Region Report : Thailand

DEVELOPMENT OF EARTHQUAKE DISASTER MITIGATION TECHNOLOGIES IN THAILAND

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Introduction

The Kingdom of Thailand is located in Southeast Asia between N5° 30' to 21° latitude and E97° 30' to E105° 30' longitude. It is neighboured by Laos and Myanmar to the north, Cambodia to the east, Malaysia to the south and Myanmar to the west. The country measures 517,000 square kilometers with a population of slightly over 60 million. The kingdom is governed under the democratic constitutional monarchy system and enjoys more than 700 years of independence. Although Thailand is low in seismic activity in the global perspective, some activities have been on-going towards development of earthquake disaster mitigation technologies, which are addressed in this paper.

Past Earthquake Events and Damages in Modern History

Thailand has long been believed to be a country of 'low seismicity' until the recent occurrence of several moderate earthquakes. On April 22, 1983, an earthquake of magnitude 5.9 on the Richter scale erupted near a dam site, about 200 kilometers from Bangkok, the capital of Thailand. The main tremor of this earthquake was felt all over the western part and most of the central part of the country. This earthquake together with the foreshocks and aftershocks were later confirmed to be reservoir-induced. Five years later on November 6, 1988, an earthquake of magnitude 7.3 hit the southern part of China near the Myanmar border. This earthquake was felt in Bangkok even though the epicenter was more than 1,000 kilometers away, a consequence of the ability of Bangkok's deep, soft-alluvial soil in amplifying the incoming seismic waves. The threat from earthquakes was realized again in the following year on September 29 and October 1 when several moderate earthquakes hit the northern part of Thailand along the Myanmar border. In the city of Chiang Mai, about 180 kilometers from the epicenter, the intensity of ground shaking was approximately VI on the Modified Mercalli scale. Since then, moderate earthquakes seem to be frequent visitors in northern Thailand, the worst one being the Phan earthquake (M = 5.1) in Chiang Rai which caused slight structural damage to a few dozen buildings (mostly schools and temples), with a few moderately damaged. In one hospital building severe shear cracks occurred in more than ten short columns (Lukkunaprasit, 1995). It should be noted that all the buildings whose damages are reported were not designed for any earthquake loading. Figure 1 shows the locations of epicenters, tremors of which were felt in Thailand from 1912-1996. Table 1 lists the major earthquake events in modern Thai history.

Recent Activities Towards Earhquake Disaster Mitigation

Seismic Monitoring Facilities

Seismograph stations and strong motion accelerographs

Since the set up of the first seismograph station in 1963 the Meteorological Department of Thailand (TMD) has constantly expanded its seismic monitoring capability. Prior to 1996, 14 out of the 15 seismographs were analog instruments. A network of 11 modern seismograph stations with digital instruments was recently set up in 1998 (Figure 2). The digitized signals from 3 stations are transmitted in real time through VSAT to the data acquisition system at the Meteorological Department in Bangkok. Data from the other 8 stations can be retrieved automatically through telephone lines once the trigger is activated. Furthermore, strong motion accelerographs have also been installed at all the 11 stations.

In addition to the recently installed strong motion accelerographs mentioned, TMD has been operating 13 analog type strong motion accelerographs (Kinemetrics SMA-1's) while the Electricity Generating Authority of Thailand (EGAT) installed more than a dozen SMA-1's and seismographs at major dam sites. The Royal Irrigation Department (RID) is presently in the process of installing a modern seismic monitoring system for the Kaeng Sua Ten Dam Project in Phrae province in the north. Four seismographs and 1 strong motion accelerograph will be installed in a few months' time

Seismic Monitoring of Building Motions and Recorded Accelerograms

Prompted by the moderate earthquakes in 1983 which stimulated general public concern on the safety of buildings when earthquakes strike, the Earthquake Engineering and Vibration Research Laboratory, Chulalongkorn University, (CU-EVR) in collaboration with the Public Works Department (PWD), the Interior Ministry set up a joint research center to monitor building motions in two selected buildings in Bangkok in 1991. This is part of the work plans initiated by the National Earthquake Committee of Thailand who drafted what might be considered as a comprehensive national seismic risk mitigation plan for Thailand (Lukkunaprasit, 1994).

In the period of June 1992 to December 1995, a total of 35 seismic events from which tremors could be felt in Thailand occurred. Eleven of these events were recorded by the CU-EVR-PWD center. They are summarized in Table 2 together with values of the peak ground accelerations (PGA)(1). The accelerograms recorded are the first digitized records from buildings in Thailand. Figure 3 locates the epicenters whose events were recorded and Figure 4 shows the accelerograms recorded at Baiyoke I Tower (a 43 storey building) for the July 12, 1995 event.

