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Analysis of Building in Hilly Areas under the Earthquake Excitation and Wind Load

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Abstract —*Planning and design of buildings in a hill settlement are tedious and challenging task due to difficult terrain, steep gradient, adverse climatic conditions, rich flora and proneness to natural hazards. In response to these harsh development conditions, numerous vernacular practices and styles have evolved with local materials and indigenous techniques to fulfil the needs of people, which cause minimal damage to environment and are sustainable. The building regulations, which are enforced in hill settlements to regulate development and minimize its ill impacts on environment, are contextually not appropriate and lead to contextually inappropriate development and environmental degradation in environmentally sensitive hill settlements. Since vernacular practices are proven to be sustainable, therefore it is essential to take lessons from sustainable vernacular practices for new development and formulation of building regulations for achieving contextually appropriate and sustainable development in hill settlements. This paper analyses the planning, design and construction considerations of buildings in hilly regions in India. In this paper qualitative research method has been used. The systematic literature review of the construction systems of the hilly regions have been explored through internet and secondary data from relevant published academic literature from journals articles and research papers. Therefore, this paper highlights the general issues and problems related to the development and building regulations of hill towns. A comparative study of existing building regulations for safety against natural hazards of various Himalayan hill towns is made to have the in-depth understanding of issues related to building regulations for safety against hazards in hill towns.*

Keywords— *planning, design, construction hilly region, Earthquake excitation and Wind load India*

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I. INTRODUCTION

Building construction in hilly regions requires comprehensive planning, site selection and design for slopes and sustainable concrete construction practices. In response to these harsh development conditions, numerous vernacular practices and styles have evolved with local materials and indigenous techniques to fulfill the needs of people, which cause minimal damage to environment and are sustainable. But, in spite of numerous benefits of these vernacular practices, these are often not used for new development due to increased demand for more built spaces due to rapid growth, availability of new construction materials and techniques and reluctance of residents to adopt vernacular practices. The economic growth and rapid urbanization in hilly regions have further encumbered the real estate development with an onus of developing multi-story buildings. Hilly regions, though tempting to construct a structure at, have wide variations in geology, geomorphology, climate, altitude and materials resources. The unpredictable geological situations and on-going development activities, precarious climatic variation, hydro geological conditions result in different types of hazards like landslides and mud flows in these areas which make planning and design of buildings in a hill settlement a herculean task

Hilly regions are the most difficult yet most exciting and challenging features to carry any development work. Construction of buildings in hilly terrain is constrained by their difficult terrain, steep gradients, complex geological structure, climatic conditions and rich flora. In response to these settings various built form construction techniques and patterns of development have emerged in different hill regions of the country.

These regions are susceptible to high magnitude earthquake and may lead to enormous destruction during the occurrence of an earthquake. Hill regions are in general prone to landslides and every year during rains massive loss of human life and resources occurs due to landslides. Along with landslides and earthquakes, hill regions are also prone to the various disasters like the cloudburst, floods, fire, wildfire, avalanche, etc. (BIS, 2000).

In spite of high proneness of hill areas to different disasters, various hill stations are established and subsequently developed as major urban centers in hill regions, thus have high population density. Shimla, Mussoorie, Manali, Dalhousie, Nainital, Srinagar, Shillong, and Itanagar are some such important tourist centers and fast-growing hill towns, which are experiencing a lot of pressure for development in present context. Hill towns are mostly located in ecologically sensitive zones (Menon, Kapoor, & Kohli, 2009). The ecological balance of towns is affected due to high-density development having multi-storied buildings and lower carrying capacities of hill towns.

degradation of natural topography, vegetation and disturbance of natural drainage pattern due to massive construction has resulted in environmental degradation in the hill towns (Kumar, 2016). Construction activity on high and unstable slopes (350–600) characterized by high percentage of ground coverage is taking place and thereby limiting natural light, air and ventilation, which is likely to affect human health and well-being (ITPI, 2004). The current scenario of development is more critical in hill towns than urban centers on flattening topography, which is characterized by steep terrain, complex geological structure, adverse climate, and fragile ecological context. The unique urbanscape present in hill towns is a result of the weaving together of topography, architecture, the arrangement of streets, urban spaces and vistas (Jutla, 2000).

