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Irregular Building over Sloped Ground Surface with Shear Walls or Bracings: A Review

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Abstract: Due to the increase in population and tourist numbers, construction works are rapidly increasing in hilly places. But the issue is hilly areas are vulnerable to various natural hazards which can cause damage to human life and other resources. The buildings in hilly areas are vertically and horizontally irregular and are much more prone to seismic activities. In this review paper, attempts are made to review the previous studies related to buildings in hilly areas. It aims at consolidating the outcomes of several attempted kinds of research to improve the overall stability of the buildings in hilly areas. Mainly shear walls and bracings are used to improve the resistance of seismic activities.
Keywords: Seismic activities, Hilly areas, Shear-wall, Bracings, Vertically and horizontally irregular

I. INTRODUCTION

The need for construction in hilly areas is very important to meet the needs increase in population and the high influx of tourists. Since level lands are limited in hilly areas the need to do construction of buildings on hilly slopes is increased. But due to the slopes of the ground building becomes irregular vertically and horizontally. Irregularity in buildings makes them more vulnerable to seismic activities.

Hilly parts are affected more by the earthquakes. When a structure is subjected to seismic force it does not cause damage to human lives directly but due to the destruction of building structures. Human lives are precious and necessary measures need to be taken to improve the resistance of buildings against seismic activities. So while constructing the buildings on hilly slopes, utmost care and safety considerations have to be taken to save human lives and resources.

II. IRREGULARITIES IN STRUCTURE

The regular buildings have no significant discontinuities of strength, mass, or strength .in horizontal or vertical planes. But on the other hand, irregular buildings have these discontinuities which cause deformations and concertation of forces at the point of discontinuity occurs. These irregularities are provided either for aesthetic purposes or the requirements of the sites. The site class significantly affects the seismic vulnerability of the structures. The soft soil leads to more damage to the buildings when compared to stiff or very dense soil. So during the structural analysis phase of the building, this consequence should be considered. The position of the geometric irregularity increases the damage possibilities in the buildings [1]. A regular building is an idealized concept since an actual building would have irregularities along with horizontal or vertical directions. Soft storey at the base of the building is more vulnerable which when combined with the in-plane stiffness eccentricity causes more damage to the building under seismic action. Stiffness at the base of a building increases the structural stability of the building when it is subjected to seismic loads. To improve the overall stability of the building in seismically active areas soft storey should be avoided in the lower half of a building [2]**.** The seismic response of a structure is significantly influenced by the presence of unreinforced masonry infills in RC buildings. The observation of post-earthquake damages, as well as various experimental and numerous studies, have shown that the structural damage of a structure is crucially influenced by the irregular placement of the infilled panel. The masonry distribution affects the seismic damage of a building, depending on the earthquake recorded and on the structural system. The influence of the infill irregularities can be reduced by making the walls of the building stronger [3]. Research on torsionally irregular buildings has been a popular discussion in the past several decades because of their poor seismic performance. In addition to floor translations, torsionally irregular buildings when subjected to seismic actions undergoes floor rotations too. It is observed during past earthquakes that the ductility of the structural system is compromised by the non-uniform distribution of displacement demands on the lateral load resisting elements because the floor rotations lead to the early collapse of the building [4]. In the modern design of multi-storey buildings using vertical geometric irregularity (setbacks) is becoming common in reinforced concrete buildings due to serviceability and aesthetic reasons. Building capacity is decreased when the setback value is increased as the structural fragility of RC building is increased. The performance of the building is affected by the vertical geometry irregularity of the building. The inelastic deformation capacity of the building is affected by the set-back value.

The movement of vertical geometric irregularity to the upper levels of the structure from the bottom parts reduces the structural capacity of mid-rise reinforced concrete buildings [5]. Different studies are being carried out based on structural integrity because of the increasing complexity of buildings, which has been the cause of building failures in earthquakes. Different parameters are chosen in different codes as guidelines for structural integrity, mainly plan and vertical irregularities. Some common parameters are average support reaction per bay, time period, the distance between the centre of rigidity and centre of mass and lateral displacement of diaphragm centre of mass with increasing storeys. The time period of plan irregular and vertically irregular buildings are shorter by about 2-12% and 5-25% respectively when compared to regular buildings. When the number of storeys is increased, lateral displacement of the diaphragm centre of mass is also increased. There is a common relationship between the seismic response of buildings with different types of irregularities [6].

