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SEISMIC ANALYSIS AND DESIGN OF IRREGULAR COMPOSITE STEEL-CONCRETE STRUCTURE AND ITS COMPARISON WITH RCC STRUCTURE

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Abstract— In developing countries like India, the increase in the population creates demand for high rise structures for which we are facing scarcity of land. In present situation it has become necessary to consider economy of the structure which is more important. Generally we have RCC type of structures for the construction of Multi storied buildings. As we all know RCC building requires bulky size of components that increases the self weight of the structure which in turn increases cost of construction. Therefore to overcome this cause resulted in the practice of new innovative and efficient building method, which is Composite steel-concrete structure. Composite structure is a type of building method consisting of composite beam, composite column and composite deck slab which is connected with shear connectors. Composite structure consists of both steel and concrete resulting in better ductile behavior than that of RCC system. In this study 10 storied building is considered which is modeled and dynamic analysis is carried out with the use of ETABS software. Results from both the type of structure are compared and concluding that which structure is more recommendable and economical.

Keywords— Composite structure, RCC (Reinforced Cement Concrete) structure, Composite beam, Seismology, Seismic weight, Storey stiffness.

I. INTRODUCTION

In developing countries like India, use of steel in the construction industry is very low. Though India has a great potential for increasing the volume of steel, we are experiencing a lack of usage of steel in construction industry which indirectly effecting the economy of the country. Now-a-days use of composite section which is steel encased with concrete is becoming more effective for the construction of high rise building and bridges. Composite sections are economic, cost and time effective for building construction. For low-rise structures RCC construction is found to be more

sufficient because of action of gravity loads alone, whereas in case of medium and high rise structure we have to face the action of both gravity and lateral loads such as earthquake (seismic) and wind load. Use of composite construction is one such method with which we can achieve safety and economy.

II. DIFFERENT METHODS OF BUILDING CONSTRUCTION

A. Concrete structures – It is the most commonly used construction material across the world. Concrete can only take compressive stresses effectively and it cannot take tensile stresses. So in order to withstand tensile loads, reinforcement is given to concrete. Because of its durability and compatibility, concrete is widely used today in construction industry. Concrete has a property to mould in any shape that makes it most useful. These structures can be made with many different ways such as Plain Cement Concrete, Reinforced Cement Concrete and Pre-stress Concrete.

B. Steel structures – It is an alloy of iron and small carbon percentage and other elements, for example silicon, phosphorous and sulphur in varying percentage. Different types of steel used are mild steel, medium carbon steel, high carbon steel, low alloy steel. Structural steel is used for building purposes. Steel which is used for the manufacture of structural elements such as rolled steel elements, fastenings and various other elements for the use in structural steel works is known as structural steel. It has been standardized by Indian Standard Institution for the use of proper quality of steel.

C. Composite steel-concrete structures – It is defined as structures in which composite action exist by bounding two different materials together so strongly that they act together act as a single unit forming structural action criteria. In general it may be steel beams supporting concrete floor slabs. The unique feature of composite structures is that it will reduce overall weight of the structure, increased performance and also increases economy of the construction. This type of



construction is dominating over more than a decade due to strength and stiffness achieved with minimum use of materials.

III. LITERATURE REVIEW

Prof. Rajendra R. Bhoir., et.al. (2017) studied seismic performance of the composite steel-concrete structures and the result is compared with RCC structures. In their work, authors have performed the static analysis on G+15 multi-storied regular composite and RCC structure using E-tabs software. They have considered two models by changing floor heights in two models. The work is carried out on commercial building, and then the result is tabulated and compared in terms of volume of construction material such as concrete, Reinforcing steel and Structural steel and other result parameters are cost of both composite and RCC structure, axial force, bending moment. They concluded that composite structure reduces the overall cost of the structure and increases the economy of the construction by minimizing the requirement of basic construction materials. Considering Earthquake factor, since composite structure has inherent ductility characteristics it performs better under the action of lateral loads than RCC structure.

K. Mukesh kumar and H. Sudarshana Rao., et.al. (2016) studied Seismic behavior of composite structure and it is compared with RCC structures. In their work, authors have considered three different models by differentiating them from low to high rise RCC and Composite structures say 5, 10 and 15 storied regular structure. Seismic analysis is carried out for earthquake zone IV which is said to be worst case or scenario. Here they have carried out dynamic analysis which includes Non-linear Time-history analysis and Response Spectrum analysis. E-tabs software is been used for modeling and analysis. The comparison of the seismic response on the displacement, story drifts, column axial forces, column bending moments and shear forces, beam shear forces and bending moments, time period of the structure and dead weight of the structure. They concluded that increased stiffness parameter in RCC structure leading to less time period and making it less flexible than RCC, maximum displacements and drifts is observed in composite structures since it is more flexible and dead weight of the composite structure is less than RCC structure because of usage of thin sections making the structure less susceptible against seismic force acting on structure.

