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Estimation of strong motion parameters in the coastal region of gujarat using geotechnical data

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ABSTRACT

Seven boreholes are drilled in the coastal region of Gujarat; three in Kachchh (at Jangi, Mandvi and Mundra), one in Saurashtra (Jodiya) and three in mainland Gujarat(Dahej, Kamboi and Dholera) to depth of 27–80 m for estimating the surface strong ground motion parameters. These parameters are required for seismic resistant design of structures in the areas. The adopted methodology comprises of three parts: (i) soil modeling and estimation of depth to Engineering Bed Layer (EBL) (a prominent subsurface soil layer with shear wave velocity of 450 m/s to 760 m/s with SPT N value of more than 80) (ii) Estimation of the ground motion at EBL (iii) estimation of ground motion at the surface by 1D ground response analysis using SHAKE program. The soil models are prepared from borehole data and shear wave velocity/ N-values. The ground motion at EBL is estimated using Stochastic Finite Fault source Modeling Technique by considering scenario earthquakes along two major faults of Kachchh (Kachchh Mainland Fault (Mw7.6) and Katrol Hill Fault (Mw7.5)), one of Saurashtra (North Kathiawar Fault (Mw 6.5)) and one of Mainland Gujarat (West Cambay Fault (Mw 6.0)). The surface ground motion is estimated by passing ground motion simulated at EBL through prepared soil models of each site using SHAKE program. The surface peak ground acceleration from 0.076g to 0.396 g and peak spectral acceleration from 0.24g to 1.4 g are estimated at seven coastal sites. Spectral accelerations are found higher than Bureau of Indian Standard (BIS) suggested values at Jangi (between 0.1 and 0.3 s & 0.8–1.4 s), Jodiya (0.1–0.3 s), Mundra (0.3–0.6 s) and Dholera (0.1–0.4 s) sites, where the importance factor of 1.5 needs to be considered. The study suggests taking BIS values at Dahej, Kamboi and Mandvi coastal sites.

1. Introduction

Major international trade traffic in oil/gas (energy sector), bulk chemicals and construction materials is through Gujarat coast because of its superior infrastructure in terms of harbors, ports, jetties and oil/gas pipelines. Some 42 ports, numerous jetties, several refineries, a large number of chemical industries and Power plants are present in the coast of Gujarat. At the same time, most part of the coastal Kachchh (western Gujarat) is classified into the most severe seismic Zone V in Seismic Zoning map of India [5]. The state of Gujarat has experienced several damaging earthquakes during the past two centuries. In 1819, an earthquake of magnitude Mw 7.8 ruptured the Allah Bund fault in northwestern Gujarat and in this earthquake, the fatalities were high in Bhuj, Anjar and Ahmedabad cities [2,13]. An earthquake of magnitude Mw 7.7 occurred in 2001 along the North Wagad Fault and caused widespread damage in Bhuj, Anjar, Ahmedabad cities and many other areas in Gujarat [21]. A magnitude M 6.1 earthquake occurred near Katrol Hill fault in 1956 and caused damage in Anjar [13]. These three faults were the cause of moderate to major earthquake in Kachchh region of Gujarat. In case of a major seismic event, large-scale damage to the facilities will severely disturb the trade traffic and push the economy of the country back by several years. Therefore, the ground response analysis using Geotechnical data is essential before planning the new structures of huge economic importance in the area.

Seven coastal sites Gujarat; three in Kachchh (at Jangi, Mandvi and Mundra), one in Saurashtra (Jodiya) and three in mainland Gujarat (Dahej, Kamboi and Dholera) are considered in the present study. Dahej is an all weather direct berthing multi cargo port situated on the southwest coast of Gujarat, in the Gulf of Cambay and at the junction of Guljaria and Ban Creek. The port is about 45 km from Bharuch, which is now being connected to the Port of Dahej through a broad gauge rail. Dholera is present in the gulf of Cambay and is economically very important; a special investment region (SIR) with airport facility is planned here. Kamboi is a village located in Jambusar Taluka of Bharuch district of Gujarat, India and present very near to the coastline. Jodiya is a village present at the coast in Jamnagar district, Gujarat, India. Jangi is a Village in Bhachau Taluka in Kachchh District of Gujarat State, India. It is located 104 kM towards East from the

