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Seismic Performance of Innovative Strengthened Hollow Corrugated Column in Multi-Storey Steel Building

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Abstract - *In many situations, lighter steel structures are used to the heavier alternatives such as reinforced concrete or prestressed concrete. With the growth of steel as a construction material, varieties of steel sections were also increased. Among these sections, the Hollow structural sections (HSS) or Structural hollow sections were the foremost reliable one. Hollow structural section is manufactured from a type of metal profile which consist of a hollow tubular cross section. The wide use of thin-walled steel structural systems in the construction industry is greatly indebted for their high strength to weight ratio attributes and remarkable fabrication versatility. Corrugated plates comes under this category have a wide range of application in various engineering fields. They are lightweight, economical, and have much higher load carrying capacities than flat plates, which make sure their popularity and have attracted research interest since they were introduced. In current project, corrugated columns are placed in different positions to determine the best and worst model in performance wise and then the worst model is strengthened externally and internally to improve their seismic performance. This project is done by using ETABS software.*

Key Words: **Hollow structural section, flat plate, corrugated column, ETABS**

1. INTRODUCTION

Nowadays steel structures becomes more popular than concrete structures. Light weight steel or cold-formed steel seeks more attention from researchers as it is easy to handle, economic and have higher load carrying capacity than concrete. With the increased use of steel, the varieties of steel sections are used. The Hollow structural sections (HSS) or Structural hollow sections were most valid one. Members of hollow structural sections can be circular, square, or rectangular in sections. Corrugated plates fall under this category and also have a wide range of application in various engineering fields. The main advantages of corrugated plates are, they are lightweight, economical, and have much higher load carrying capacities than flat plates, which ensure their acceptance and have attracted research interest since they were introduced. The corrugation shape provides stable and continuous stiffening which permits the use of thinner plates. A corrugated plate can be effortlessly bent in one direction, whereas it keep its rigidity in the other direction. Corrugated steel is a type of building material composed of sheets of hot-dip galvanized mild steel, cold-rolled to produce a linear corrugated pattern in them. The corrugation shape increase the bending strength of the sheet in the direction perpendicular to the corrugations, but not parallel to them. Corrugated steel is lightweight and can easily be transported.

1.1 Corrugated plate

Corrugated steel is a building material consists of sheets of hot-dip galvanized mild steel, which is cold-rolled to produce a linear corrugated pattern. The corrugated plates are also known as self-strengthened plates. They are regularly produced from flat plates. The corrugation shape increases the bending strength of the sheet in the direction which is perpendicular to the corrugations, but not parallel to them. Normally each corrugated sheet is manufactured longer in its strong direction. The profile of a corrugated plate may have different shapes: triangular, trapezoidal, sinusoidal and rectangular

1.2 Trapezoidal Corrugated Plate Cross Section and Dimension Notation

The corrugated plates are regularly produced from flat plates. The most common profiles used for corrugation are trapezoidal and sinusoidal profiles. In this research, trapezoidal profile is chosen because it exhibits more ductility and higher bearing capacity compared to sinusoidal profile. Trapezoidal corrugated plates used in this study. The geometry dimension of corrugated plate is given in Table 1

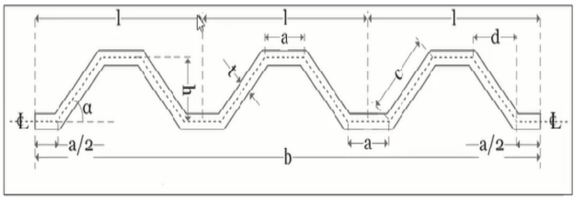

Fig 1: Cross section of corrugated plate

Table -1: Dimension notation

	α (°)	A (mm)	H(mm)	T (mm)	L (mm)	D(mm)	C(mm)	B(mm)
TYPE 1	45	20	15	10	70	15	21.21	210

2. SCOPE

This paper highlights the benefits of corrugated column in multi storey steel building. We know, overall benefits of a corrugated column includes lightweight, economical, higher load carrying capacity etc. , thus the buildings become environmentally responsible, profitable and better place to live and work in. Research on corrugated column is already firmly established. There are many global platforms that discusses on corrugated column which aims to create a better and cost effective buildings when compared to conventional steel buildings. Considering the relevance of this topic, corrugated column in steel buildings is one of the most important and one of the most discussed topics worldwide. The main aim of the project is to investigate the seismic performance of the innovative strengthened corrugated column in multi storey steel building.

