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Study the Behavior of Geometric Non-Linearity in High-Rise Building

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Abstract

Generally, in any analysis method adopted in the construction industries it should be useful forthe stability, economy and strength point of view. For such structures the different analysis method is adopted based on the requirement of the building. From which the structure loads and other loads are coming over the structure are calculated and applied over foundation. But in practical execution the method of working is a little bit different where step by step construction sequence is used and for such condition the load over structure create the larger displacement and deformation because of not getting full strength in structural members. Similarly, nonlinear structure needs to check over micro level of consideration in which geometric non-linearity cause measure effect to the structure.

Keywords: Rcc Structure, Etabs software, FEM, IS456, IS1893.

INTRODUCTION

Different types of buildings are there in the construction industry. Those buildings have different importance in their respective areas and are based on the different functions. Those buildings with different purpose have different number of floors and these multistory structures are necessary to analyze with different consideration of loads and analysis. So, for analysis multistory structure, it is necessary to check it with larger displacement caused because of different non-linearity, such as geometric, etc. and based on working condition the behavior of the structure is to be analyzed for safety and economy. Now-a-days most of the high-rise structures are being widely constructed as irregular structures. There are many non-linearity in the structure in the form of shape, size, material executions, weight, stiffness, etc. The differentiation between regular and irregular structure has been shown in detail by IS code (IS 1893 (Part 1): 2016 – Criteria for Earthquake resistant design of structures which are stated below[1].

These are made up of multiple frame systems that vary in height and width, tall buildings are the ones that demand stability the most. First-order analysis, frequently referred to as linear static analysis, is typically used by structural designers to determine the design forces, moments, and displacements resulting from loads operating on the structure. Small deflection behavior is taken for granted while doing first order analysis, and the resulting moments, forces, and displacements do not account for the additional effect caused by the structure's deformation under vertical loads that come before applying lateral loads. The alteration in structure brought about by structural deformations is disregarded in the conventional first order evaluation.

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Material Properties

Concrete Properties

- Grade: M25 Rebar
- HYSD: 500

Description of Building Dimension

- *Site location:* Bhuj
- *Floor plan*: 22.23 x 52.25 m.
- *No. of story* = G+35
- *Floor to floor height:* 3.0 m.
- *Total height of building* = 105 m.
- *Slab depth:* 150 mm thick
- *Slab depth attransfer floo*r: 1000 mm thick.

Different Loads Considered

- *Live load in floor area:* 3 kN/sq m (as per IS 875 Part 2).
- *Live load in passage area*: 3 kN/sq m (as per IS 875 Part 2).
- *Wall thickness:* 150 mm thick wall (assumed (7.65 kn/m)).
- *Stair case loading:* 3 kN/sq m (as per IS 875 Part 2).
- *Shear wall thickness*: 300 mm (assumed).

Earthquake Parameter Considered

1. *Zone* – 3.
2. *Soil type* -- III.
3. *Importance factor* -- 1.5.
4. *Frame type* = OMRF.
5. *Response reduction factor* – 5

Method of Analysis Considered

Equivalent Static Analysis

Equivalent static analysis is an analysis in which the link between applied forces and displacements is linear and it is known as a linear static analysis. This may be applied in real-world circumstances to structural issues when stresses stay within the linear elastic range of the material being employed. When doing a linear static analysis, the stiffness matrix of the model keeps constant, and the solution time is comparatively less than when performing a nonlinear analysis on the same type[2].

Response Spectrum Analysis

This approach can be used with structures where the reaction is substantially influenced by modes other than the basic one. This approach uses the earthquake actions (or design) spectrum to directly determine the peak reactions of a structure during an earthquake. The Multi-Degree-of-Freedom (MDOF) system's response is represented as the superposition of its modal comments, each of which is derived from the Single-Degree-of-Freedom (SDOF) system's spectral analysis and then combined to calculate the response in its entirety.

Construction Sequence Analysis

With staged construction, a series of events may be defined, allowing for the addition or removal of structural components, the application of load to specific regions of the structure, and the consideration of time-dependent material behavior, such as creep, aging, and shrinkage. There are several names for staged construction, e.g., sectional, incremental, and sequential developing. As the structure may vary while the analysis is being conducted, staged construction is regarded as a kind of nonlinear static study.

