Structures
- Composite or hybrid Construction

1.3 Composite construction

Now a day's composite is famous one in foreign countries due to their suitability in construction, also it overcomes the disadvantages of RCC & Steel construction which make the composite or hybrid beneficial for high rise construction though the composite resist lateral forces more effectively compared to the RCC & steel.

In composite structure the advantage of bonding property of steel and concrete is taken in to consideration so that they will act as a single unit under loading. These essentially different materials are completely compatible and complementary to each other; they have almost the same thermal expansion; they have an ideal combination of strengths with the concrete efficient in compression and the steel in tension; concrete also gives corrosion protection and thermal insulation to the steel at elevated temperatures and additionally can restrain slender steel sections from local or lateral-torsional buckling. In conventional composite construction, concrete rests over steel beam and under loading conditions these two component acts independently and a relative slip occurs at the interface of concrete slab and steel beam, which can be eliminated by providing appropriate connection between them. So that steel beam and slab act as composite beam and gives behavior same as that of Tee beam.

In steel concrete composite sections both steel and concrete resists external loads together and helps to limit sway of the building frame. It should be added that the combination of concrete cores, steel frame and composite floor construction has become the standard construction method for multi-story commercial buildings in several countries. The main reason for this preference is that the sections and members are best suited to resist repeated earthquake loadings, which require a high amount of resistance and ductility.

1.3.1 Composite Frame Element

A composite member is constructed by combining concrete member and steel member so that they act as a single unit. As we know that concrete is strong in compression and weak in tension on the other side steel is strong in tension and weak in compression. The strength of concrete in compression is complemented by strength of steel tension which results in an efficient section. By the concept of this composite member the concrete and steel are utilized in well-organized manner.

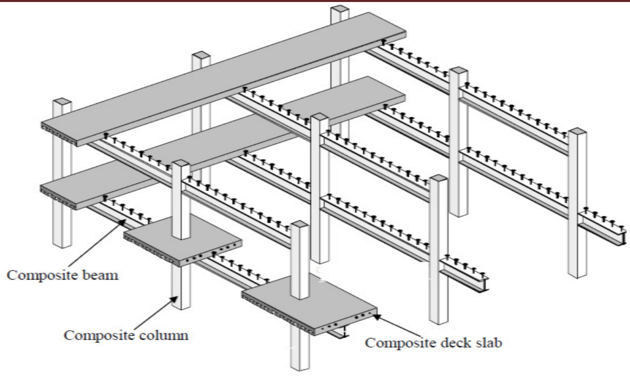


Fig no.1: Composite Frame

Composite Element-

The primary structural components used in composite construction consist of the following elements.

a. Composite Slab
b. Composite Beam
c. Composite Column
d. Shear Connector

II. METHODOLOGY

To perform the proposed project work it is necessary to adopt the proper methodology, which can helpful to meet requirement of proposed objective of this work in all respect. It also provides the base and gives the strong support for this work. It contains theoretical concepts, design philosophy & analysis of members etc.

Adaptability of computer programs

It is well known fact the distribution of mass and rigidity is one of the major considerations in the seismic design of moderate to high rise buildings. Invariably these factors introduce coupling effects and non-linearity in the system; hence it is imperative to use non-linear static analysis approach by using specialized programs viz.SAP2000, STAADPRO2005, ETAB, IDARC, NISA-CIVIL, etc., for cost-effective seismic evaluation and retrofitting of buildings.

2.1 Methods of Analysis

Seismic Analysis

Seismic analysis is a subset of structural analysis and is the calculation of the response of a building (or non-building) structure to earthquakes. It is part of the process of structural design, earthquake engineering or structural assessment and retrofit (see structural engineering) in regions where earthquakes are prevalent.

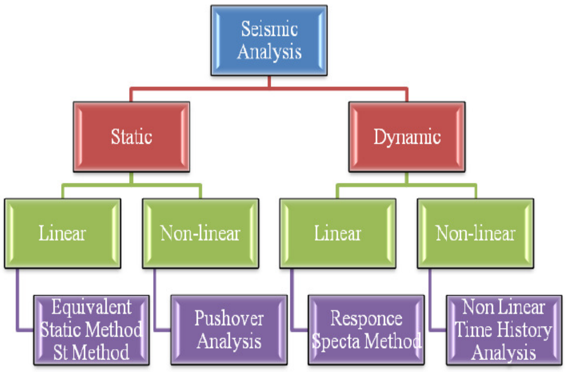
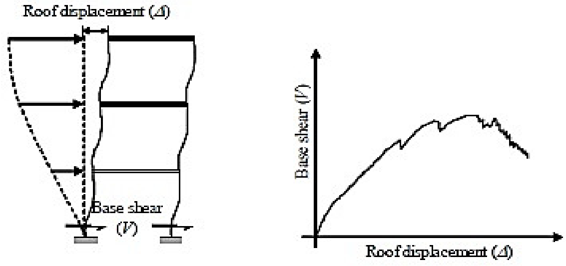


Fig No.2 Tree Diagram of Seismic Analysis

2.2 Pushover analysis (Non-Linear Static Analysis)

This is the important chapter in this project work considering meeting the requirement of proposed objective. This chapter gives the information regarding pushover analysis which is going to be performing using ETABs. It describes the concept of pushover analysis which is helpful in understanding the phenomena of building performance during its performance.