All the accelerations recorded at the base of the buildings are less than 0.25%g except the July 12, 1995 earthquake (M_S 7.2) which resulted in an acceleration of about 0.25%g. (N-S) at the basement and 2%g at the top of the Baiyoke I building. It should be observed that despite the long distance of about 900 km from Bangkok, the ground motion was large enough to excite the building whose motion could be perceived by occupants. This clearly confirms the potential of amplification of ground motion by the deep soft soil strata underlying Bangkok.

Seismic Hazard Assessment

Hazard assessment in Thailand is still at an early stage of development. Relevant data are quite scarce. It is not surprising to get sometimes results different even when they are based on practically the same set of data. Estimates of peak ground accelerations (PGA) have been proposed by Nutalaya and Shrestha (1990), Lukkunaprasit and Kuhatasanadeekul (1993), and Warnitchai and Lisantono (1996) The corresponding maximum PGA values associated with a probability of exceedence of approximately 10% in 50 years in Thailand obtained by those researchers were 0.11g, 0.14g and 0.27g, respectively. It should be noted that assessments of peak ground accelerations (PGA) have been based on past seismic events (prior to research findings in recent years) and 'estimates' of source characteristics rather than on actual results from field investigation. Discrepancies in the predicted PGA's can thus be attributed to different assumptions made in the analyses. Moreover, significant uncertainties exist due to paucity of 'good' data. Refined seismic hazard assessment incorporating accurate data from geology and seismology studies is obviously needed, with the assistance of specialists so that uncertainties will be reduced to a minimum.

Research on Active Faults

The Electricity Generating Authority of Thailand has been engaged in research on some active fault systems in the northern and western parts of Thailand, mainly the Yuam, Mae Chan and part to the Three Pagoda fault zones. (2) Most of the work has been carried out in collaboration with the State Seismological Bureau of China.

The Department of Mineral Resources jointly with the Department of Geology, Chulalongkorn University have undertaken extensive research on dating the seismic activities of the major faults in Chiang Rai. Some trenching has been done, and preliminary investigations reveal that the Mae Chan fault may be capable of generating an M 7.0$^+$ earthquake with a recurrence interval of about 2,000-4,000 years.(3)

An extensive study of the geomorphic data for the central and eastern parts of the Northern Basin and Range in northern Thailand was carried out in the environmental impact assessment of Kaeng Sua Ten Dam Project, Changwat Phrae (Department of Mineral Resources 1996). From the slip-per-event data along the major fault zones in the region (Thoen and Phrae Basin faults) and the range of calculated slip rates in a subsequent and related study, Fenton et al. (1998) inferred that the faults in the region are capable of generating earthquakes as large as M_w 7 with an estimated return period in the order of 2500 to 15000 years.

Research on Soil Amplification of Ground Motion

Ashford et al. (1996, 1997) investigated the amplification of earthquake ground motions in Bangkok due to soil effects. Seismic site response analyses were conducted using the equivalent linear method. Soil properties used as input to the analysis, specifically shear wave velocity, were first estimated using existing correlations with field and laboratory data, then confirmed by a limited number of in-situ tests by the downhole method.

The deep soft soil, whose shear wave velocity in the top 15 m is as low as 60-100 m/s, has the ability to amplify earthquake ground motions 3 to 7 times, with peak spectral acceleration centered near the 1 second period, and secondary peaks occurring out to periods of about 2 seconds, depending on the depth to the rock-like stratum.

The finding clearly indicates the potential threat from tremors generated by long distance large earthquakes (e.g. from the subduction zone and associated fault system in the Andaman Sea) and locally amplified by soft soil strata underlying Bangkok. The remaining unsolved problem is the determination of the probable magnitude of peak input bedrock-like accelerations in Bangkok. If it were 3%g or more, a situation similar to the 1985 Mexico City earthquake event could possibly occur in Bangkok.

Research on Earthquake Engineering

Selective areas of research on earthquake engineering are as follows :

a) Development of nonlinear response spectra (Kuhatasanadeekul 1996, Sangrayakul 1997, Warnitchai and Panyakapo 1998)
b) Cyclic behavior of reinforced concrete beams (Pokharel 1998) and shear walls (Sittipunt and Wood 1998)

c) Performance improvement of reinforced concrete tied columns by means of hook clips (Lukkunaprasit 1998)
d) Design of multi-story reinforced concrete frame buildings (Tangaereemankong 1998)
e) Investigation of dynamic soil properties (Teachavorasinskun 1998a, 1998b)

Contact Agencies

The main contact agencies and key persons are listed below.

