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SEISMIC RISK TO SCHOOL BUILDINGS IN SOME ASIAN COUNTRIES

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1. Introduction

Human race is estimated to have lost 75 million lives during the past about 5000 years due to earthquakes. One of the worst enemies of mankind, an earthquake is unpreventable and, as yet unpredictable. The greatest seismic activity on the earth is noted to be concentrated along the Circum-Pacific belt, the Alpide-Himalayan belt and the mid-oceanic ridges in the Atlantic, Pacific and Indian Oceans. The occurrence of these belts is now attributed to the earth building process still going on which gives rise to the phenomenon of plate tectonics. One of the major seismic belts, that is, the Alpide-Himalayan belt lies along the junction of the Indian and Chinese plates and meets the Circum-Pacific belt in the south-east Asian region.

The loss of life has mostly occurred due to the collapse of the so called non-engineered buildings. Educational buildings like other buildings, are also often damaged or destroyed in earthquake shocks. They are even more vulnerable due to larger spacing between walls in both directions dictated by functional requirements, than usually provided in residential buildings. Failure of schools may result in cutting short the lives of the future intellegentia of a country and cause terrible upsetting to the parents of the pupils killed. Besides the educational function, the school buildings in rural and semiurban areas of underdeveloped as well as developing countries are used as multipurpose community buildings too since these may be the only public buildings in a village or a group of villages. This calls for greater safety and durability in the construction of school buildings in earthquake areas.

2. Object and Scope of Study

The present study forms part of UNESCO's continuing program of research and development of methods for protecting educational buildings against natural disasters. The object of the study was to collect and analyse the relevant information about school buildings and develop the measures that should be taken before, just after and some time after the occurrence of an earthquake for the benefit of the school buildings and their inmates. This naturally calls for the study of seismicity level and materials and techniques of construction in each unit of the region studied. In the present study, only the countries of west, south and south-east Asian regions were included namely, Afghanistan, Bangladesh, Burma, India, Indonesia, Iran, Iraq, Malaysia, Nepal, Pakistan, Philippines, Thailand and Turkey. The data presented herein includes that related to space planning of the schools giving idea of the wall spans and heights, materials and methods of construction, macro-seismic zoning based on Modified Mercalli Intensities and damages that occurred to such buildings during past earthquakes. Summary and analysis of the information brings out the seriousness of the situation.

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3. Collection of Information

The information presented herein was collected from published literature, through a questionnaire and personal survey missions to the concerned countries.

A questionnaire was designed to solicit information from the various countries under study about the planning of space in the primary, junior and higher secondary schools; structural elements used for roofs, walls and foundations; seismicity and zoning, and norms for earthquake resistant construction of buildings. The questionnaire was kept simple purposely so that response could be obtained surely and quickly. Most countries responded sufficiently quickly and the survey mission could be planned. Besides getting the needed information, the questionnaire also served another very useful purpose. It created appreciable consciousness about the problem of earthquake resistance of school buildings in the concerned authorities and made the subsequent survey missions very successful.

Visits were undertaken to study the prevailing practices of school building construction in the various countries, and to spot check the data received through the questionnaire. Contact was also made with the staff of the geological and meteorological departments to collect information about seismological studies and work carried out towards seismic zoning. The opportunity was also utilized to collect the published or unpublished reports and typical school drawings. These together with the information available through published literature and the above questionnaire served well to bring into focus the seismic problems in construction of school buildings at various places. A brief status report is presented about each country in the following paragraphs.

4. Afghanistan

4.1 Planning of Space

The sizes of class rooms, assembly halls etc. are fixed depending upon the number of children and the type of teaching aids and furniture to be used in the room. On an average the class rooms of primary schools have a size approximately 6.30m by 4.30m while higher secondary classes are accommodated in 8.60m by 5.10m area. Similarly assembly spaces for younger pupils are 9.0m by 8.0m and the senior ones have 10m by 20m. The usual heights of rooms are 2.80m and 3.20m for the two groups. Buildings for primary schools are invariably single storeyed structures while about 50 percent of the higher secondary schools have two storeys also.

4.2 Materials and Techniques of Construction

The usual materials of construction include brickwork, stone masonry and adobe. In almost all cases the foundation consists of unreinforced strip footings for walls and isolated footings for columns. Roofs are made of either timber poles with tiles or have masonry domes or are sloping covered with sheeting.

4.3 Seismicity

Afghanistan has been experiencing a large number of earthquake shocks most of which originate from Hindukush range. A compilation of historic data, seismicity and tectonics of the area lists the earthquakes above a magnitude of about 5.4. These had focal depths of the order of 70km or more. This report which covers the periods dating back to 50 B.C. and includes information upto the end of 1970, shows isoseismals of several past earthquakes based on damage surveys. The data was later utilized in preparing the seismic zoning map of the country in the same way as is done in some other countries like Canada, India, USA and USSR. According to this map the country is divided into four zones named as Major, Moderate, Minor and No risk zones. The zoning map is shown in Fig. 1. The destruction and heavy damage risk zone corresponds to MM intensity VIII or more, moderate damage risk zone pertains to intensity VII, slight damage risk zone to intensity VI and no damage risk zone to intensity V or less.

4.4 Damage in Past Earthquakes

It is gathered that adobe and brick buildings suffered considerable damage during Ishkamish earthquake (Richter Magnitude 6.6). Many houses of this type collapsed completely and many others were rendered inhabitable even though they escaped complete collapse. The failures were mainly due to separation of walls and cracking of masonry around openings. In stone masonry construction, absence of 'through' or bond stones was one of the main causes of collapse of walls.

4.5. Construction Norms for Schools

Even though there is no code of practice for aseismic design in Afghanistan, some specifications have been drawn up specially for schools. These are based on a report submitted by UNESCO Regional Office for Education in Asia in 1973. According to this, the following special provisions must be incorporated in the structures to be built in earthquake areas:—

(a) In random rubble stone masonry, 'through' elements (from one face of the wall to its opposite face having an area of about $0.5m^2$) must be provided at regular intervals of 80cm in horizontal and 60cm in vertical direction. These elements can be either stones (of length equal to thickness of wall) or steel bars (10mm dia) hooked at ends or reinforced concrete ties 5cm × 8cm with two 6mm dia bars bent in U-shape.

(b) At plinth level, a reinforced concrete runner (8cm thick) is to be used in all brick and stone walls.

(c) In Pukhta construction, vertical steel bars (12mm dia) one at each corner and junction of walls and a reinforced concrete band (10cm thick) at lintel level of doors and windows are to be provided on all walls.

(d) In Kham construction, timber poles (10cm dia minimum) at corners and junctions of walls vertically is to be provided. Horizontal timber runners on all walls (at lintel level) must be well nailed together at junctions as well as with vertical poles. In addition, timber elbows at junctions of walls every 60cm height above plinth to lintel band may be provided. Timber runners should be 5cm × 5cm or equivalent, one on each face of wall with interconnecting links.

(e) Roofing elements must be tied together to avoid relative displacements during shaking. Precast reinforced concrete joists may have a cast-in-situ runner on the wall at the 'ends wherein hooks from the joists may be embedded. In case of timber poles, these should be spiked into wall plates and timber planks must be nailed to these roof poles.

In zones of lesser intensities some of the above provisions may be omitted.

The designs drawn up for new schools in Afghanistan incorporate some of these specifications. During the course of visit to Kabul and on discussion with concerned officials, it was learnt that these are being increasingly used in rural and urban areas. Fig. 2 shows a typical plan for one such school.

4.6 Conclusions

It seems certain that the older school buildings are not adequately resistant and are susceptible to earthquake damage in future. However, the newer construction now being undertaken by the government seems to be good from the view point of earthquakes. However for private constructions, it would be better if municipal bye laws incorporate similar specifications as for government schools in the absence of a seismic code for the country.

5. Bangladesh

5.1 Planning of Space

The most common building module is 2.03 m giving front verandah of one module width and class rooms of 3 module size each way, that is, 6.1 m×6.1 m. There are variations of these sizes as well. The width of the verandah is being reduced for economy and may be replaced with a much smaller cantilever projection of the roof. The class room may have its width as small as 5.4 m and as big as 8.2 m. Another important development is the omission of internal cross walls so as to provide flexibility in the arrangement of classes or to reduce the number of teachers. Thus long unbroken spaces result wherein pupils of different classes are seated in groups in the most convenient way depending upon number of pupils in each class and the number of teachers. The class room sizes in higher secondary schools are about the same. But the area of laboratories and assembly halls is bigger requiring longer horizontal spans of walls. For example, specified laboratory size is about 8 m × 18 m and assembly hall size 12 m × 17 m.