P-Delta Analysis

A model deflects when it is loaded. When the ends of the model's members might not be vertical when they've been deflected, deformations in the members may result in subsequent moments. It is possible to approximate these members' secondary effects properly by adopting P-Delta analysis[3].

Modeling with E-TAB

Figure 1 shows the 3D skeleton model for the multistory building modeled in Etabs for G+35 story.

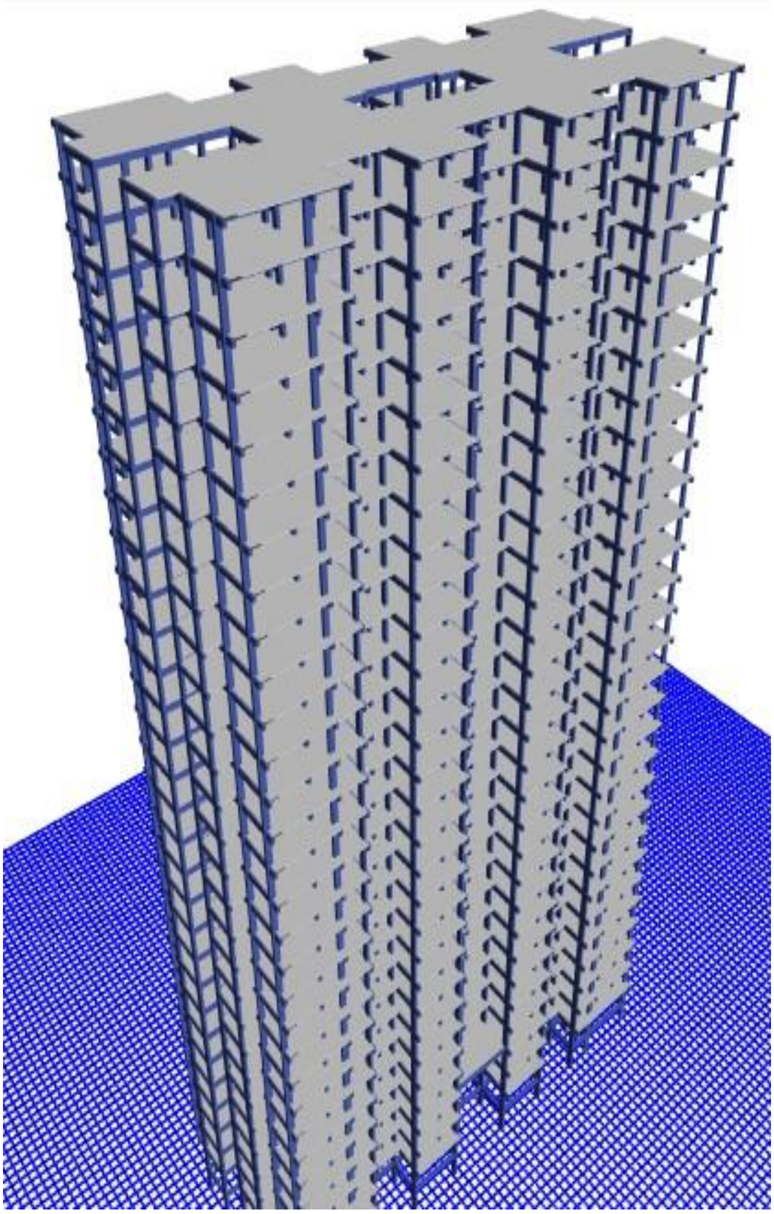

Figure 1: 3D building.

Transfer slab of thick 1000 mm is shown in the center of the building plan (see Figures 2 and 3).

