https://doi.org/10.36375/prepare_u.iei.a124

Risk Assessment of Earthquake on Historical Structures and Monuments

P.K. Tiwari [1*], G. Pandey [2] and V. Kumar [3]

[1] Assistant Superintending Engineer, Archaeological Survey of India, [2] Prof. & Dean, Infrastructure & Planning and [3] Assistant Professor, Civil Engg. Dept.

([1] Ministry of Culture, Govt. of India, [2] M.M.M.U.T. Gorakhpur, U.P, India. and [3] CUH, India)

([1] Assistant Superintending Engineer, Archaeological Survey of India, Sarnath Circle, Varanasi-221007,India [2] Prof. & Dean, Infrastructure & Planning, M.M.M.U.T., Gorakhpur-273010,India and [3] Assistant Professor, Civil Engg. Dept., Central University of Haryana-123029, India)

{*Corresponding author's email: pankajtiwari.asi@gmail.com}

Abstract - This paper discusses the risk assessment of earthquake on historical structures and monuments as per their height and shape with reference to the earthquake that occurred on 25 April 2015 and on 12 May 2015. Heritage Site, Dharahara tower, which was very high-rise in height, totally collapsed. Owing to such height the upper portions of 9-storied Basantapur Durbar, the Dasa Avtar temple were demolished by the quake.

In an earlier earthquake in India near Aravali hill range in 1505, damaged Qutub Minar, Delhi built in 12th century, was fallen off its top two story, after like some quake due to sky/cloud bursting electric happening, but no such damage to ground, first and second story structures was noticed. Generally many old forts in India, were safe during earthquakes due to large in plan area and low in height , but further the high-rise old buildings suffered during earthquake at some specific intensity of earthquake at several times in past .

It is important to point out the height and shape of historical structures and monuments for further safety measures and precautions as for as possible for load bearing structures, in Zone V with less than 400 sqm (appox.) in plan area of foundation with plinth may be risk affected during/after earthquake.

Keywords – Height and shape; Earthquake; Monuments; Plinth Area; Load bearing Structure; Seismic Zone;

INTRODUCTION

The historical buildings are the landmark of the any culture and nation and conservation of such structure must be on priority to protect the culture of the nation. A very less literature is available on the prediction of damage and losses in historical building as compared to other residential building. The main aim of the paper is to study the seismic risks associated with the earthquake on the historical structures and monuments situated in India and Nepal. Further, the study delineates measures to be adopted proactively for mitigating the severe damaging affects of earthquake on cultural and historical/heritage buildings.

Many of the structures which exist, their natural occurrences of ground motion lay in that area of greatest energy occurrences due to seismic activities. These heritages buildings because of regular happing of earthquake lying in that band amplifies the earthquake motions and hence new accelerations generates around heritage building. These accelerations/energies increased more from lower level/ground level to the top point of super structure/heritage building. For achieving the goal of seismic isolation, the structure has to be designed such that the most powerful and harmful frequencies of seismic motions regarding heritage structures may less affects the structure from ground level to top level. Base isolation is one of the techniques to shifts the dominant frequency of earthquake from the natural frequency of the structure. Also the fundamental frequency of structure which has fixed-base superstructure can be fixed as per the foundation area and height of structures as per the geographical location of structures and the respective seismic zone location, as depicted in Fig.1 and 2.

Seismic Hazard

Prevention from seismic hazard depend on the response of the structure to the past earthquakes. In case of an affected structure from an earthquake, the soil stratification and the foundation and, topographic amplification effects may be the reasons for same [2]. For important monuments, the seismic action may be modified by taking into account local soil dynamic conditions, geomorphology, an estimation of the duration of the earthquake and especially the effects of neighbouring active faults in respective seismic zones.