But, these hill towns have been experiencing enormous pressure for development from last three decades this has changed the urban scenario of hill towns considerably (Meshram, 2008; Kumar, Pushplata, 2013). As growth in a city is regulated and guided by different building regulations that are enforced in that urban area are strong and rigid (Sridhar, 2010), but are poorly implemented and lead to most of the problems of the built environment in hill towns (Kumar and Pushplata, 2015).

Likewise, to mitigate the impact of above mentioned natural hazards/disasters and safety of buildings and protection of human life during any catastrophe, various structural and non-structural measures for disaster mitigation are employed in the hill towns. Building regulations, being the most valuable tool to regulate and guide development, and most important non-structural measure for disaster mitigation are enforced in different hill towns (Kumar and Pushplata, 2015).

Various building regulations related to safety against landslides, earthquake, slope stability, fire, and floods have been incorporated in building regulations of different Indian hill towns (Kumar and Pushplata, 2013). Various problems related to the safety of buildings stock in hill towns still prevails and further intensified due to massive development on the steep and dangerous slope, improper or insufficient site development and stabilization, irregular drainage pattern, dilapidated housing stock (Pushplata and Kumar, 2012) (TCPO, 2011).

Moreover, due to extensive use of wood as construction material, most of the hill towns are also prone to fire, and many instances of fire have already been taken place in hill towns, which has resulted in significant loss of human life and precious heritage available in the form of traditional buildings. Also, due to poor compliance and enforcement of different building regulation, most of the buildings that are constructed or being constructed without adhering to safety provisions against natural hazards and are susceptible to substantial damage from any natural catastrophe (Kumar and Pushplata, 2015).

Moreover, the land holdings or plots follow natural topographical profile and are irregular in shape. Residents purchase irregular shaped land (without requisite essential services and infrastructure) from landlords to construct buildings (Kumar and Pushplata, 2017).

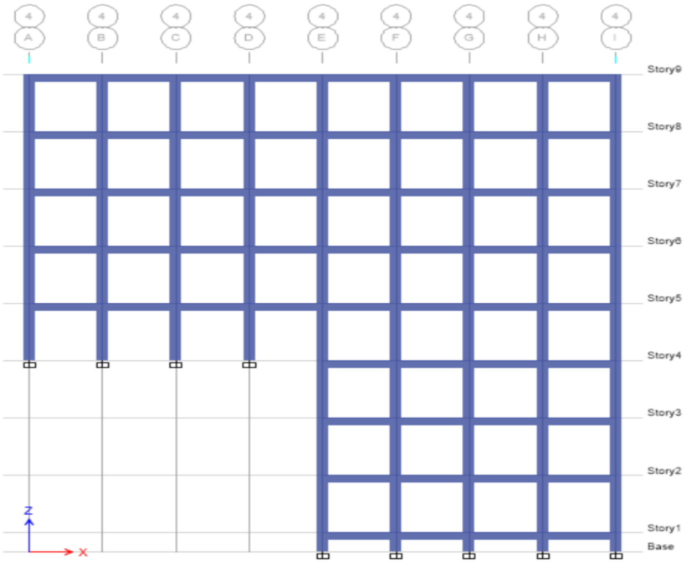
The aim of this study Is to analyse and study the behaviour of a G+8 structure in an earthquake and wind load -prone area, including a review of seismic characteristics including story displacement, drift, and shears, as well as the proposed structural model. As part of our ongoing research, we also perform Time history analyses for the same building using unscaled data from the Centre for Engineering Strong Motion Research Ground Motion Database for the BHUJ Earthquake, which struck Gujarat on January 26, 2001.