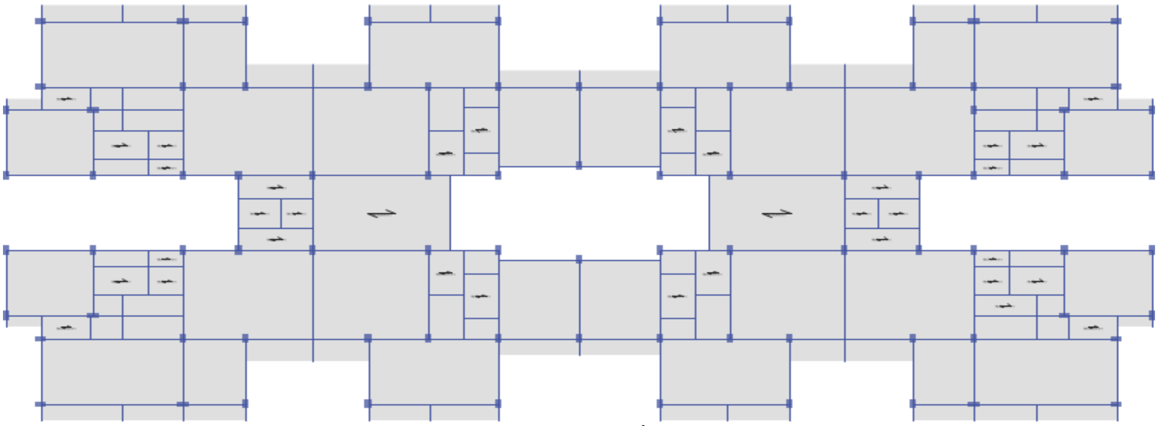

Figure 2. Shows the plan of the building up to 1st to35th floor without transfer slab building.