- Pushover analysis is a static, nonlinear procedure using simplified nonlinear technique to estimate seismic structural deformations.
- It is an incremental static analysis used to determine the force-displacement relationship, or the capacity curve, for a structure or structural element.
- The intensity of the lateral load is slowly increased and the sequence of cracks, yielding, plastic hinge formation, and failure of various structural components is recorded.
- The process continues until the design satisfies pre-established performance criteria. The performance criteria for pushover analysis are generally established as the desired state of the building given roof-top or spectral displacement amplitude.
- Pushover analysis is a simplified nonlinear analysis whose central focus is generation of the pushover curve or capacity curve.
- This represents the lateral displacement as a function of force applied to the structure.
- This capacity curve is representation of the structures ability to resist the seismic demand.
- To generate the capacity curve, the structure is pushed in a representative lateral load pattern which is applied monotonically while the gravity loads are in place.
- For a given structure and ground motion, the displacement demand is an estimate of maximum expected response of building during ground motion. Once capacity curve and demand displacement are defined, a performance point can be determined.
- The analysis techniques are recommended by FEMA-356 and a main component of the Spectrum Capacity Analysis method (ATC-40)



a) Building model b) Pushover curve

A predefined lateral load pattern as shown in fig. which is distributed along the building height is then applied. The lateral forces are increased until some members yield.

The structural model is modified to account for the reduced stiffness of yielded members and lateral forces are again increased until additional members yield. The process is continued until a control displacement at the top of building reaches a certain level of deformation or structure becomes unstable.

2.2.1 Purpose

The purpose of pushover analysis is to evaluate the expected performance of structural systems by estimating performance of a structural system by estimating its strength and deformation demands in design earthquakes by means of static inelastic analysis, and comparing these demands to available capacities at the performance levels of interest. The evaluation is based on an assessment of important performance parameters.

2.2.2 Necessity

The existing building can become seismically deficient, since seismic design code requirements are constantly upgraded and advancement in engineering knowledge. Further, Indian buildings built over past two decades are seismically deficient because of lack of awareness regarding seismic behavior of structures. The widespread damage especially to RC buildings during earthquakes exposed the construction practices being adopted around the world, and generated a great demand for seismic evaluation of existing building.

2.2.3 Description

The nonlinear static pushover procedure was originally formulated and suggested by two agencies namely, Federal Emergency Management Agency (FEMA) and Applied Technical Council (ATC), under their seismic rehabilitation programs and guidelines. This is included in the documents, FEMA356 and ATC40.

a) FEMA356

The primary purpose of FEMA356 document is to provide technically sound and nationally acceptable guidelines for the seismic rehabilitation of buildings. The guidelines for the seismic rehabilitation of buildings are intended to serve as a ready tool for design professionals for carrying out the design and analysis of buildings, a reference document for building regulatory officials, and a foundation for the future development and implementation of building code provisions and standards.

b) ATC40

Seismic evaluation and retrofit of concrete buildings commonly referred to as ATC40 was developed by the Applied Technology Council (ATC) with funding from the California Safety Commission. Although the procedures recommended in this document are for concrete buildings, they are applicable to most building types.
ATC40 recommends the following steps for the entire process of evaluation and retrofit:

1. Initiation of a project: determine the primary goal and potential scope of the project.
2. Selection of qualified professionals: select engineering professionals with a demonstrated experience in the analysis, design and retrofit of buildings in seismically hazardous regions. Experience with PBSE and nonlinear procedures are also needed.
3. Performance objective: choose a performance objective from the options provided for a specific level of seismic hazard.
4. Review of building conditions: perform a site visit and review drawings.
5. Alternatives for mitigation: check to see if the nonlinear procedure is appropriate or relevant for the building under consideration.
6. Peer review and approval process: check with building officials and consider other quality control measures appropriate to seismic evaluation and retrofit.
7. Detailed investigations: perform a nonlinear static analysis if appropriate.
8. Seismic capacity: determine the inelastic capacity curve also known to pushover curve, covert to capacity spectrum.
9. Seismic hazard: obtain a site specific response spectrum for the chosen hazard level and convert to spectral ordinates format.
10. Verify performance: obtain performance point as the intersection of the capacity spectrum and the reduced seismic demand in spectral ordinates (ADRS) format. Check all primary and secondary elements against acceptability limits based on the global performance goal.