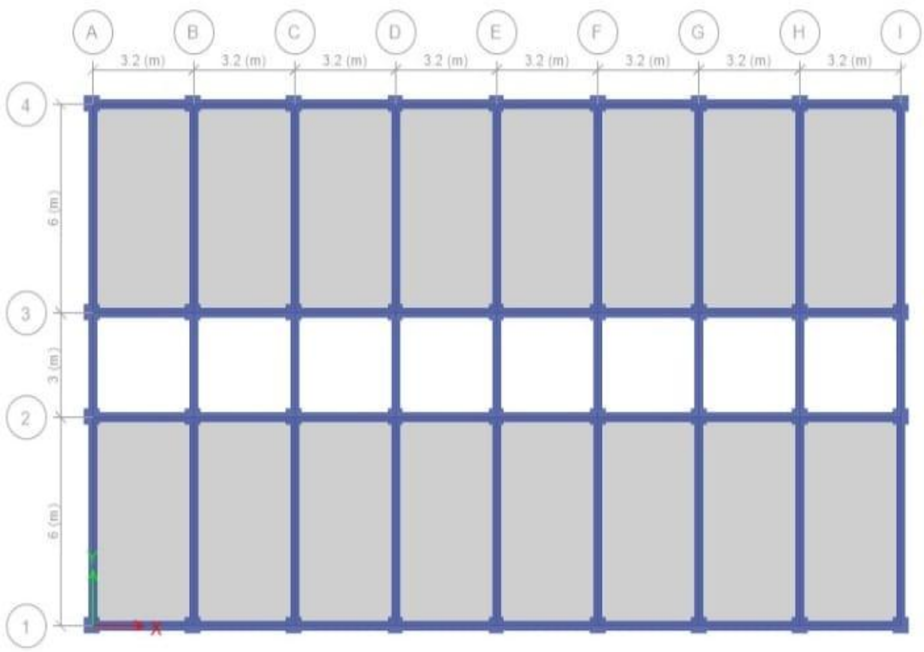
Modelling on ETABS:

Three-dimensional bare frame model of split-foundation (SF) and flat-land (FL) buildings are modeled using beam element in ETAB 2016

The story ratios considered for the split foundation models are 0.5 ,1 and 2 keeping the constant 4-stories below the upper most foundation level (UFL).

Building models are considered as special moment-resisting frames according to IS1893(2016)Part1 for Seismic Zone-V and soil type as rock and hard soil.





Geometric parameters	Seismic parameters
Plan dimension 25.6 m× 15m	Zone = V
Building Height= 25.6m	Response reduction Factor = 5
Floor to floor height = 3.2 m	G+8
Beam size = 230 mm× 450 mm	Live load = 3 kN/m2
Column size = 450mm × 500mm	Concrete= M30
Thickness of slab = 150 mm	Steel Bar =HYSD415
Time history Analysis	Bhuj Earthquake (2001) GUJRAT

Wind load

The mathematical expression of design wind speed (Vz) is given by

$Vz = Vbk1k1k3k4$

here, Vb is the basic wind speed and taken as 39m/sec as specified in IS 875 (2015) part 3. The design wind pressure (pd) is defined as

$pd = KdKaKcpz$

where pz =0.6Vz2 is the wind pressure at height z.

Wind load on the individual members acting in the direction normal to the structural member can be calculated by

$F = \left(C_{pe} - C_{pi}\right)_{Apd}$

here, Cpe and Cpi are the external and internal wind pressure coefficient; A is the tributary area.