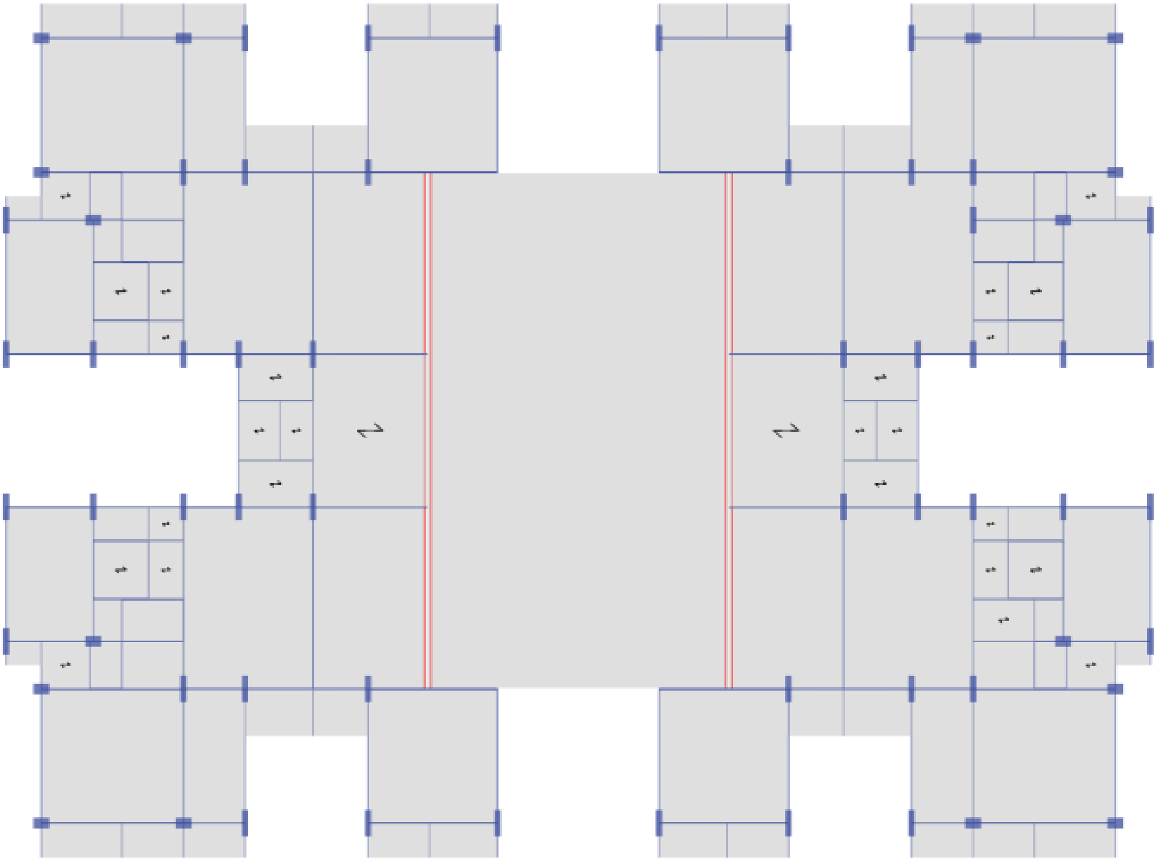

Figure 3. Shows the plan of the building on transfer slab.

Load Combinations

Load Combinations have been depicted in Table 1.

Table 1. Load combinations.

1.5(DL + LL)	1.5(DL -- EQY)	DL -- Dead L
1.2(DL + LL -- EQX)	0.9DL + 1.5EQX	LL -- Live load
1.2(DL + LL + EQY)	0.9DL -- 1.5EQX	EQX -- Earthquake in X direction
1.2(DL + LL -- EQY)	0.9DL + 1.5EQY	EQY -- Earthquake in Y direction
1.5(DL + EQX)	0.9DL -- 1.5EQY	
1.5(DL -- EQX)	0.9DL + 1.5EQX	
1.5(DL + EQY)		

Results

Modal Time Period (Seconds)

Conventional (A) and non-conventional (B) (Transfer slab) frame have been shown in Table 2.

Table 2. Modal time for Mode-1, 2 and 3.

Mode-1	5.93	6.25
Mode-2	5.70	5.81
Mode-3	3.98	4.23

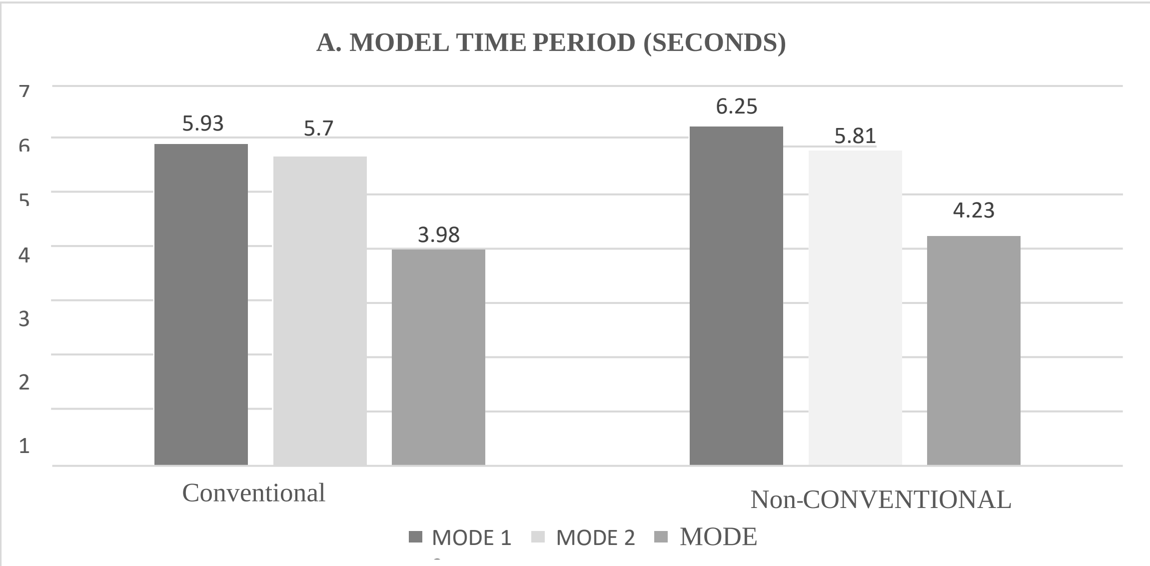

Figure 4. Model time period results.

