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Study on Effect of Shear Wall on Plan Irregular Buildings

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Abstract— In today's world, buildings are often designed with different irregular shapes based on what the owner's requirement, how the buildings will be used, the available land, and how they should look. These irregularities engender a reduction in the structural efficacy of the structures. So, this study aims to understand how buildings made of reinforced concrete (RCC) with irregular shapes perform when there's an earthquake. This study aims to find out Response of Plan irregular building under seismic load, evaluate and compare the seismic performance of RC building having plan irregularities with shear wall and without shear wall and to determine optimum position of shear wall in irregular plan buildings. In order to meet the objective, seismic responses of various building configurations (regular, O, H, C, T, L) are examined using response spectrum analysis and ETABS 18 software, following NBC 105:2020. Responses are evaluated for storey displacement, drift, torsion, overturning moment, and base shear. Among the chosen building configurations, the L-shaped building exhibits the least favorable performance in terms of storey displacement, storey drift, and torsion. Consequently, shear walls are introduced at various locations within the L-shaped structure, leading to further investigation to optimize the shear wall's placement and enhance performance. After considering multiple shear wall placements, it becomes evident that introducing a shear wall at the adjacent joint along both X and Y directions enhances the L-shaped building's performance specifically in terms of drift/displacement, base shear, and overturning moment within the respective directions. However, this placement does not fully mitigate the torsional irregularity beyond permissible limits. On the other hand, positioning shear walls at all corners, spanning the entire length of the adjacent corner bays, results in minimal torsional irregularity while satisfying other performance criteria. Moreover, situating a shear wall at the outer corner, extending the full length of the adjacent bay, considerably improves displacement, drift, and base shear, while resulting in increased torsion and overturning moment. Overall, optimal shear wall placement is observed at all corners with full length along adjacent bays.

Index Terms— Response Spectrum Analysis, Plan Irregular,Torsion,Storey Displacement,Storey Drift,Base Shear.

1 Introduction

THE Earthquake is known to be one of the most devasting phenomenon experienced on the earth which is caused due to the sudden release of huge energy in the earth's crust which will results in seismic waves. When such seismic waves reach the foundation level of buildings it experiences motion due to which large damage to various manmade structures like buildings, bridges, dams etc

Nepal is situated upon the Alpine-Himalayan or Alpine Belt, where 17 percent of world's largest earthquake occurs as the Indian Plate pushes upwards into the Eurasian plate, causing great stress to build up in the Earth's crust, only to be relieved through earthquakes [1]. Due to large earthquake most of vulnerable structure prone to damages. In previous days most of the building in Nepal were found to be built in irregular shape and it was experienced that the damages to building with irregular shape was more than the building with regular shape**.**

Structures with simple and regular configurations suffer much less damage during a large earthquake. Irregular structures on the other hand suffer heavy damage during a large earthquake. Therefore, efforts shall be made to make the structure as regular as possible.[2]

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2 Literature Review

1. *Lamichhane et al., n.d.,2021* 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
2. *Khanal B & Chaulagain H, 2020* In this, one regular and six different L-shaped RC building frames were modeled for numerical analysis. The analysis was done through an equivalent static lateral force method and response spectrum analysis (dynamic analysis) The results indicate that buildings with plan configuration irregularity are more sensitive to the varying angle of the input response spectrum as compared to the symmetrical building model. . It is concluded that to account

for the irregularities present within the buildings, current code provisions are insufficient and should be amended

3. *Banerjee & Srivastava,* 2019The location should be such that it should distribute the gravity loads and the lateral loads such that the building retains it centre of gravity in best way possible. Configuration of MODEL 03(Shear wall at central location) is such that it easily distributes the lateral forces in best possible manner. Thus, this reduces the values of Spectral Displacement, Storey drift, Storey Displacement due to earthquake forces. Apart from that, seismic forces increase in the buildings in terms of base shear. This indicates that building with shear wall is able to capture more seismic loads

3 STATEMENTS OF PROBLEM

It is undeniable that in medium/high seismic prone areas, human and economic loss is due to severe physical damage and partial or total collapse of non-seismically designed buildings.so life safety is prime importance during Earthquake Event. From past studies it was found that the building which are irregular in plans are more verge in damage than that of buildings with regular configurations ,even of poor performance of irregular buildings such buildings are also in construction practice which might be because of architectural view ,owners requirement and availability of land .This types of buildings irregular in plan are found to be designed with addition of shear wall to enhance the seismic performance of the irregular buildings but for better enhancement of seismic performance of the building the study need to be carried out for failure of such structure due to lack of sufficient lateral load resisting structure ie shear walls and most efficient and effective location of shear walls in irregular buildings.