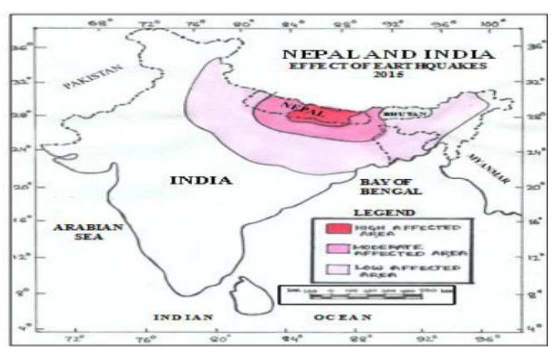

Fig. 1 Affected area of Nepal earthquake, (2015)

https://doi.org/10.36375/prepare_u.iei.a124

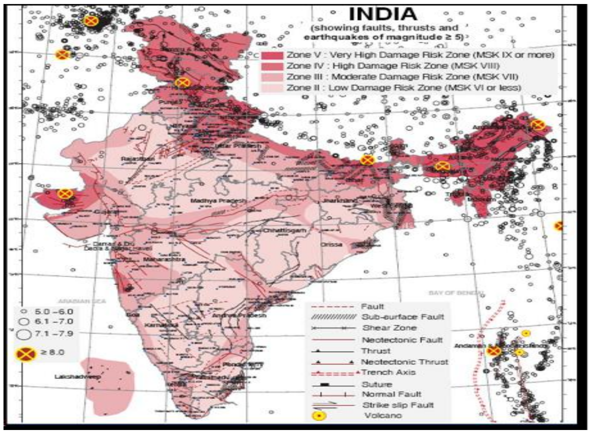

Fig. 2. Seismic Map of India
(As per Vulnerability Atlas of India by BMTPC)

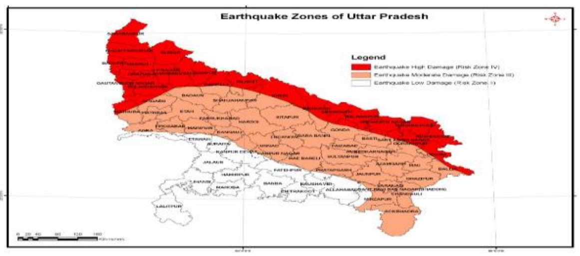

Fig. 3**.** (Vulnerability Atlas by BMTPC/ Uttar Pradesh state of India/attached geographically with Nepal)

Fig. 4. Epicentre of Nepal earthquake/ M 7.8 25.04.2015 (from: USGS information/ internet)

Nepal lying in the mountainous region geographically becomes a highly active area regarding seismic activities and important region for earth quake engineering/related safety parameters. The location of Nepal on the boundary of two earth plates, Eurasian and Indian plates is very important because this region is seismically active. As many faults in Himalayan area have been active and dangerous for human being/heritage and Nepal and Himalayan region therefore are the region with high seismic activity. Numerous seismic happenings of Mw greater than 7.5 have been noticed in the past many decades in this area, example, in 1905 Kangara earthquake, Himachal Pradesh in India, the Mw was 7.8, also in 1934 Bihar-Nepal earthquake with Mw 8.1 was very hazardous [1].

In Nepal, most of the buildings are adobe structures and can be divided under four categories first are those which are made up with stone and or brick with mud and lime mortar or masonry with cement mortar with some wooden parts in buildings and structures, and now a day's reinforced concrete structures. With reference to, the design or planning, the Himalayan buildings and temples may be square or rectangular in plan. The wooden parts and segments are very common in roof of structures in these areas. Many components made from wooden like partition wall of rooms beams with rafters [1]. Teakwood and Salwood are mostly in practice in Nepalese and Himalayan region temples. The Heritage structures are classified in this region as one roof temple, two roof temples and so on.

Fig. 5a & 5b**.** Maju Dega Temple, before quake and after quake (Source: ICIMOD)

