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Effect of shape irregularity on flat slab and waffle slab industrial building under lateral loading

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Abstract-The rapid growth of the urban population needs to construct big prestigious buildings for companies and industrial purpose. The construction of multi-storey buildings and large span structures is becoming a necessary part of our living style. Construction of large span structure using flat slab and waffle slab system is simple to construct and also efficiently provides maximum clear height. The present objective of this work is to compare the various parameters like base shear, story displacement and story drift acting on flat slab and waffle slab system. With that behavior of expansion joint which is provided between existing building and industrial structure in earthquake prone region is also checked. Analysis of the large industrial structures constructed using flat slab and waffle slab in square shape and rectangular shape layout will be done with the help of Etab software by using IS 456-2000 code

Keywords **- Flat slab, forces, base shear, story displacement.**

I. INTRODUCTION

A. Flat Slab

A flat slab is a one-way or two-way system with thickenings in the slab at the columns and load bearing walls called „drop panels". Drop panels act as T-beams over the supports. They increase the shear capacity and the stiffness of the floor system under vertical loads, thus increasing the economical span range. This form of construction has become popular in recent years because of the large spans of about 10 m for reinforced slabs and about 12 m for prestressed slabs. Reinforced flat slabs may need to be sensibly pre-cambered (not overdone) to control deflection.

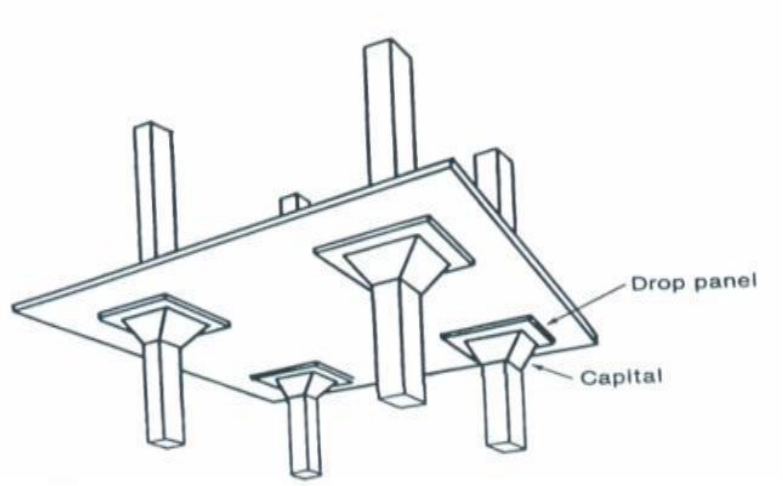

Fig. 1: Flat slab with drop & column head structure

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B. Waffle Slab

Ribbed floors consisting of equally spaced ribs are usually supported directly by columns. They are either one-way spanning systems known as ribbed slab or a two-way ribbed system known as a waffle slab. This form of construction is not very common because of the formwork costs and the low fire rating. A 120-mm-thick slab with a minimum rib thickness of 125 mm for continuous ribs is required to achieve a 2-hour fire rating. A rib thickness of greater than 125 mm is usually required to accommodate tensile and shear reinforcement. Ribbed slabs are suitable for medium to heavy loads, can span reasonable distances, and are very stiff and particularly suitable where the soffit is exposed.

II. METHODS OF ANALYSIS

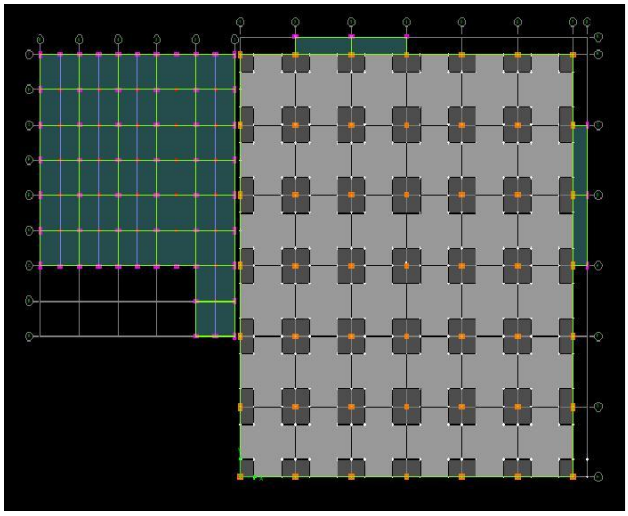
There are various methods of analysis of industrial structures such as;

