Analysis of Irregular Structure with Addition of Shear Walls as Per Nepal Building Code (NBC 105:2020)

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Abstract:- Retrofitting of building mostly hospital buildings after the earthquake of 2015 and following the amendments made in Nepal Building Code (NBC 2020) has been implemented for the safe hospital functionality and to ensure that the structure has every criteria fulfilled as per the new code. In this paper, an irregular hospital building is analyzed as per the site measurements and NDT test to evaluate its seismic performance and retrofitting techniques are provided in case the structure does not qualify as a safe structure. Here, we are adding shear walls instead of column, beam jacketing or any other retrofitting techniques to overcome the torsional effect that arises due to the irregularities in plan and stiffness of the structure.

Keywords: Torsional irregularity, retrofitting, shear walls, storey drift, NBC 105:2020

INTRODUCTION

After the implementation of the new Building Code in Nepal i.e. NBC (Nepal Building Code) 105:2020, the check for retrofitting for a public structure is preferably carried out to justify its safety in functionality. Most of the buildings structures with irregular plan are subjected to the torsional effects, which governs the analysis and design of the building structural members. For nullifying such torsional effects on a building structure, retrofitting technique of adding shear walls is generally opted for the building structure to be safe in its functions and services. During earthquake ground motions, structures much of the time will encounter torsional vibration in addition to lateral oscillations. A significant torsional reaction hotspot is due to asymmetrical distribution of mass or horizontal load opposing components in the plan of the structure, which is usually, refers to eccentricity of mass or rigidity [6]. In this research, we focused on optimizing the position of shear wall and thickness introduced in the structure to reduce the torsional effect caused by the plan irregularity of the building structure.

LITERATURE REVIEW

Rahila Thaskeen, Shinu Shajee(2016)[1], the objective of their work aimed at enhanced understanding of the torsional behavior of building systems. In the analysis, both symmetric and asymmetric structures with plan irregularity were compared. To assess the torsional effect on the structures they modelled four types of structures having same outer perimeter area and strengthened by introduction of shear wall cores. A simple linear comparison based on eccentricity is carried out for G+12 and G+17 structures. The analysis of structural models are carried out using ETABS software. From their investigation on reviews, they concluded that the eccentricity shows the tendency of the structure for torsional effects. C-shaped structures had the maximum tendency for torsional effects with higher value of eccentricity. Strengthened model yielded shorter-period, which permitted smaller drift limits and longer-period structures that, is the ideal symmetric structure allowed larger drift limits.

P.S Pajgade, Vipin Guptha(2015)[2] explains that the torsion is the most basic element prompting significant harm or completes collapse of building; therefore it is necessary that symmetric buildings should also be analyzed for torsion. As result, the buildings should be designed by considering the design eccentricity and accidental eccentricity. They observed that the irregular profile buildings got larger forces and displacement as compared to regular one. Structures are never consummately consistent and this the architects routinely need to assess the feasible level of irregularity and the impact of this irregularity on a structure during an earthquake.

Arvindreddy and R.J Fernandes (2015) [3] presented a review about the seismic analysis of RC regular and irregular structures. They considered two types of reinforced concrete structures with regular and irregular 15 storey structures and analyzed for static and dynamic methods. They concluded the static analysis strategy demonstrate lesser story displacements when compared with response spectrum analysis. This variation may be because of nonlinear distribution of force. In diaphragm irregularity, storey displacement and story drift observed to be less when compared with normal structures in both static and response spectrum analysis.

O.A Mohamed and O.A. Abbas (2015) [4] explains review about the consideration of torsional irregularity in Modal Response Spectrum Analysis. The motivation behind their work is to determine the impacts of torsional irregularity on seismic reaction as per ASCE 7-10, when

MRSA is utilized for count of seismic forces and drifts. They discuss about torsional irregularity must be represented, notwithstanding when MRSA is utilized. From their investigation on reviews they concluded that the torsional irregularity of building diaphragm or floor frameworks prompts increased structural reactions including bending moments and drift and should be represented in computational model to maintain a strategic distance form structural failures and building pounding effects.

Turut Ozturk, Zubeyde Ozturk and Onur Ozturk (2015) [5] presented a review about the seismic behavior analysis of multi- storey reinforced concrete buildings having torsional irregularity. The purpose of their work is to understand the characteristics of an earthquake and correct determination of the behavior of buildings under earthquake excitation. Turn out to be the most important requirement to build earthquake resistant buildings. In their study, torsional effects that occur during earthquake excitations are analyzed in multi storey reinforced concrete buildings. It is essential that shear wall location and cross-sectional areas must be properly selected, and the shear walls must be symmetrical in the plan in order to prevent torsional irregularity.