5.2 Materials and Techniques of Construction

The most common building material for construction of walls and footings is burnt brick 25 cm long and 12.6 cm wide. Timber posts and Ekra walling is used for temporary construction in some areas. The foundation depth is usually kept 0.53 m to 0.75 m below ground level. In most areas water table is quite high. Unreinforced strip footings are used for brick walls, 0.63 m wide for one storey buildings, and individual column footings 0.56 m×0.56 m are used for verandah columns. The plinth height is kept 0.45 m above ground level. The footing consists of a cement concrete layer 7.5 cm thick in 1: 3: 6 mix at the base and brick work in 1:6 cement sand mortar.

There are three types of construction—permanent, semi-permanent and temporary—having planned life of 75, 25 and 10 years respectively. In one type of permanent construction, the end walls are 25 cm thick, long walls 12.5 cm thick with built-in columns 25 cm×25 cm or 25 cm× 50 cm for supporting roof beams; the verandah columns are usually 25 cm×25 cm or 25 cm×37.5 cm in size. The mortar used in brick work is 1:6 cement-sand. The walls are 2.94 m high from plinth to the underside of roof slab. The doors are 0.91 m×2.06 m and windows 0.91 m×1.22 m placed at 0.4 m above plinth. Thus the door and window lintels are some times at different levels and individuals lintels are used above the openings. As an alternative to column-wall combination, all walls are made 25 cm thick. The roof consists of reinforced concrete beam slab construction laid monolithically over the whole block of rooms and a separate slab over verandah. The mix used is 1:2:4. The room slab is 10 cm thick and beam projection below slab 17.5 cm×25 cm. The verandah slab is 7.5 cm thick which is monolithic with a continuous beam over all the columns of the verandah. A typical building plan is shown in Fig. 3.

The typical semipermanent construction consists of foundations and column-wall combination as for permanent construction. But the roof differs. King-post timber trusses resting on columns are used with corrugated iron sheeting. Local timbers, Sal, Mehagoni, Kari, Chambol, Sien, Loha and Pusheer are considered suitable. Horizontal bracing between trusses is recommended. Timber sizes are: purlins 5 cm× 10cm, rafters 10 cm× 15 cm, king-post 10 cm× 10cm, bracing members 5 cm×10 cm respectively. Bamboo mat ceiling is indicated at main tie level.

The typical temporary construction of primary school has Ekra walling and corrugated iron sheet roofing. In this construction, 25 cm wall is built upto window sill level. 10 cm×10 cm timber posts, embedded in brick work at base, supports timber trusses at top. In between the wall and roof truss, ekra walling consisting of double 'darma' mat covered by 1 cm plaster is constructed.

Besides the above three types, there are country—type schools having timber posts embedded in ground and supporting the roof trusses, the cladding wall being GI, roof or bamboo matting (Photo 1).

A cyclone resistant roof for primary schools, made from jute-reinforced polyester resin, is also being tried. The roof is bolted down to brick walls of desired height. A school completely built from this material above plinth level (without longitudinal walls) exists in Dacca (See Photo 2).

Reinforced concrete bands are provided in most permanent and semi-permanent buildings, one at plinth level and the other at lintel level. The bands are 25 cm wide, 15 cm deep in 1:2:4 concrete mix rainforced with 4 bars 10 mm dia tied through 6 mm dia links (Photo 3, 4).

5.3 Seismicity

Bangladesh has only one seismological observatory at Chittagong which is also not working for some time now. Therefore seismic data could be available only from world-wide network or from Shillong observatory in India. There is no accepted seismic zoning map as yet. A committee of scientists and engineers under the convenorship of Jt. Secretary, Ministry of Petroleum and Mines has worked on the problem of Earthquake Damage Minimization in

Bangladesh and submitted an interim report. The main conclusions arrived at are the following :

(i) Except a narrow belt on the northern border of the country facing the Shillong Plateau of India, Bangladesh is not highly earthquake prone area.

(ii) The existing facilities for seismic data collection analysis and interpretation are grossly inadequate and need urgent improvement.

A tentative earthquake intensity map is also suggested by the committee. As an extrapolation of the seismic zones adopted in India in the area surrounding Bangladesh on three sides, it appears that three to four seismic zones will be appropriate in Bangladesh based on MM Intensity IX, VIII, VII and smaller. Fig. 4 shows a preliminary zoning map prepared by the Meteorological Department.

5.4 Damage in Past Earthquakes and Cyclones

Not much data could be collected on earthquake aspect of the problem. Thousands of schools have, however, been damaged in the coastal areas due to the cyclones which are repeated frequently. The weather in the cyclones is rather uncertain. Wind velocities of 220 to 280 km/hour are not rare. Rainfall higher than 500 mm in 24 hours are common in the cyclones; in one cyclone, the rainfall in a single day was 1150 mm. The tide in the sea begins to rise when the cyclone gets to a point 500 to 800 km from the coast and continues to rise untill it reaches the land. The tidal height ranges from 3 to 4.5 m drowning vast areas of land and causing saltification of the soil. In some of the cyclones in the past, huge loss of human lives, as many as 215,000 in one of them in 1876, has taken place. Buildings have been destroyed by blowing off roofs and overturning of walls. Many times the twisting action of the cyclonic storm takes the most dangerous shape. Therefore in some areas, the school building must be designed to withstand earthquakes, wind-storms as well as inundation. A design wind pressure of about 200 kg/m² may perhaps be considered appropriate for the coastal areas.

5.5 Construction Norms for Schools

Several standard designs of school buildings, particularly primary schools, have been prepared by the Design Centre, Education Directorate, Dacca from time to time which have been classified, as described above, under permanent, semi-permanent and temporary constructions. Permanent school buildings cum shelters have also been proposed in cyclone affected areas. No specific norms have yet been laid down for earthquake resistant construction of buildings for schools or other purposes.

5.6 Conclusions

The school buildings as described above are not fully earthquake resistant but there are certain good features. The use of 1 : 6 cement-sand mortar for brickwork in foundations and walls and provision of plinth and lintel level bands are good features for earthquake resistance but may be adequate in mild seismic zones only. Absence of cross walls and converting the building into a long barrack type enclosure will very largely reduce its resistance to earthquake ground motions as well as cyclone wind pressures due to large unsupported length of walls.

6. Burma

6.1 Planning of Space

The class room sizes in Burma are comparatively larger than other countries. The size is about 8.25 m ×6.7 m for primary schools, 9.15 m ×6.7m for junior secondary and 12 2 m ×6.7m for higher secondary schools. The respective assembly hall sizes are 18.3m ×12.2m, 30m ×12.3m, and 30m ×15 m. A 110 year old Missionary School now accommodating 2000 girl students in Rangoon has an assembly hall cum gymnasium measuring 50 m ×18 m. The usual room heights are 3.6m for all types. Primary schools are generally single storeyed whereas the junior secondary schools have single and two storeys by about 50 percent each. The higher secondary schools are mostly two-storeyed (about 80 percent) some single storeyed (18 percent) and a few three storeyed. Most schools have simple rectangular plan with a row of rooms having a verandah in front. Others have a series of blocks suitably connected through passage ways.

6.2 Materials and Technique of Construction

The most common materials of construction in the plains are brick and timber. In the hilly areas stone is mostly used. Sloping roofs with corrugated galvanised iron or asbestos sheeting on timber trusses are common for schools. In modern urban school reinforced concrete slab floors are being used in place of timber floors which were quite commonly used earlier. Whereas load bearing brick wall construction is popular for other buildings, framed construction with suitable infills is predominant for school buildings. The framing posts may be timber square sections, or reinforced concrete pillars, or brick columns. The typical spacing of the posts in both directions is about 3 m. The infilling panels may be made from bamboo mat or half brick thick in cement-sand mortar. In the latter case it is usual to provide light expanded metal every fourth course which is nailed to timber posts at the ends.

The unreinforced strip foundation in 1:3:6 cement concrete about 23cm thick with stepped brick work over it is the most common. Under brick columns or posts, individual stepped brick footings are used. Reinforced concrete footings are used with RC columns. Foundation depth is kept 90cm to 1.1 metre below ground level.