- The National Earthquake Committee of Thailand. Capt. Kajit Buajitti, R.T.N. is the Chair man of the Committee.
- The Office of Seismology, Meteorological Department. It is currently directed by Ms. Sumalee Prachuab.
- The Geological Survey Division, Department of Mineral Resources. The contact person is Mr. Chaiyan Hintong.
- The Electricity Generating Authority of Thailand, Survey Division. Ms. Supawan Klaipongpan is in charge of research for the division.
- Universities
  - Chulalongkorn University, Earthquake Engineering and Vibration Research Labo ratory (CU-EVR). It is directed by Prof. Dr. Panitan Lukkunaprasit.
  - Chulalongkorn University, Department of Geology. The active persons are Assist. Prof. Dr. Nopadon Muangnoicharoen and Dr. Punya Charusiri.
  - Asian Institute of Technology. The key persons are Prof. Dr. Prinya Nutalaya and Assoc. Prof. Dr. Pennung Warnitchai.

Up to now research activities related to earthquake mitigation technologies have been mainly conducted in the two universities mentioned. However, some researchers in other universities are beginning to enter into research in this field.

Multi-Lateral Collaboration for Disaster Mitigation
The EDM Mission

Long distance major earthquakes pose a threat not only to Bangkok but also to some other cities in the APEC economies, e.g. Singapore and Malaysia. Certain unsolved problems (mentioned in sections 3.2 and 3.4) need the assistance of experts to obtain realistic and reliable results. It is thus sensible to undertake multi-lateral collaboration between scientists and engineers in less seismic prone countries and those in Japan who have the expertise. The mission of the Earthquake Disaster Mitigation Research Center, RIKEN, in response to the APEC vision of promoting multi-lateral projects for disaster mitigation, would be most beneficial to the region and contribute to the realization of the ideology set forth for the International Decade for Natural Disaster Reduction.

Acknowledgements

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Fotnotes

(1) Due to the long distances from the epicenters, long period waves prevailed and, from the practical standpoint, the accelerations recorded at the base of the buildings can be approximately taken as the peak ground acceleration (PGA).(2) S. Klaipongpan, personal communication

(3) P. Charusiri, personal communication

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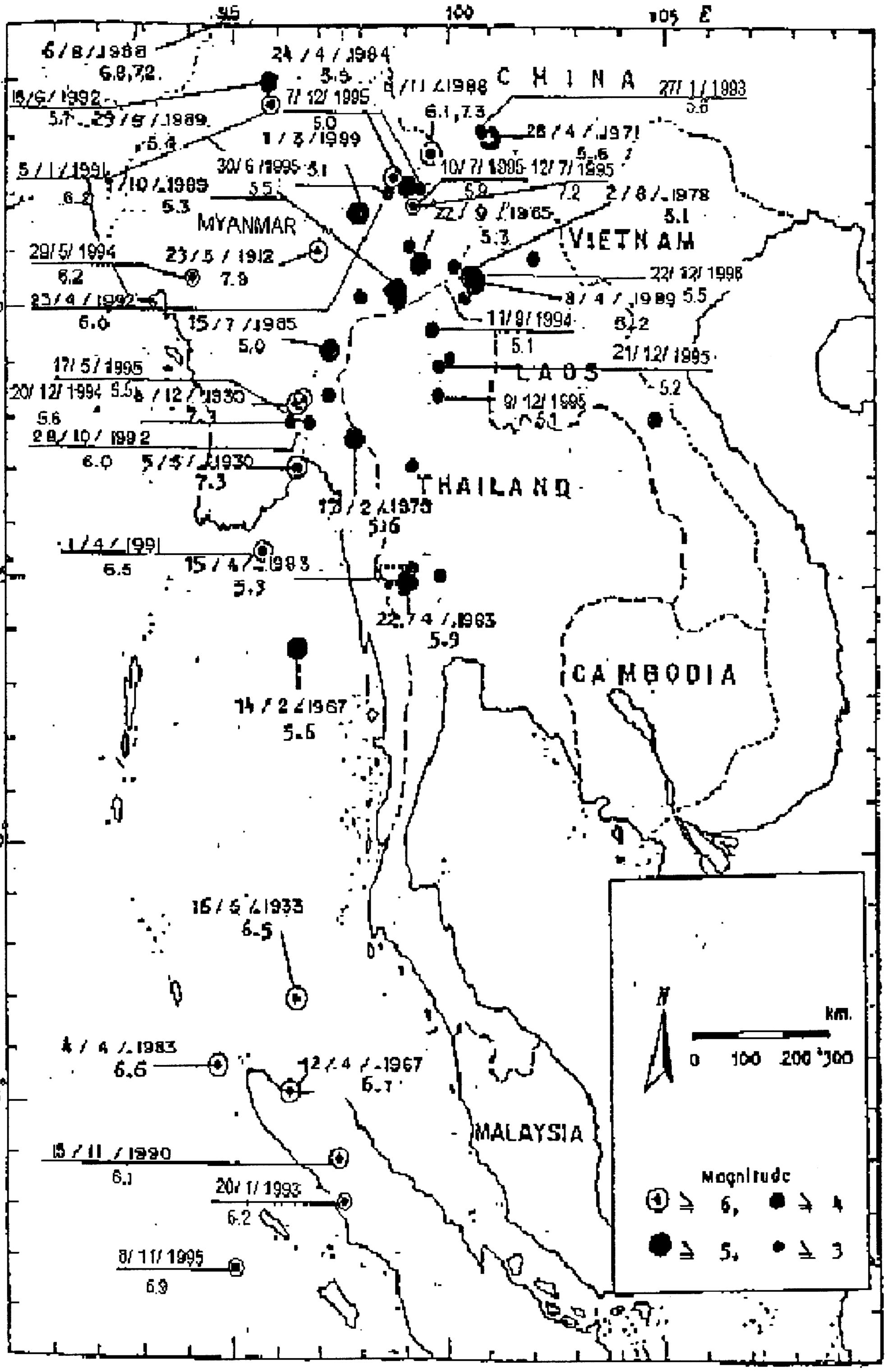