4 OBJECTIVES OF STUDY

The aim of this research is to study the effect of shear wall on plan irregular buildings.

5 DIMENSIONS AND MODELS

Different shape of irregular buildings are selected and each building are analyzed with considered load and maximum section which satisfy critical buildings are considered for all buildings to compare results which are

Beam Size=550mmX650mm
Column Size=750mmX750mm

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Slab Thickness=125mm
Shear Wall Thickness=250mm
Wall Thickness=230 mm for outer wall 100mm for partition wall
Grade of Concrete =M25
Grade of steel =HYSD-500
Seismic Parameter= Seismic Parameter of Surkhet District

As sampling Techniques Firstly different plan irregular buildings were drafted. ie, Regular shape, O shape, H shape, T shape, C-shape and L-Shape as shown in figure 1 below

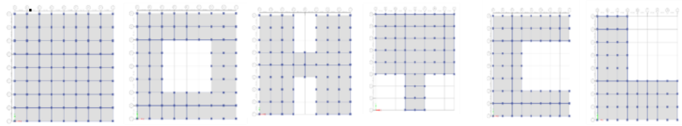


Figure 1: Different Shaped Buildings Plans

Then after analysis of above model, L shape Buildings showed poor performance among all other model and Shear wall at different location along with was modeled for L shape Buildings .as shown in figure 2 below

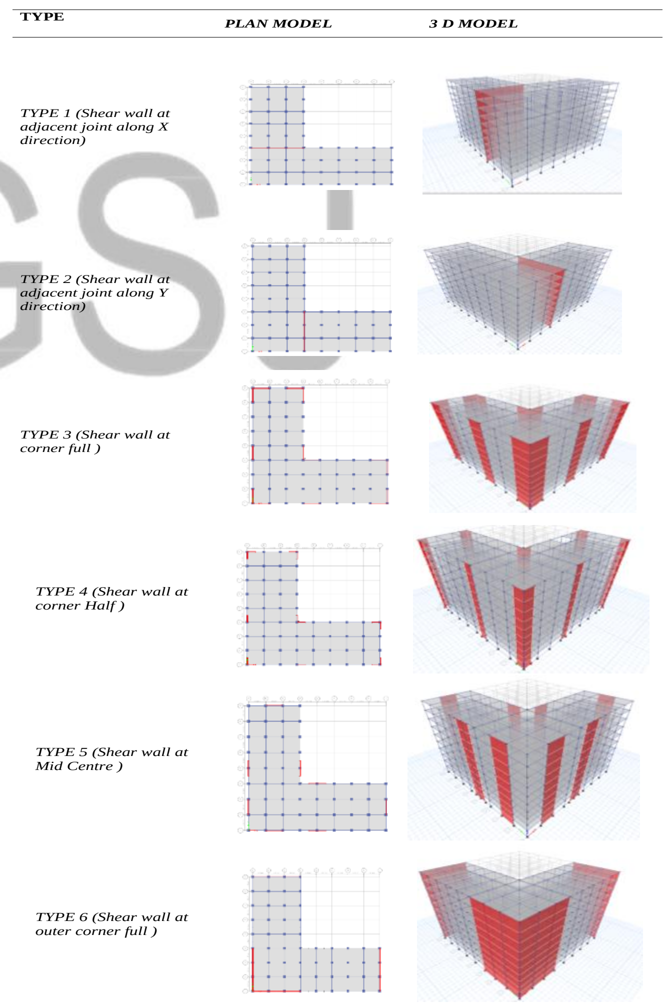


Figure 3: Different Locations of Shear wall in L shaped Building

5 DATA PROCESSING PROCEDURES

For Data Processing ETABS software and NBC :105:2020 code is used Response Spectrum analysis is done for different selected models and the response curve for this method is generated on the basis of NBC 105:2020 as shown in figure 4,Also for the selected models for this study as per NBC 105:2020 the permissible displacement is 187.5mm For ULS as per Clause 5.6.1.1and permissible drift is 0.00625 mm For ULS as per Clause 8.1.3.1 and permissible torsional irregularity is 1.5 as per NBC 105:2020 Clause 5.5.2.1

Data analysis is done by the following steps

Step 1: Preparation of 2-D and 3-D model of building frame, using different irregular plan geometry, and material properties.

