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Seismic hazard assessment at micro level in Gandhinagar (the capital of Gujarat, India) considering soil effects

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ABSTRACT

Gandhinagar City (the Capital of Gujarat, India) falls under Zone III on the seismic zoning map of India where an earthquake of magnitude 6 can be expected. It is a well established fact that the site amplification/ shaking and damage is large in soil covered areas. To estimate the effect of soil on ground motion and to estimate the strong ground motion parameters at surface, soil modeling and the ground response analysis have been conducted along uniformly distributed 14 boreholes drilled upto a depth of 50 m. The methodology is divided into three parts (i) Estimation of depth of Engineering Bed layer (EBL) (a layer with a shear wave velocity 400 m/s ≤ Vs ≤ 750 m/s, N value > 80 and minimum soil variation below it) through soil modeling, (ii) Estimation of Ground Motion at EBL due to scenario earthquake at nearby active fault and (iii) Estimation of surface strong ground motion using 1D ground response analysis through SHAKE 2000 program. The EBL is found at a depth of 21–33 m (shallower in central part and deeper in northern and southern parts). The Near-Field scenario earthquake (Eq.) of magnitude Mw 6.0 has been considered along East Cambay Fault (normal fault, 60° dip) located at about ~ 20 km east and Far Field scenario Eq. of Mw 7.6 is considered along Kachchh Mainland Fault located ~270 km west. The Peak Ground acceleration (PGA) of 0.172–0.237 g have been estimated at surface due to near field earthquake scenario. The mean spectral acceleration maps for 0.1–0.4 s, 0.4–0.7 s, 0.7–1.0 s and 1.0–1.5 s have also been computed. The mean spectral acceleration for the period of 0.1–0.4 s has been varying from 0.330 g to 0.508 g, for period of 0.4–0.7 Sec, it has been varying from 0.151 g to 0.161 g and for period between 1.0 and 1.5 Sec, it has been found from 0.83 g to 0.09 g. The PGA is found increased by 5–38% in the first subsurface soil layer in Gandhinagar city. The PGA of the order of 0.059–0.072 g and peak Spectral acceleration of the order of 0.187–0.259 g have been computed (with predominant periods of ~0.1 s and 0.31 s) due to Far-Field Eq. scenario and are found less than Indian code. The PGA and Spectral acceleration (Sa) values are found higher than the Indian code in the period range of 0.1–0.4 s (one to four storey buildings) for Near Field Eq. Scenario.

1. Introduction

Large earthquakes that have occurred in recent years in densely populated areas of the world dramatically highlight the inadequate structural designing of the buildings including consideration of near surface ground motion amplification due to soil. The Gujarat state of India falls under three seismic zones V, IV, III of the seismic zoning map of India, Bureaue of Indian Standard [6] with likely earthquakes of magnitude 8, 7, and 6, respectively. The state is one of the most seismic prone regions of the world. It has experienced two large earthquakes of magnitude Mw 7.8 and Mw 7.7 in in 1819 and 2001, respectively and seven earthquakes of magnitude about Mw 6.0, during the past two centuries. The devastation due to Mw 7.7, Bhuj earthquake of 2001 has been observed at distances of upto 300 km. This earthquake is the first major earthquake to hit an urban area of India in the last 50 yrs. During the 2001 Bhuj earthquake, the medical facilities were also disrupted in the epicentral zone (due to fall of main Bhuj Civil Hospital).

Gandhinagar is one of the most important city of western India and is the capital city of Gujarat state. It is situated 32 km NE from Ahmedabad. Gandhinagar is a well-planned city divided into 30 sectors. The city is covered with Government buildings like State Assembly (Vidhan Sabha) Udhyog Bhavan (Business governance house), Mahatma Mandir (an International convention center) and economically important structures like Thermal Power Plant, Infocity (a hub of IT sector) and Civil Hospital. A metro connecting Gandhinagar to Ahmedabad is also been planned.

Gandhinagar falls in Zone III on the seismic zoning map of India [6]. An earthquake of magnitude Mw 5.7 occurred 100 km south of

