ELSEVIER

Soil Dynamics and Earthquake Engineering 22 (2002) 743–754

SOIL DYNAMICS AND EARTHQUAKE ENGINEERING

www.elsevier.com/locate/soildyn

Seismic hazard model for loss estimation and risk management in Taiwan

K.W. Campbell[a,*], P.C. Thenhaus[b], T.P. Barnhard[b], D.B. Hampson[b]

[a]ABS Consulting and EQECAT Inc., 1030 NW 161st Place, Beaverton, OR 97006, USA
[b]ABS Consulting, 2942 Evergreen Parkway, Suite 302, Evergreen, CO 80439, USA

Abstract

We developed a seismic hazard model for Taiwan that integrates all available tectonic, seismicity, and seismic hazard information in the region to provide risk managers and engineers with a model they can use to estimate earthquake losses and manage seismic risk in Taiwan. The seismic hazard model is composed of two major components: a seismotectonic model and a ground-shaking model. The seismotectonic model incorporates earthquakes that are expected to occur on the Ryukyu and Manila subduction zones, on the intermediate-depth Wadati-Benioff seismicity zones, on the active crustal faults, and within seismotectonic provinces. The active crustal faults include the Chelungpu fault zone, the source of the damaging M_W 7.6 Chi-Chi earthquake, and the Huangchi-Hsiaoyukeng fault zone that forms the western boundary of the Taipei Basin. The ground-shaking model uses both US, worldwide, and Taiwanese attenuation relations to provide robust estimates of peak ground acceleration and response spectral acceleration on a reference site condition for shallow crustal and subduction zone earthquakes. The ground shaking for other site conditions is obtained by applying a nonlinear soil-amplification factor defined in terms of the average shear-wave velocity in the top 30 m of the soil profile, consistent with the methodology used in the current US and proposed Taiwan building codes.

Keywords: Earthquakes; Portfolio management; Risk management; Risk modeling; Seismic hazard; Seismic risk; Seismic zonation; Seismicity; Taiwan

1. Introduction

Risk managers are increasingly relying on computer models to help them identify and manage the risk from catastrophic perils such as earthquakes, hurricanes (typhoons), and flooding to portfolios that can be widely distributed geographically. This requires the use of hazard models that cover entire countries or in some cases even larger regions in a format that is consistent with the models used to quantify the resulting risk in terms of monetary and human losses. In this paper, we describe such an earthquake hazard model for the island of Taiwan. This model combines information on earthquake zonation, earthquake frequency, the attenuation characteristics of strong ground motion, and the dynamic response of the site profile beneath the site (site amplification) in a coherent and consistent representation of earthquake hazard throughout the country.

Previous seismic hazard models [1–3] have been based primarily on historic seismicity or on generalized faulting models in which faults have been randomly distributed within seismotectonic provinces [4]. Recurrence rates have been determined based exclusively on historic seismicity. The 1999 M_W 7.6 Chi-Chi earthquake that ruptured 85 km of the Chelungpu fault zone, the largest earthquake to strike onshore Taiwan in several hundred years, demonstrated the importance of including individual fault sources in the assessment of seismic hazard. However, there is very little information on the slip rates of crustal faults in Taiwan. In this study, we have attempted to account for these faults using slip rates inferred from global positioning system (GPS) velocity vectors.

2. Tectonic setting

The island of Taiwan lies along the boundary of the Philippine Sea and Eurasian tectonic plates (Fig. 1). The Philippine Sea plate is moving northwest toward the Eurasian plate where it subducts beneath the Eurasian plate along the Ryukyu Trench and overrides the Eurasian plate in the south along the Manila Trench. The Philippine Sea plate collides with the island of Taiwan forming an oblique plate boundary along the Longitudinal Valley fault zone that forms the extreme eastern edge of the island.

The island of Taiwan comprises an actively growing mountain belt that is located at the northwestern corner of the Philippine Sea tectonic plate [5,6]. The predominantly

* Corresponding author.

0267-7261/02/$ - see front matter © 2002 Elsevier Science Ltd. All rights reserved.
PII: S0267-7261(02)00095-7