Typical plan is shown in Fig. 5. An existing building with timber framing and brick nogging is shown in Photo 5.

6.3 Seismicity

Burma has a long recorded history of moderate and major earthquakes, There are more than 20 earthquakes in which the Magnitude on Richter scale exceeded 6.5 and the maximum MM intensity exceeded VIII or IX. The Meteorological Department has prepared a catalogue of earthquakes upto 1970 listing 111 earthquakes having magnitude 4.5 and more. The list can not be said to be complete for the lower of these magnitudes. The problems of seismotectonics and seismicity zoning of the territory of Burma have been studied by G.P. Gorshkov, who has prepared a seismic zoning map based on intensity scale of the Institute of Physics of the Earth, Moscow which are approximately the same as Modified Mercalli scale. This map is shown in Fig. 6, wherein it is seen that no part of the country is free from the risk of damage and quite a large area has susceptibility of destruction risk and revere damage risk. This zoning map is however not final yet and has to be approved by the national authorities.

6.4 Damage in Past Earthquakes

Damaging effects of earthquakes in Burma have been summarised in tabular form by the Meteorological Department of Burma. Table 1 shows the relevant effects on building and ground. The appearance of mud volcanoes clearly indicates the phenomenon of liquefaction of soil that is, complete loss of shear strength. Buildings resting on such ground will sink during a severe earthquake and suffer much damage due to tilting and unequal settlements. In hilly areas rock falls are very dangerous to buildings and life.

Table 1 Some of the Severe Earthquakes in Burma

Sl. No	Date	Epicentre Lat N Long E	M* & I**	Effects of Earthquake
1	Apr. 2, 1762	North of Arakan	— X	Elevation and submergence of land. Houses destroyed, Beach raised. Mud volcanoes erupted.
2	Mar. 3, 1839	21.7 96.0 (Amarapura)	— IX	Every pagoda and brick building destroyed in Amarapura and Sagaing. Spring, deep and extensive fissures formed. About 300 person killed. At Kyaukpyu, mud volcano erupted.
3	Aug. 24, 1858	19.0 94.8 (Near Thayetmyo)	— IX	Most of the pagodas were greatly damaged, tops knocked down. Dislodged bricks out of walls of buildings and plaster fell. Masonry building suffered damage. Entire disappearance of False Island, (South-east of Cheduba Island).
4	Mar. 25, 1912	21.0 97.0 (North of Taunggyi)	8.0 IX	At Mandalay, much damage done to buildings. At Mogok nearly every brick building was cracked, and about 60 pagodas collapsed. Cracks occurred in cliffs. At Maymyo, bricks and plaster fell from many buildings.
5	Mar. 6, 1913	17.4 96.5 (Pegu)	— VIII	Damage to hti (umbrella) of Shwemawdaw Pagoda for the thirtieth time.

Sl. No.	Date	Epicentre Lat N	Long E	M* & I**	Effects of Earthquake
6	Jul. 5, 1917	17.4 (Pegu)	96.5	— VIII	Damage to hti of Shwemawdaw Pagoda for the thirty first time.
7	Jan. 19, 1929	25.9 (Htawgaw)	98.5	— VIII	All stone masonry badly damaged, no longer fit for living.
8	Dec. 16, 1929	25.9 (Htawgaw)	98.5	— IX	Cracks, landslips and rockfalls in several places.
9	May 5, 1930	17.0 (Pegu)	96.5	7.3 IX	Practical destruction of Pegu with loss of about 500 lives; also about 50 deaths and great damage to property in Rangoon Large cracks forming spring. Big pieces of river bank slide into stream.
10	Dec. 3, 1930	18.0 (Pyu)	96.5	7.3 IX	Most of masonry buildings in Pyu were wrecked, some 30 persons killed. Embankments displaced. Cracks in ground and sand vents. Wrecking of a timber houses and destruction of flimsy huts.
11	Jan. 27, 1931	25.6 (Kamaing)	96.8	7.6 IX	All masonry buildings in Kamaing, just outside the epicentral tract severely damaged. Two small pagoda destroyed. Small bamboo house collapse. People thrown out of beds. A bridge 82m long and 3m wide, had a general tilt down-stream, and sagged in middle by 1.2m. Another bridge wing walls and abutments badly cracked. In epicentral area, even bamboo and wooden houses were completely wrecked, big fissures developed, spouting of sand and water. Big cracks in hill slopes, block fissures landslips and rockfalls.
12	Sep. 12, 1946	23.5	96.0	7.5 IX	Many Pagodas were destroyed.
13	Aug. 15, 1950	28.5	96.5	8.6 XII	Great Assam Earthquake, Very destructive. In Burma. Chindwin river at Mawlaik and Kalewa, and Irrawaddy river at Aunglan flowed upstream.
14	Jul. 16, 1956	22.0 (Sagaing)	96.0	7.0 IX	Pagodas and buildings at Sagaing destroyed. More than 40 people killed. Ava bridge shifted.

*Magnitude on Richter Scale.
**Approximate Maximum Intensity on MM Scale.

6.6 Construction Norms for Schools

There are no earthquake resistance norms adopted in Burma as yet for schools or other buildings.

6.7 Conclusions

It is seen that Burma is a highly seismic locality and there is a need of increasing the number of seismological observatories with instruments of adequate magnification. Areas of high liquefaction potential are to be demarcated so that either these are avoided as building sites or suitably compacted before taking up the construction. Unreinforced brick or stone masonry construction will be unsuitable in most parts of Burma but the post-panel construction using timber or reinforced concrete posts has good earthquake resistance features and could be improved further to become suitable even in Intensity IX area.

7. India

7.1 Planning of Space

The sizes of classrooms vary considerably from place to place but the commonly used dimensions are of the order of 7m by 6.2m or 6.5m by 5m. The height of rooms varies from 3.2m to 3.6m. Almost 80 percent of primary schools are single storeyed buildings and the remaining have two, three or four storeys. In most cases the entire school is housed in just two rooms particularly in the rural areas, where classes are arranged in the open areas also. The secondary school in urban areas are mostly two or three storeyed.

7.2 Materials and Techniques of Construction

India has a wide range of building practices which have developed as a result of experience gained by local inhabitants through several generations. These take into account the climatic requirements, availability of building materials and economic potential of people. As such there is considerable variation in the form and material of construction from east to west and from north to south. In the northern (Jammu and Kashmir) and eastern (Assam) parts, light timber construction is very popular although brick and reinforced concrete construction is also prevalent. Similarly in Himachal Pradesh one would find stone masonry in mortar and dry rubble masonry with intermediate timber runners (horizontal) at regular intervals in vertical direction.

The most common form of construction is unreinforced brick work in mud, lime or cement mortar. The walls are usually one brick thick (23 cm) and the roof and floors have reinforced concrete or reinforced brick slabs. A typical primary school building recently planned and constructed in several thousand numbers is shown in Fig. 7. In this building precast reinforced channel units are used for roofing. A prefabricated steel truss of very light design supports the channel units at intermediate line. In some cases the roofs are sloping with trusses covered by GI or AC sheeting or titles. Such structures have unreinforced strip footing for their foundation or isolated column footings. Where bricks are not available stone masonry or hollow concrete block masonry is employed Photo (6.7). In Assam type construction (Ekra) buildings upto two storeys are made employing timber framing which divides the

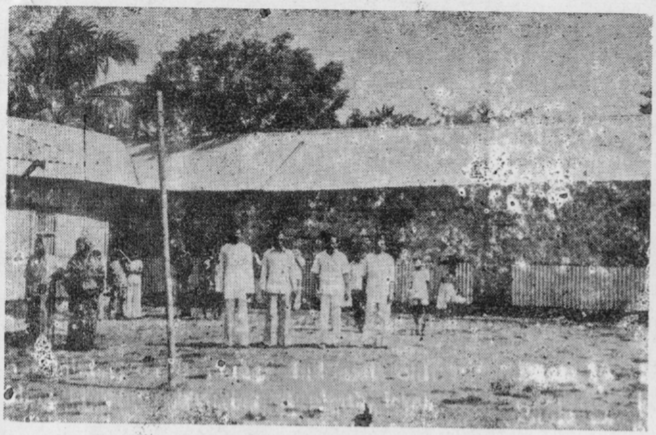
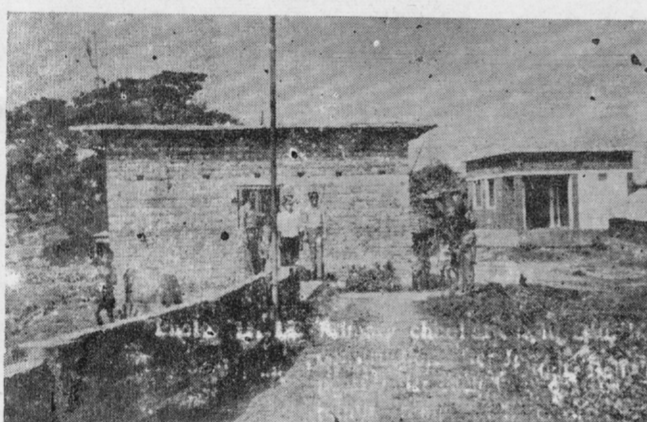


Photo 1 Government Primary School, Khilgaon, Dacca, Bangladesh. Building at left with timber post-truss construction, aluminium sheet roofing and GI cladding. Building at right with wooden rounds posts, GI sheet roofing and bamboo mat cladding.