A.S. Mahajan and L.G. Kalurkar., et.al. (2016) compared the behavior of high rise composite and RCC building using E-tabs 2015 software. Their work made us to understand the fact that application of composite model is not just habitable, stable and safe but also time saving and cost effective. They carried out analysis on G+20 multi storied building for which American standards provisions are considered for composite building and the conventional RCC structure is designed

according to IS 456-2000. Seismic assessment and comparison is done considering different parameters such as bending moment, shear force, base shear, cost of structure, Time period and weight of structure are studied for composite and RCC model. Response spectrum analysis is carried out for knowing seismic performance. They concluded that composite structure performs better in every aspect than RCC structure.

Umesh Rajendra Tubachi and Manohar. K., et.al. (2019) carried out analysis of steel concrete composite structure and its comparison with RCC structure. In this work they have considered G+30 high rise regular building and analysis is done with the help of E-tabs software, and working out analysis considering static, dynamic and wind analysis. Results are compared with the help of plotting graphs. Composite structure is analyzed using American standards and for RCC structures Indian codes has been used. They concluded that in terms of dead load of structure, storey drift, displacement and torsion moment of composite structure is lesser than the RCC structure making it more preferable for the adoption in construction industry.

Venkateswar Reddy. K., et.al. (2019) carried out seismic behavior of steel-concrete composite structure using Euro code. In this work authors have analyzed behavior of composite beam using ANSYS and SAP software; and also analysis of G+3 residential building is analyzed using STAAD Pro software. Column end moments and Beam maximum moments is tabulated and concluded that dead weight of structure is much lesser than RCC building; composite column has more flexural stiffness than the RCC section.

IV. OBJECTIVES OF PRESENT INVESTIGATION

- To study the response of composite steel-concrete building subjected to lateral loads such as seismic loads.
- To study the importance of steel in the construction industry and its application to multi-storied irregular building.
- To analyze the behavior of the composite steel-concrete building for the critical earthquake zone scenario.
- To compare the RCC and Composite steel-concrete structures and concluding the results considering parameters such as dead weight, storey deflection, storey drift, base shear etc.

V. SEISMIC ANALYSIS OF RCC AND COMPOSITE STRUCTURES

Seismic Analysis is carried out to determine the effect of earthquake load on the structure. Seismic analysis is done in order to determine the seismic response which is necessary for high rise buildings since they are more vulnerable to seismic activity. Load parameters are considered as per IS: 875 Part 1 and 2 for both RCC and Composite structures whereas Seismic parameters for RCC model is as per IS: 1893-2002 and for composite model is as per AISC 7-10.

Methods of seismic analysis includes following four types:

- Linear Static Analysis
- Nonlinear Static Analysis
- Linear Dynamic Analysis
- Nonlinear Dynamic Analysis

Details of RCC model:

TABLE I
BUILDING DETAILS

Sl.No	Quantity	Preliminary data
1	Plan dimension	44.14m x 47.995m
2	Height of the building	30.00m
3	Height of each storey	3.00m
4	Size of beam	300 x 600mm, 300 x 650mm 300 x 700mm, 300 x 750mm
5	Size of column	300 x 900mm, 300 x 1200mm
6	Slab thickness	125mm
7	Wall thickness	200mm
8	Grade of concrete	30 N/mm ²
9	Grade of steel	500 N/mm ²
10	Live load	2.00kN/m ²
11	Floor finish	1.20kN/m ²
12	Wall load	10.00kN/m
13	Partition load	5.00kN/m
14	Earthquake zone	V
15	Zone factor	0.36
16	Importance factor	1.00
17	Soil type	Hard soil
18	Response reduction factor	3.00
22	Fundamental natural period	0.40 sec

ETABS model:

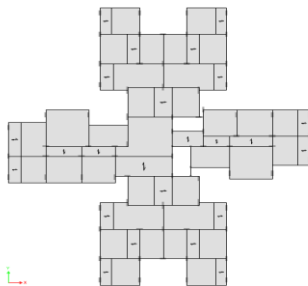


Fig 1: ETABS plan of RCC model

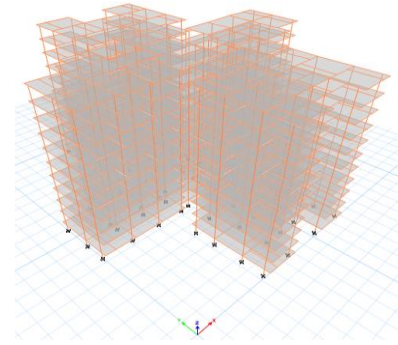


Fig 2: Isometric view of RCC model

Details of Composite model:

TABLE II
BUILDING DETAILS

Sl.No	Quantity	Preliminary data
1	Plan dimension	44.14m x 47.995m
2	Height of the building	30.00m
3	Height of each storey	3.00m
4	Size of beam	W18 x 130
5	Size of column	W18 x 106, 450 x 650mm
6	Slab thickness	125mm
7	Wall thickness	200mm
8	Grade of concrete	4000psi
9	Grade of steel	A992fy50
10	Live load	2.00kN/m ²
11	Floor finish	1.20kN/m ²
12	Wall load	10.00kN/m
13	Partition load	5.00kN/m
14	Earthquake zone	V
15	Zone factor	0.36
16	Importance factor	1.00
17	Soil type	Hard soil
18	Response reduction factor	3.00
22	Fundamental natural period	0.96 sec

ETABS model:

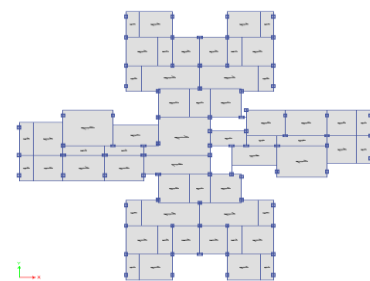


Fig 5: ETABS plan of Composite model

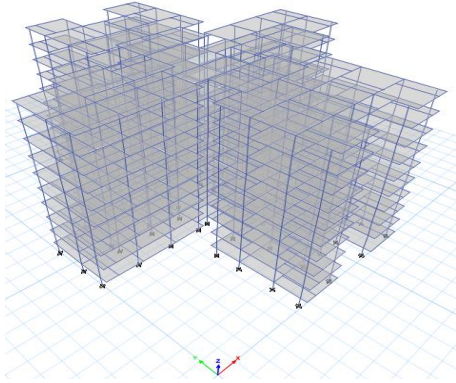


Fig 6: Isometric view of Composite model

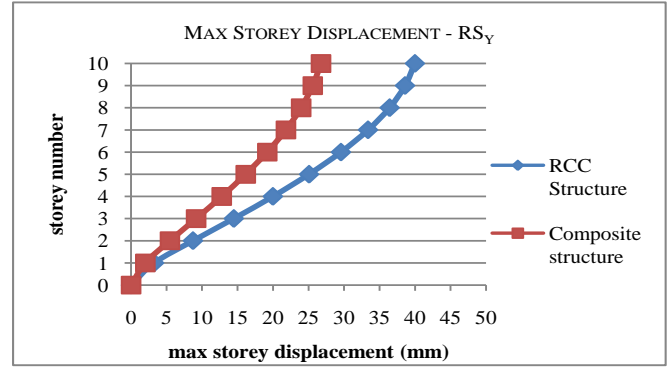


Chart 2: Max storey displacement in y-direction

2) Storey drift

VI. RESULTS AND DISCUSSION

RESULTS:

1) Storey displacement

TABLE III
MAX STOREY DISPLACEMENT

Sl.No	RCC STRUCTURE		COMPOSITE STRUCTURE	
	RS _x	RS _y	RS _x	RS _y
10	56.392	39.979	45.356	26.754
9	53.499	38.595	42.894	25.595
8	49.171	36.418	39.54	23.959
7	43.592	33.392	35.328	21.811
6	37.652	29.579	30.383	19.186
5	31.33	25.074	25.126	16.147
4	24.478	19.992	19.397	12.773
3	17.268	14.475	13.365	9.166
2	10.04	8.736	7.323	5.471
1	3.441	3.257	2.202	2.017
B	0	0	0	0

TABLE IV
MAX STOREY DRIFT

Sl.No	RCC STRUCTURE		COMPOSITE STRUCTURE	
	RS _x	RS _y	RS _x	RS _y
10	3.707	2.943	1.406	1.169
9	5.455	4.057	2.209	1.65
8	6.736	4.969	3.063	2.163
7	6.807	5.592	3.847	2.639
6	6.883	5.674	4.535	3.05
5	7.189	5.981	5.107	3.38
4	7.369	6.148	5.538	3.61
3	7.286	6.077	5.756	3.696
2	6.617	5.125	5.494	3.455
1	3.441	2.202	3.257	2.017
B	0	0	0	0

