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# SEISMIC RESPONSE OF BUILDINGS WITH STEEL ROOF DIAPHRAGMS

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## ABSTRACT

Buildings with flexible floor diaphragm, rigid floor diaphragm and wood floor diaphragms are common in America, Japan and other parts of the world. Based on the in-plane stiffness assumption of floor system, SAP 2000 is used to model flexible floor diaphragm model, rigid floor diaphragm, wood floor diaphragm and steel roof diaphragm. Detailed non-linear dynamic analysis done in the models and results are compared. The seismic analysis for a six-storey hybrid structure with four different models is analyzed. The diaphragm is modelled based on the in-plane stiffness. The stiffness of the roofing material determines the seismic safety of buildings. In the time history analysis, the displacement of the four-building model is compared. Steel is more durable and with high strength characteristics compared to wood . The buildings with steel floor diaphragms tend to show high seismic safety.

**Keywords –** Flexible diaphragm, rigid diaphragm, steel diaphragm, time history method, wood diaphragm

## 1. INTRODUCTION

### 1.1 GENERAL

A horizontal component called a diaphragm transmits lateral forces to vertical resisting elements. The seismic reaction of the buildings is significantly influenced by the diaphragm's flexibility. The diaphragm's in-plane stiffness aids in its ability to withstand lateral loads like wind and seismic loads. The diaphragm can be classified as flexible, rigid, or semi-rigid depending on flexibility. The building model was examined under lateral stress scenarios to ascertain the diaphragm's flexibility. The materials used to build the roof members can be steel, hybrid, or wood. Steel is a robust building material that is more durable than wood and is used extensively worldwide. A six-storeyed building model of wood, flexible floor diaphragms, rigid floor diaphragms and steel floor diaphragm is modeled .Time history method is used to analyze the storey displacement of each model .

### 1.2 FLEXIBLE DIAPHRAGM

When the midpoint displacement under lateral load exceeds twice the average displacement of the end supports, a diaphragm is said to be flexible. Here, it is believed that these non-yielding end supports have extremely high relative stiffness in comparison. Consequently, rather than focusing on relative stiffness, diaphragms are frequently constructed as straightforward beams between end supports with a distribution of the lateral stresses to the vertical resisting elements on a tributary width.

### 1.3 RIGID DIAPHRAGM

When a diaphragm's midpoint displacement under lateral force is less than twice the average displacements at its ends, the diaphragm may be regarded as rigid. The vertical resisting elements are directly proportional to the horizontal forces distributed by the rigid diaphragm. It is predicated on the idea that the diaphragm won't deform by itself and will instead generate an equal amount of deflection in each vertical element.

### 1.4 WOOD DIAPHRAGM

In the US, both large-scale commercial structures and residential structures frequently have wood roof diaphragms. The classic diaphragm design method is frequently used in diaphragm design because it is straightforward, especially when designing diaphragms with relatively small dimensions.

### 1.5 STEEL DIAPHRAGM

Outside of the West, Southwest, and Pacific Northwest, bare steel deck diaphragms are more common. Welds, screws, power actuated fasteners (PAFs), also known as power-driven fasteners, and occasionally a variety of other specialized fasteners are used to secure the steel decking to the adjacent deck panels and supporting open-web steel joists. These diaphragms' in-plane shear strength and stiffness depend on the steel deck gauge, deck profile, joist spacing, and kind and spacing of the fasteners (SDI, 2015). Contrary to composite steel decking covered in concrete, which is a common floor and roof solution in multistory buildings, bare steel deck diaphragms are relatively light, frail, and flexible in relation to the adjacent walls.

## 2. METHODOLOGY

### 2.1 SYSTEM INFORMATION

Codes, manuals, and journal articles provided the information and data needed for the structural model study. The codes that were used were AISI S310-20 (AISI, 2020), AISI S310-16, GB 1499.2 - 2018, and the manuals that were used were SDI DMM04, Diaphragm Design Manuals, and Wood Diaphragm Design Manuals, FEMA- 1026 is used for modelling. Journal papers are used to gather information on the values to be entered into the software. The stiffness of the diaphragms is derived from several journal papers in which the experimental investigation of the stiffness of the diaphragms is conducted.

### 2.2 DESCRIPTION OF NUMERICAL MODELS

The building model is a six-story structure with a floor height of 3 m, with concrete beams and columns. Fig 1 displays the model's structural plan view. Seven is the specified seismic fortification intensity. Ground motion's fundamental design acceleration is 0.1g, and the location is classified as II. Three is the design anti-seismic grade. The seismic coefficient is 0.08 and the characteristic period of ground motion is 0.40 seconds.