3. OBJECTIVES

- To investigate the seismic performance of multi storey steel building with corrugated column.
- To study the seismic performance of multi storey steel building with externally and internally strengthened corrugated column by using pipes on outer corners and using plate stiffeners in inner side.

4. MODELLING AND ANALYSIS

4.1 Modelling

A 9 storey steel building with and without corrugated column were taken for the investigation. In order to reduce weight, storey displacement, drift, time period and base shear of conventional multi storey steel building corrugated columns are placed in different ways. Strengthening of the worst model also done in this project. Modelling and analysis of the 9 storey steel building is done by using ETABS software

4.2 Building configuration

Columns (345mpa):

Box sections a ∗ b ∗ c indicate the section has a height of a, width of b, and a wall thickness of c.

- 1st level 430 ∗ 430 ∗ 18 mm
- 2nd–5th level 400 ∗ 400 ∗ 15 mm
- 6th–9th level 380 ∗ 380 ∗ 12 mm

Beams (235MPa):

H a ∗ b ∗ c ∗ d (units: mm) indicates the section has a height of a, width of b, web thickness of c, and flange thickness of d.

- 1st–5th level H 500 ∗ 180 ∗ 11 ∗ 16 mm
- 6th–9th level H 440 ∗ 150 ∗ 10 ∗ 16 mm

Restrains:

Columns fixed at base Dimensions:
All measurements are center line
-1st level height 4.0m
-2nd–9th height 3.6m
- Bay widths (all) 7.0m

Seismic mass:

-1st level 8.525 × 10^5 kg
-2nd–5th level 8.442 × 10^5 kg
-6th–8th level 8.342 ×10^5 kg
-9th level 6.580 × 10^5 kg

4.3 Modelling

14 Models are studied in this analysis. They are,

Model 1: Conventional building

Placing of corrugated columns in different plans

Model 2: Corrugated column at exterior
Model 3: Corrugated column at interior
Model 4: Alternative in x direction
Model 5: Alternative in y direction
Model 6: Corrugated column at diagonals
Model 7: Zigzag at external
Model 8: Zigzag at internal
Model 9: Zigzag at corner

Corrugated columns at different storeys

Model 10: Corrugated column at first 2 storeys
Model 11: Corrugated column at first 4 storeys
Model 12: Corrugated column at first 6 storeys
Model 13: Corrugated column at first 8 storeys
Model 14: all columns replaced by corrugated column