III. BUILDINGS ON SLOPED SURFACE

During strong earthquakes, structures near slopes pose more damage because of seismic action when compared with the structures on the flat ground surface. The seismic response of 5-storey buildings is less affected by slope topography when compared to the 10 and 15-storey buildings. Buildings near slope crests have a greater impact on topography on the seismic response. At a distance of 2-3 times the slope height from the crest slope, topographic irregularities magnify the acceleration [7]. Buildings in hilly areas are asymmetric and irregular so that the centre of stiffness and centre of mass of the buildings do not coincide which makes the buildings subject to larger shear force and torsion. The effect of soil-structure interaction is favourable to the response of the building. The building becomes more irregular when the slopes are increased, hence base shear and torsion will be increased when slopes are increased. Displacement of the building decreases about 70% in the case of buildings with fixed bases and around 14 % when the base is flexible or under soft soil conditions [8]. For ages, it is known that proper foundation conditions influence the durability of the structures. Unfavourable water conditions of soil influence the efficiency of the foundation. Lack of effective drainage causes damage to the foundations. Because of it, the stability of the slope on which buildings are located will be affected. Rather than spending money on repairing buildings because of damages caused by defective water protection, proper protection should be given to ensure the long service life of buildings [9]. Earthquakes on slopes could trigger landslides, which becomes the main damage mechanism which will result in larger damage to buildings which were near to collapsing. Buildings which experiences the combined effect of earthquake and landslides causes more damage to the buildings on the slope when compared to the same building on a flat surface [10]. The performance of step-back building and step-back set-back building configurations are different to each other and they will be significantly different to a building resting on a flat surface. Due to the more seismic weight of the structure, step-back building configurations experience more torsional moments and seismic forces as compared with step-back set-back building configurations. There is a 45% reduction in base shear value in step-back set-back buildings when compared to step-back buildings. Step-back buildings are more vulnerable to earthquakes since they have higher storey drift and storey shear. In both the configurations maximum storey shear is observed in the top most stories [11]. The performance of step-back buildings is more vulnerable when subjected to seismic forces. Columns at the ground level of the step-back and step-back set-back configurations are the worst affected members during seismic forces, so special attention needs to be given to them. Set-back building configurations on plain ground attract fewer action forces when compared to other configurations but levelling the ground slope is not very economical [12].

IV. BUILDINGS ON SLOPE WITH SHEAR-WALL OR BRACINGS REINFORCEMENT

Structures on the slope are different from structures on a flat surface as they are vertically and horizontally irregular. Shear walls when provided on the buildings will reduce lateral displacement and member forces. So there is a significant improvement in the seismic efficiency of buildings on slopes provided with shear walls under seismic actions. The risk of collapse of buildings increases with an increase in slope as maximum displacement is observed under 45^o slope. For better lateral load resistance, the optimum position of the shear walls is at the periphery. For countering axial load optimum shear wall position is at corners. For the sloping ground of a 45^o, maximum bending moment and maximum shear force are significantly increased. The axial force is increased when shear walls are provided in the building. Base shear of the building is increased when shear walls are provided due to the increase of dead load because of shear walls [13]. With the increase in the height of the building frame on sloping ground, the maximum moment in the column increases. The value of base shear can be increased by providing shear walls and bracings separately or together. Minimum displacement is observed in buildings with shear walls when compared to other configurations. The seismic performance of the building can be enhanced by the inclusion of a bearing wall system. With the increase in the number of storeys, lateral displacement of the building also increases.

Providing shear walls in the buildings is more efficient when compared to buildings with a bearing wall system [14]. Both step-back and step-back set-back buildings on the sloped ground surface, including shear walls and bracings with different configurations independently and in a combined manner, showed improvement in seismic resistance when compared to conventional buildings. Combined configurations of shear walls and bracings show better performance in the earthquake when compared to the performance of individual configurations. Combined configurations have a 5% increase in performance in step-back set-back configurations and 20% more performance in step-back building configurations. As the open storey effect occurs in lower areas, higher storey drift is found in the lower section of the buildings [15]. When bracings are provided in buildings, the value of maximum base shear is increased. The increase of maximum base shear is due to the increase in stiffness of buildings when bracings are provided. As the stiffness of the building is increased when bracings are provided, vibration caused by the earthquake will be reduced thus reducing the joint displacement of the structure. Displacement of building with cross bracings is lesser than that of buildings with single diamond bracings [16]. In a rectangular building plan, story displacement along the slope is lesser when compared to the across the slope direction. The steel bracings are economical to use as a lateral load resisting system as bracings have less base shear value as compared to concrete bracings. The time period decreases as stiffness is increased so that, shear wall building shows a small time period when compared to bracing system building. The X bracings are more efficient when compared to V and diagonal bracings. It is more efficient to place the shear divider facing the shorter segment side for having good control over the powers and displacement. When shear dividers are provided, storey float is reduced from around 28% to 90%. When the ground slope is increased, the maximum value of storey shear at the upper storey is decreased. When the ground slope is increased, the maximum fundamental time period of the building is also increased [17].