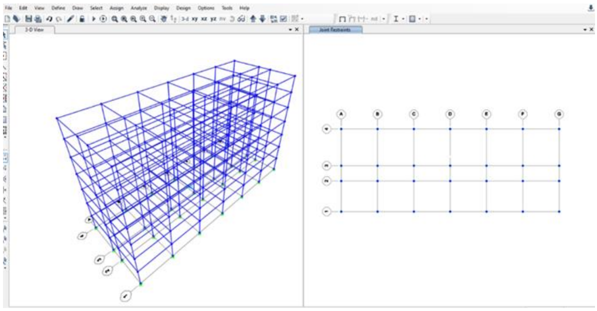


Fig 1 : Six storey building model in SAP 2000

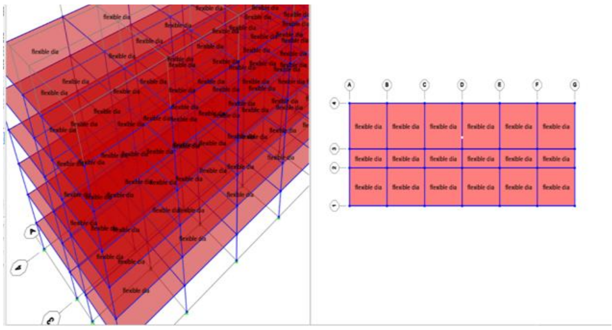


Fig 2 : Flexible diaphragm model in SAP 2000

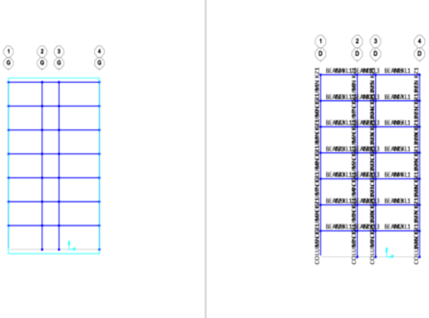


Fig 3 : XZ view of the model in SAP 2000

The longitudinal bar is HRB 400, the stirrup is HPB 235, and the concrete grade is C30. The arrangement of the beams and columns is seen in the figure. The dead load and live load are 1.0 KN/m2 and 2.0 KN/m2, respectively. Flexible floor model stiffness Ks = 0, rigid floor diaphragm stiffness Ks = ∞, wood floor diaphragm stiffness Ks = 1.06 KN/mm, and steel diaphragm stiffness Ks = 0.1875 KN/mm.

### 2.3 ANALYSIS OF NUMERICAL MODELS

Both a rigid floor assumption and a flexible floor assumption are considered when analyzing the structural model's in-plane stiffness under lateral loads.

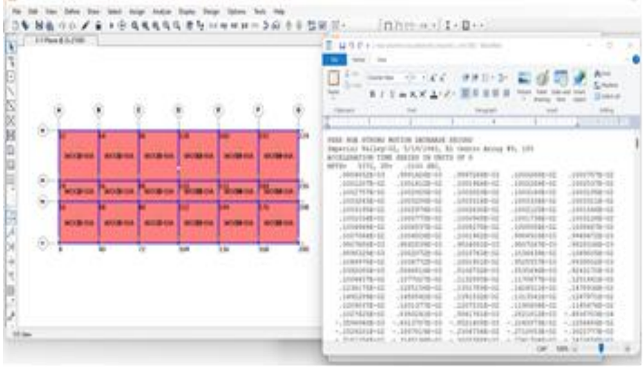


Fig 4 : El Centro earthquake file

According to the rigid floor diaphragm assumption, the floor is viewed as a rigid panel, and the stiffness of the lateral resisting components determines how the lateral seismic forces are distributed the lateral load dissipation depends on how much vertical loads the lateral force resist elements can withstand in the flexible floor assumption, where the in-plane stiffness of the floor is zero. Based on the diaphragm's rigidity, a model of the wood diaphragm is created. The models are examined using EL Centro seismic loads, live load, and dead load. The specified dead load is 1.0 KN/m2 and the specified active load is 2.0 KN/m2.

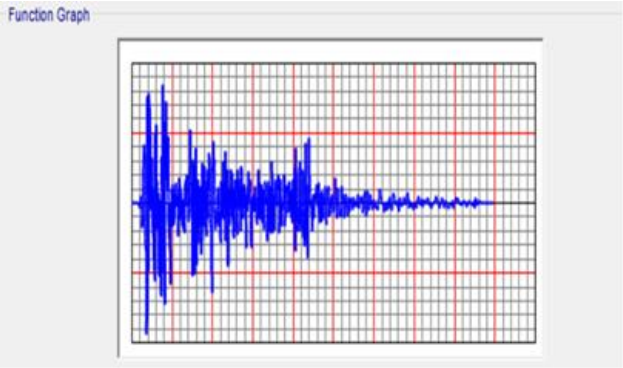


Fig 5 : Function graph of El Centro eathquake

## 3. MODELLING

The SAP 2000 software was used to construct and analyze the four structural models of flexible roof diaphragms, rigid roof diaphragms, steel diaphragm and wood roof diaphragms. The stiffness of the diaphragms is used to model the diaphragms. Models are created for a six-story structure with concrete frames and various diaphragm conditions.