OBJECTIVES

The main objective of this paper are listed as below

I. To determine optimum position of shear walls and cross section required for an irregular building plan.

II. To carry out the seismic analysis for an irregular building under seismic loads as per NBC 105:2020.

III. To compare between the analytical parameters of the structure before and after the addition of shear wall.

IV. To compare the response of building under seismic loading as per IS 1893:2016 and NBC 105:2020.

V. To compare the parameters like storey drifts, displacements, base shear for both codes with and without the addition of the shear wall.

METHODOLOGY

To study the torsional effects for an irregular building we modelled a seven-storied existing hospital building with load patterns and cases as per IS 875 for a building with hospital functions and services. Firstly, we designed the existing structure of the building as per our site and as per the NDT, test data, which are tabulated, bin table 1. The analysis is done in ETABS 2017 Software.
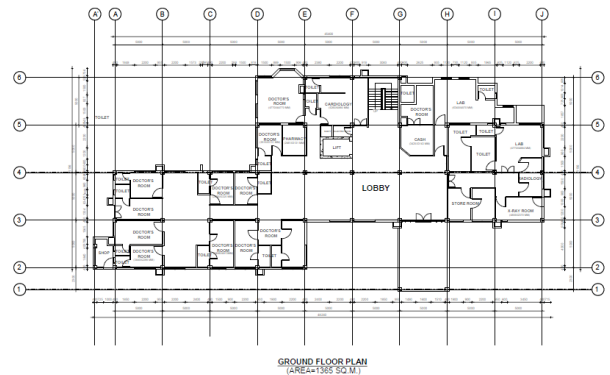

Fig: Plan of the Building

Structural analysis of the structure in carried out by using ETABS 2017 software. Three –Dimensional models have been prepared. Concrete M25 (as per the NDT report) is used for all the structural members whereas Fe 250 is used for steel structures. Centre-line dimension is followed for the analysis and design. Firstly, the analysis of the structure without adding any shear walls in carried out. Then we started adding shear wall generally starting from 200 mm thickness and gradually increased to 300 mm thickness.

MODEL DESCRIPTION

TABLE 1. GENERAL FEATURES

Building Type	Hospital
Plan	Irregular
Building Dimension	45m X 20m
Grade of concrete	M25
Grade of Steel	Fe500
Number of Storey	6
Storey Height	3m
Column dimension	400mmX400mm
Main beam Dimension	300mmx450mm
Slab Thickness	150 mm
Added Shear wall	300 mm
Footing Type	Raft Footing
Footing depth	2m

Load Combinations for NBC 105:2020

S.N	Load combinations
1	1.2DL + 1.5LL
2	DL + λLL$\pm$ EQx
3	DL + λLL$\pm$ EQx

Where,

λ = 0.6 for storage facilities.
= 0.3 for other usage.
DL= Dead Load, LL= Live Load,
EQx= Earthquake load in X-direction.
EQy= Earthquake load in Y-direction.

Note: For the simplicity of the structure, the wind load is ignored for this analysis.

Live Loads for each slabs are taken as per their functions and services accordance to IS 875: (part 3).

Self-weight of the structural members, (columns, beams, slabs) are automatically included in ETABS software.

S.N	Type	Value
1	Reinforced Concrete	25 KN/m³
2	Brick Masonry	19 KN/m³
3	Screed	21.0 KN/m3
4	Marble	26.7 KN/m³
5	Mosaic finish	23.1 KN/m³
6	Plaster	20.4 KN/m³
7	Steel Rebar	78.6 KN/m³

Table: Unit Load of Material Used.

The earthquake load, base shear coefficient as per NBC 105:2020 is calculated as below:

1 General Data

Height for time period calculation (H)	18 m
Time period from empirical formula= 0.05XH^0.75	0.44
Increasing time period by 25% cl 5.1.3 0.63 sec	0.55
Time period used (T)	055

Parameter (for soil type D)

Ta	0
Tc	0.7
α	2.25
K	1.8

Spectral shape factor as per cl.4.1.2 (Ch(T))

$$C_h(T) = \begin{cases} 1 + (\alpha - 1) \times \frac{T}{T_a} & if\ T < T_a \\ \alpha & if\ T_a \leq T \leq T_c \\ \alpha \left[K + (1-K)\left(\frac{T_c}{T}\right)^2 \right]\left(\frac{T_c}{T}\right)^2 & if\ T_c \leq T \leq 6 \end{cases}$$

Values of (Ch(T)) X-direction   = 2.25
Values of (Ch(T)) y-direction   = 2.25

Seismic zoning factor as per cl. 4.1.4 (Z) for Kathmandu
=   0.35
Importance factor as per cl 4.1.5 (I)   =
1.5
Elastic site spectra C (T) = Ch.(T)ZI   =
1.18125