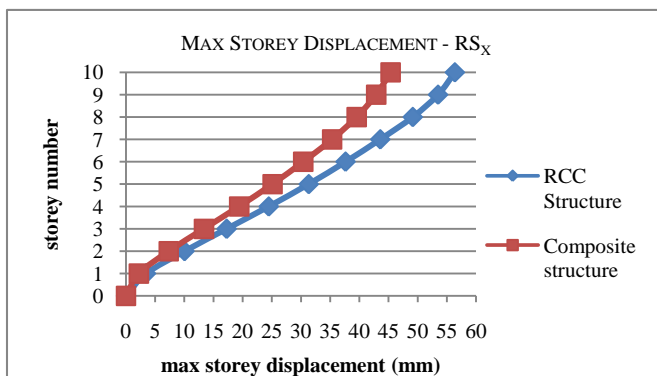


Chart 1: Max storey displacement in x-direction

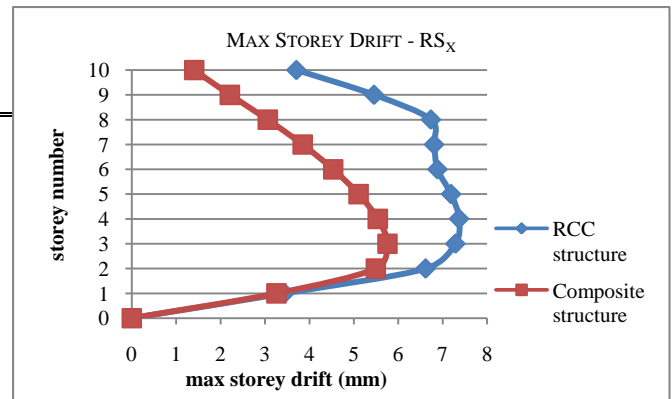


Chart 3: Max storey drift in x-direction

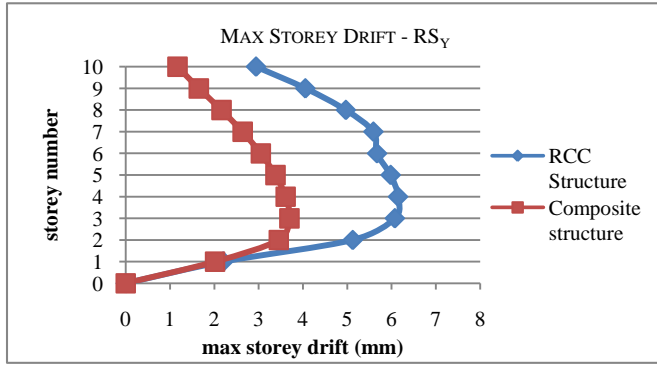


Chart 4: Max storey drift in y-direction

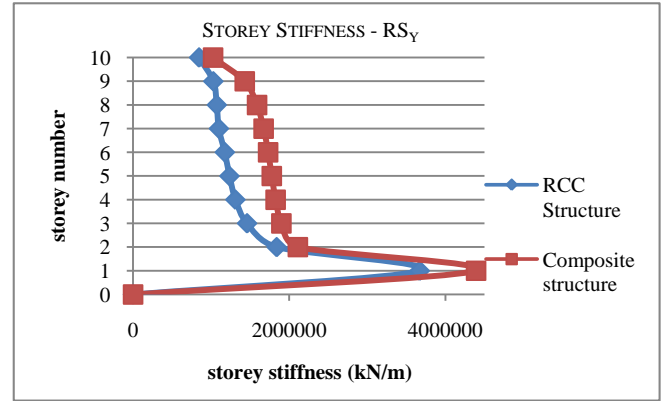


Chart 6: Storey stiffness in y-direction

3) Storey stiffness

TABLE V
STOREY STIFFNESS

Sl.No	RCC STRUCTURE		COMPOSITE STRUCTURE	
	RS _x	RS _y	RS _x	RS _y
10	691625	845072	785827	1024223
9	782925	1028905	1005381	1429236
8	804934	1072331	1065569	1587415
7	884878	1098759	1094806	1671823
6	983796	1175295	1113709	1729009
5	1031206	1235281	1129300	1776279
4	1109347	1311680	1146230	1825222
3	1177335	1460325	1219828	1899646
2	1284141	1840152	1439678	2110060
1	2203989	3671087	2923621	4392933
B	0	0	0	0