The above graph (see Figure 4) shows the different time period of the structure where there are two building structures in which one is without transfer slab (conventional frame) and another is the non-conventional frame which is with transfer slab[4,5]. If you consider structures where the time period in the conventional frame is lower whereas non-conventional frame shows the higher time period values as shown.

Base Shear Details (KN)

Conventional (A) and Non-conventional (B) (Transfer slab) frame is shown in Base shear details structure (see Table 3).

Table 3. Base shear details for static condition in X and Y direction**.**

Base Shear	**A (KN)**	**B (KN)**
EX	28561	28049
EY	34389	33774
DX	29747	29684.5
DY	45606	44938.33

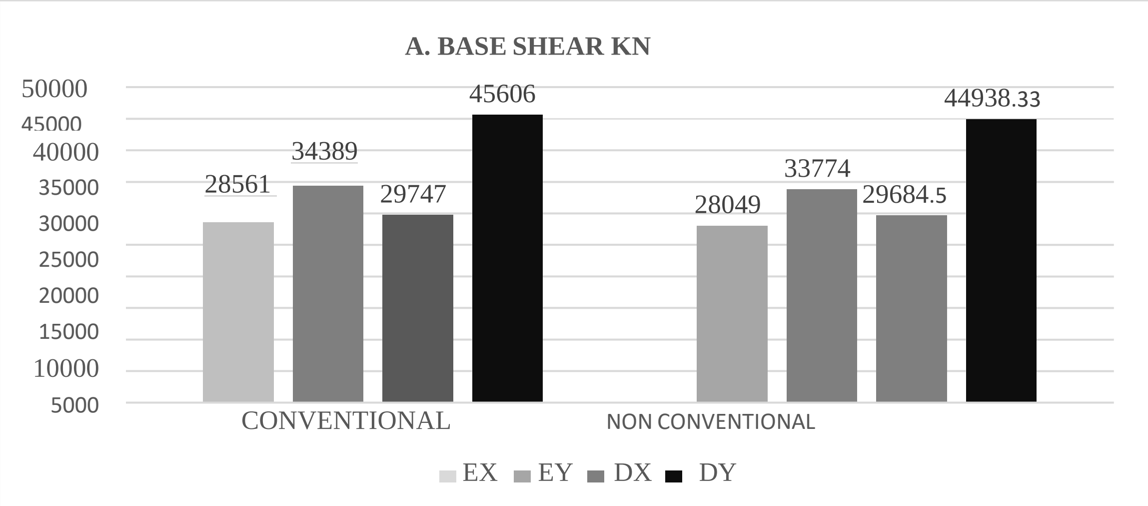

Figure 5. Base shear details.

The above graph (Figure 5) shows the different base shear results in Kn where the mass of the structure is most dependent property over this base shear results in both the structures the mass of the conventional frame is more and that is the reason the base shear values are getting higher when compared with non-conventional frame[6].

Displacement Details (M)

Displacement details (see Table 4) are shown both in conventional (A) and non-conventional (B) (transfer slab) frame.

Table 4. Displacement details in X and Y direction for seismic condition.