2.3 Design Parameters

1. Total load
2. Base shear
3. Storey displacement
4. Storey drift
5. Pushover curve
6. Capacity curve
7. Capacity spectrum
8. Performance point value
9. Plastic Hinge Formation

2.4 DETAILS OF PROJECT WORK

The proposed building presented in dissertation work for inelastic analysis is an existing multistoried (G+13) building located in Pune city. The elements of the building are make composite i.e. encased & in filled concrete section by using the proposed formulae presented from journals and are given here. Mostly the columns are design as encased & in filled by using these formulae and the beams are kept as RC & steel element.

In this work we are created the steel-concrete composite frame using ETAB as an EIS-RC (Encase I section column with RC Beam), EIS-SB (Encased I Section with Steel Beam), CFT-RC (Concrete filled Square Tube with RC Beam), CFT-SB (Concrete filled Square Tube with Steel Beam) RCC frame, Steel frame. The geometrical details of existing multistory building frame as shown in fig.

Future scope

Try to suggest the suitability of composite structure as compared to RCC & steel structures. The project work helps to understand the different parameters of pushover analysis of composite, RCC & steel structure respectively. Further extension of work gives the capacity based design concept which is measure parameter of strong column & weak beam theory.

Geometric & material properties

Description	RCC structure & Steel Structure	Composite structure
Plan dimension	31mX19m	31mX19m
Height of each story	3.00m	3.00m
Total height	33.2m	33.2m
Depth of footing	2m	2m
Size of beam	300 mm X650 mm	300 mm X650 mm ISWB 500
Size of column	750mmX900mm 450mmX900mm	Encased I section ISWB 550
		300mmX900mm
		450mmX900mm
		600mmX900mm
		750mmX900mm
Slab thickness	125 mm	125mm
	150mm	150mm
Dead load	2kn/m2	2kn/m2
Live load	4kn/m2	4kn/m2
Seismic zone	V	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 steel	Fe500	Fe500
Damping ratio	5%	5%

Table no. 1

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Plan of G+11 Commercial Building

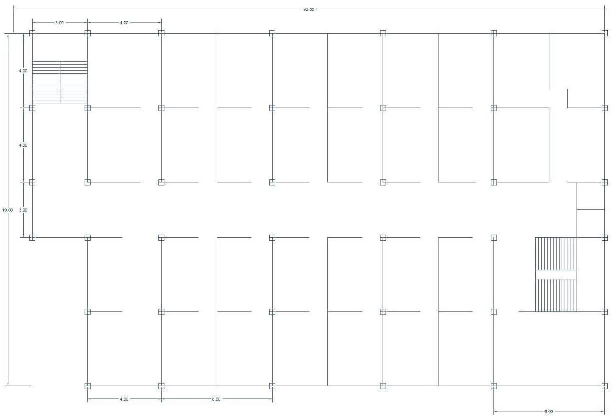


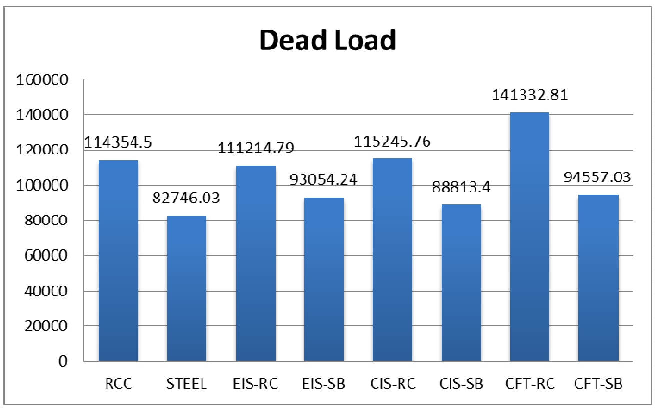
Fig 3. Plan of G+11 Commercial Building

2.4.1 Dead load

It is the total dead load of frame. Results show that the total load of RCC is maximum as compare to the steel-concrete composite frame which is given in table no. 2

Description	Dead load (KN)
RCC	114354.50
STEEL	82746.03
EIS-RC	111214.79
EIS-SB	93054.24
CIS-RC	115245.76
CIS-SB	88813.40
CFT-RC	141332.81
CFT-SB	94557.03