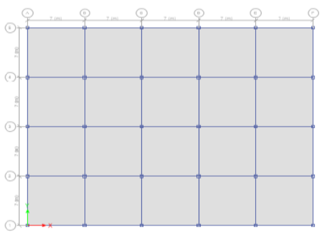

Fig2: Model 1

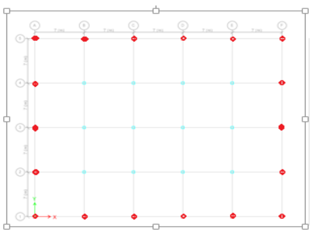

Fig3: Model 2

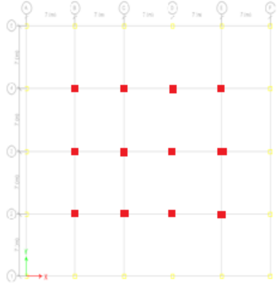

Fig4: Model 3

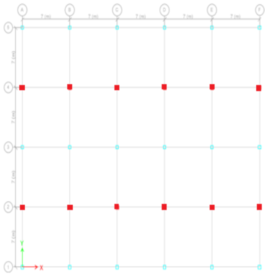

Fig5: Model 4

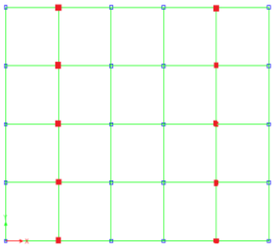

Fig6: Model 5

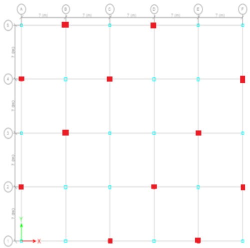

Fig7: Model 6

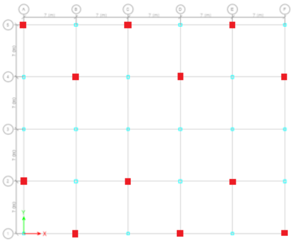

Fig8: Model 7

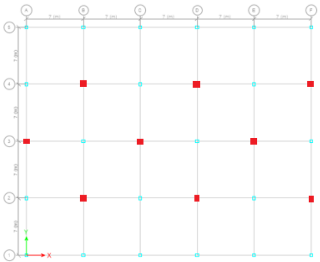

Fig9: Model 8

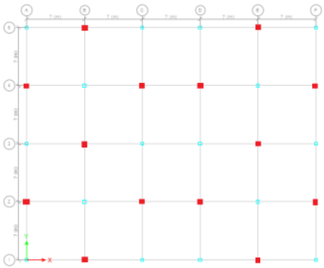

Fig10: Model 9

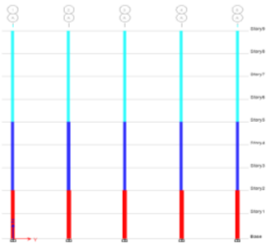

Fig11: Model 10

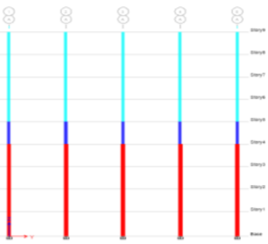

Fig12: Model 11

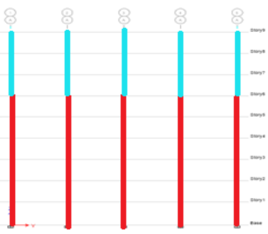

Fig13: Model 12

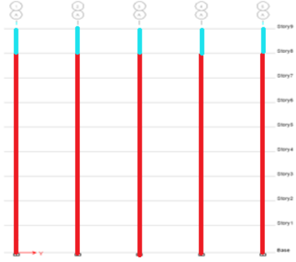

Fig14: Model 13

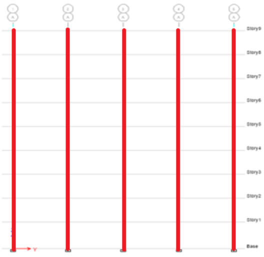

Fig15: Model 14

14 models are completed using ETABS software. Seismic analysis is done by response spectrum method. The values of storey drift that, displacement and storey shear obtained from Response spectrum analysis is tabulated below

Table -2: Maximum storey displacement

MODELS	DISPLACEMENT (mm)		% reduction in displacement	
	X	Y	X	Y
Model 1	79.63	85.81	0	0
Model 2	44.34	44.04	44.32	48.68
Model 3	43.76	45.25	45.05	47.27
Model 4	58.64	38.79	26.36	54.80
Model 5	47.24	62.56	40.68	27.10
Model 6	48.79	43.99	38.73	48.73
Model 7	48.13	49.74	39.56	42.03
Model 8	63.33	50.96	20.47	40.61
Model 9	43.94	38.95	44.82	54.60
Model 10	59.32	67.27	25.51	25.1
Model 11	78.17	79.46	1.83	7.40
Model 12	82.14	82.27	-3.15	4.13
Model 13	86.65	87.33	-8.81	-1.77
Model 14	89.25	89.98	-12.08	-4.86

Table -3: Weight of building

models	Weight (kg)	Difference in weight	%reduction in weight
Model 1	2550541	0	0
Model 2	2478135	72406	2.84
Model 3	2502185	48357	1.90
Model 4	2502245	48296	1.89
Model 5	2510296	40245	1.58
Model 6	2502255	48286	1.89
Model 7	2502260	48281	1.89
Model 8	2514319	36222	1.42
Model 9	2494204	56337	2.21
Model 10	2513605	36936	1.45
Model 11	2484470	66071	2.59
Model 12	2459943	90598	3.55
Model 13	2440024	110517	4.33
Model 14	2429830	120711	4.73