1) Response Spectrum Analysis
2) Non-Linear Static Analysis
3) Linear Dynamic Analysis
4) Non-Linear Dynamic Analysis

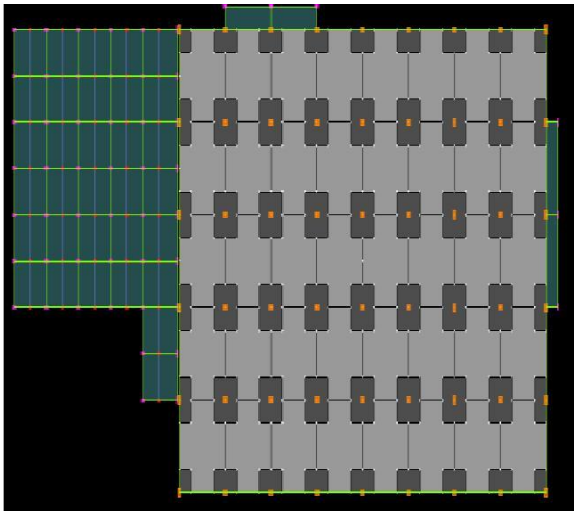
Thus in this research work response spectrum analysis is carried out for analysis using Etabs software version *9.7.3*. The analysis is carried out on four models with various configurations having square panels and rectangular panels. E combinations of these panels are as given below.

I. Model-1 = Flat slab having square layout.
II. Model-2 = Flat slab having rectangular layout.
III. Model-3 = Waffle slab having square layout.
IV. Model-4 = Waffle slab having rectangular layout.

The structural configuration of these models is as shown in Fig. 2 below. Extensive research has been carried out to find out the behavior of slab-column connection. The failure mode depends upon the type and extent of loading. Punching shear strength of slab-column connection is of importance which very much depends on the gravity shear ratio. The mechanism of transfer of moments from slab to column is very complex when subjected to lateral loading and unbalance moments. These unbalanced moments produce additional shear and torsion at the connections and then get transferred into the column which results in excessive cracking of slab leading to further reduction in the stiffness of the slab.



(a) Model-1 = Flat slab having square layout



(b) Model-2 = Flat slab having rectangular layout.

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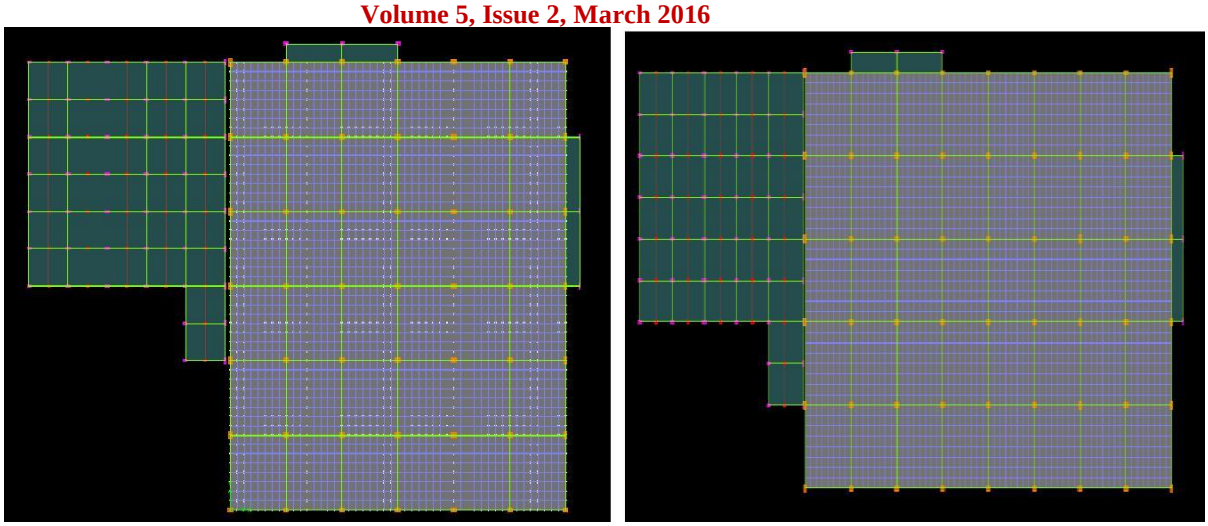