Table No. 2 : Dead Load



Graph No. 1

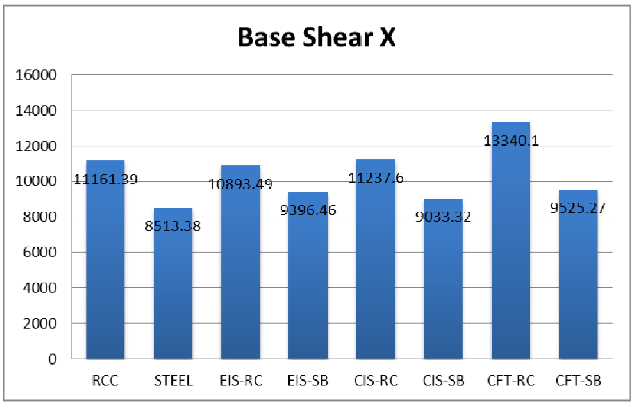
2.4.2 Base shear

As per cl. no. 4.7 in IS 1893-2002 Design Seismic Base Shear (V_B) is the total design lateral force at the base of a structure. The base shear in direction X & Y are describes as given below. The following table 3 & 4, graph shown in graph No. 2 & 3 gives variation in base shear of conventional & steel-concrete composite frame

Variation in base shear in X-direction

Description	BASE SHEAR EQX (KN)
RCC	11161.39
STEEL	8513.38
EIS-RC	10893.49
EIS-SB	9396.46
CIS-RC	11237.60
CIS-SB	9033.32
CFT-RC	13340.10
CFT-SB	9525.27

Table No. 3 Base Shear in X Direction

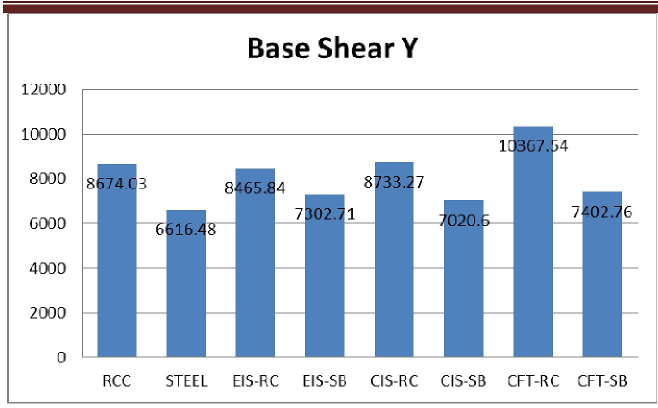


Graph No. 2

Variation in base shear in Y-direction

Description	BASE SHEAR EQY (KN)
RCC	8674.03
STEEL	6616.48
EIS-RC	8465.84
EIS-SB	7302.71
CIS-RC	8733.27
CIS-SB	7020.60
CFT-RC	10367.54
CFT-SB	7402.76

Table No. 4 Base Shear in Y Direction



Graph No. 3

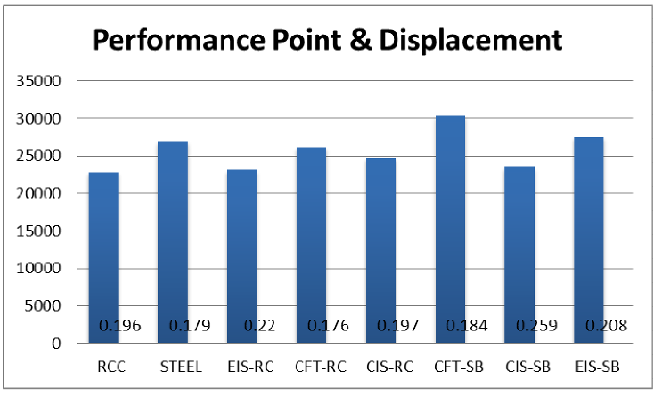
2.4.3 Performance point value & displacement

The results present here are describes the performance point value & displacement of both RCC & steel-concrete frame as shown in table no. 4

Performance point & displacement of frame

TYPES OF MODELS	PERFORMANCE POINT	DISPLACEMENT IN M
RCC	22839.57	0.173
STEEL	26929.41	0.179
EIS-RC	23140.67	0.172
CFT-RC	26146.69	0.176
CIS-RC	24764.99	0.170
CFT-SB	30366.63	0.157
CIS-SB	23571.85	0.159
EIS-SB	27496.11	0.158

Table No. 5 Performance point & displacement of frame



Graph No. 4

RESULTS AND CONCLUSION -

Inelastic/pushover analysis of both RCC & Composite frame is carried out using ETAB. The outcome from the analysis is described with respective to various parameters in this chapter and comparative analysis is done with RCC frame. The results from above analysis shows that in case of dead load and Base Shear the sections of Steel, EIS-SB, CIS-SB & CFT-SB gives minimum dead load as compare to RCC. The Performance Point of CFT-RC is maximum as compare to RCC.

Hence we can conclude that the composite sections are more preferable than RCC for high rise building.

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