2. Horizontal base shear coefficient

Over strength factor for ULS as per table 13 (Ωs) =
1.3
Ductility factor as per NBC 105   =
3
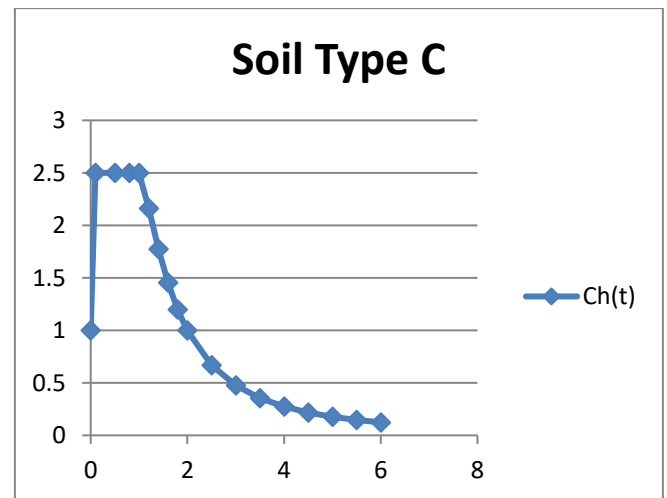Horizontal base shear coefficient , Cd(T) = C(T) / (Ru*Ωs) = 1.18125/(1.3*3)= 0.302
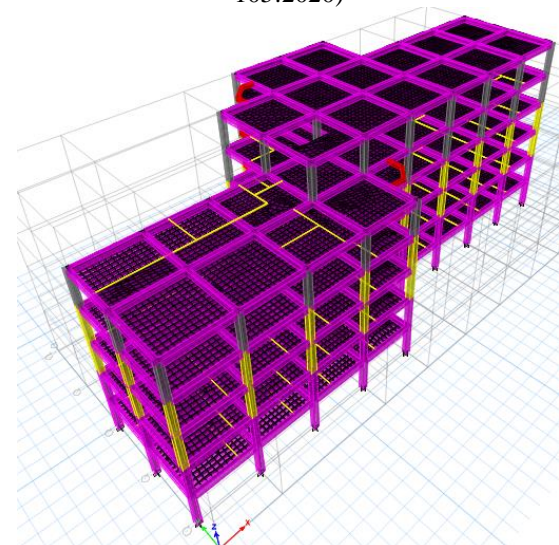

Fig: Spectral Shape Factor for Soil Type C (NBC 105:2020)

Fig: 3D model in ETABS

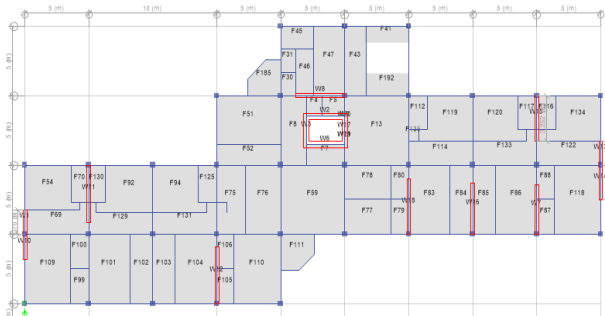| Base Shear	10040.40 kN	
Maximum Storey Displacement(X)	71.328 mm	Top Storey
Maximum Storey drift(X)	0.0168	Top Storey
Maximum Storey Displacement(Y)	87.238mm	Top Storey
Maximum Storey drift(Y)	0.010558	Fifth Storey

Table 1

Fig: Plan of building with added shear walls

	11020.87 kN	
Base Shear		
Maximum Storey Displacement(X)	45.255 mm	Top Storey
Maximum Storey drift(X)	0.0118	Top Storey
Maximum Storey Displacement(Y)	19.953	Top Storey
Maximum Storey drift(Y)	0.003295	Top Storey