(c) Model-3 = Waffle slab having square layout. (d) Model-4 = Waffle slab having rectangular Layout

Fig. 2: Models used for analysis

A. Salient Features of the Building

The structural configuration of the building is as given in Table 1 below

1. Type of the structure is Industrial structure.
2. Seismic zone is taken as IV as per IS 1893(Part I):2002
3. Numbers of storeys are G+3.
5. Total height of the building above ground level is 24m
6. Each floor is 8m high.

Table 1: Details of Building

Parameters	Flat Slab	Waffle Slab
Plan dimension	62.5m X 62.5m	62.5m X 62.5m
Floor to floor height	8 m	8 m
No of stories	3	3
Total height of building	24 m	24 m
slab thickness	300 mm	100 mm
Drop thickness	375 mm	-
Rib size	-	200 X 750 mm
Rib spacing	-	1250 mm
Grade of steel	Fe 500	Fe 500
Grade of concrete	M30	M30
Column size	600 X 1000 mm	350 X 750 mm
		300 X 450 mm
		300 X 300 mm
		300 X 600 mm

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III. LOAD COMBINATIONS

In the limit state design of reinforced and prestressed Concrete structures, the following load combinations shall be accounted. In this analysis all the combinations of load has been used and the results obtained for worst combination is selected.

_ 1.5 DL + 1.5 LL
_ 1.5 DL+1.5 EQX
_ 1.5 DL - 1.5 EQX
_ 1.5 DL+1.5 EQY
_ 1.5 DL - 1.5 EQY
_ 1.2 DL + 1.2 LL+1.2EQX
_ 1.2 DL + 1.2 LL - 1.2EQX
_ 1.2 DL + 1.2 LL+1.2EQY
_ 1.2 DL + 1.2 LL - 1.2EQY
_ 0.9DL +
1.5EQX -
1.5EQX 1.5EQY
0.9DL - 1.5EQY
_ 0.9DL
_ 0.9DL +
_
_ 1.5 DL + 1.5 RSPX
_ 1.5 DL+1.5 RSPY
_ 1.2 DL + 1.2 LL+1.2RSPX
_ 1.2 DL + 1.2 LL+1.2RSPY
_ 0.9DL + 1.5RSPX
_ 0.9DL + 1.5RSPY

IV. DYNAMIC ANALYSIS

Response spectrum method is the linear dynamic analysis method. In this method the peak responses of a structure during an earthquake is obtained directly from the earthquake responses. The maximum response is plotted against the undamped natural period and for various damping values, and can be expressed in terms of maximum relative velocity or maximum relative displacement.

Response spectrum method is used for the analysis. Importance factor and response reduction factor are considered as 1 and 3 respectively. Eigen Vector analyses are used for analysis. Rigid diaphragm action is considered for analysis.

V. RESULTS AND DISCUSSON

A. COMPARISION OF STORY DISPLACEMENT

Comparison of story displacement between industrial structure constructed using flat slab and Waffle slab having square and rectangular layout is as shown below;

