Soil Dynamics and Earthquake Engineering 89 (2016) 171–184

Contents lists available at ScienceDirect

Soil Dynamics and Earthquake Engineering

journal homepage: www.elsevier.com/locate/soildyn

Gorkha (Nepal) earthquake of April 25, 2015: Actual damage, retrofitting measures and prediction by RVS for a few typical structures

Sekhar Chandra Dutta [a,*], Sanket Nayak [a], Gokul Acharjee [b], Sarat Kumar Panda [a], Pranab Kumar Das [a]

[a] Department of Civil Engineering, Indian School of Mines, Dhanbad 826004, Jharkhand, India
[b] Rural Development Centre, Indian Institute of Technology, Khargpur 721302, West Bengal, India

ARTICLE INFO

Article history:
Received 23 December 2015
Received in revised form
12 April 2016
Accepted 8 August 2016

Keywords:
Nepal earthquake
Masonry structures
RVS
Strengthening technique
Vulnerability

ABSTRACT

This study is an attempt to underline the lack of preparedness and the nature of immediate further measures to be taken for facing a moderate earthquake in Indian subcontinents. Surprisingly, moderate to severe damage was noticed in structures located in hundreds of kilometres away from epicentre during last Gorkha earthquake. In this context, the present study makes an effort to validate a proposed modified rapid visual screening schemes for low cost houses frequently available in India. This may be used extensively for quick vulnerability assessment of a locality. Examples of retrofitting measures for typical buildings presented in this study may be useful for upgrading the valuable structures. Thus this study may be helpful for quick vulnerability assessment and adopting retrofitting measures for identified structures for earthquake prone developing countries.

1. Introduction

Enormous damage has been caused by the Nepal earthquake to many buildings in the bordering states with Nepal, e.g. Bihar of India. This has prompted the need for assessment of actual damage and its urgent requirement for suggesting strategies. This is particularly needed for retrofitting of typical low to medium rise buildings as well one to two storey masonry structures which are frequent in Indian subcontinent and in many other developing countries. In fact, the after-effect of seismic hazard on the non-RC (reinforced concrete) based structures has created the high level of distraction for population belongs to lower economic bracket. Similar nature of damage has also been observed due to Sikkim earthquake of 2011 as reported in a recent study by Dutta et al. [1]. This paper is an attempt to present a typical study to establish suitable retrofitting strategies in the context of actual damage cause by the earthquake on a few typical RC based buildings and also a few masonry structures. A strategy proposed elsewhere, Mukhopadhyay [2] for rapid visual screening (RVS) suitable for Indian subcontinent is also attempted to be validated here. In RVS methodology the building stock to be surveyed is classified into different types based on predominant building materials used. A 'basic score' (BS) representing the risk category is assigned to each building type. As performance of a building type is a function of peak ground acceleration values, BS values for the same building type will differ in different seismic zones. However, in general, building type having a relatively higher BS value will be able to withstand higher seismicity and vice versa. The total score is calculated by adding or subtracting stipulated scores for vital structural features reducing or increasing the vulnerability from the basic scores (details are elaborated in the relevant section). After such validation, this scheme may be used for assessing vulnerability of building in India and other neighbouring countries. For understanding the severity of the earthquake a brief detail about the earthquake popularly named as Gorkha earthquake is presented in subsequent section.

1.1. Gorkha earthquake

An earthquake of magnitude 7.8 measured on Richter scale strucked Nepal on April 25, 2015 at 11:26 UTC (11:56 NST; 11:41 ISD) [3,4]. This, earthquake occurred as the result of thrust faulting on or near the main thrust interface between the sub ducting Indian plate and the overriding Eurasian plate to the north. Its epicentre was approximately 34 km east of the district of Lamjung, Nepal, and its hypocenter was at a depth of approximately 15 km which is considered shallow and therefore more damaging than

* Corresponding author.
E-mail addresses: scdind2000@gmail.com, dutta.sc.civ@ismdhanbad.ac.in (S.C. Dutta), sanketiitbbsr@gmail.com, nayak.s.civ@ismdhanbad.ac.in (S. Nayak), gokul@hijli.iitkgp.ernet.in (G. Acharjee), sarat.iitm@gmail.com, panda.sk.civ@ismdhanbad.ac.in (S.K. Panda), prnb_28@yahoo.co.in (P.K. Das).

http://dx.doi.org/10.1016/j.soildyn.2016.08.010
0267-7261/

earthquakes that originate deeper in the ground given in Fig. 1. It was the worst natural disaster to strike Nepal since the 1934 Bihar–Nepal earthquake. The tremor was caused by a sudden thrust, or release of built-up stress, along the major fault line where the Indian Plate, carrying India, is slowly diving underneath the Eurasian Plate, carrying much of Europe and Asia. Kathmandu, situated on a block of crust approximately 120 km wide and 60 km long, reportedly shifted 3 m to the south in just 30 s. The Modified