Photo 2 Government Primary School, East Khilgaon, Dacca, Bangladesh. Long sides and roof of jute plastic, ends brick wall upto cave levc (too hot, but no corrosion problem in coastal areas).



Photos 3, 4 Matual pashchim Para Primary School Dacca, Bangladesh. One brick wall in 1:6 cement-sand mortar, RC T-beam roof, RC lintel band all round. No partitions, several classes in same room.

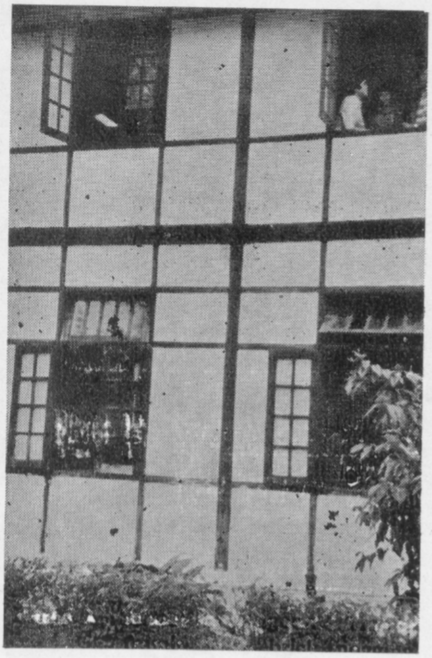


Photo 5. School in Rangoon. Timber framig with brick nogging on diagonals, good quality construction

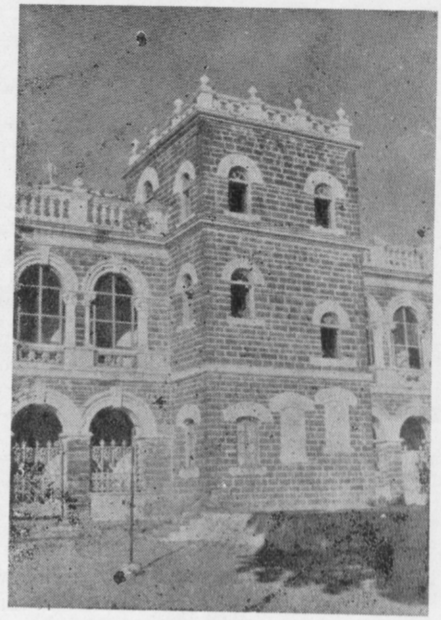


Photo 6. Alfred High School at Bhuj, India. A dressed stone masonry construction. It is a hundred year old buiding and has withstood several earthquakes due to excellent construction.

Photo 7. Primary School at Anjar, Random rubble masonry construction, has no strengthening provisions for seismic forces, no damage to the builiding in 1956 Anjar Earthqake to good construcion.

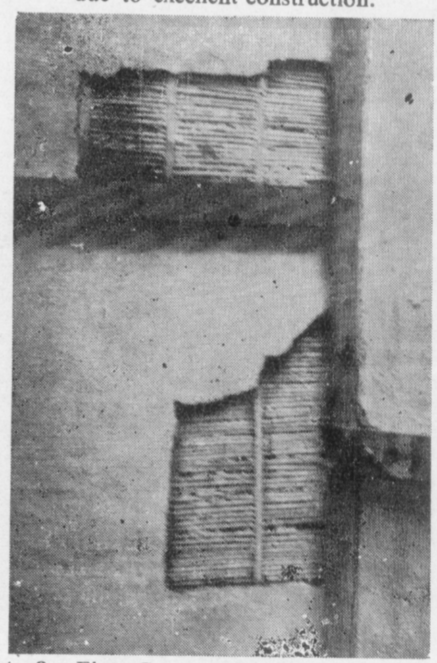


Photo 8. Ekra Construction of Assam, India wooden frames filled with Ekra, plastered with mortar, An earthqake resistant construction.

walls into rectangular panels of size 1m×1.5m (max). The panels are then clad with Ekra and later mud plastered. Care is taken to provide one continuous horizontal member at sill, one at lintel and one at roof level. The sections of timber usually employed range from 10cm×6cm to 15cm×8cm. The main vertical members of timber go into the ground upto about 1m and no plate of concrete pad is provided. Timber is however tar painted or treated to avoid eating by white ants. In some cases mixed form of construction employing RC posts (12cm×12cm) are also used as main members (See Photo 8).

7.3 Seismicity

India has a big percentage of her area lying in moderate to severe seismic zones. Seismic activity in parts of this country can be considered to be comparable to any other active zone in Japan or California. A number of large size rather giant earthquakes have occurred in the past and the biggest earthquake shock on earth (Magnitude 8.7) also had its origin in this country.

In India, Kashmir and Western Himalayas, Nepal Himalayas, Assam, Gangetic basin, Rann of Kutch and peninsular part can be identified as the regions to describe the seismicity. Kashmir lies in active zone and has been subjected to moderate to heavy earthquake damage in the past. Most disastrous shock of May 30, 1885 (Magnitude 7.0), Badgam shock of Sept. 2, 1963 (Magnitude 5.3) and Anantnag shock of Feb. 20, 1967 (Magnitude 5.7) are some of the notable earthquakes in this region. In the western Himalayas, the great Kangra valley earthquake of April 4, 1905 (Magnitude 8) and Kinnaur earthquake of Jan. 19, 1975 (Magnitude 6) occurred close to the main boundary fault. Bihar-Nepal earthquake of Jan. 15, 1934 had magnitude 8.3. The north-eastern part of the country is most active region marked by a number of faults and thrusts aligned in EW and NS directions. It is in this region that the giant earthquake of magnitude 8.7 occurred on June 12, 1897 and another equally big shock struck the area on Aug. 15, 1950. In the Gangetic plains, several earthquakes (upto magnitude 6) have occurred at Bulandshahr, Moradabad and Delhi. Likewise, Rann of Kutch had magnitude 7.0 shock at Anjar on July 21, 1956. In peninsular India, Broach earthquake of March 23, 1970 (Magnitude 5.4) and Koyna earthquake of Dec. 11, 1967 (Magnitude 6.5) are the two major shocks which have led to considerable amount of thinking regarding the seismic status of various regions in this country. The seismic zoning map of India is shown in Fig. 8.

7.4 Damage During Past Earthquakes

Earthquakes have caused extensive damage to buildings and other structures during 1905 Kangra, 1934 Bihar Nepal earthquake, 1950 Assam shock and 1956 Anjar earthquakes. Kapkote earthquake of 1958 in northern part caused severe damage to a large number stone masonry buildings built in mud mortar. Timber buildings in this area were not affected at all. In Kashmir earthquakes of 1963, 1966 and 1967, old buildings having rotten timber frames and loose masonry infills were badly damaged whereas the ones with sound timber frames were highly earthquake resistant. Damage consisted of vertical cracks at corners, separation of walls, cracking of jack arches over openings and falling of ceiling plaster. In 1967, Koyna earthquake caused extensive damage to modern construction in random rubble masonry. In villages the construction was of timber framework which performed much better than other structures, and damage was mostly confined to cladding walls. In a school building, the roof was supported by wood purlins on wood trusses carried on side walls and bond beams were not used. This resulted in total collopse of the structure. In the 1970 earthquake in Broach a number of buildings with sloping roofs were responsible for damage to adjacent buildings because their gable ends got severaly damaged and collapsed on them. Most of the old construction with stone or brick arches over openings in portices, verandahs, doors and windows showed cracking. In a two storeyed load bearing brick building housing a science college, diagonal cracks were observed around openings. Kianaur earthquake of 1975 razed many a rubble masonry structures to ground since most of these were either in mud mortar or dry packed. Dressed stone masonry in cement mortar with light sloping roofs suffered little damage. Light weight structures made of corrugated iron sheets nailed on timber framework did not suffer any damage during this shock.