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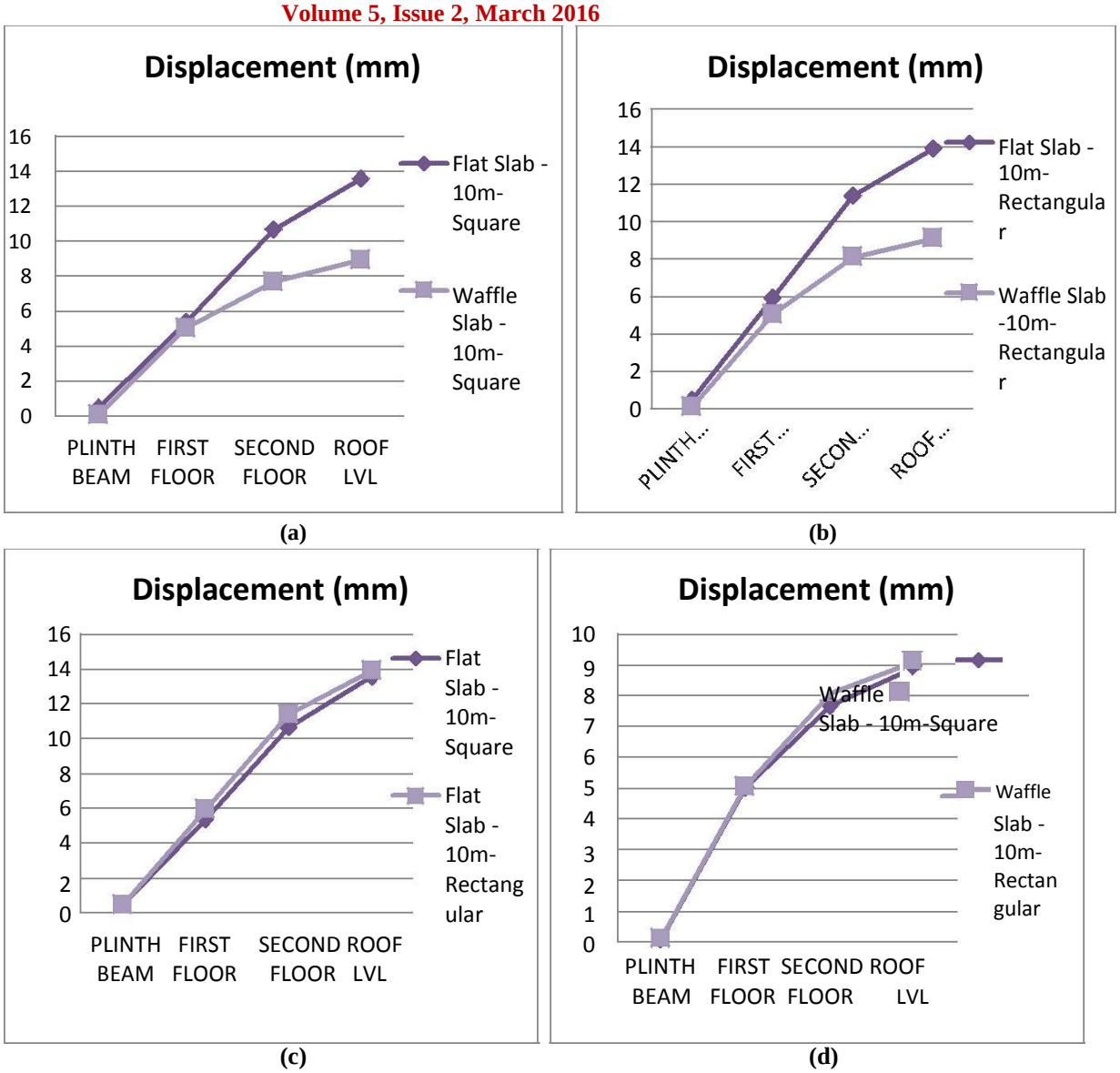

Fig 3: Load-Displacement Curve for Square and Rectangular Building

B. COMPARISION OF BASE SHEAR

Comparison of base shear between industrial structure constructed using flat slab and Waffle slab having square and rectangular layout is as shown below. The total base shear is determined by the following expression; VB=Ah **x** W

Where- Ah =Design horizontal acceleration spectrum W= Seismic weight of the building

