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### POTENTIAL SEISMIC HAZARD IN HONG KONG

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#### Introduction

In the past three decades, most of research efforts in earthquake engineering were concentrated on the earthquake disaster mitigation for regions of high seismicity. However, the attention to the potential seismic hazard in a region of moderate seismicity was revived until the earthquake in Newcastle of Australia in 1991 occurred, which was only a moderate earthquake ( $M = 5.6$ ) but caused 2.5 billion US dollars of damage. The earthquake indicated that although the seismic intensity of an earthquake is not high, it could cause a great loss of life and economy in a moderate seismicity region where there is no any earthquake disaster management programme. This is the typical case of low probability but high consequence [7].

Therefore, attention has recently been raised to the possible earthquake disaster in regions of moderate seismicity in the world, particularly in the Asia-Pacific region, where many countries are not located among the most active seismic areas. More recently, potential problems of the earthquake disaster mitigation for moderate seismicity regions were discussed in two successful workshops [1,5] held in March and August 1998, organised by Earthquake Disaster Mitigation Research Center, RIKEN, Japan, and Korea Earthquake Engineering Research Center, respectively. A workshop on earthquake engineering for regions of moderate seismicity will be held in December 1998 in Hong Kong, which is organised by three Hong Kong universities and the Mid-American Earthquake Engineering Research Center in Illinois, USA. The workshop is intended to provide a forum for researchers and engineers to discuss recent advances in technologies and limitations of current practice on earthquake engineering for regions of moderate seismicity.

In this paper, the potential seismic hazard in Hong Kong is discussed. The current status of seismic design for buildings and structures and the current needs of the earthquake preparedness in Hong Kong are presented. The research works, which are being conducted in the Civil Engineering Department of the Hong Kong University of Science & Technology, are also presented briefly.

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### Seismic Intensity in Hong Kong

Geographically, Hong Kong is not located among the areas of frequent destructive earthquake activity in the Asia-Pacific region. Reviews of the data on historical earthquakes within a region about 350 km radius of Hong Kong have been published [3,8,9]. The data include an assessment of 'observed' and 'felt' effects of earthquakes going as far back as more than 900 years ago. Although Hong Kong is not among the most seismic active regions, the earthquake risk is not nil. Destructive earthquakes did occur in southern China and the Southern China sea that have potential of affecting Hong Kong significantly. The distribution of major earthquakes in Hong Kong and the vicinities is shown in Fig. 1. From the records, there are sixteen events between M 4.7 and 4.9; thirty-seven events between M 5 and 5.9; nine events between M 6 and 6.9; and two events rated larger than M 7. The most significant event was the M 7.4 one occurred in Shantou of Guangdong Province, about 300 km from Hong Kong in 1918. And there were some reports of damaged buildings in Hong Kong.

The investigation [8] indicates that Hong Kong has a peak ground acceleration of about 0.1g with a 10% probability of exceedance in 50 years. The study also evaluates the hazard in terms of the seismic intensity in Chinese code and rates Hong Kong is located within a region of intensity 7. Base on these investigations, as can be seen the rate of earthquake activity in the vicinity of Hong Kong is similar to eastern USA, and the seismic hazard of Hong Kong can be considered to be similar to that in New York state. Both areas would be rated as Zone 2A seismic region according to the zoning in UBC [4]. Therefore, Hong Kong is located in a region of moderate seismicity.

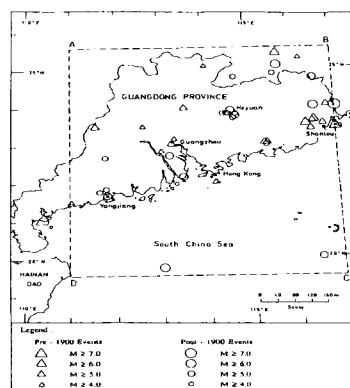


Fig.1. Major earthquakes in the vicinity of Hong Kong (GCO 1991)

### Current Situation and Needs

At the present time, the earthquake preparedness in Hong Kong is relatively low. Two aspects may make the Hong Kong situation differ from other regions of moderate seismicity [10]. First,

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the earthquake effect is not a major effect traditionally required to be considered in design of buildings and structures. Currently, official earthquake regulations do not exist in Hong Kong for design of civil structures; while structures are normally designed to carry their service loads - dead, imposed and wind loads. Second, the subject of seismic analysis and design is not yet within the standard curriculum for civil and structural engineers trained in Hong Kong. As a result, there is lack of manpower with enough knowledge to handle the earthquake disaster problems.

Hong Kong is a densely built region, and both commercial and residential buildings are very tall buildings (Fig. 2). Considering the high density of population (6.7 millions) and the extensive infrastructure built-up in the region during the past several decades, even the seismic intensity of an earthquake may be low, the consequence of the earthquake could be enormous. Therefore, it could be the time for Hong Kong as a highly developed region to seriously consider earthquake disaster mitigation procedures.