7.5 Norms for Construction of Schools

India has two codes for earthquake resistant design and construction of buildings. One deals with seismic zoning, determination of seismic forces on the structures and their distribution along height. The country has been divided into five seismic zones, as shown in Fig. 8, which vary from destruction risk to no-damage risk zone. The other describes the details of construction necessary to make the structure better earthquake resistant. It may be pointed out that while there is good deal of awareness amongst builders to design earthquake resistant buildings, many private buildings still do not conform to these codes. The norms as laid down are quite comprehensive. Some of the highlights of the codes are as follows:

(a) The main structural elements and their connections are to be ductile so that seismic energy is absorbed and sudden collapse of structure is avoided. The code gives details for reinforced concrete and steel structures to achieve this objective.

(b) For masonry construction well burnt bricks having crushing strength of 35 kg/cm^2 (minimum), squared stone masonry or random rubble masonry brought to courses at every 60 cm intervals or hollow concrete block masonry of adequate strength are to be used.

(c) Masonry mortar should not be leaner than 1:6 cement—sand or 1:3 lime—sand or equivalent.

(d) Masonry bearing walls should not be built higher than 15 m or four storeys upto roof level/tie level in case of trussed roofs. Bearing walls must be strengthened depending on the design seismic coefficient for the building. For the most active zone the following strengthening measures are necessary.

(i) A continuous reinforced concrete band 7.5 cm thick and having width equal to thickness of walls is to be provided alround at lintel level on all bearing walls. The band should have two bars, 16 mm dia, one on each face connected together by 6 mm dia links at 15 cm intervals.

(ii) A band similar to (i) must also be provided below the roof or floors except plinth level. However such a band need not be provided underneath reinforced concrete or brick work slabs resting on bearing walls provided the slabs are continuous and cover that part of building completely.

(iii) In case of sloping roofs a gable band must be provided at the top of gable masonry below the purlins and must be made continuous with the roof band at tie level.

(iv) At tie level, all the trusses and the gable end must be provided with diagonal braces in plan so as to be able to transmit the seismic shear to the gable ends.

(v) Jack arched roofs or floors where used should be provided with steel ties in the end spans. Where number of span is large, such ties should be provided in every fourth span.

(vi) Vertical steel at corners and junctions of walls should be provided. The recommended diameter of such reinforcement bars varies from 12 mm for a single storey building to 25 mm for bottom storey of 4 storeyed buildings. In second, third and fourth storeys the size of reinforcement bar may be reduced to 20, 16 and 12 mm respectively. The bars should be properly embedded in plinth masonry of foundation and roof slab or roof band at top. For less intensity zones the quantity of steel may be reduced appropriately.

(vii) Openings in bearing walls must also be reinforced by providing reinforced concrete members or by providing jamb steel embedded in lintel and sill masonry.

(viii) Openings should be planned such that their total width in a wall does not exceed half the length of wall between adjacent cross walls. Minimum clear distance equal to 1/4 height of opening must be there between the corner of wall and the opening. Minimum horizontal distance between two openings should be half the height of shorter opening and the vertical distance 60 cm.

(e) Timber buildings must be restricted to two storeys. The structure below the plinth should be in masonry while timber superstructure may either simply rest on it or may be rigidly connected to plinth masonry. The timber frame members should have a minimum of 40 cm × 90 cm section and should be spaced not more than 1 m apart. Timber buildings can have either stud walls or brick nogged construction.

7.6 Conclusions

The present norms for aseismic construction of buildings, the type of which are likely to be used for schools, appear to be adequate for wall spans upto about 7 m. These incorporate the strengthening arrangements without altering the basic forms of construction prevalent in the various regions. However it is implement to see that various construction agencies should follow and implement the recommendations of the relevant codes in this regard. It is this part which may require attention of appropriate authorities responsible for planning, design and construction of buildings for educational facilities. Most existing school bnildings however do not have these anti-earthquake provisions and there is a need to check them for safety and install strengthening measures as found necessary.

8. Indonesia

8.1 Planning of Space

Standard or prototype designs of school buildings are prepared for basic education at all levels, from kindergarten till upper secondary schools for the whole of the country. The elementary education upto first six grades is compulsory. Presently two types of standard designs have been made so as to suit the economics situation, (i) minimum type, (ii) complete type. The materials of construction of these standard designs are not strictly defined to permit flexibility of adapting the local traditional materials, techniques and skills. The class room size adopted is the following: Kindergarten 6 m × 8 m, elementary school 6 m × 7 m and 7 m × 8 m and secondary schools 8 m × 8 m with two special rooms 126 m² in area each. One general purpose or assembly room is provided in secondary schools having an area of 180 m² to 280 m². Most school buildings are single storeyed (more than 93 percent), few two storeyed (about 5 percent) and just about 1 percent are three storeyed. The storey height is generally 3 m for primary schools and 3.0 to 3.5 m for others. The class room blocks usually consist of single row of rooms with a narrow coverd verandah in front, the blocks being connected through a covered passage of light open construction. Typical plans are shown in Figs. 9 and 10.

8.2 Materials and Techniques of Construction

The common building materials in Indonesia are wood, bamboo, burnt clay bricks, lime-trass blocks, cement and lime. Wood is very commonly used for structural as well as non-structural purposes. Similarly, bamboo finds its uses in structural framing and roof framing as well as flooring and cladding in various forms of matting. In Bali island bamboo used to be traditional material for building construction (See Photo 9-12).

Most school buildings have sloping roofs made of timber roof trusses, rafters and purlins and carrying galvanized iron sheet roofing or burnt clay titles. Where load bearing walls are used, there is a wooden wall plate on which the trusses rest and are anchored to it through nails. The walls are commonly constructed of burnt clay bricks having sizes 5 cm × 10 cm × 20 cm and 6 cm × 12 cm × 22 cm) or lime-trass blocks in 1 : 6 propertions (size 8 cm × 14 cm × 25 cm). Some old building walls are in random rubble 40 cm thick. In Bali island walls were constructed of dressed soft stone joined with coconut water. The mortar in rural areas is mud or lime-sand or lime-trass in 1 : 5 ratio. New constructions use cement-sand mortar and walls are 24 cm thick when without any frame. Alternatively reinforced concrete columns are used under the trusses and brick walls are used as tight infills. In such cases, a reinforced concrete ring beam is used at plinth level. But no such bond beam is used at lintel or eave levels. As a replacement of collapsed schools in Bali island, school buildings using timber posts and trusses with plywood side covering and GI roofing have also been adopted as light construction. Bamboo matting is also used as wall clading in rural areas.

For the single storeyed school buildings, shallow reinforced strip footings are used for bearing and non-bearing walls and isolated footing for columns.

8.3 Seismicity

Indonesia is one of the highly seismic countries in which the greater part of the land is susceptible to damage by earthquakes. The spatial distribution of shallow focus shocks in the area shows that nearly all the activity is confined to long zones which are rarely wider than 200 km. Intermediate and deep shocks are also clearly distributed in long narrow zones parallel to the adjacent zones of shallow focus activity. The active seismic zones which are generally associated with other forms of tectonic activity seem to divide the Indonesian-Philippine regions into four plates (that is, large relatively inactive regions), namely the Indian-Australian plate in the south, the Pacific ocean plate in the east, the Asian plate and the Philippine sea plate. The boundaries of these plates are generally associated with seismic activity where most major earthquakes have been caused. In these areas seismic intensities of MM VIII and more have been observed in the past. The division of Indonesia in seismic zones is shown in Fig. 11.