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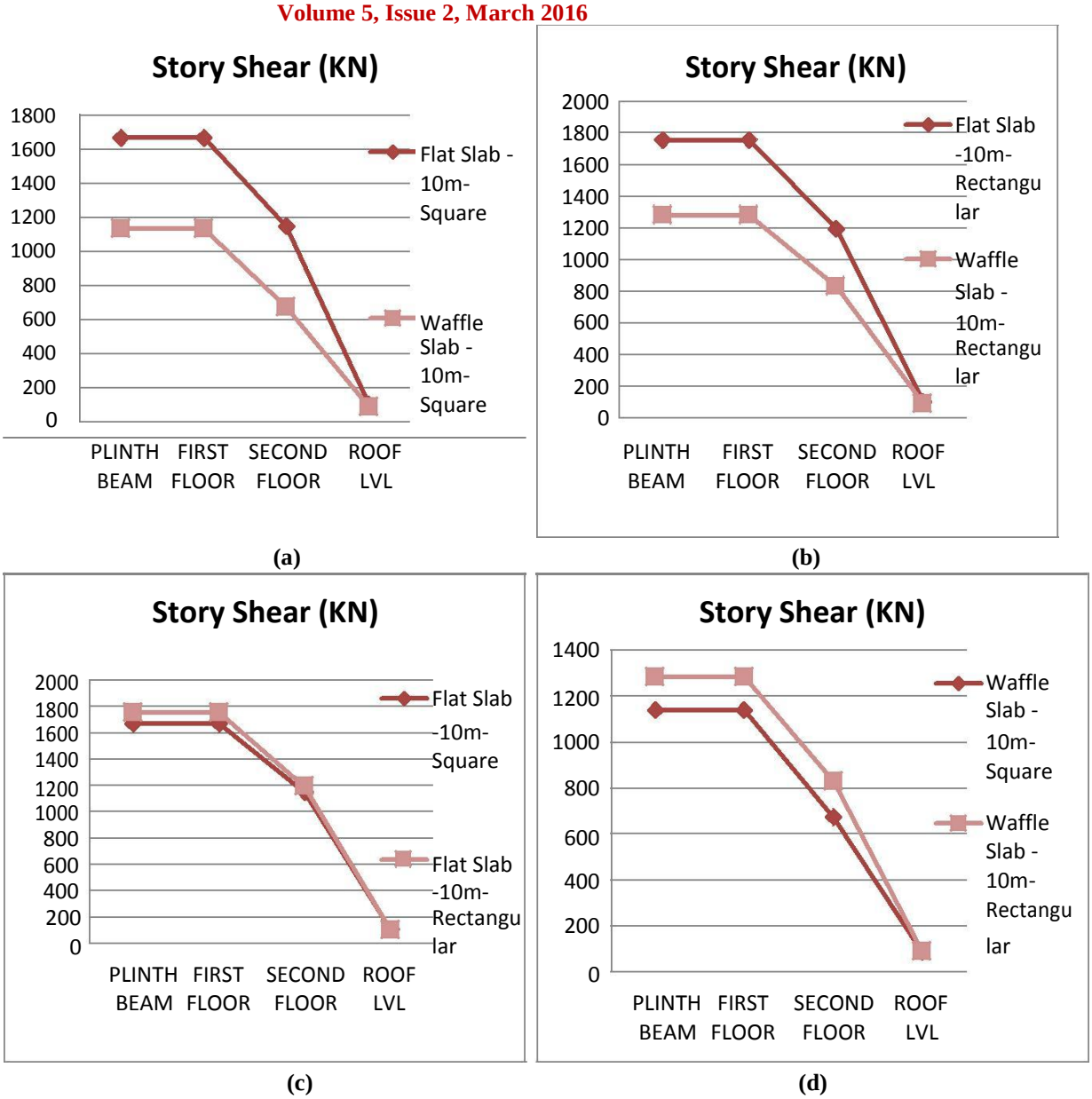

Fig. 4: Storey Shear for Square and Rectangular Buildings

C. COMPARISION OF STORY DRIFT

Storey drift is defined as difference between lateral displacements of one floor relative to the other floor. Total building drift is the absolute displacement of any point relative to the base. Comparison of story displacement between industrial structure constructed using flat slab and Waffle slab having square and rectangular layout is as shown below;