Table 4: Maximum storey drift

model	Storey drift	
	X	Y
Model 1	0.0033	0.0036
Model 2	0.0020	0.0020
Model 3	0.0021	0.0020
Model 4	0.0022	0.0025
Model 5	0.0025	0.0024
Model 6	0.0028	0.0028
Model 7	0.0023	0.0024
Model 8	0.0022	0.0025
Model 9	0.0023	0.0023
Model 10	0.0025	0.0022
Model 11	0.0026	0.0021
Model 12	0.0022	0.0021
Model 13	0.0023	0.0021
Model 14	0.0018	0.0018

Table -5: Maximum storey shear

model	Base shear	
	X	Y
Model 1	2902	2770
Model 2	1473	1520
Model 3	1320	1493
Model 4	1080	1612
Model 5	1205	1042
Model 6	1170	1345
Model 7	1180	1167
Model 8	1037	1079
Model 9	1474	1616
Model 10	1246	1141
Model 11	916	893
Model 12	958	994
Model 13	1090	1124
Model 14	1083	1110

From the result obtained best and worst models in performance wise using corrugated column can be determined. . For the better performance of worst model using corrugated column external and internal strengthening is provided. From comparison of all models percentage reduction in weight for all columns replaced by corrugated column is very much higher. But storey displacement is higher than conventional steel building. So all columns replaced by corrugated column is externally and internally strengthened.

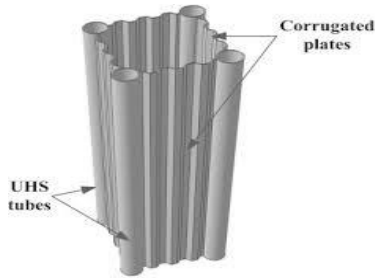

Fig16: Corrugated plate with UHS tubes

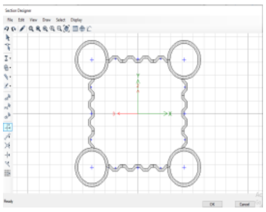

Fig17: Corrugated column with UHS tube

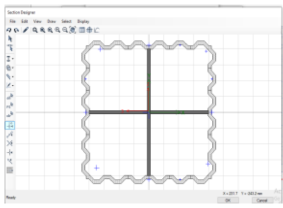

Fig18: Internally strengthened corrugated column

Table -6: comparison of building with externally and internally strengthened corrugated column

		ALL STOREYS- STEEL TUBE	ALL STOREYS -STIFFENER
WEIGHT(KG)		2466085.5	251470680.8
DIFFERENCE IN WEIGHT		84455.8	69470.3
% OF DECREASE IN WEIGHT		3.3	2.7
TIME PERIOD	X	3.355	3.573
	Y	3.397	3.633
STOREY DISPLACEMENT(mm)	X	39.90	66.54
	Y	41.09	74.65
STOREY DRIFT	X	0.0015	0.0018
	Y	0.0016	0.0017
BASE SHEAR	X	1576	979
	Y	1475	867

5. RESULT AND DISCUSSION

The analysis of 14 models using ETABS software is completed and response spectrum method is used to determine the storey drift, storey displacement and storey shear.