Instrumental observation of earthquakes in Indonesia had starded in 1908 with one horizontal motion instrument in Jakarta. More stations and instruments were added later and upto 1967 there were five seismological stations at Medan, Jakarta, Tangerang, Lemband and Bandung. At present there are 11 stations, the average interstation spacing still being about 1000 km. Most of the stations operate at low magnification due to noise level being high. Under the UNESCO Project Regional Seismological Network in South-east Asia which started in 1974, six existing stations and five new station will receive high magnification instruments. operating at magnifications from 7000 to 450000. Besides, eight strong motion instruments will also be installed.

8.4 Damage to Buildings in Past Earthquakes

Damage to buildings has occurred in many earthquakes in various islands of Indonesia in the past. The recent striking example of destruction and damage occurred in Bali island in July 14, 1976 earthquake. Besides thousands of residential buildings, a large number of schools and associated buildings were damage during this earthquake. Teaching was dislocated for a period of two months. Table 2 shows the statistics of damage to schools and

Table 2 Number of Damaged Buildings

Building	Number of Buildings Having		Total
	Serious damage	Minor damage	
Primary School	390	83	473
Junior High School	34	3	37
Senior High School	8	—	8
Offices	15	6	21
Teachers' houses	134	8	142

teachers' houses. During this earthquake, 96 students and 3 teachers lost their lives. The main reasons of damage were weak masonry walls, inadequate connections in wooden members, lack of ring beams and lack of vertical reinforcement in the form of columns, etc. Overturning of walls was a common feature.

8.5 Construction Norms

The Indonesian Loading Code N.I. 18, 1970 provides specification for earthquake loads. The earthquake force is specified in the form of horizontal and vertical [illegible] coefficients based on seismic zones, height of structure, soil [illegible] and importance of the building. Small and simple buildings with a total maximum height of [illegible] from foundation and with enough walls that provide sufficient stiffness to the main structure may be exempted from these regulations. Since the school buildings are of lower height, generally, they become exempt and remain non-engineered from the earthquake viewpoint. There are no specifications for strengthening laid down for such buildings.

8.6 Conclusions

In view of extensive seismic areas in Indonesia, a large amount of effort is required in order to achieve safety from destructive effects of earthquakes such as the following :

(a) Extensive of seismological network so as to record all earthquakes of magnitude 4 or more, as well as to install strong motion accelerographs.

(b) Preparation of earthquake resistance regulations for small buildings of traditional types including school buildings.

9. Iran

9.1 Planning of Space

The room sizes in primary schools are usually of the order of 7m×6m, increasing to 7m×6.8m for junior secondary schools and 8.80m×6.80m for higher secondary schools. Similarly, the assembly spaces also vary from 36 to 180m² for primary classes, from 162 to 216m² and 189 to 252m² for the junior secondary and higher secondary students. The room heights are kept as 2.8 to 3.2m for classes, 3.0 to 3.4m for laboratories and 3.4 to 4.2m for assembly area. The classrooms generally have arrangements for heating in view of extreme cold climate during winter. About 80 percent of the primary schools are single storeyed buildings and the remaining two storeyed. In case of junior secondary schools, only 30 percent have single storey, 50 percent two storeys and the remaining 20 percent go upto three storeys. Higher secondary schools however are mostly two and three storeyed structures.

9.2 Materials and Techniques of Construction

Brick and random rubble stone masonry construction are the most popular for school buildings although timber frames with clay infills are also used in some cases. The usual unreinforced strip footing foundation and isolated column footings are used under such construction. A variety of forms is available for roofs/floors e.g. timber joists with tiles, jack arches or flat arches on steel joists and flat reinforced concrete or brickwork slabs etc. A new school plan is shown in Fig. 12. Similarly different types of lintels are employed e.g. timber poles or planks, flat or segmental arches and reinforced concrete or brick work. In some cases the buildings have sloping roofs necessitated by the extreme climate.

9.3 Seismicity

Iran is seismically very active and has had a large number of shocks during the past. The earthquake activity is more in the south and north compared to the rest of the area. The magnitude of earthquakes have been upto 7.0 on Richter scale and the maximum intensity has exceeded IX (on the MM scale) on several occasions. Most earthquakes have had focal depths less than 70km or so and as such are classified as shallow focus shocks. Almost no area in Iran can be considered as free of earthquake activity and it is perhaps for this reason that no attempt has so far been made to draw up a seismic zoning map of the country. The anti-seismic provisions are therefore uniformly applicable in the entire country at present.

9.4 Damage in Past Earthquakes

Iran has had a number of strong earthquake shocks covering almost the entire country. Buyin earthquake of Sept. 1, 1962 which shock north-western part of Iran had magnitude 7.0 and caused widespread damage particularly to the buildings constructed of mud and adobe. Similar effects were observed in Aug. 31, 1968 Dasht-E-Bayaz earthquake in east-central part of Iran. Bandar-E-Abbas shock of Nov. 1971 caused cracks in a number of brick and concrete buildings while damage was more in case of adobe structures. Another very strong earthquake in south-western area in Fars province at Ghir in April 1972 (Magnitude 6.3) caused more damage to buildings built on alluvium compared to those on rocks. Modern reinforced concrete structures which were well designed and constructed did not suffer any significant damage while poorly designed structures were completely ruined. A newly constructed school built in stone masonry employing 50 cm thick walls with roof made of jack arches over steel I-beams collapsed completely. The room sizes were 4.8 m×3.4 m to 5.4 m×7.1 m. It was found that damage was heavy where steel beams were not anchored tightly to the walls. In Mansoorabad, the building of Hafez Elementary School was seriously damaged and part of the roof collapsed due to weakness of the walls which were sun-dried brick. Serious damage occurred in six newly built single storey school buildings with roofs made of steel I-beams and jack arches. In fact the buildings collapsed despite the provision of tie beams presumably due to poor quality of walls. Similarly the school building in the village of Marand was completely destroyed due to discontinuous tie beams, lack of anchorage, lack of bracing and inferior quality bearing walls. It is gathered that out of about 2500 small rural elementary schools constructed in stone masonry with steel beam and shallow brick arch roofs, three collapsed completely while some others were badly damaged.

North-east part of Bandar-Abbas was again shaken by a 5.6 magnitude shock in March 1975. Like the earlier cases, most serious damage occurred in large sized concrete block and masonry buildings with roof of I-beams and jack arches. Most of the adobe buildings collapsed and damage to masonry buildings was seen in the walls parallel to I-beams.

9.5 Construction Norms for Schools

(a) Iranian antiseismic code for building construction specifies that seismic force for school buildings must be 25 percent higher than normal buildings in view of their importance as public utility structures. In order to avoid earthquake hazards, the code restricts the height of load bearing walls construction to three stories or 11 meters. Buildings with precast concrete blocks are not supposed to exceed two storeys plus a basement or 8 meter from natural ground level while stone buildings in random rubble masonry are not allowed to be more than just one storey plus basement or 5 meters from ground level.

(b) The maximum height of a storey should not exceed 3.5 m. In case however if it is so, a reinforced concrete tie beam should be provided at 3 m intervals along the height in all walls in that storey. The tie beam should be at least 20 cm thick and its width must be equal to wall thickness. The minimum reinforcement in tie beam should be 4 bars of 12 mm dia.

(c) The maximum unsupported length of a wall is 8 m.

(d) Openings in an exterior wall should not exceed one third of total wall area and total length of openings must not exceed one half the length of that wall.

(e) A tie beam of specifications as in (b) above must be provided at plinth level under all walls. Similar tie beams must be provided under ceilings and floors in all buildings.

(f) Arch ceilings of brick are permitted only in single storey buildings. The bearings of this type of ceiling must be reinforced concrete tie beams. Such tie beams which face each other must be connected to each other by steel bars at intervals of about 1.5 m.

(g) In case of domical brick roofs, the rise of dome is to be not less than 25 percent of span length.

(h) Slabs of hollow blocks and prefabricated joints are permitted, provided.

(i) Thickness of cast-in-situ concreate should be at least 5 cm over top of hollow blocks;

(ii) Prefabricated joists shall not bear on reinforced concrete tie beams on the perimeter of slab, but shall be connected into these beams;

(iii) Steel bars 6mm diameter shall be provided at right angles to the direction of prefabricated joists, on top of hollow block at intervals of 20 cm, and

(iv) tie beams, joists and slab must be concreted simultaneously.

(i) Masonry mortar must have at least 200 kg of cement or lime in one cubic meter of mortar.