Fig. 6a. & 6 b Fasidega Temple before earthquake and after earthquake

Fig. 7 a & b. Dharahara Tower before & after quake

https://doi.org/10.36375/prepare_u.iei.a124

Studies on Effect of Seismic Zone, Height and Shape of the Historical Structure

Country	Structure Name & E.Q Year	Structure Description	*Floor*	*Height*	*Shape in plan*	Material	Collapsed height	*Ground area*	*Seismic Zone*
Nepal	Maju Dega Temple, Kathamandu 2015	Platform	9	14 mtr	Rectangular	Brick	Safe	500 sqm	V
		Super Structure	3	9 mtr	Square	Brick & wooden	9 m	-	“
	Fasidega Temple, Bhaktapur Darbar 2015	Platform	6	11 mtr	Rectangular	Stone & Brick	Safe	600 sqm	V
		Super Structure	2	7 mtr	Square	Brick	7 mtr	-	“
	Dharahara Tower, Kathamandu 2015	Platform	9	8 mtr	Square	Stone	Safe	380 sqm	V
		Super Structure	9	62 mtr	Circular	Brick	52 mtr	-	“
India	Qutb Minar, Delhi 1505	Foundation	1	0.5 mtr	Circular	Stone	safe	161 sqm	IV
		Super Structure	6	72 mtr	Circular	Stone	2 upper story	-	“
	Mahaparinirvan Stupa , Kushinagar (U.P.) 2015	Platform	1	2.75 mtr	Rectangular	Brick	Safe	1050 sqm	IV
		Super Structure	2	22.7 mtr	Circular	Brick	minor hair cracks	223 sqm	“

By the above discussion, the following table prepared for the risk assessment parameters for Heritage Structures, considering the details given in Fig. 3,4,5,6 and 7.

Table 1. Assessment Parameters for Collapsed / Damaged Heritage Structures

(All dimensions are in SI system & based on approximate, from different sources such as Archaeological Survey of India , field visit of authors & Internet.)

In table 1, we comparatively assessed the height and shape parameters with respective seismic zones, for collapsed/damaged Heritage Structures.

- In Maju Dega Temple, Kathamandu, situated in Zone V, the 14 mtr high stepped Foundation / Platform Rectangular in plan area 500 sqm, safe during & after earthquake, but 9 mtr high Square shaped in plan Super Structure complete collapsed during & after earthquake.
- In Fasidega Temple, Bhaktapur Darbar, situated in Zone V, the 11 mtr high stepped Foundation / Platform Rectangular in plan area 600 sqm, safe during & after earthquake, but 7 mtr high Square shaped in plan Super Structure complete collapsed during & after earthquake.
- In Dharahara Tower, Kathamandu, situated in Zone V, the 8 mtr high stepped Foundation/Platform square in plan area 380 sqm, safe during & after earthquake, but 62 mtr high circular shaped in plan Super Structure tower, above plinth/platform collapsed 84 % in height, during & after earthquake.
- On other side in India near Gorakhpur, the Mahaparinirvan Stupa, Kushinagar, India, situated in Zone IV, the 2.27 mtr high Foundation/Platform, Rectangular in plan area 1050 sqm , safe during & after earthquake, & also 22.7 mtr high circular shaped in plan Super Structure safe/only few minor hair cracks on wall surface, during & after earthquake.

By above observation/studies, we assessed here that high rise super structure in Zone V with less than 400 sqm (appox.) in plan area of foundation may be risk affected during/after earthquake.

CONCLUSIONS

The height and shape of historical structures and monuments with foundation covering area and seismic zone of that particular location of historical building may be useful, for further safety measures and precautions as for as possible for *load bearing structures* and the effect of earthquake is more prominent in the case of Zone V on the historical structures.

REFERENCES

[1] Durgesh C. Rai, Vaibhav Singhal, S Lalit Sagar, Bhushan Raj S Department of Civil Engineering, Indian Institute of Technology Kanpur (2015) “Effects on Built Environment & A Perspective on Growing Seismic Risk in Bihar-Nepal Region” 2015 Gorkha (Nepal) Earthquake 12 May 2015 National Information Center on Earthquake Engineering www.nicee.org.

[2] A. Furukawa, J. Kiyono & M. Tatsumi Department of Urban Management, Kyoto University, Kyoto, & K. Toki, H. Taniguchi & H. Parajuli Disaster Mitigation of Urban Cultural Heritage, Ritsumeikan University, Kyoto (2012) “Earthquake Risk Evaluation

https://doi.org/10.36375/prepare_u.iei.a124

of Historic Masonry Buildings in Kathmandu Valley, Nepal" 15 WCEE LISBOA 2012

[3] "Catalogue of Earthquakes in India and Neighborhood from Historical period upto 1979" ISET 1983