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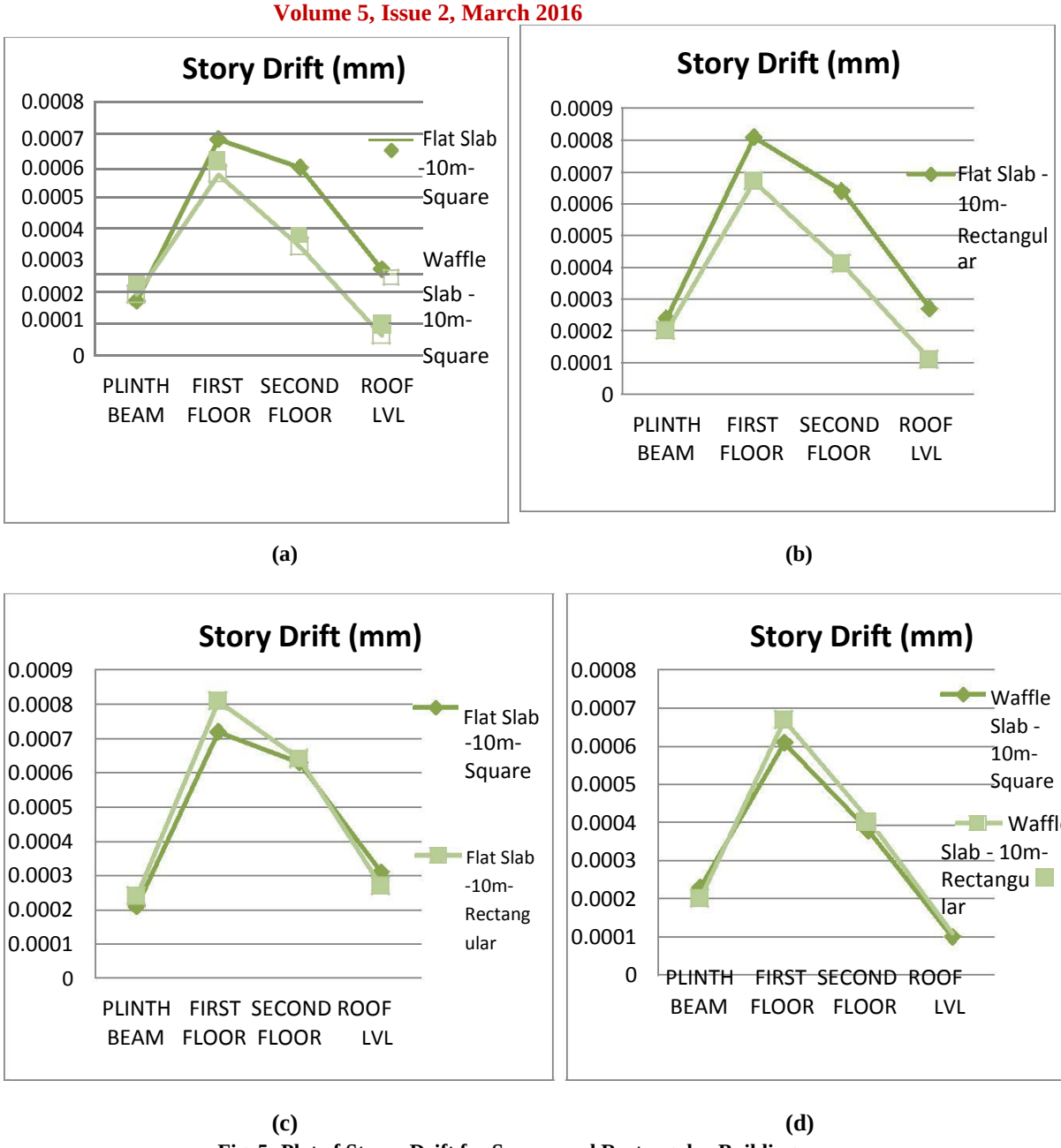

Fig. 5: Plot of Storey Drift for Square and Rectangular Buildings

VI. CONCLUSION

1) Displacement of industrial structure constructed using flat slab system is more than the waffle slab system for both square and rectangular layout.
2) Displacement of rectangular shape layout of industrial structure constructed using flat slab and waffle slab is more than the square shape layout structure.
3) With the increase in height of structure displacement is also goes on increasing.
4) Story shear of industrial structure constructed using flat slab system is more than the waffle slab system for both square and rectangular layout.

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5) Story shear of rectangular shape layout of industrial structure constructed using flat slab and waffle slab is more than the square shape layout structure.
6) Story shear is maximum at base level and it decreases as height of structure increases.
7) It is seen that story drift is maximum at first floor i.e. at 8m from ground level.
8) Story drift of industrial structure constructed using flat slab system is more than the waffle slab system for both square and rectangular layout.
9) In both flat slab and waffle slab system, it is seen that story drift is more for structure constructed with rectangular layout than square layout.
10) Maximum story drift is 0.0009 mm and maximum displacement is 15 mm, hence all the structures have less displacement and story drift than 50 mm.

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