V. CONCLUSIONS

The following are the findings of the study on the use of shear walls and bracing on irregular buildings on a sloped surface. Irregular buildings are affected more during earthquakes when compared to regular buildings. Since sloped ground also affects the building negatively during earthquakes, irregular buildings over the sloped ground surface will be the worst combination during earthquakes. Step-back set-back buildings are more efficient when compared to step-back building configurations. With the increase in the number of storeys, lateral displacement of the building also increases. The value of base shear can be increased by providing shear walls and bracings separately or together. Providing shear walls or bracings or both as a combination can increase the stability of the irregular building on a sloped ground surface during earthquakes. Shear walls when provided on the buildings will reduce lateral displacement and member forces. Combined configurations of shear wall and bracings show better performance in the earthquake when compared to the performance of individual configurations. Cross bracings provide more resistance to seismic forces when compared to other bracing configurations. For countering axial load optimum shear wall position is at corners.

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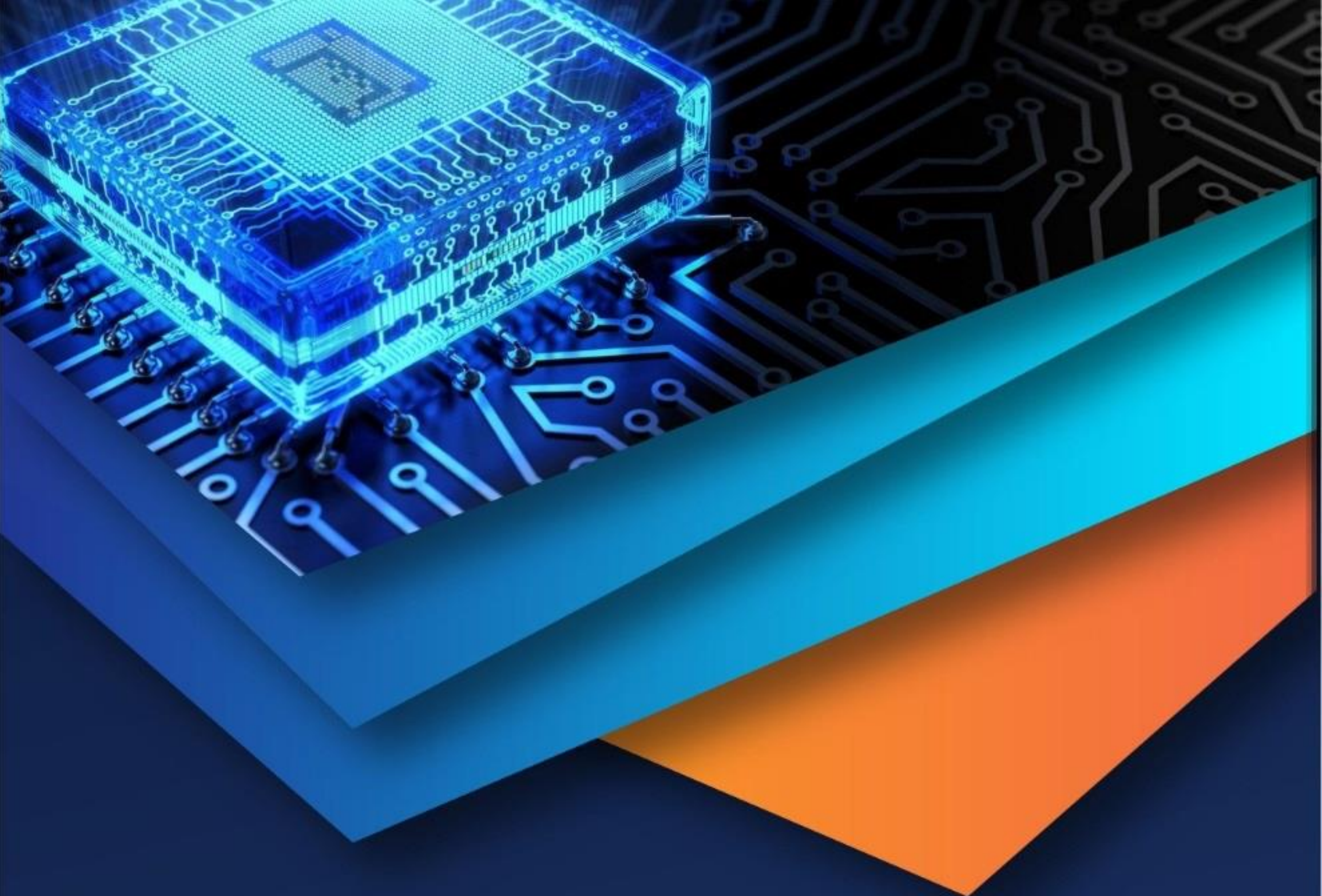

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