4) Storey forces

TABLE VI
STOREY FORCES

Sl.No	RCC STRUCTURE		COMPOSITE STRUCTURE	
	RS _x	RS _y	RS _x	RS _y
10	2424.54	2326.22	1055.16	1071.14
9	4058.48	3984.20	2133.39	2158.51
8	5145.49	5120.07	3138.86	3164.71
7	5878.26	5893.32	4054.93	4074.89
6	6471.11	6516.55	4867.17	4875.55
5	7088.11	7135.18	5562.02	5554.40
4	7771.89	7838.21	6126.30	6099.99
3	8486.42	8542.38	6547.22	6501.51
2	9111.87	9139.57	6813.20	6750.60
1	9439.32	9401.27	6921.85	6848.96
B	0.00	0.00	0.00	0.00

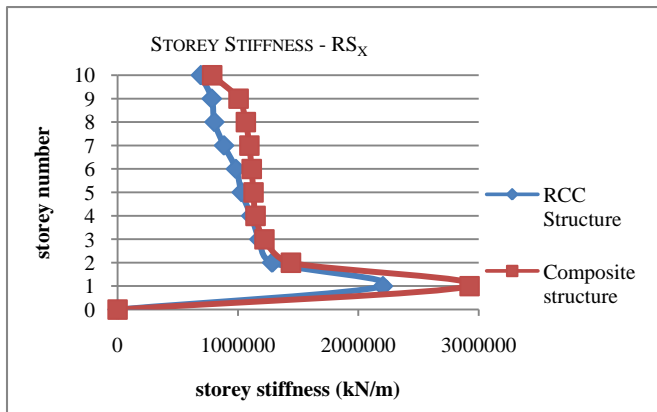


Chart 5: Storey stiffness in x-direction

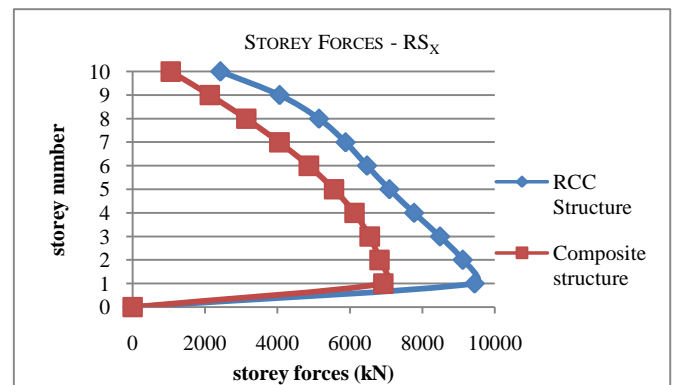


Chart 7: Storey forces in x-direction

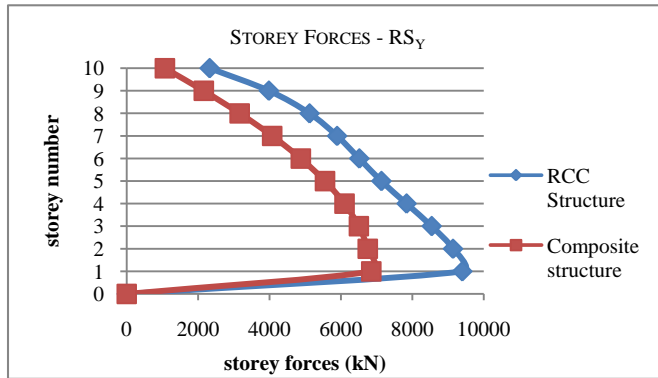


Chart 8: Storey forces in y-direction

DISCUSSION:

- Maximum storey displacement in composite structure is less when compared to RCC structure in both the direction.
- Maximum storey drift evaluated is minimum in composite structure compared to RCC structure in x and y direction respectively.
- Storey stiffness in composite structure is greater compared to RCC structure.
- Storey forces in composite structure is less when compared to RCC structure in both x and y direction respectively.

VII. CONCLUSION

- A. Max storey displacement of the composite structure is varying in between the range 20.00% to 36.00% less than the RCC structure.
- B. Max storey drift of the composite structure is varying in between the range 10.00% to 60.00% less than the RCC structure.
- C. Storey stiffness of the composite structure is 17.50% higher than RCC structure.
- D. A storey force of the composite structure is less by 35% when compared to RCC structure.

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