Step 2: Assigning of Different load to the model

Step 3: Estimation of design lateral force on building using NBC105:2020

Step 4: Analysis of the model by Response Spectrum Method

6 RESULTS

6.1 Seismic Parameters Results of Different Irregular Models Due to RSA

The storey displacement,storey drift and torsional irregularity for the buildings of Type C, Type H ,Type T in X direction and Y direction are found to be different but the for regular building ,Type O building and Type L building is almost same in X direction and Y direction. Among all the models maximum top storey displacement, storey drift and torsional irregularity is found to be in L shape buildings in both X and Y direction but ,Minimum Displacement is found to be in C type buildings in X direction and for Y direction minimum displacement is found in H type Buildings

6.1.1 Maximum storey Displacement

Figure 4 represents the maximum storey displacement for X and Y direction respectively 1.The permissible displacement for our model as per NBC 105:2020 is limited to 187.5 mm for ULS and for all models displacement is under 187.5mm.The order of top storey displacement along X direction due to RSx ULS is L-Type (129.20mm) >T-Type (127.357mm) > H-Type (112.74mm)>RegularType(109.17mm)>OType(106mm)>C-Type (96.93mm).Similarly the order of top storey displacement along Y direction due to RSy ULS is L-Type(128.43mm) >C-Type(96.93mm)>T-Type(112.55mm)>Regular-Type (109.92mm)>OType(106.41mm)>H-Type(105.56mm).Here maximum top storey displacement is for L shape building in both direction

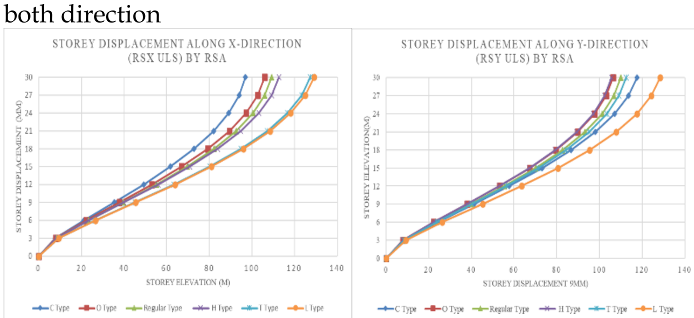


Figure 4: Storey Displacement

6.1.2 Maximum Storey Drift

The permissible drift for our model as per NBC 105:2020 is limited to 0.00625 mm for ULS and for all other models drift is under 0.00625mm ,but in case of Type L building 0.006307 mm drift was observed in X direction and 0.00627mm in Y direction at storey 3 which is more than permissible drift. The order of maximum storey drift along X direction due to RSx ULS is at storey 3(9 m from base) which isL-Type(0.00630mm)>T-Type(0.00625mm)>H Type (0.005552)> RegularType (0.00541mm)>OType(0.00522mm) >C-Type (0.00478mm) Similarly the order of maximum storey drift along Y direction due to RSy ULS is at storey3 which is L-Type(0.00627mm)>C-Type(0.00565mm)>T-Type(0.00556mm)>Regular-Type (0.005449)>OType(0.00524mm)>HType(0.00522mm).Here maximum storey drift is for L shape building in both direction

