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Seismic Strengthening of Reinforced Concrete Frame Located in Unstable Slope using Shear Wall

Sabin Sapkota [a], Dipendra Gautam [b]

[a, b] *Department of Civil Engineering, Thapathali Campus, IOE, TU, Nepal*
Corresponding Email: [a] 070bce134@pcampus.edu.np, [b] strdyn33@gmail.com

Abstract
Buildings on unstable slopes are vulnerable to landslides which are usually triggered by several events such as heavy rainfall, typically producing huge losses. This paper focuses on the effects of flow-type landslide on the buildings. Two building models with masonry infill walls and shear wall are taken. Finite element software SAP 2000 16 was used for linear static analysis of buildings The flow-type landslide was modelled using momentum equations. The displacement of the corner points of roof and stresses developed were studied. The results show that replacement of masonry infill walls by shear wall strengths the buildings with the reduction of displacement of corner points of roof.

Keywords
Flow-type landslide, displacement, shear wall

1. Introduction

Large no of landslides occur every year due to several triggering factors like intense rainfall event, earthquake and rapid stream erosion, causing severe damages to buildings and infrastructure system and resulting in fatalities. Flow-type landslides are rapid landslides with high proportion of water to solid materials [1]. The shallow landslide on slope that generally flows down to slope in very high velocity is found to be most devastating landslide in Nepal [2].

Based on velocity data and estimates of flow density, the values of impact pressure on buildings were assessed through the calculation of hydrostatic pressure and dynamic overpressure. Study show that at flow velocities $> 4.5ms^{-1}$ the dynamic overpressure accounts for most of the observed damage, whereas at lower velocities the contributions of the hydrostatic and dynamic pressures become similar [3].

In this paper, the flow-type landslide is modelled and applied to building models. The stresses and displacement are measured to study the effect of replacement of masonry wall by shear wall.

2. Objectives

The general objective of carrying out this study is to investigate the vulnerability of RC frame subjected to flow-type landslide located on unstable slope. Specific objectives of the study are:

1. To observe the effect of flow-type landslide on displacement and stress developed in RC frame
2. To determine the increase in strength of RC frame after replacement of masonary wall with shear wall.

3. Methodology

In this study, a simple single storied single room building with RC frame (plan shown in Figure 1) is modeled using finite element software. Two separate building models were taken, one with masonry wall and another with shear wall on all the four sides of the building.

Flow – type landslide was modelled using momentum equations and the impacted pressure is applied along the X-direction. This impacted pressure is assumed to consist of a Hydrostatic pressure and a dynamic overpressure which are linearly and uniformly distributed over the flow depth as shown in Figure 8.

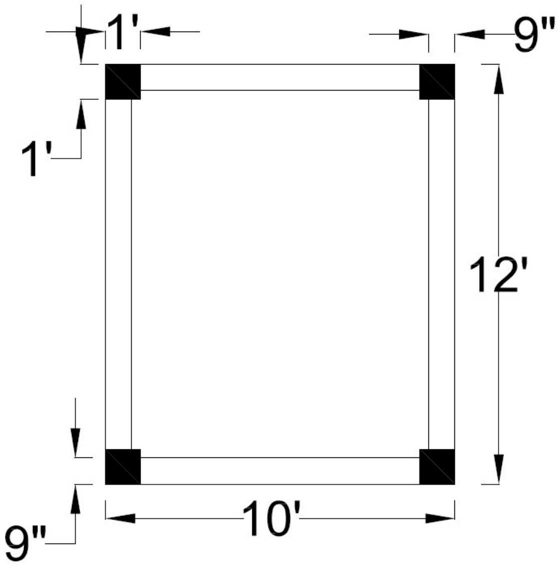

Figure 1: Plan of Building

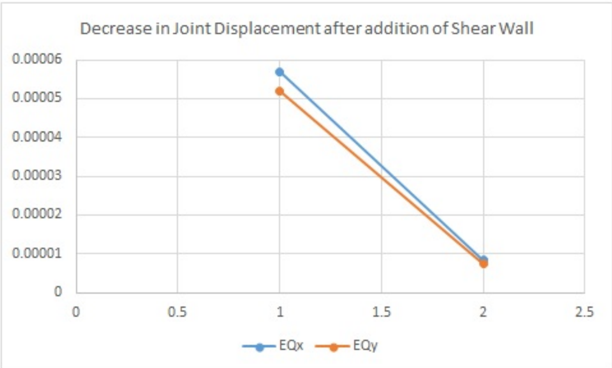

Figure 2: Joint displacements before and after replacement of masonry walls by shear walls