NOTES:-

$k1$ = Risk coefficient

$k2$ = Terrain roughness and height factor

$k3$ = Topography factor

$k4$ = Importance factor for the cyclonic region

Kd = Wind directionality factor

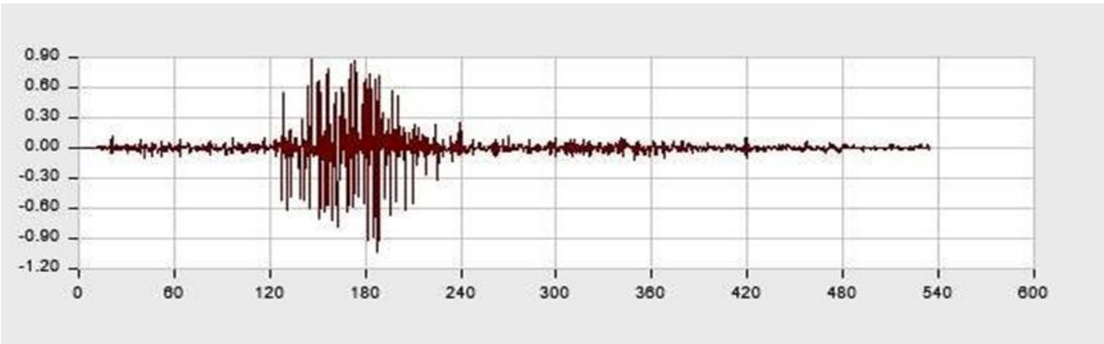
Ka = Area averaging factor

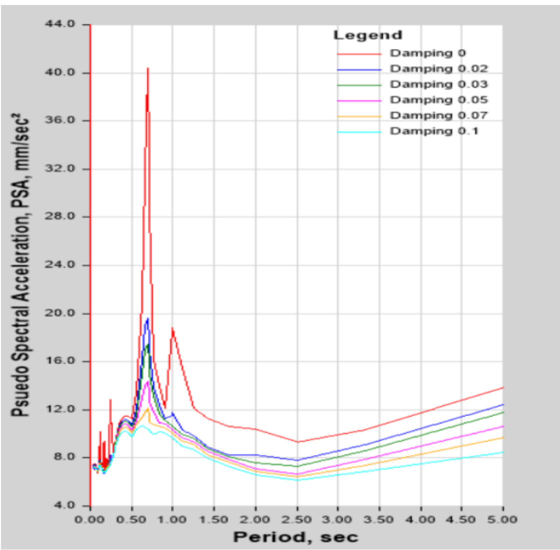
Kc = Combination factor

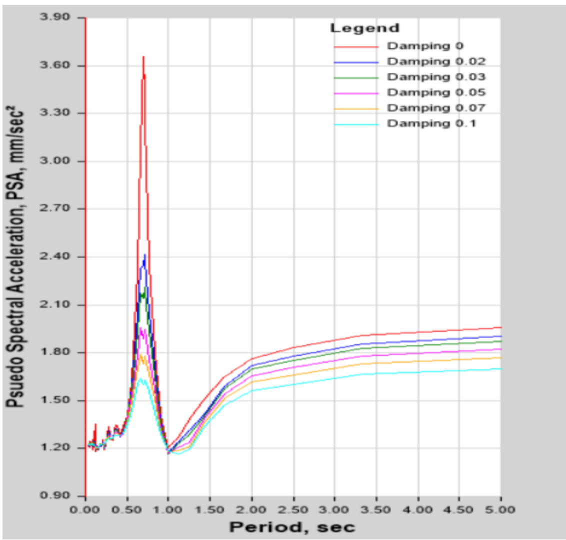
The value of internal pressure coefficient is considered as ±0.05 considering 5 to 20% opening in the building models.

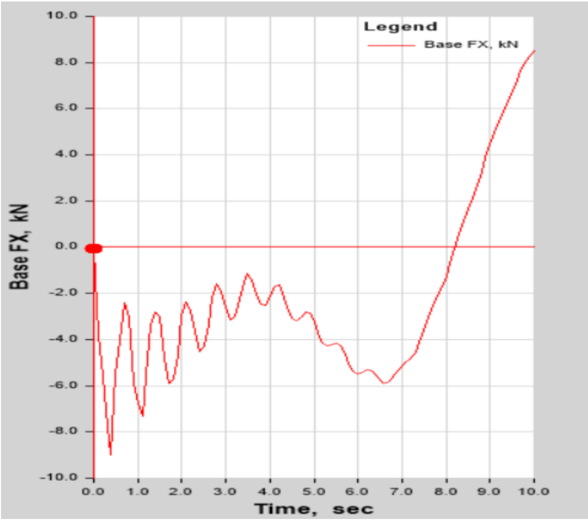
Response Analysis under Earthquake Excitation