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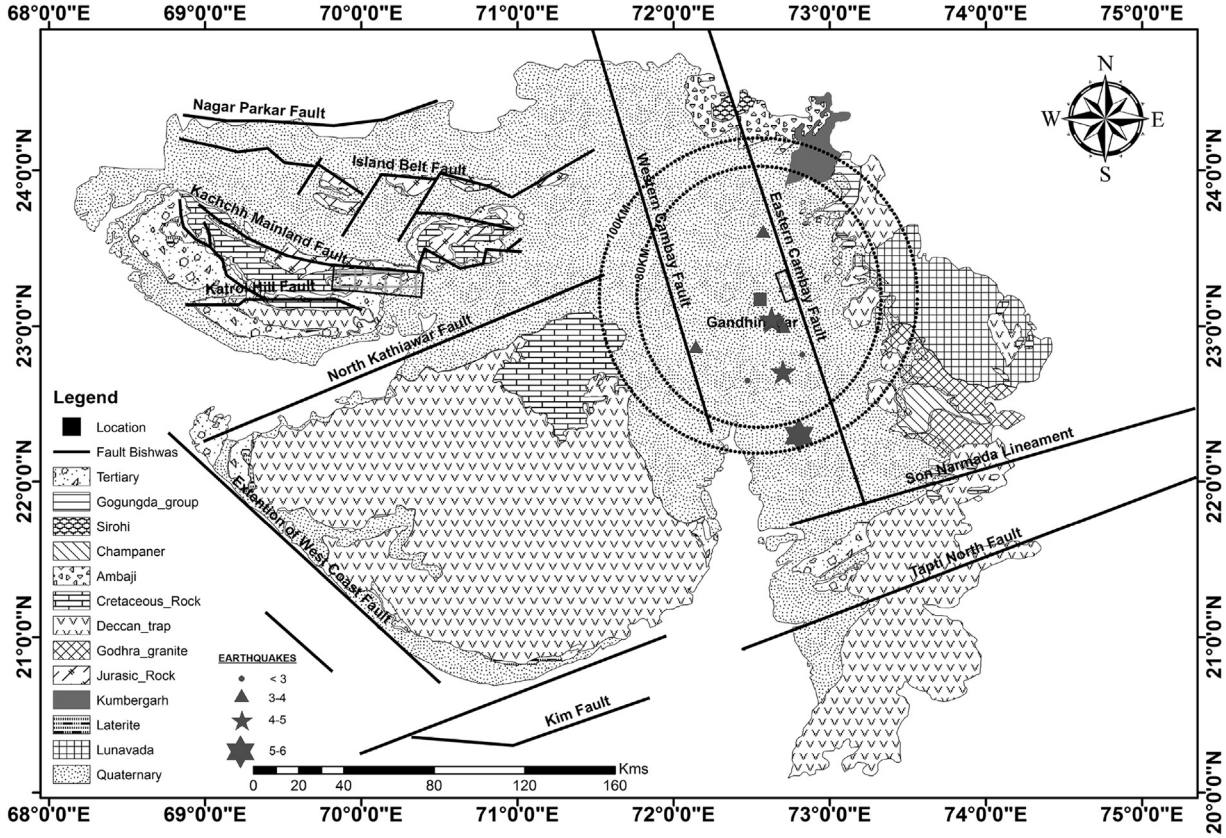

Fig. 1. Geological [31] and Tectonic Map (major faults adapted from [7]) of Gujarat.

Table 1
Classification of Soil in Gandhinagar City (After Merh., 1995).

Period	Epoch	Lithology	Thickness
Quaternary	Holocene	Sand, Silt, Clay and Gravels	80–100 m
	Pleistocene	Yellow and Grey Clays, Coarse Sand, Gravel and Kankar	300 m
Tertiary	Pliocene	Claystone, Sandstone, Conglomerate	200 m
	Miocene	Ferruginous Sandstone, Conglomerate and Grey Clay	400 m
	Oligocene	Grey Shale, Sandy Shale and Argillaceous Sandstone	~600 m
	Eocene	Black Shale, Carbonaceous Shale	430 m
	Paleocene	Volcanic conglomerates, Deccan trap Basalt	+1000 m

Gandhinagar city in 1864. The Gandhinagar City falls in Cambay basin surrounded by West Cambay fault and East Cambay fault dipping towards the Gandhinagar City. The East Cambay fault is located only 15 km east of the Gandhinagar City. The Mw 7.7, Bhuj earthquake of 2001 occurred at a distance of 300 km to the Gandhinagar city and devastation was observed in the neighboring Ahmedabad City.

The Macro Seismic Hazard Assessment work was carried out by Petersen et al. [41], Iyengar and Raghu Kanth [23], Chopra et al. [14] and Mohan [33] in the adjacent Kachchh region of Gujarat. Mandal et al. [30] have estimated the site response by H/V method in the vicinity of Kachchh Mainland fault and Wagad uplift. The Micro Seismic Hazard Assessment study was conducted only in Gandhidham- Kandla area by Gujarat State Disaster Management Authority (GSDMA), OIC, Japan and ISR by considering the effect of active faults, shear wave velocity and Geotechnical datasets. Geological survey of India conducted the 1st phase of Micro seismic hazard assessment in Ahmedabad city. The National Disaster Management Authority have prepared the Probabilistic seismic Hazard Map of India on A-type site (with a Vs_{30} > 1.5 km/s) [38]. Parvez et al. [40] have prepared a Deterministic seismic hazard map of India. Chopra et al. [14] has estimated the PGA at surface by Deterministic seismic hazard assessment approach at one site in Gandhinagar City without considering East Cambay fault. The micro seismichazard assessment of Gandhinagar city was not conducted yet considering geological, geophysical and geotechnical parameters.

The strong motion data of 2001 Bhuj earthquake and past earthquakes in the region is not available at good number of sites to guide earthquake resistant designing. Hence estimation of the ground motion scenarios considering past seismicity and tectonic setting of the area will be quite helpful to estimate the possible ground motion shaking at the site of interest and in turn to guide the earthquake resistant designing. It will also be useful for estimation of earthquake risk and loss assessment.

In practice , the ground response analysis covers the source path as well as site effect by considering rupture mechanism, propagation of seismic waves and effect of soil on the strong ground motion. In the present work, the Peak Ground Acceleration (PGA) and Peak Spectral Acceleration (PSA) distribution maps at surface level have been prepared to cover all these three effects.

2. Geology and tectonics

Gandhinagar City is situated within the 50 km wide Cambay Basin, which is characterized by two NNW-SSE trending faults : (i) East Cambay Fault and (ii) West Cambay Fault. East Cambay Fault lies close to Gandhinagar. Some small earthquakes in the historical past are listed to have been felt at Ahmedabad that might have occurred along East Cambay Fault or even as far away as Kachchh (Fig. 1). The West Cambay Fault has also experienced earthquakes. The basin is filled with 300–400 m thick Quaternary and 2–3 km thick Tertiary sediments [31] constituting alluvial plains of Mainland Gujarat. The detailed stratigraphy of the Gandhinagar City and surroundings has been given in Table 1.