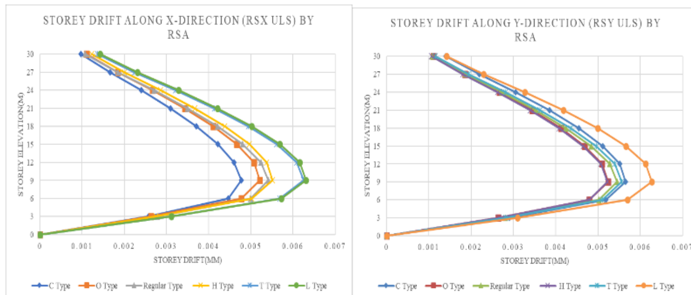


Figure 5: Storey Drift

Torsional Irregularity

The permissible torsional irregularity (ratio of Maximum displacement to minimum displacement) for our model as per NBC 105:2020 is limited to 1.5 for ULS and for all other models torsional irregularity is under 1.5 ,but in case of Type L building 1.489 mm drift was observed in X direction and 1.476 in Y direction which is almost same as permissible limit. The order of maximum torsional irregularity ratio along X direction due to RSx ULS is L-Type(1.489)>T-Type(1.455> RegularType (1.239)>)>H Type (1.229)> C-Type(1.106)>O Type(1.096) Similarly the order of maximum storey drift along Y direction due to RSy ULS is at storey3 which is L-Type(1.476)> C-Type(1.423)> T-Type (1.274)> H-Type(1.250)>Regular Type (1.247) >O-Type(1.104).Here maximum torsional irregularity is for L shape building in both direction.

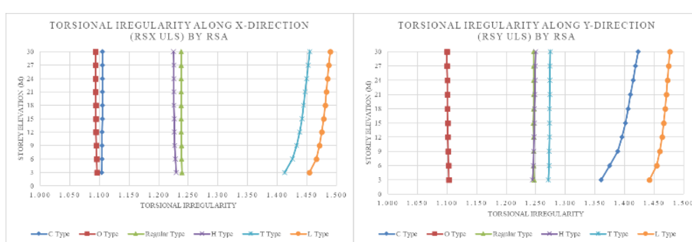


Figure 6: Torsional Irregularity

6.2 Seismic Parameters Results of L-Shape Models with shear walls at different location Due to RSA

The storey displacement, storey drift, storey shear and torsional irregularity f.1or the buildings of type 6 is found to be minimum in both X and Y direction and overturning moment for type 6 building is maximum among all models. The storey displacement, storey drift,storey shear and torsional irregularity for the buildings of Type 2 is maximum in X direction and for Type 1 it is maximum in Y direction .Similarly For Type 3 ,Type

4, Type 5, and Type 6 Seismic Parameter are found to be relatively same in both X and Y direction.

6.2.1 Maximum storey Displacement

After addition of shear wall at different location the order of top storey displacement along X direction due to RSx ULS is Type-(129.97mm)>Type-4(68.62mm>Type-5(61.82mm)>Type-1(55.87mm)>Type-3(30.06mm)>Type-6(15.73mm).Similarly the order of top storey displacement along Y direction due to RSy ULS is Type-1(129.5mm) > Type-4 (68.286mm > Type-5(61.668mm)>Type-2(55.89mm)>Type-3(29.97mm)>Type-6(15.716mm).

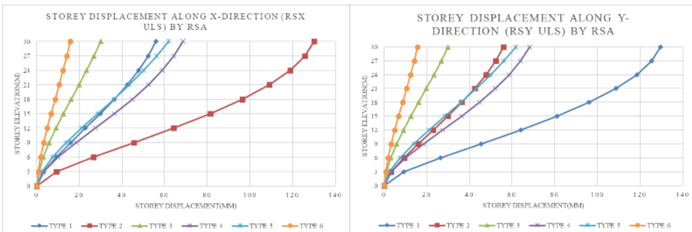


Figure 7: Storey Displacement

6.2.2 Maximum Storey Drift

After addition of shear wall at different location the order of maximum storey drift along X direction due to RSx ULS is Type-2 (0.006343mm) > Type-4 (0.003012) mm > Type-5 (0.002529mm)>Type-1(0.002327mm)>Type-3(0.001218mm) >Type-6 (0.000624mm) .Similarly the order of maximum storey drift along Y direction due to RSy ULS is Type-1(0.006321mm)>Type-4(0.002999mm>Type-5(0.002523mm) >Type-2(0.002329mm)>Type-3(0.001215mm)> Type6(0.00623mm).