Fig. 1 Locations of epicenters with tremors felt in Thailand
(1912 - 1996, M > 5.0)

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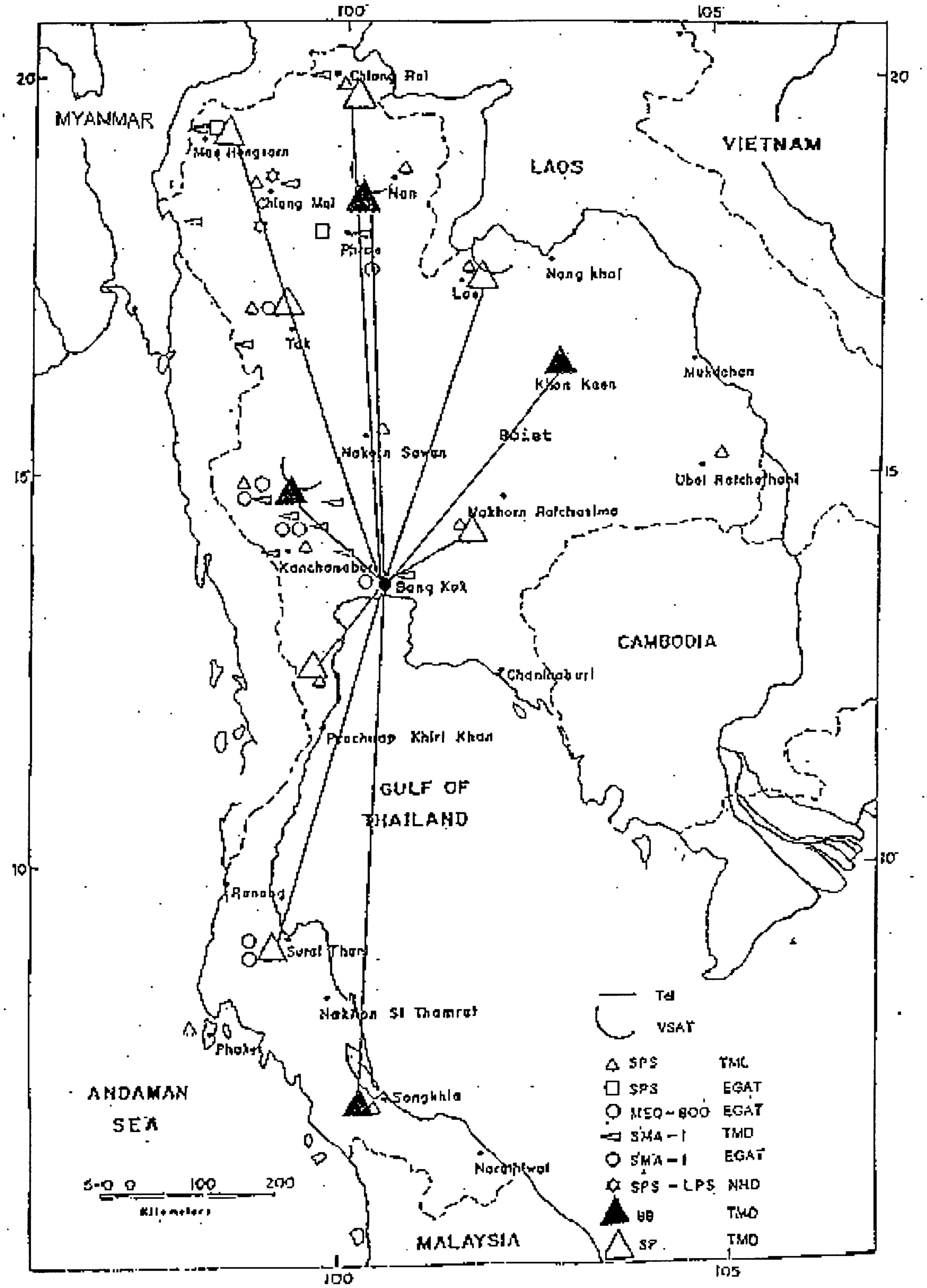