In Hong Kong, buildings and structures are generally required to be designed for wind load,

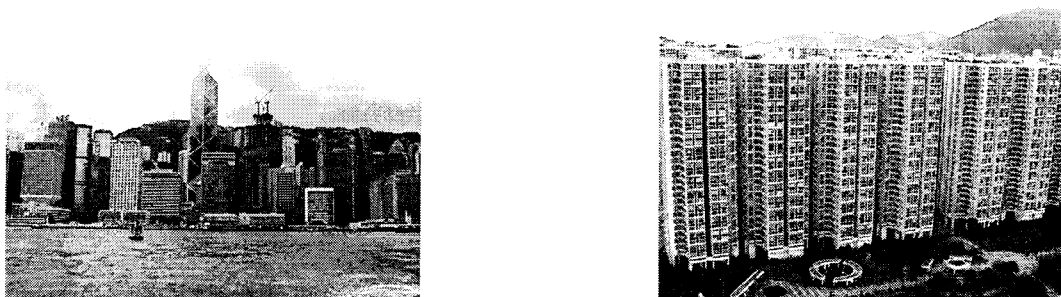


Fig. 2. Tall commercial and residential buildings in Hong Kong

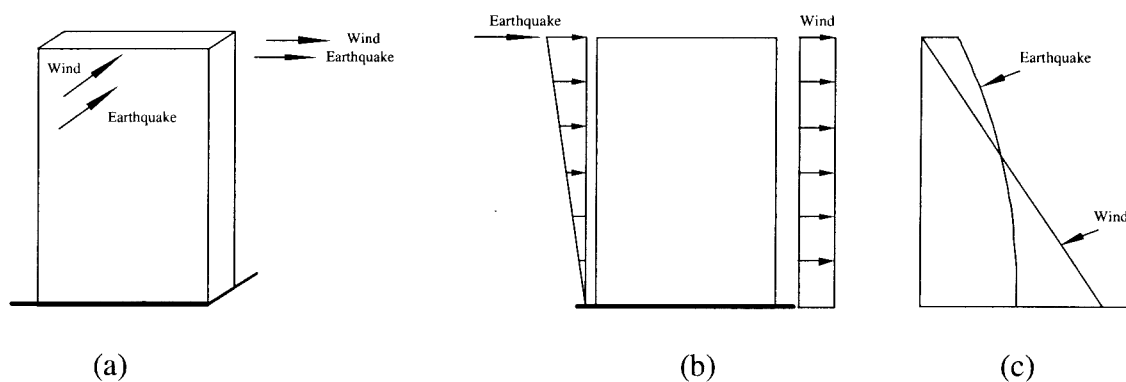


Fig. 3 (a) A rectangular building; (b) Wind and earthquake loads; (c) Interstorey shear

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ignoring the effects of earthquake. What is lacking at the moment for the civil engineers in Hong Kong is the general awareness that a satisfactory design for strong wind does not mean it will automatically be satisfactory for earthquakes, even if for a low or moderate earthquake. What has been missed in the past in Hong Kong is the routine checking that could be performed in some regions of moderate seismicity to show whether the wind effect is in fact the dominant effect. Fig. 3 gives two situations to illustrate this point. A rectangular building with a high aspect ratio in plan is shown in Fig. 3a. While the base shear from wind exceeds the base shear from earthquake many times normal to the broad side, the base shears from wind and earthquake can be comparable normal to the narrow side of the building. Fig. 3b shows the equivalent wind and earthquake loads acting on the structure, and Fig. 3c shows the comparison of the interstorey shear from wind and earthquake for tall buildings. Due to the higher modal effect, it is not uncommon that the interstorey shear at the upper part of the buildings from earthquake exceeds that from wind. Moreover, the seismic design problems in connection with buildings having 'soft storey', or located in soft grounds, do not have their counterparts in the wind design.

It is very clear that there are needs [10] to raise the effort of Hong Kong in terms of earthquake disaster mitigation: (1) to identify and classify the situations when the earthquake effect exceeds the wind effect, based on actual Hong Kong structures, and prepare a data base on these structures for possible retrofit in the future; (2) to evaluate the ductility capacity of Hong Kong buildings and the structural members, based on currently used design and detailing; (3) to formulate a set of earthquake regulations for new constructions, based on the current practice so that the regulations can be implemented conveniently; (4) to train the current and future crop of engineers to carry out the earthquake regulations in practice; and (5) to develop plans and procedures to follow in case of a destructive earthquake to hit the place.

### **Current Studies**

Samples representative of reinforced concrete buildings are analysed for comparison of wind and earthquake effects on existing Hong Kong buildings [6], which are classified as from low-rise to high-rise buildings built in different time, and have different structural forms. General findings from the analysis are: (1) for the low-rise buildings, the shear and moment capacities demanded for earthquake resistance are significantly more than those for wind. These structures may perform woefully under a moderate earthquake; (2) for the medium-rise to high-rise buildings, the shear and moment capacities demanded at upper storeys for earthquake resistance are more than those for wind. It means that the upper parts of the structures may perform woefully under a moderate earthquake; (3) the seismic effects are even more pronounced for unequal directional stiffness.

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The investigation of moderate earthquake problems for design of built-up structures in Hong Kong has been carried out by the government building agencies and universities of Hong Kong. The goal of the investigation which is being conducted by the Hong Kong University of Science and Technology is to examine the feasibility of earthquake regulations for Hong Kong. The studies include: (1) to assess the adequacy of existing design practice for reinforced concrete buildings of Hong Kong in resisting moderate seismic forces; (2) to recommend appropriate parameters for use at the design and analysis stages for reinforced concrete buildings; (3) to recommend a steel reinforcement detailing technique suitable for Hong Kong in order to enhance seismic performance of reinforced concrete structures. Both theoretical and experimental investigations are being carried out.

### Conclusions

Hong Kong is not located in the most seismic active areas in the Asian-Pacific region, but the earthquake risk of the place is not nil. The potential seismic hazard does exist and could affect Hong Kong significantly. By considering the high density of population and the extensive infrastructure built-up in Hong Kong, although the seismic intensity of an earthquake which attacks Hong Kong may be low, the consequence of the earthquake could be enormous. A case-study for comparison of the wind and earthquake effects on Hong Kong buildings has been indicated that the consideration of earthquake resistance is necessary for design of buildings and structures in Hong Kong. Therefore, it may be the time for Hong Kong as a highly developed region, and probably for other regions of moderate seismicity in the world, to examine the feasibility of earthquake regulations and to seriously consider earthquake disaster mitigation procedures.

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