DISPLACEMENT	**A (M)**	**B (M)**
EX	0.927	0.963
EY	0.970	1.004
DX	0.769	0.841
DY	0.839	0.922

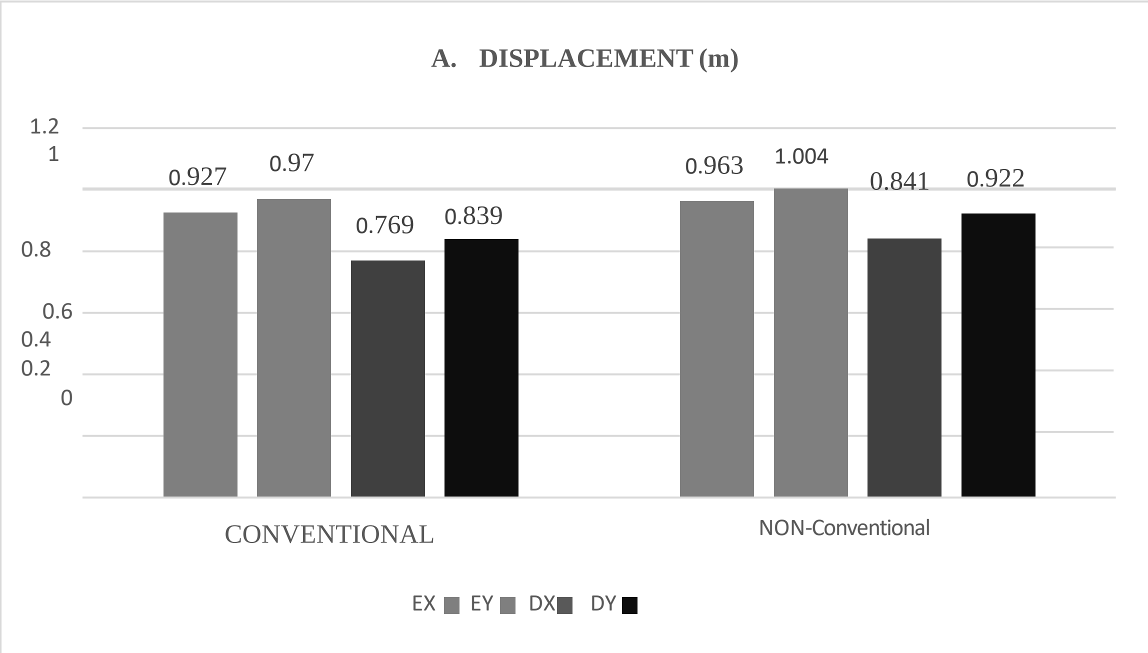

Figure 6. Displacement results details.

Displacement results (Figure 6) show the minimum displacement variation in both the cases of conventional and non-conventional structures where conventional frame has max displacement value of 0.92 m and similarly, if we observe, the same positional value in non-conventional structure is 0.96 m which is not exceeding the conventional frame structure[7].

Drift Details

Drift details are shown (see Table 5) for both the conventional (A) and non-conventional (B) (transfer slab) frame.

Table 5. Drift details in X and Y direction for seismic condition.

DRIFT	A	B
EX	0.0115	0.0114
EY	0.0116	0.0120
DX	0.0098	0.0109
DY	0.0103	0.0111

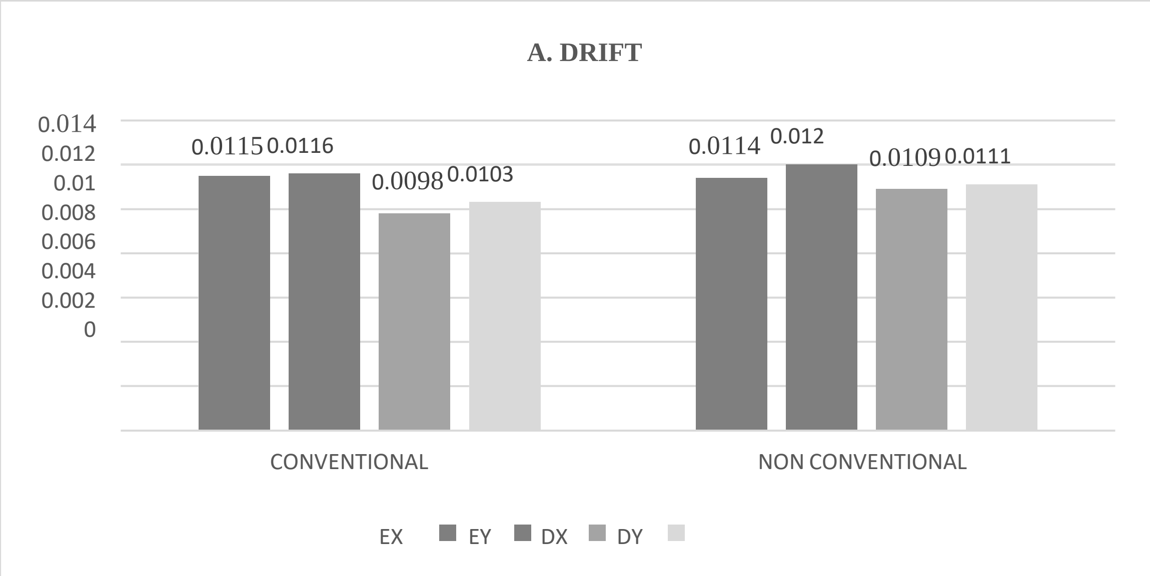

Figure 7. Drift results details.