Fig. 2 Seismograph network in Thailand

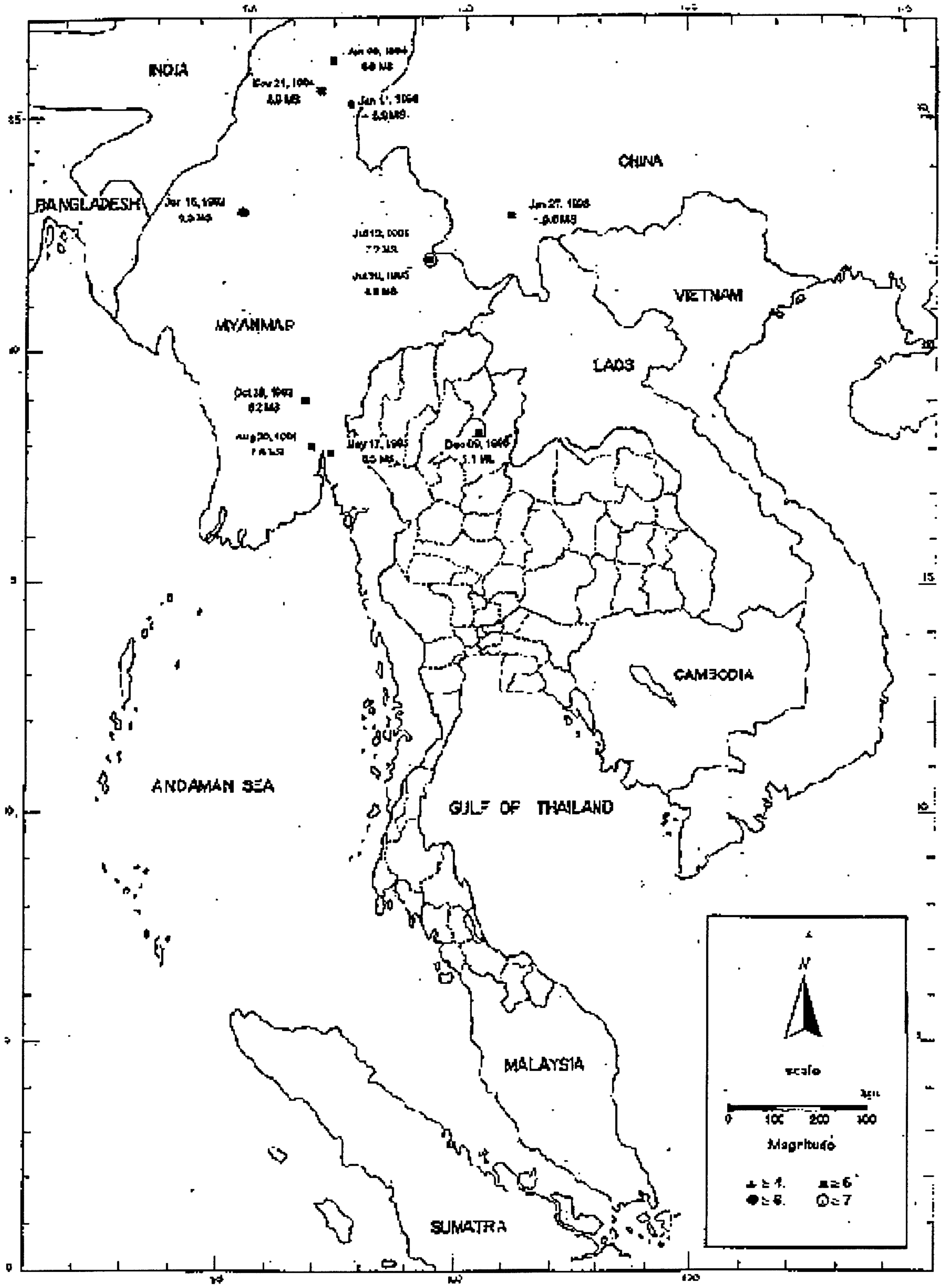

Fig. 3 Locations of epicenters with tremors