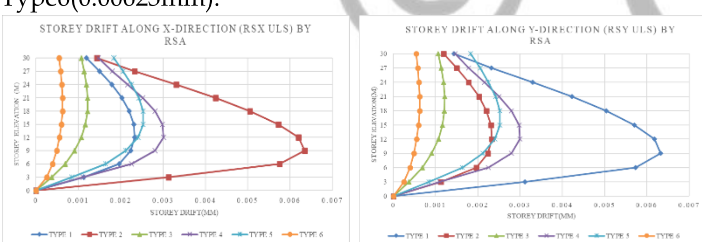


Figure 8: Storey Drift

6.2.3 Torsional Irregularity

After addition of shear wall at different location the order of maximum storey drift along X direction due to RSx ULS is Type-1(2.412)>Type-2(1.466)mm>Type-5(1.404)>Type-4(1.288) >Type-6(1.223)>Type-3(1.138). Similarly the order of maximum storey drift along Y direction due to RSy ULS is Type-2(2.414)>Type-1(1.459)>Type-5(1.399)>Type-4(1.282) > Type-6(1.220)> Type3(1.139).Here it was observed that Torsional irregularity along X direction for Type 1 building and Torsional Irregularity in Y direction for Type 2 building is more than the permissible limit

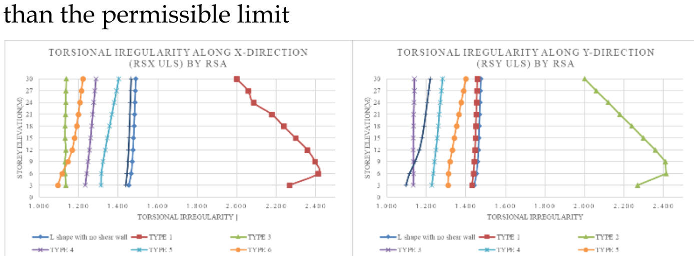


Figure 9: Torsional Irregularity

6.2.4 Base Shear

The observed base shear for the model building with shear wall at different location due to RSx ULS along X direction is Type-2(20114.49KN)>Type-4(19391.28KN)>Type 5(19213.6KN)> Type 1(18904.17 KN)>Type 3(17213.81 KN)>Type 6(15364.86 KN). Similarly the order of maximum storey drift along Y direction due to RSy ULS is Type-1(20143.68KN)> Type-4(19397.24KN)>Type 5(19224.85KN)> Type 2(18907.43 KN)>Type 3(17212.1 KN)>Type 6(15366.74 KN).It is observed that the base shear is minimum for Type 6 Building in both X and Y direction.

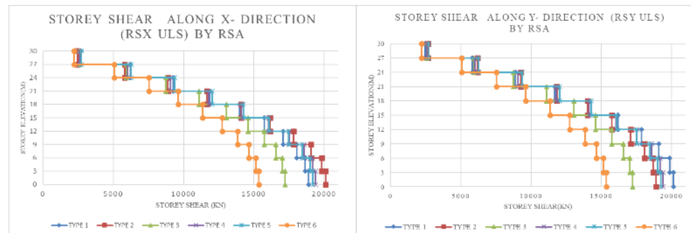
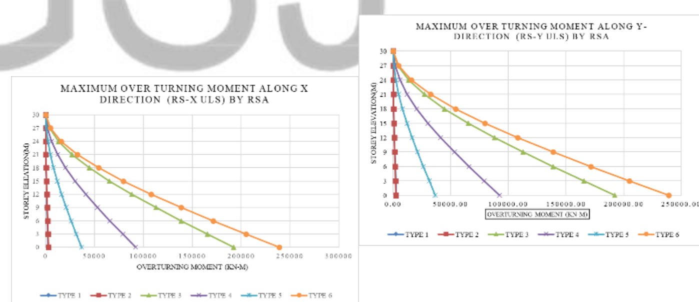


Figure 10: Base Shear

6.2.5 Overturning Moment

Maximum overturning moment for L shape model with shear wall at different location due to RSx ULS along X direction is in the order of Type 6>Type 3>Type 4>Type 5>Type 2> Type 1 and due to RSy ULS along Y direction Type 6>Type 3>Type 4>Type 5>Type 1> Type 2.Here Maximum overturning moment is observed in Type 6 building ani both X and Y direction and Minimum in Type 2 in X direction and Type 1 in Y direction