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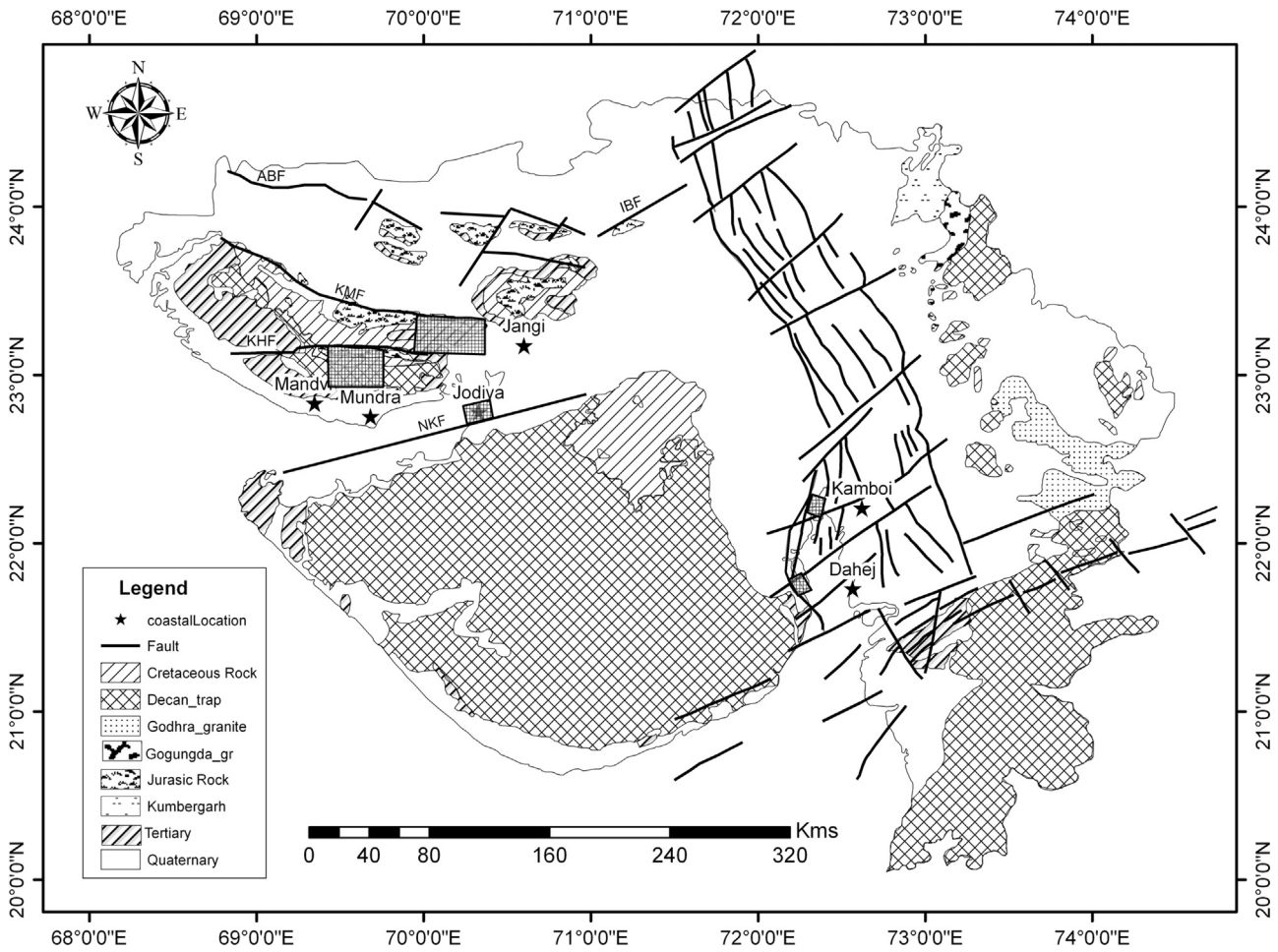

Fig. 1. : The location of sites considered for ground response analysis plotted on Geology (after [14]) and Tectonic Map of Gujarat. The ruptures considered along the faults are also shown with shaded area.

District head quarter (Bhuj). Mandvi is a city and a Municipality in Kachchh district of Gujarat. It was once a major port of the region. The city has more than four hundred-year-old ship building industry that still manufactures small ships. Mandvi is a port city which is located where the Rukmavati River meets the Gulf of Kachchh. It is about 56 km south Bhuj. It is better to estimate seismic ground motion from earthquake source to the ground surface in one go, but currently it is difficult to do so, because of the information shortage and impreciseness or limitation of the theory and methodology to be used. Thus usually, the process is divided into several parts. One is the earthquake source; the second is the earthquake source to base rock; the third is base rock to engineering bed layer and the final portion is engineering bed layer to the ground surface through soil. Sometimes first two or three portions are combined depending upon the strong motion simulation technique. In semi-empirical technique [15], the first two portions are combined. In the Empirical Green Function (EGF) technique [11], all four are combined without concentrating on near-surface soil effect. The near-surface soil has a great influence on ground motion. Mexico city earthquake of 1985 and effect of 2001, Bhuj earthquake at Ahmedabad city are the best examples of amplification of ground motion due to near surface soil. In general, the usage of a particular technique depends upon the available input parameters, source and site conditions. In the present case, the first three portions are combined, and the ground motion is estimated at Engineering Bed Layer (EBL) considering scenario earthquakes along active faults present in the vicinity. The surface motion is then estimated by passing the motion calculated at EBL through the soil models prepared from geotechnical and geophysical data using equivalent linear analysis through SHAKE 2000 software. In the current work, seven boreholes are drilled for soil modeling and ground response analysis at selected port/nearby port sites in Gujarat. The boreholes are drilled for 27–80 m depth. The methodology is divided into three major parts: Soil Modeling and Estimation of EBL, (ii) Estimation of Ground Motion/ Input Motion at EBL and (iii) Estimation of Ground Motion at Surface. The borehole lithologs, soil classification, shear wave velocity/ N-Value and density are the essentially required inputs to prepare a soil model along a borehole for ground response analysis.

The outcrop strong motions at the EBL of all boreholes are estimated using Stochastic Finite Fault source Modeling Technique [18] by considering scenario earthquakes along the nearest faults to borehole locations. The magnitudes of the scenario earthquakes are decided based on previous active fault studies and /or past seismicity in the vicinity. In the last step, outcrop motions estimated at EBL of all boreholes are converted to input base motion through SHAKE 2000. The input base motions are passed through the prepared soil models of each borehole to compute surface strong ground motion.

2. Geology and tectonic setting

The Gulf of Kachchh is situated in western most part of India and is bounded by Kachchh in the north, Saurashtra in the south and Little Rann of Kachchh to its east and the Arabian Sea to its west. The geological setup of Kachchh mainland shows that it comprises of sandstone, shale and limestone of Jurassic, Cretaceous and Tertiary