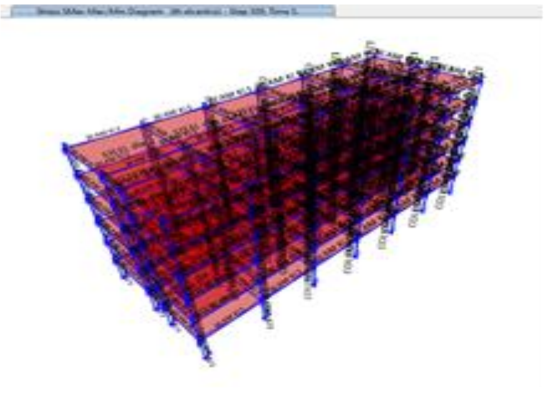


Fig 6 : Steel diaphragm model in SAP 2000

The EL Centro earthquake in time history approach was used to examine the building model. Flexible roof diaphragms, rigid roof diaphragms, steel floor diaphragms and wood roof diaphragms are compared for the resulting storey displacement. The four models' time displacement curves are plotted. The findings demonstrated that the displacement of a building with a flexible roof diaphragm under seismic analysis is greater than that of a concrete frame with a wood roof diaphragm.

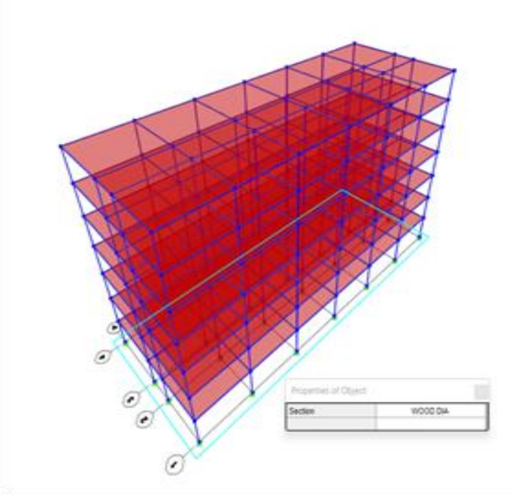
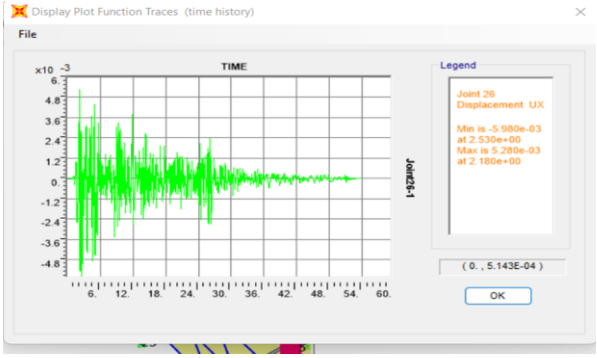


Fig 7: Wood diaphragm model

## 4.ANALYSIS

The most precise way for determining how seismically vulnerable a structure is nonlinear dynamic analysis. This method involves actually moving the building on the ground, which represents the ground's acceleration over time. To provide the ground motion record, the ground acceleration is calculated at each short time step. In order to determine the structural response's time history, every time instant is calculated, and the time history's peak value is selected as the design demand. Hence, "A mathematical model directly incorporating the nonlinear property of individual component and element of the building shall be subjected to earthquake shaking represented by ground motion timehistory to obtain forces and the displacement."



Joint 26
Displacement UX

Min is -5.980e-03
at 2.530e+00
Max is 5.280e-03
at 2.180e+00

( 0. , 5.143E-04 )