The drift values (see Figure 7) are showing the interstudy drift values of both buildings and the building is stable against the drift as the values are coming under limitation[8-10].

Story Stiffness Details

Story stiffness details are shown in Table 6 for both the conventional (A) and non-conventional (B) (transfer slab) frame[11-14]

Table 6. Story stiffness in X and Y direction for seismic condition**.**

STORY STIFFNESS	A KN	B KN
EX	1867568	1572172
EY	1397943	1642460
DX	1601189	1574646
DY	1880508	1689189

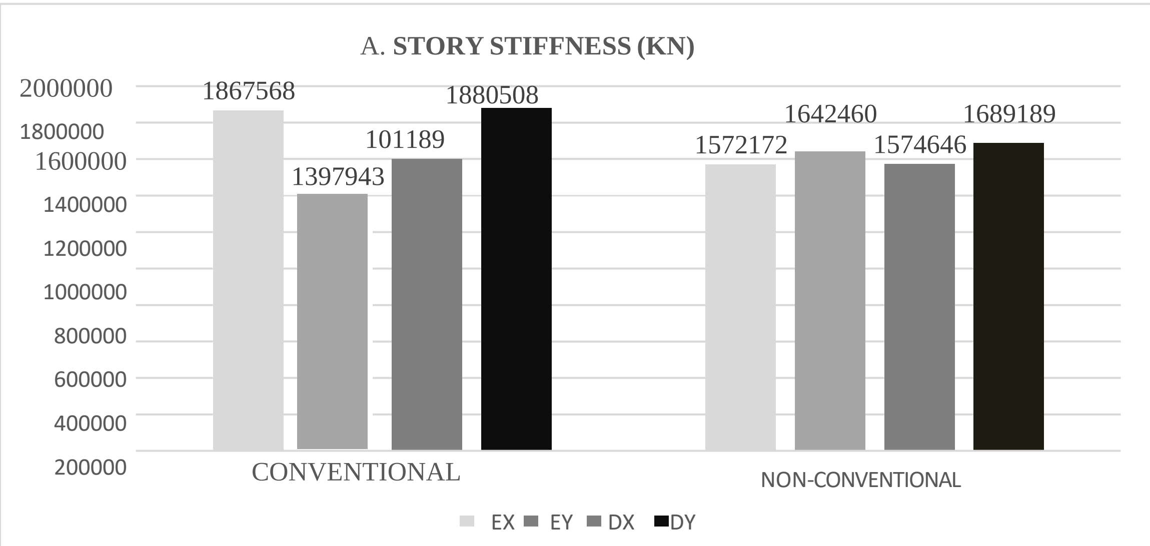

Figure 8. Story stiffness results in details.

Story stiffness values (see Figure 8) in both structures are almost close to each other as the stiffness is mostly depends on the mass of the structure the higher the value of stiffness shows the more resistance against the deformation.

CONCLUSION

After analyzing the structure of both conventional and non-conventional frame we obtained following conclusion.

- The time period of the conventional structure is 5.93 to 3.98 from Mode 1 to 3 respectively and in case of non-conventional frame it is 6.25 to 4.23 which is more than that of conventional frame due to more rigidity and foundation support in the structure.
- In other Graph, the sizes of the member are increases due to which the results show the better values to resist the structure as per IS codal provisions.
- Base shear values are getting higher in the case of conventional frame due to continuous support from top to bottom as shown in the tables.
- The displacement values are higher as 0.92 to 0.97 from conventional to nonconventional frame because of less support and stiffness in the structure.
- Drift values are quite similar in the both structure because of no major changes.
- The stiffness values of conventional frame is higher due to more numbers of columns, beams and slab as compared with non-conventional frame.

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