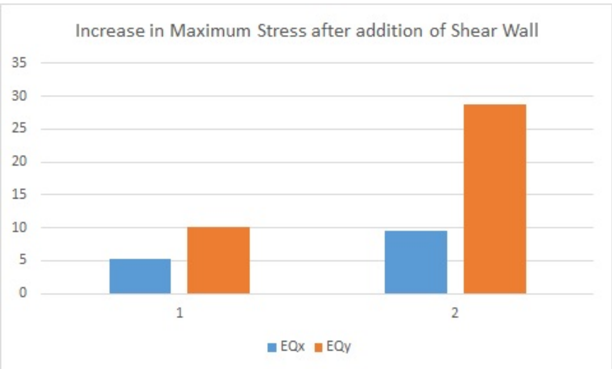

Figure 3: Maximum stress before and after replacement of masonry walls by shear walls

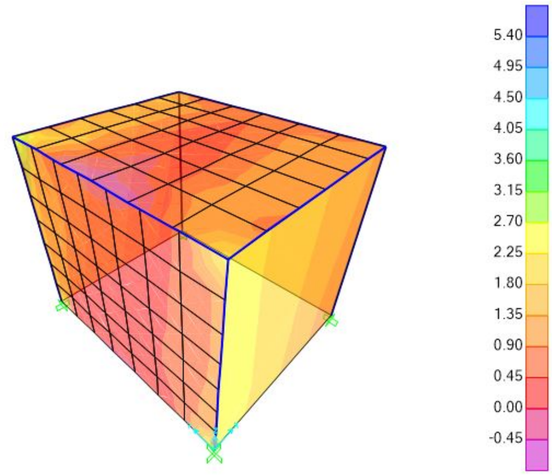

Figure 4: Stress Distribution for Earthquake acting along X-direction for model with masonry wall

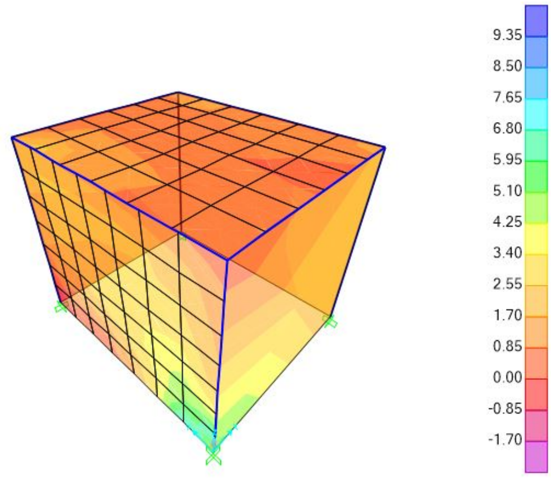

Figure 5: Stress Distribution for Earthquake acting along Y-direction for model with masonry wall

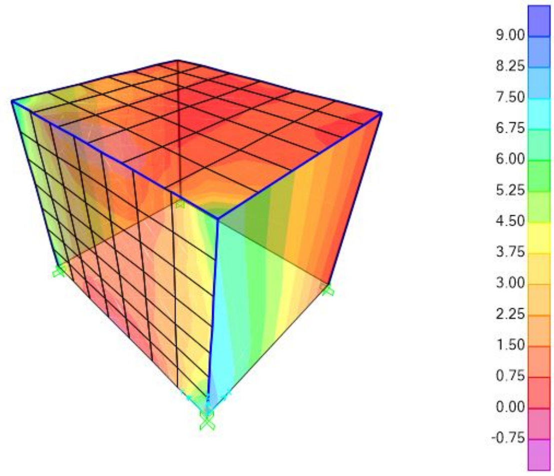

Figure 6: Stress Distribution for Earthquake acting along X-direction for model with shear wall

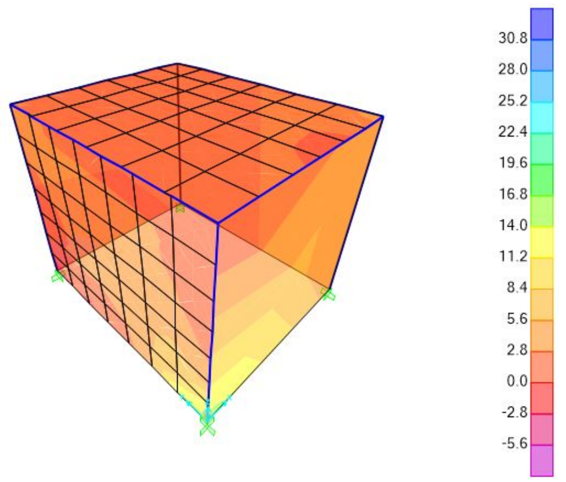

Figure 7: Stress Distribution for Earthquake acting along Y-direction for model with shear wall