Fig 8 : Displacement time graph in SAP 2000

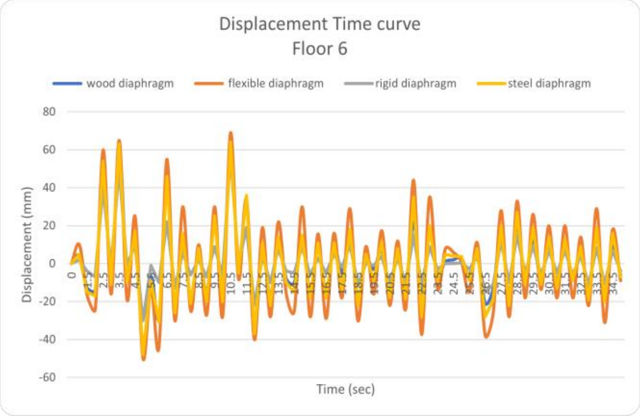


Fig 9 : Displacement Time curve of Floor 6 of the four models

Table1- Storey Displacement obtained

| FLOOR | FLEXIBLE | STEEL | WOOD | RIGID |
|---|---|---|---|---|
| 1 | 7.22 | 6.94 | 6.29 | 6.60 |
| 2 | 22.95 | 22.81 | 22.50 | 21.05 |
| 3 | 40.22 | 36.87 | 35.99 | 35.50 |
| 4 | 56.98 | 50.08 | 48.54 | 46.56 |
| 5 | 64.39 | 57.67 | 55.44 | 53.76 |
| 6 | 68.82 | 61.92 | 59.83 | 56.44 |

## 5. CONCLUSION

This paper presented a type of hybrid structure, brought up the flexible roof diaphragm, rigid roof diaphragm, simplified wood diaphragm model and steel roof diaphragm. Seismic analysis for a six-storey hybrid structure with four different floor models. The four models are analyzed with EL Centro earthquake in non -linear time history analysis. Wood is not a durable material compared to steel. Use of steel diaphragm increases the lifespan of the building. Steel diaphragms are stronger than wood diaphragms. The four building models are modelled in SAP 2000 software, the diaphragm designed based on the stiffness of the diaphragm roof. Results showed that, the lateral forces and the displacement of the concrete frame with the steel diaphragm model lay between rigid floor model and flexible model, using wood diaphragm could maximally lower down the seismic load and foundation cost. The use of steel as roof diaphragm showed that the storey displacement is between the displacement of flexible and rigid roof diaphragms. On adding stiffners to steel roof diaphragm, the stiffness of diaphragm can be increased. If the stiffness is increased the storey displacement can be decreased.

## REFERENCE

[1] Arturo Tena-Colunga, Karen Lineth Chinchilla-Portillo, Gelacio Juarez-Luna , Assessment of the diaphragm condition for floor systems used in urban buildings, *Engineering Structures 93* ,(2015*)* 70–84.

[2] Minjuan HE, Shuo LI , Suyi Guo , Chun NI, The Seismic Performance in Diaphragm Plane of MultiStorey Timber and Concrete Hybrid Structures, The Twelfth East Asia-Pacific Conference on Structural Engineering and Construction,*Procedia Engineering 14* (2011) 1606–1612

[3] Astrid W. Fischer, James K. Guest, Benjamin W. Schafer, Topology optimization of steel deck building diaphragms, *Journal of Constructional Steel Research 191*, (2022), 107186

[4] Maria Koliou, A.M.ASCE1 ; Andre Filiatrault, M.ASCE2 ; Dominic J. Kelly, M.ASCE3 ; and John Lawson, M.ASCE , Distributed Yielding Concept for Improved Seismic Collapse Performance of Rigid Wall-Flexible Diaphragm Buildings*, Engineering Structures 93* ,(2015*)*

[5] Zhiyong Chen, A. M. ASCE, Ying H. Chui, and Chun Ni, M. ASCE, Seismic Performance of Mid-Rise Hybrid Light Wood Frame Buildings and Influence of Diaphragm Flexibility , *Structures Congress*,ASCE 2013, 1229

[6] Sejal P Dalal, S A Vasanwala,Surat A K Desai, Comparison of Elastic Design and Performance Based Plastic Design Method Based on the Inelastic Response Analysis using SAP2000 , *International Journal of Computer Applications (0975 – 8887) Volume 45– No.9*, 2012

[7] Shuo LI , Minjuan HE , Suyi GU , Chun NI , Lateral load-bearing capacity of wood diaphragm in hybrid structure with concrete frame and timber floor , *Journal of structural engineering, 130(12),* 2040-2050, 2014

[8] Ming-juan HE, F. Lam, Properties of North American Wood Frame Residential Constructions, *Structural Engineers, pages 1~5*, China, 2004

[9] J. W. Bott, J. D. Dolan, Easterling, W.S. Preliminary literature review of wood diaphragms. Wood-frame project testing and analysis literature reviews. CUREE Publication W-03, *Consortium of Universities for Research in Earthquake Engineering*, Richmond, Calif., 2011

[10] Peralta David F., Bracci Joseph M., Hueste Mary Beth D. *Journal of Structural Engineering, 130(12),* 2040-2050, 2004.