7 CONCLUSION

After the completion of analysis of different shape buildings G+9 storey ie regular shape,O shape ,C shape,T shape,H shape , L Shape buildings and selecting building with poor performance among regular shape,O shape ,C shape,T shape,H shape ,L Shape and placing shear wall at different locations of L shape building using Response Spectrum Method as analysis tool with reference code NBC 105:2020 ,conclusions drawn from the discussion above can be listed as followings:

1. Based on the selected model ie Regular,O,C,T,H,and L shape buildings C shape Building showed better performance in X direction for which the reason is in this study C shape is oriented in X direction and maximum load resisting element are oriented in X direction ,whereas H shape building showed better performance in Y direction because of more number of load resisting element are oriented in Y direction. O shape building safer in both directions than of regular shaped building due to decreased seismic weight of the building and

better orientation of beam and column in both directions than other shaped buildings and Response of L shape building is poor in both direction in terms of displacement, drift and torsion due its poor configuration, hence shear wall introduction in better location can enhance the performance of L shaped building.

2. Here after introduction of shear wall at different location in L shape Building the maximum percentage decrement in displacement along X direction is of TYPE 6 (Shear wall at outer corner full) by 87% but for TYPE 2 (Shear wall at adjacent joint along Y direction) it is increased by 0.59%,similarly maximum percentage decrement in displacement along Y direction is of TYPE 6 (Shear wall at outer corner full) by 87.76% but for TYPE 1 (Shear wall at adjacent joint along X direction) it is increased by 0.82%.Maximum percentage of decrement in drift along X direction is of TYPE 6 by 90% but for TYPE 2 it is increased by 0.57% similarly maximum percentage decrement in drift along Y direction is of TYPE 6 by 90.07% but for TYPE 1 it is increased by 0.74%.In case of torsional irregularity along X direction minimum torsional irregularity is in TYPE 3 (Shear wall at corner full) which is 1.138 and maximum in TYPE 1 is 2.412 which is beyond the permissible limit similarly along Y direction minimum torsional irregularity is in TYPE 3 (Shear wall at corner full) which is 1.139 and maximum in TYPE 2 is 2.414 which is beyond the permissible limit. The Base shear along X direction for L shape building without shear wall is 19583KN which is decreased to 15364 KN in TYPE 6 building but is increased to 20114.49 KN in TYPE 2 building, similarly in Y direction the base shear for L shape building without shear wall is 19583KN which is decreased to 15366.74 KN in TYPE 6 building but is increased to 20143.68 KN in TYPE 1 building .Also maximum overturning moment along X direction is maximum in TYPE 6 building and minimum in TYPE 1 Building and along Y direction it is maximum in TYPE 6 building and minimum in TYPE 2 Building.

3. TYPE 1 (Shear wall at adjacent joint along X direction) showed better performance in X direction only on the basis of displacement drift ,base shear and overturning moment but torsional irregularity is beyond permissible limit and its performance along Y direction is very poor , TYPE 2 (Shear wall at adjacent joint along Y direction) showed better performance in Y direction only on the basis of displacement drift ,base shear and overturning moment but torsional irregularity is beyond permissible limit and its performance along Y direction is very poor from which it can be concluded that shear wall in single direction cannot enhance the seismic performance of the building rather it degrade the performance of the building. TYPE 3 (Shear wall at corner full), TYPE 4 (Shear wall at corner Half), TYPE 5 (Shear wall at Mid Centre) and TYPE 6 (Shear wall at outer corner full) in which shear wall orientation is orthogonal almost exhibit the same seismic response in both direction ie X and Y direction which shows that shear wall orientation in orthogonal manner is most important to enhance building performance. Since TYPE 6 (Shear wall at outer corner full) shows comparatively low Displacement, Drift and base shear and high overturning moment than that of TYPE 3 (Shear wall at corner full) in both direction, torsional irregularity is minimum in TYPE 3 (Shear wall at corner full) in both X and Y direction than that of TYPE 6 (Shear wall at outer corner full). So, it is concluded that the optimum position of shear wall is TYPE 3 (Shear wall at corner full).

Acknowledgment

The authors would like to acknowledge their beloved parents.

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