recorded in Bangkok (1992 1995)

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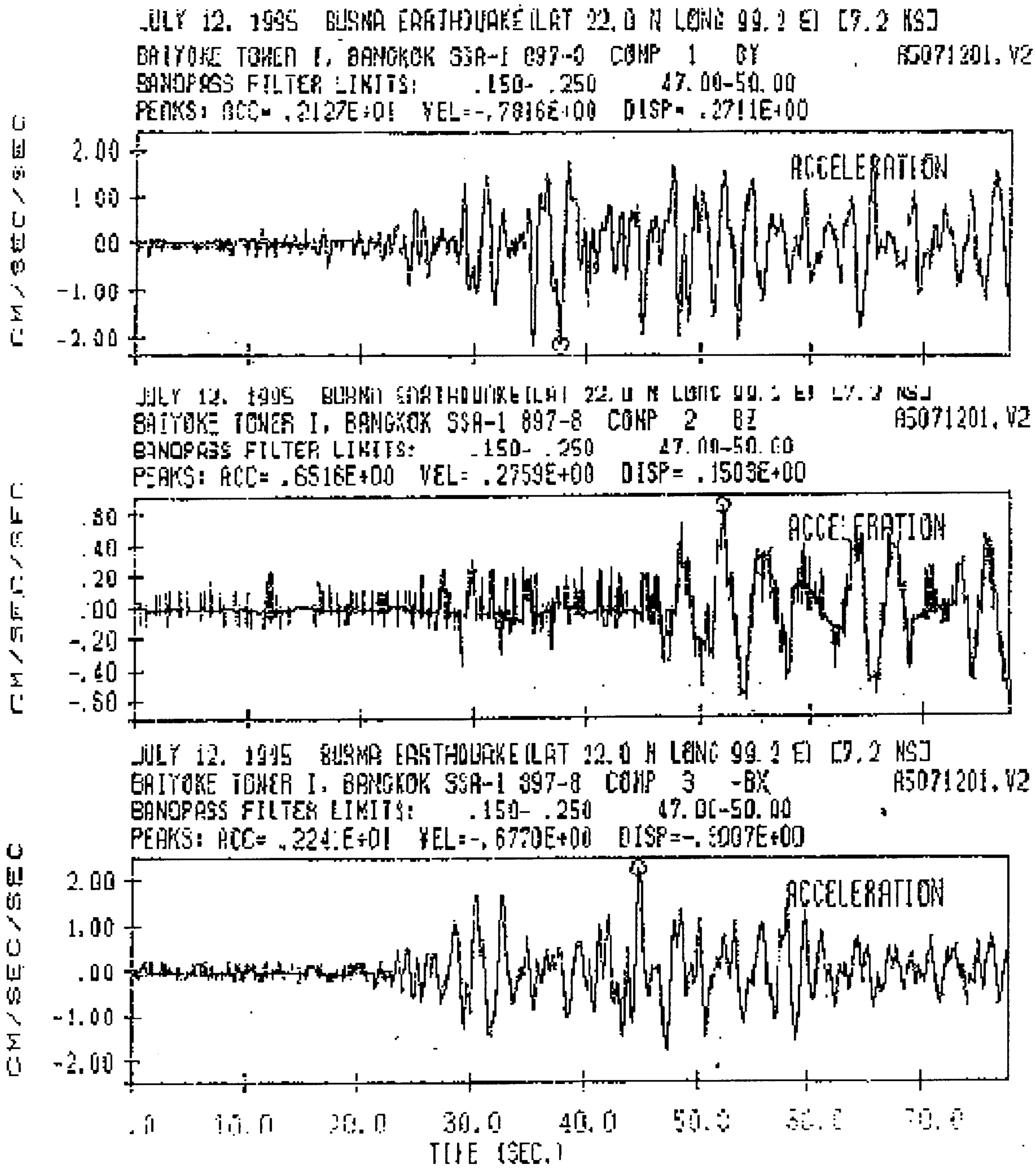