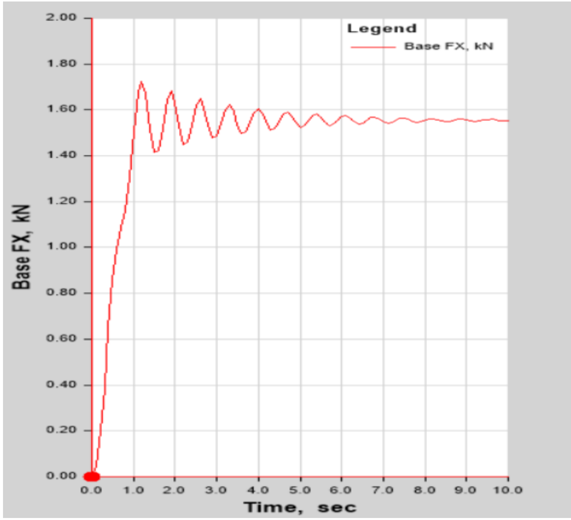
The numerical investigations of hilly buildings under multiple hazards namely earthquake, Wind load were carried out. The nonlinear time history analysis (for earthquake load case) and nonlinear static analysis (for wind and blast load case) of the buildings are performed in structural analysis software ETAB 2016





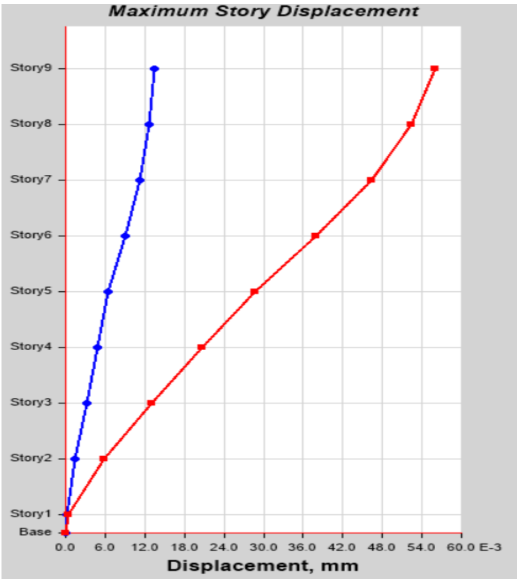




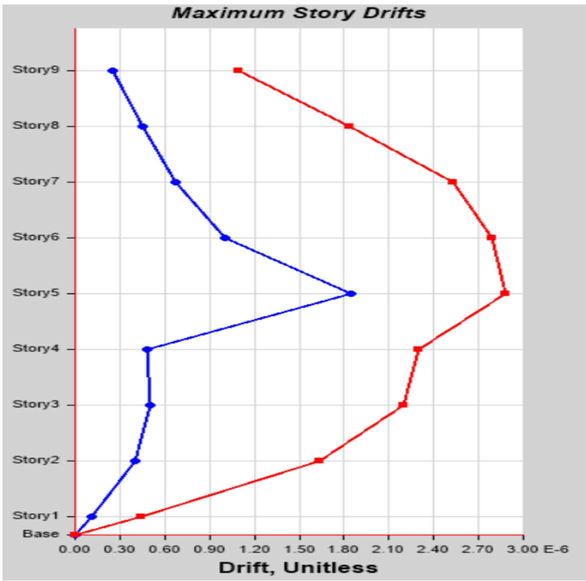


II. Results and Discussion:-

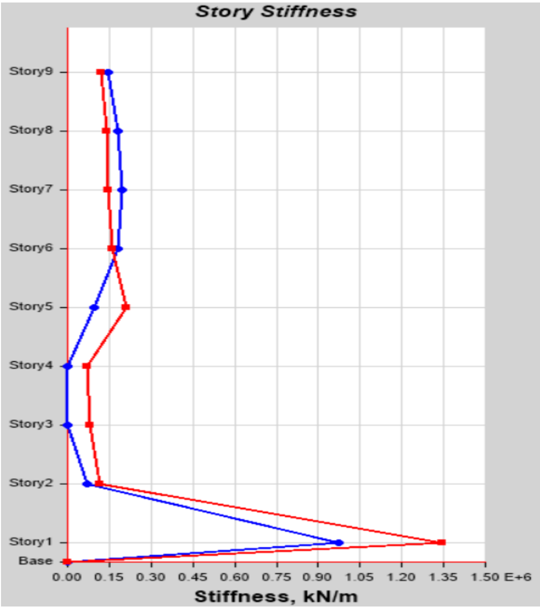
STORY DISPLACEMENT

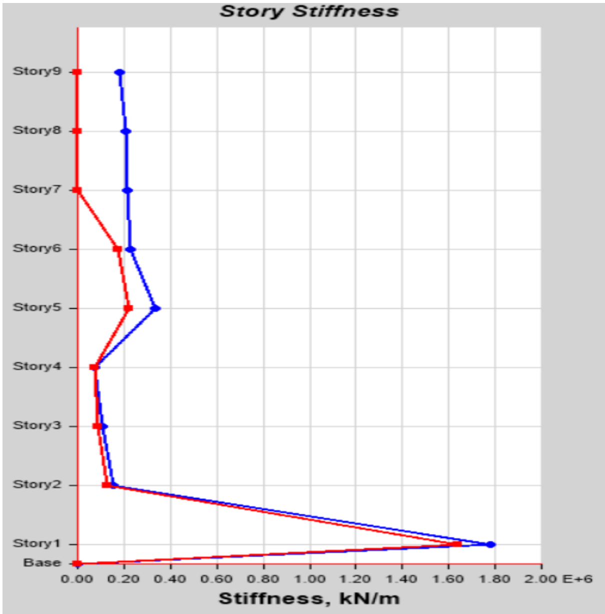


STORY DRIFT



STORY STIFFNESS





III. Conclusion

Safety against disasters is the most critical concern of new development in Indian hill towns and existing building regulations are not appropriate to provide safer buildings having sufficient resistance to disasters as the provisions and enforcement mechanism present in building regulations are ineffective and incomplete. The safety of new development against hazards can be improved by revisiting the basis of different safety regulations and formulation new building regulations for providing safety against disasters to new and existing buildings in hill towns.

Different Interventions needed for formulation and implementation of safety regulations against disasters can be divided into different categories as interventions for formulation of safety regulations for new buildings, formulation of safety regulations for existing buildings, ensuring effective enforcement and compliance, and upgradation of technical expertise of professionals and authorities. Also, there is a need to have continuous monitoring and condition assessment of retrofitted structures to ensure the efficient functioning and performance of retrofitted components.

Following conclusions are drawn from the present study:

To improve the condition of development and formulation of appropriate building regulations, different institutions/ organizations/ authors have suggested different criteria or factors which can become basis for formulation of building regulations for specific context of hill towns. Importance of local conditions both physical and environmental for formulating various norms and standards for urban development plans in hill areas are highlighted in Model Building Byelaws (2004) Chapter III. Local conditions and physical context must provide the threshold for formulation of standards and codes. Regulations should be place-based, emphasize details, and be buttressed by common approval. When a model code is adopted by a higher authority, the local jurisdiction must review and amend it to its unique circumstances. Codes and standards must be drafted in clear and simple terms. (Joseph, 2005). New development in hill towns is based on a piecemeal approach and lack in proper planning and design. Development is considered as a visual blight and inappropriate in terms of scale, material and style having no apparent design guidelines; and unfair development approval process.

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