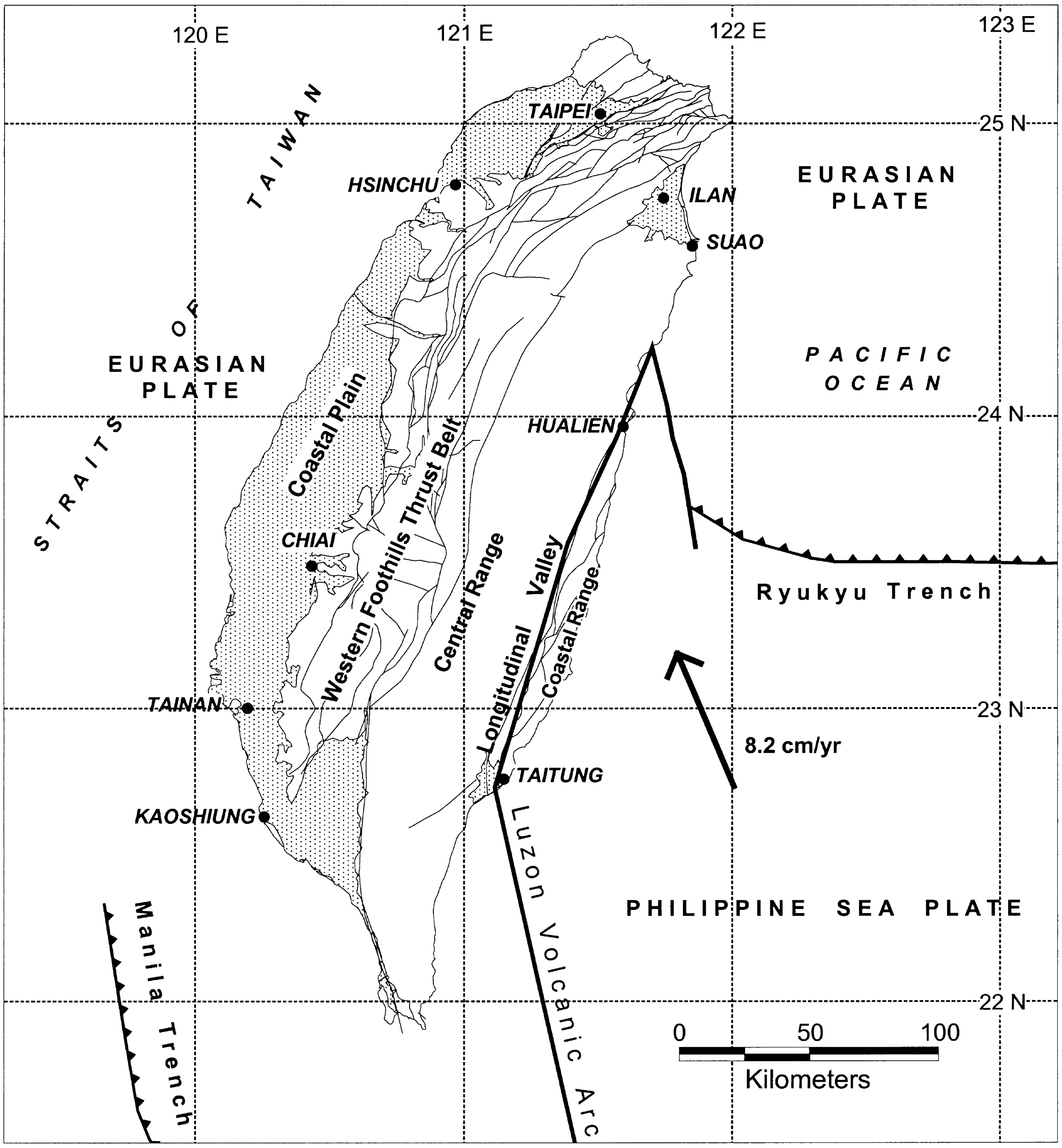

Fig. 1. Generalized plate tectonic setting of Taiwan. Bold lines are plate boundary zones. Barbs point down-dip of the plate interface megathrust. The large arrow indicates the relative direction of the 8.2 cm/yr [12] convergence of the Philippine Sea and Eurasian plates.

compressional tectonism of this region is governed by the oblique collision between the Luzon volcanic arc that occupies the western leading edge of the Philippine Sea plate and the Eurasian continental margin [7–13]. The mountain belt links oppositely dipping subduction zones to the north and south [10,14–16].

Offshore of southwestern Taiwan the northernmost segment of the Manila trench dies out toward the continental slope of China [17]. In this region, the accretionary prism of the subduction zone is in the initial stages of collision with the continental slope of China and forms a southward-propagating collision zone known as the Taiwan orogen [18–21]. The rate of southward propagation of the collision zone relative to the continental margin of China has been estimated to be 95 km/ma [22]. The distance between the accretionary prism formed by the collision of the Manila subduction zone and the Luzon volcanic arc (Philippine Sea plate) narrows as it approaches Taiwan due to shortening related to this collision. The top of the accretionary prism emerges above sea level to form the Hengchun Peninsula at the southernmost tip of Taiwan.

Farther to the north, the Luzon volcanic arc is colliding with the Manila subduction zone's accretionary prism and is being sutured to the Taiwan orogen along the Longitudinal Valley fault zone [23]. The orogenic belt culminates in a mature collision stage in central Taiwan where it reaches its