Fig. 4 Recorded accelerograms at Baiyoke I Tower, July 12, 1995
(B = Basement, T = Top of Building)

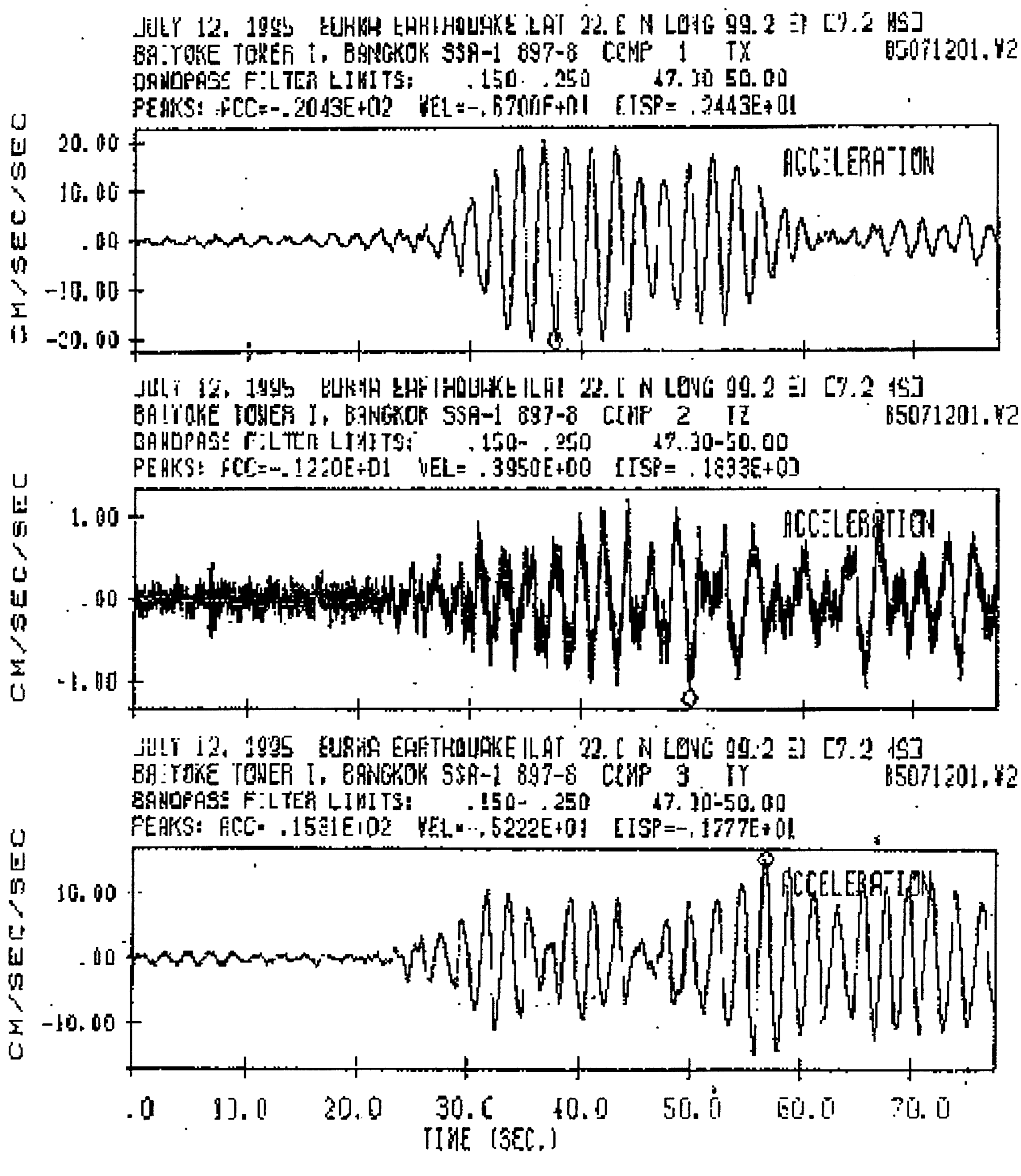
JULY 12, 1995 BURMA EARTHQUAKE LAT 22.0 N LONG 99.2 E M7.2
BAIYOKE TOWER I, BANGKOK SSA-1 897-8 COMP 1 TX
BANDPASS FILTER LIMITS: .150- .250 47.30-50.00
ACCELERATION
CM/SEC/SEC
JULY 12, 1995 BURMA EARTHQUAKE LAT 22.0 N LONG 99.2 E M7.2
BAIYOKE TOWER I, BANGKOK SSA-1 897-8 COMP 2 TZ
BANDPASS FILTER LIMITS: .150- .250 47.30-50.00
ACCELERATION
CM/SEC/SEC
JULY 12, 1995 BURMA EARTHQUAKE LAT 22.0 N LONG 99.2 E M7.2
BAIYOKE TOWER I, BANGKOK SSA-1 897-8 COMP 3 TY
BANDPASS FILTER LIMITS: .150- .250 47.30-50.00
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Table 1 Major Earthquake Events in Thailand