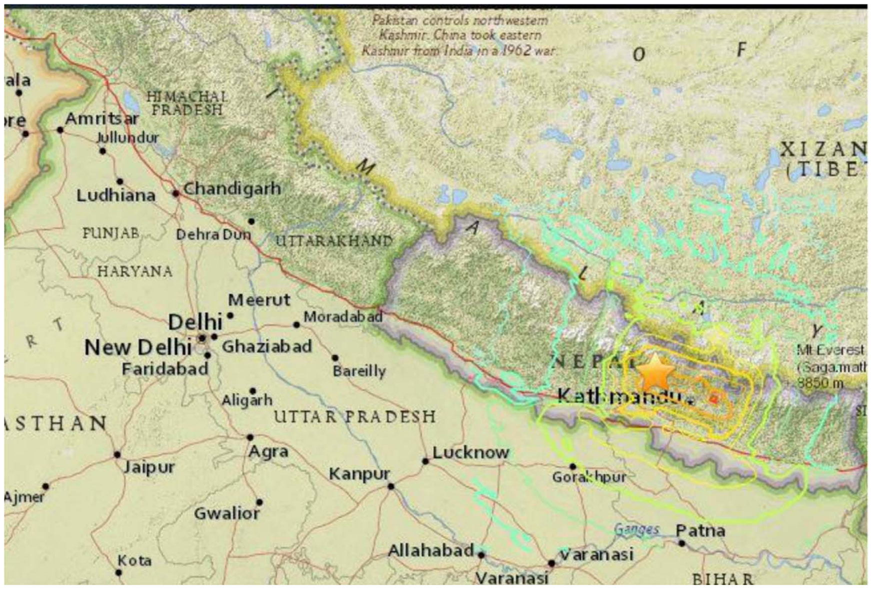

Fig. 1. Map of April 25, 2015 earthquake epicentre, extracted from USGS [3].

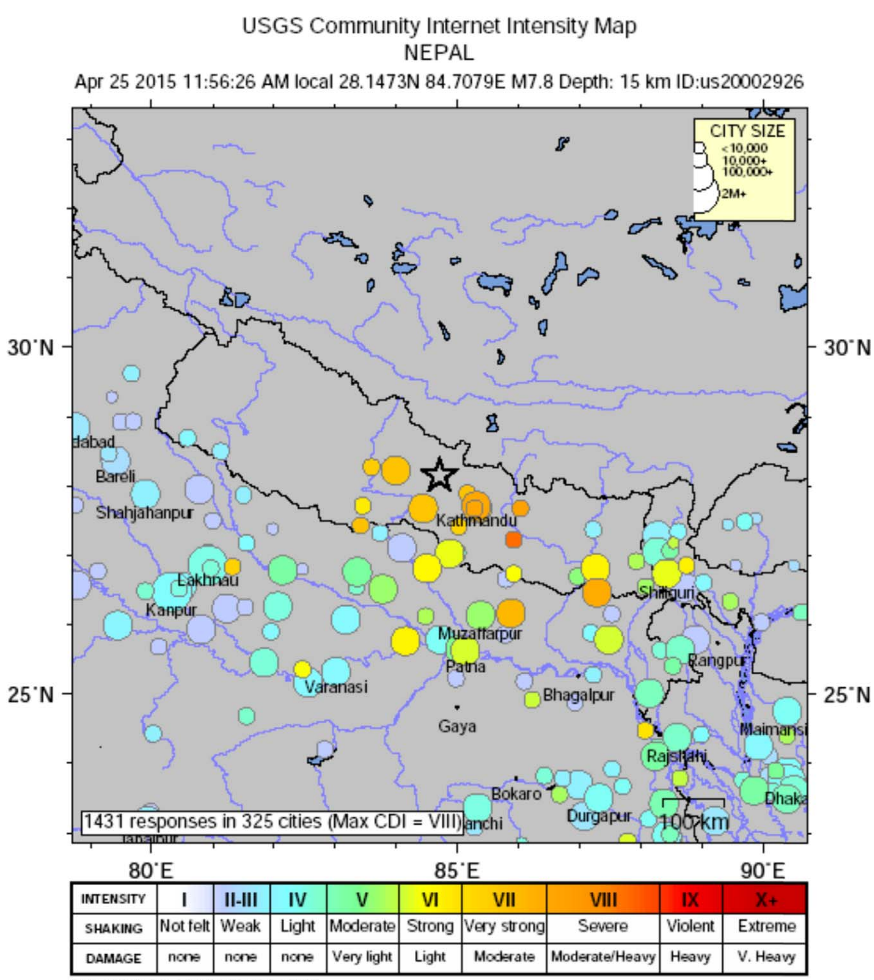

Fig. 2. Intensity map of April 25, 2015 Earthquake, extracted from USGS [3].