(j) The tie beams in any floor should be tied to tie beams in the floor above and below by vertical bars placed at corners and junctions of walls.

(k) In case of jack arches and steel I-beams, the beams must be securely fixed in the reinforced concrete tie beams.

(l) Roofs of timber, straw mats or clay are prohibited.

(m) Masonry infill walls must be tied to columns and to tie beams.

(n) In buildings with trussed roofs, it is advisable to use a truss each at the two ends and not allow purlins to come directly on the masonry walls.

(o) All partition walls must be tied to main walls. For this, horizontal steel bars 10 mm dia must be fixed at their junctions with adequate anchorage into both the walls.

For framed structures the seismic forces are to be computed giving due consideration to the vibration characteristics. However there are no details given in the code for the constructional aspects.

9.6 Conclusions

On the basis of study it is concluded that the codal provisions if followed properly can lead to a fairly good earthquake resistant structural system. There are however a number of schools constructed prior to the introduction of the code, which would require a checkup of the design and possibility some strengthening in order to meet the challenge posed by the seismic activity in the country.

10. Iraq

10.1 Planning of Space

According to data supplied by Director of School Building Division of the Ministry of education, the average size of classrooms is 7.2 m by 6.3 m for primary, junior secondary and higher secondary schools. Assembly halls have approximately 24 m by 18 m space. The usual height of rooms is 3.0 m. Most of the primary schools are single storey buildings and a few are double storeyed. But higher secondary schools have 50:50 proportion of single and double storeyed systems.

10.2 Materials and Techniques of Construction

The usual materials of construction of school buildings are brickwork in the middle and southern parts of the country while stone masonry is more popular in north. In some places concrete blocks are used. The foundations are unreinforced continuous footings. Floors consist of either flat reinforced concrete slabs or jack arches on steel joists. A modern school building drawing is shown in Fig. 13. in some cases trusses covered with absestos sheets are also used for roofs.

10.3 Seismicity

There seems to have been no earthquakes in the living memory of the present generation. According to the Scientists of the Seismological Unit of Foundation of Scientific Research, small magnitude earthquakes have occurred in the past but a major shock has not occurred so far. In the northern part of the country bordering with Turkey, earthquakes of moderate size can be expected in future.

10.4 Damage in Past Earthquakes

There is no information available to illustrate damage of any kind to any structure in any earthquakes.

10.5 Norms for Construction of Schools

There are no special provisions specified in the construction practices to cater for the seismic forces that may arise during earthquakes.

10.6 Conclusions

In Iraq, there is little awareness among the people about the earthquake problem. This seems to be due to the present generation having not experienced any major shock during their living memory. However, the northern part of the country is a potential earthquake area and could get such earthquake shocks which would damage the type of construction prevalent in the area. One step which is immediately required is to start monitoring the seismic activity in the country. Foundation of Scientific Research which has got a seismological unit attached to it could include this in its programme of work.

11. Malaysia

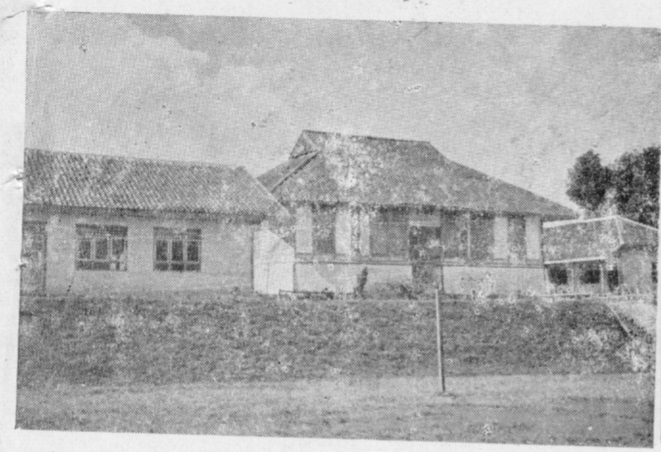
11.1 Planning of Space

Viewed in the context of the context of the Asian Region, the new schools in Malaysia set a very high standard of design, construction and amenities. The general pattern of school plans is rectangular blocks of class rooms with lavatories at end. Most such blocks are two storeyed particularly in primary school. Secondary schools have three and four storeys as well, particularly the hostel blocks. The blocks are laterally connected by covered passages of light tubular construction, structurally separate from the main blocks. There is special emphasis on fire escapes. There are a minimum of two staircases which are separated from the main blocks except at the roof level where the roof rafters are continuous.

The typical class rooms are 9.1m×7.6m in size and the storey height is 3.0m. Assembly rooms in primary schools are created by removing partitions and combining 3 rooms in a row. The assembly halls in junior and higher secondary schools are bigger, usually 37.3×12.2m in size.

11.2 Materials and Techniques of Construction

The most common building materials used for school buildings are timber, brick and concrete. Most buildings have reinforced concreate framing, consisting of columns, beams and slabs except at the roof level. The older buildings had timber trusses or rafters but new designs have reinforced concrete eave level beams. The roofting rafters are still of timber but



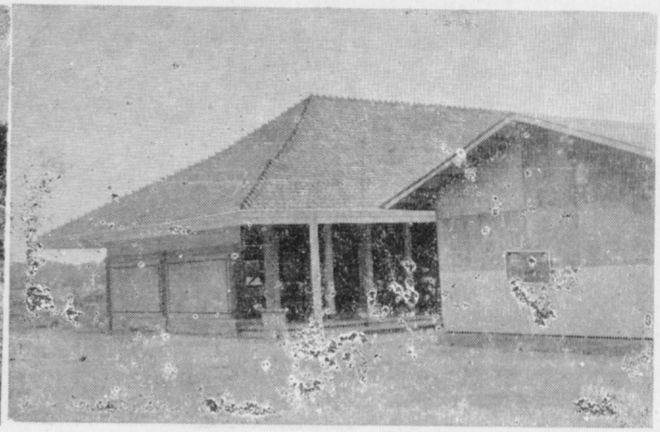
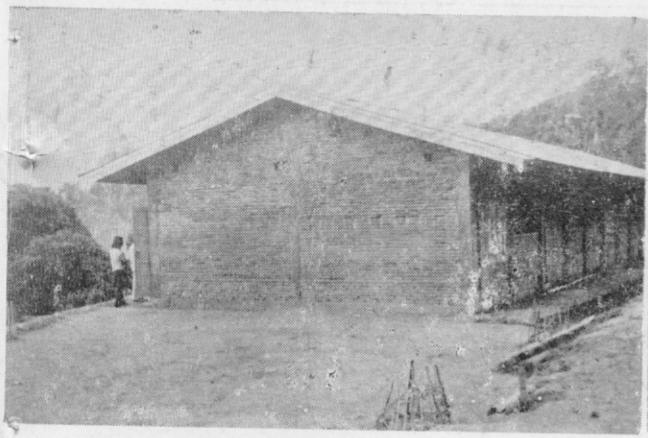


Photo 9. School Buliding off Bandung. Indonesia old building at centre has ring at plinth level, Buliding at left, new addition, has no such provision.

Photo 10. School in North Bali, Indonesia Building at left, in excellent brickwork survived July 1976 earthquake with almost on damage, Building at right, new after earthquake with braced timber frames and plywood cladding.



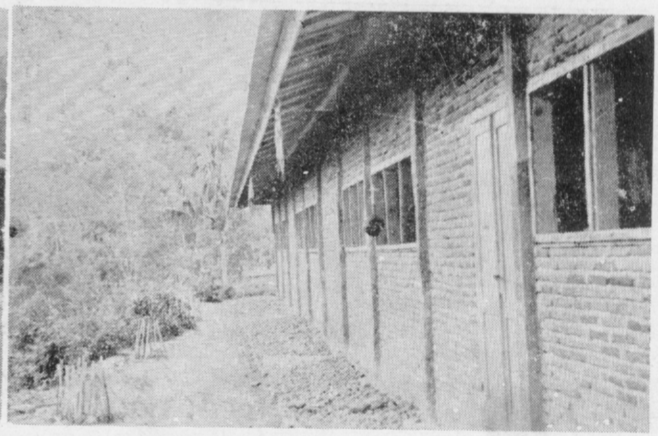


Photo 11, 12 Primary school at Gitgit, Bali. Indonesia New construction after July 1976 earthquake. RC posts under each wooden truss, Ring beam at plinth, none at lintel or eave level, Brick wall panels, brick, gable, Quality of construction substandard

Photo 13. National Secondary School, Kualalumpur. Malayasia RC Frame Building with Wooden truss roof. Stair block separate, structurally connected at roof level.