Date	Magnitude (Richter)	Epicenter	Brief Accounts of Event
1545 A.D.	-	Chiang Mai	Chiang Mai (The top of the Luang Pagoda toppled)
February 17, 1975 (1)	5.6	Myanmar-Thailand Border	Northern (V) and Central Region
April 22, 1983	5.9	Kanchanaburi	Kanchanaburi and Central Region (Reservoir-induced earthquake; minor damages reported)
October 1, 1989 (2)	5.3	Thailand-Myanmar Border	Upper Northern Region
September 11, 1994 (3)	5.1	Chiang Rai	Northern Region (VI-VII)
July 12, 1995 (4)	7.2	Myanmar	Upper Northern Region and Bangkok (in high-rise buildings)
December 9, 1995	5.1	Phrae	Northern Region (Minor non-structural damage)
December 22, 1996 (5)	5.5	Loas-Thailand Border	Northern Region (V-VI)

References : Prinya Nutalai et al. (1985); Sumalee Prachuab (1990); Panitan Lukkunaprasit (1995).

(1) Slight damages in non-structural elements, particularly in plastered brick walls.

(2) The epicenter was about 180 km from Chiang Mai. The earthquake caused mainly slight damages in non-structural plastered brick walls. The top part of the metal core of a tiered-decoration umbrella on the top of Doi Suthep Pagoda toppled due to combined action of corrosion and vibration from the quake.

(3) The earthquake caused minor damages to more than 50 schools and temples in Chiang Rai. Buildings with lower soft stories and torsional irregularity showed signs of distress whereas buildings without such irregularities were almost unscathed. An OPD 2-storey r.c. building in the Phan Hospital was moderately damaged. Shear cracks occurred in more than ten short columns. Moderate damages were also observed in a commercial low rise building with torsional irregularity.

(4) Minor cracks in the structural components of the Chiang Rai Airport terminal, aviation control tower, hospitals and several schools in Chiang Rai were observed.

(5) Minor cracks occurred in the non-structural components of approximately 13 buildings and temples in Chiang Rai. The top 6-meters of a pagoda in Chiang Saen district toppled due to the cumulative damages from previous earthquakes.

Table 2 Seismic events recorded in Bangkok from long distance earthquakes (1992-1995)

Event	Date Local Time	Magnitude * (Richter)	Epicenter		Distance**	Station	PGA (gal)	Direction
			Lat. (°N)	Long.(°E)				
1	Jun 15, 1992 09:49	6.3	22.996	94.869	1190	BYK	0.38	N-S
2	Oct 28, 1992 14:02	5.2	19.004	96.277	740	EE	1.20	N-S
3	Jan 27, 1993 03:32	5.6	23.027	101.062	1030	BYK	0.27	N-S
4	Jan 11, 1994 07:52	5.9	25.231	97.203	1330	BYK	0.32	E-W
5	Apr 06, 1994 14:03	5.6	26.174	96.940	1430	BYK	0.38	E-W
6	Aug 20, 1994 04:03	5.6	17.974	96.415	650	BYK	0.65	N-S
7	Nov 21, 1994 15:17	5.9	25.540	96.657	1370	BYK	0.41	E-W
8	May 17, 1995 04:48	5.5 MB	17.904	96.874	610	BYK	0.76	E-W
9	Jul 10, 1995 03:32	5.9	21.961	99.208	930	BYK PWD	0.57 0.57	E-W ESE-WNW
10	Jul 12, 1995 04:47	7.2	21.970	99.213	930	BYK PWD	2.24 1.26	N-S NNE-SSW
11	Dec 09, 1995 20:26	5.1 ML	18.2	99.8	500	EE	0.35	E-W

* The magnitudes are given in MS unless otherwise stated.
**The distances are referred to Chulalongkorn University (Lat. 13.74°N Long. 100.54°E)

<u>Legend</u> :
BYK = Baiyoke I Tower
EE = Electrical Engineering Building, Chulalongkorn University
PWD = Public Works Department Building, Sam Saen