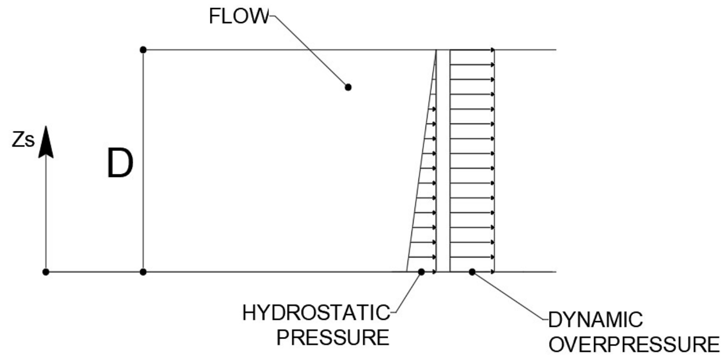

Figure 8: Distribution of Impact Pressure

Design and modeling of flow-type landslide

For modelling the flow-type landslide, a case–study of Kathmandu Valley (Matatirtha), July 2002, was taken.

Based on momentum equation, the impact pressure of the flow was predicted as follows:

$$P_d(z_s) = \frac{1}{2}\rho g(D - z_s) + \rho v^2 cos^2\delta$$

where ρ= flow density; g = acceleration of gravity; D = flow depth; z_s = height of generic soil layer with respect the sliding surface of the flow, i.e. bottom surface or bed soil; v = impact flow velocity; and δ = angle of flow direction with respect to the axis perpendicular to the impacted surface. For maximum impact pressure, perpendicular flow (i.e. δ = 0) is assumed.

Table 1: Flow-type landslide parameters and material properties

Dry Unit weight of soil	17 kN/m^3
Velocity of flow	50 m/s
Flow depth	3.048 m
Height of generic soil layer wrt sliding surface of flow	0 m
angle of flow direction wrt the perpendicular axis	0°

Building parameters and material properties

A single story with a single room and no openings with regular bare frame has been considered for this study. The stiffness due to infill wall has been considered for the analysis. There are two bays in X-direction and two bays in Y-direction. Span length in X-direction is 3.048 m and that in Y-direction is 3.6576 m. The size of the slab is taken to be 127 mm and the size of the beam is fixed to 228.6 mm X 304.8 mm. The size of the columns is taken as 304.8 mm x 304.8 mm.

The building parameters and material properties used for the development of the models are listed in Table 2

Table 2: Building parameters and material properties

Concrete grade	M20
Unit weight of concrete	25 kN/m^3
Modulus of elasticity of concrete	22360 MPa
Poisson's ratio of concrete	0.2
Poisson's ratio of masonry	0.15
Unit weight of steel	7850 kg/m^3
Modulus of elasticity of steel	200 GPa
Modulus of elasticity of masonry	2112 MPa
Thickness of slab	127 mm
Width of Shear Wall	250 mm
Storey height	3.048 m
Size of beams	228.6 mm × 304.8mm

Design and modeling of building

The frame building was designed using seismic coefficient method taking in reference design codes IS 456:2000 and IS 1893: 2002. Finite element software SAP 2000 16 was used for design and modeling of the building.

Dead loads and live loads are assigned as per IS 875 (part 1) and IS 875 (part 2) respectively. Live load of the roof is taken as 1.5 kN/m^2. The thickness of masonry walls is considered to be 230 mm with no openings. The specific weight of the brick wall is taken as 19.0 kN/m^3. The design load combination was taken as given in the seismic code. The building is considered as special moment resisting frame and is designed for seismic zone V, and for importance factor 1.

The floor was assumed to be rigid in its own plane by assigning rigid floor diaphragm. Soil structure interactions were not considered and hence, the foundations were modeled as rigid. Secondary effects such as temperature, shrinkage or creep were not considered.

4. Result and Discussion

Based upon analysis of buildings carried out using finite element software, the displacement of the corner points of first story was found. The values of displacement along X-direction and Y-direction for Earthquake forces acting along same respective direction is plotted for both model and is shown in the Figure 2.

After the addition of shear wall, it was found that the displacement along X-direction and Y-direction was decreased by 86% and 84% respectively.

Replacement of masonary walls by shear wall increases the lateral stiffness which in turn causes the reduction in displacement of observed corner points.

Stress were also measured for Earthquake acting along X and Y directions. Stress contour shows increase in maximum and minimum stress after addition of stress wall as shown in Figures 4, 5, 6, and 7.

The maximum and minimum stresses for individual models is shown in Figure 3.

The reduction in displacement causes the stresses to increase which is already seen above.

5. Conclusion

In this paper, flow-type landslide was modelled and applied to two building models i.e. building with masonry infill wall and shear wall to examine the effectiveness of shear wall in strengthening of RC frames. The following conclusions can be drawn:

1. The displacement of the corner points decreases as the masonry walls are replaced by shear walls.
2. The stresses however is increased as the displacement is limited due to addition of shear wall.

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