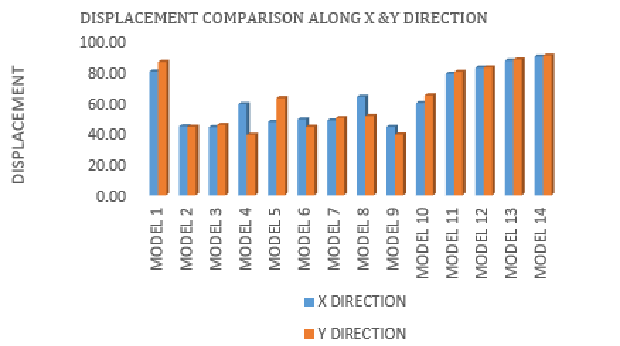

Chart -1: Displacement comparison

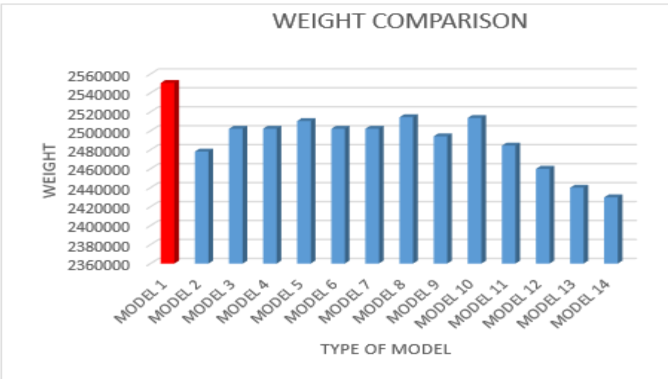

Chart -2: Weight comparison

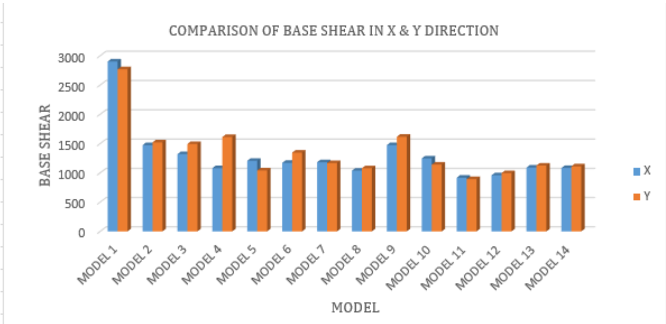

Chart 3: Comparison of base shear

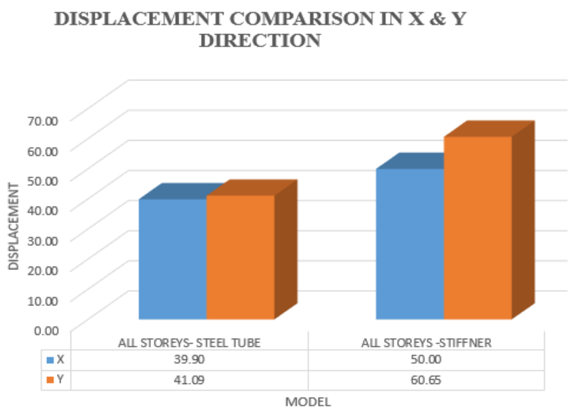

Chart 4: Comparison of displacements for building with internally and externally corrugated column

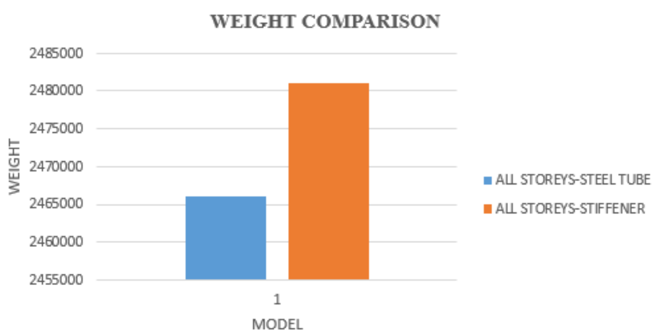

Chart5: Comparison of weight for building with internally and externally corrugated column

6. CONCLUSIONS

From the analysis of 9 storey steel building buildings with and without corrugated column following conclusions are obtained.

- The behaviour of multi storey steel building with and without corrugated column is studied.
- Response spectrum method is used to find storey drift, store displacement and storey shear.
- The structure with corrugated column is subjected to minimum displacement than conventional column structure. The value of displacement is very less for building with corrugated column at exterior.
- The weight of the conventional steel building is reduced when corrugated columns are provided. Number of corrugated column effects the weight of building. The weight of building is reduced when the number of corrugated column is increased. When all columns are replaced by corrugated column then the weight became very less.
- The value of storey drift for building with corrugated column is very less when compared to conventional steel building. Structure with corrugated column at exterior has got very less value of storey displacement when compared to all other models.
- Building with corrugated column at exterior is the best when compared to all other models. It has got less value of storey drift, displacement, weight and base shear when compared to all other models.
- The worst model in performance wise is building with all the columns replaced by corrugated column. When it is externally strengthened then the value of displacement is reduced than building with corrugated column at exterior.
- When building with all columns replaced by corrugated column is externally strengthened then it became the best model.

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