Table 2

As we can observe that, the addition of the shear wall in the building structure plan decreases the maximum storey displacement of the whole structure in both the directions. Furthermore, the optimum positioning of the shear wall with optimum thickness/cross sectional area of added shear walls should be recognized for an economical and efficient design. The point to be noted here is that as the additional shear wall are adjusted such a way to minimize the lateral effect in Y-direction, the displacement due to lateral forces decreases more in Y-direction than in X-direction which can also be demonstrated from graph 1 and graph 2.
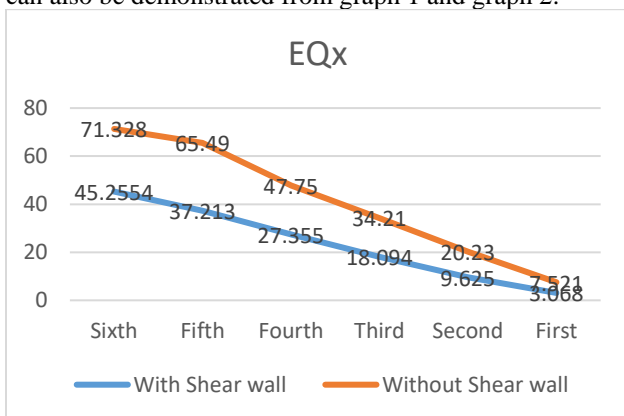
Graph1: Max Storey Displacement (mm) X-direction
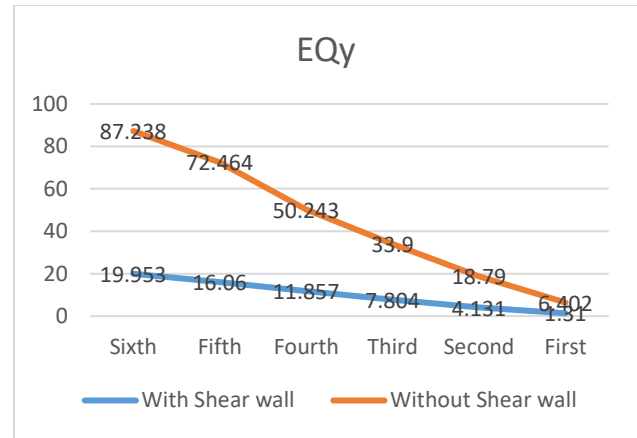
Graph 2: Max Storey Displacement (mm) Y-direction

Also, we looked into the modal mass participation ratio for the both structures (with and without the addition of shear walls) and realize that the addition of the shear wall in optimum position and optimum cross sectional area can help in reducing the torsional effect occurred due to the plan irregularity of the building significantly. Here, we are only focused on the first three modes.

Mode	Sum Ux	Sum Uy	Sum Rx	Sum Ry	Sum Rz
1	0.0557	0.0024	0.0124	0.0086	0.7616
2	0.0662	0.6736	0.334	0.0125	0.7629
3	0.6467	0.6823	0.3356	0.3632	0.8108

Table 3 a

Mode	Sum Ux	Sum Uy	Sum Rx	Sum Ry	Sum Rz
1	0.6812	0.001	0	0.3359	0.0051
2	0.6818	0.6544	0.3126	0.3396	0.0315
3	0.6849	0.6807	0.3545	0.3468	0.6879

Table 3 b

For the optimum positioning and cross section of the additional shear walls, the focus point was targeted to nullify the torsional effect arising in the structure due to its plan irregularity. As observed in Table 3 a, the effect of torsion clearly disrupts the modal mass participation ratio of the structure in first three modes participating less than 5% of total mass in both directions in first mode. In addition, the first two modes are induced by torsional effect rather than being translational modes. After the addition of the shear walls, Table 3 b shows the uniform participation of modal mass in the first three modes, the first and second modes being the translational modes and the third acting as a torsional mode.

SUMMARY

The dynamic analysis of the structure for an existing building and addition of shear walls to minimize the torsional effect induced by the plan irregularity of the building are carried out in ETABS 2017. From this analysis, the conclusions can be summarized as follows:

1. Focus on minimizing of the torsional effects for an irregular building can ultimately minimize the storey displacement of the building and hence minimizing the demand for the structural members.

2. The positioning of the shear walls in an irregular building is found to be more sensitive than the selection of cross sectional area of the additional shear walls.

3. The first two translational modes and the torsional mode in the third can be obtained by optimizing the location and thickness of the additional shear walls for an irregular building plan considering the stiffness and mass irregularities as well.

4. The addition of shear walls in a structure ultimately leads to lower storey displacement keeping the allowable maximum storey drift criteria in limits.

5. Retrofitting of an irregular building can be carried out by adding shear walls to avoid the torsional effect caused by the irregularities of the building.

6. The base shear coefficient for a Shear walled Structure as per NBC 105:2020 has higher value compared to IS 1893:2016 leading to higher demand in reinforcement in the structural elements resisting the earthquake loads.

CONSLUSION AND DISCUSSION

Addition of shear walls in position such that they carry out the torsional effect of the building due to its irregularities significantly decreases the demand for reinforcement in structural members i.e. columns and beams. As well, the displacement, storey drift of such buildings are decreased with the addition of such shear walls. The point to be noted is that the positioning and selecting the right thickness for each added shear walls should be correct for countering the irregularities of the structure.

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