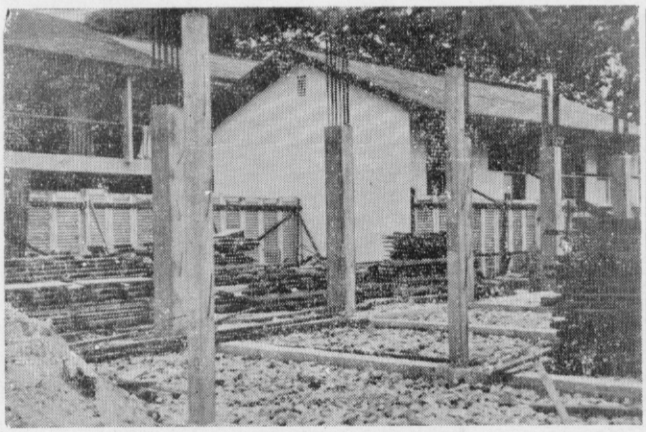


Photo 14. Two storey school building under construction at Kualalumpur. Malayasia RC piles, RC columns, interconnecting RC beams at plinth level.

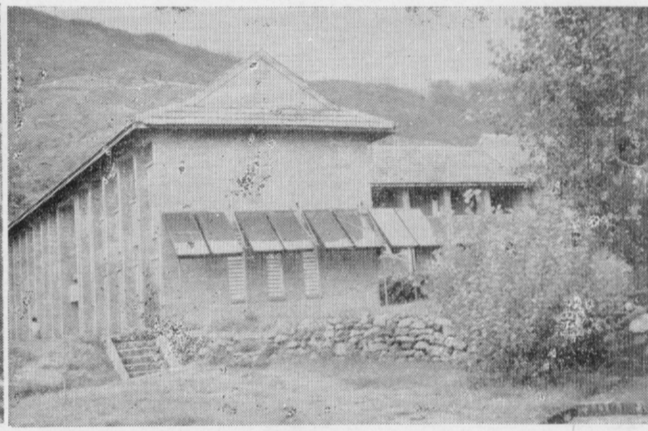


Photo 15. British Aided School in Kathmandu, Nepal. Good quality brick construction with RC ring beams, slab and beam floors (inclined plates are for collecting solar heat for water heating).

the trusses or replaced by reinforced concrete posts sprung from the eave level beams and the rafters are bolted to these posts through steel plates, straps or cover plates. The centre to centre span of the beams is about 7.6 m and bays of 3.05 m are common. The columns are founded on open individual footings where buildings load is light and soil is good. Otherwise, either timber piles of 3 to 4 m length or reinforced concrete piles going to 15 to 18 m depth are employed. It was customary to use connecting R.C. ground beams transverse to the building length at plinth level. Now such beams are provided in both directions. The frames are designed for vertical loads only. In view of the small number of storeys the wind load is usually ignored in design although wind velocities of 160 km per hour could occur at times.

The cladding or partition walls are constructed in brick work with half brick thickness in 1:3 cement and sand mortar. The standard brick size is 22.5 cm × 10 cm × 7.5 cm, so these walls have a thickness of 10 cm. Galvanized expanded metal of light weight is used every fourth course. Dowel bars 10 mm or 6 mm dia project out from reinforced concrete columns by about 30 cm at about 60 cm vertical spacing which are built into the brick walls. In long walls, R.C. posts are built into these walls at about 2.5 to 3 m spacing to provide them stability. Paper-thin gap is left between the soffit of the beams and the walls. It is customary to build the top course with bricks inclined to the horizontal so that the gap is properly filled. Many times in place of brick walls, timber partitioning frames, which may sometimes serve as cupboards too, are fitted between the R.C. frames. These are held to R.C. columns through Ramset or bullet nails.

The roofing material is mostly asbestos cement sheet or clay tiles supported on timber purlins. Typical buildings are shown in Photos 13, 14.

11.3 Seismicity

Malaysia has no record of damaging earthquakes and there were no seismological observatories prior to 1976. Three observatories have since been installed under UNESCO plan with head office at Manila, two in Peninsular part and one in North Borneo. Intensities of IV to V on Modified Mercalli scale have been experienced in Kualalumpur and Penang from distant earthquakes in the west, originating in Sumatra island of Indonesia.

11.4 Damage in Past Earthquakes

During the past, the only damage known to occur to ground shaking was the collapse of a market in Panang. It was a very old brick building and the damage is believed to be due to aging.

11.5 Construction Norms

There are no norms for earthquake resistant construction nor a need has been felt so far.

11.6 Conclusion

In view of the light seismicity and comparatively good form and quality of construction, there appears to be no earthquabe hazard to schools in Malaysia.

12. Nepal

12.1 Planning of Space

The old school buildings are in poor shape. Recently new plans have been developed with UNESCO, Norwegian and AID assistance. The class room sizes are 5.3 m × 6 m for primary schools and 6 m × 7.33 for junior and higher secondary schools. Separate assembly halls are rare. Many times intermediate cross walls are omitted or spaced at larger distances such as 10 to 20 m or more to provide larger rooms and to seat more than one class in the same room. Most primary schools, about 90 percent, are single storeyed and only about 10 percent are two or three storeyed. These percentages for junior and higher secondary schools are 67, 33 and 61, 39 respectively. The storey heights are 2.44 m for primary and junior secondary and 3.35 m for higher secondary schools. The roofs are usually pitched. About 50 percent primary schools have upto 3 rooms and another 20 percent from 3 to 5 rooms.

12.2 Materials and Techniques for Construction

The terrain in Nepal is mostly hilly with narrow river valleys in between. The usual materials of building construction are stone, brick and wood (Photo 15). The walls are mostly constructed in random rubble masonry 45 cm thick (90 percent constructions) or in brickwork 34 cm thick. Usually clay mud is used as mortar. Cement-sand or lime-surkhi mortar is used in very few cases (5 to 10 percent). The door and window openings are 90 cm wide with 90 cm wide piers in between them and have their lintels at the same level. The foundation is taken about 90 cm below the ground level and the footing is constructed in random rubble or brickwork as the case may be with the wall. The footing is widened towards base by stepping, the base width being 90 cm for a one story building. The roof is mostly made slopping using nailed timber roof trusses spaced 1.80 m apart and covering with slates, corrugated iron or asbestos sheeting. Some times flat roof is made by wooden poles or joists along with wooden planks nailed to them and covered wiih clayey earth. No reinforcement is used either in walls or footings. Window and door openings are generally spanned by wooden planks or poles. Many new primary schools have been roofed by using UNICEF supplied aluminium or plastic sheeting and steel trusses made from light gauge channel shaped sections. These trusses have been suitably anchored into the walls by using holding down U bolt for a length of about 90 cm embedded in 1 : 2 : 4 cement concrete pockets. Quality of construction of most primary schaols is rather poor. (The Sos Children village school outside Kathmandu present a happy contrast in that high quality 23 cm brick walls have been constructed in cement mortar with rainforced-concrete bands at plinth and eave levels). A typical school plan is shown in Fig. 14. Some details are shown in Photos 16, 17.

12.3 Seismicity

The whole area of Nepal lies in the major seismic belt called the Himalayan Alpide belt and is highly seismic. There is no seismic observatory in Nepal as yet and the earthquake epicentres occurring in the territory of Nepal are located though records obtained in the observatories in India and through world wide network. Major earthquakes have been known to have occurred in Nepal in historical times, like those in 1259, August 1407, November 1679, June 1681, October 1809, October 1823 and September 1833. The 1934 Bihar-Nepal earthquake was a giant earthquake with magnitude 8.3 which caused damage, in practically 25 percent area of Nepal territory in the South East sector. Tremors occur in different parts of Nepal practically every year as a reminder about the importance of seismic and earthquake engineering studies. Strangely most big earthquakes fall on Mondays and that is why Monday is considered as the most unluckly day of the week by Nepalees peoples. The most severe earthquake areas in Nepal are the south-eastern and the western. The central part has shown relatively smaller seismicity. The southern terai regions are less seismic than the northern hilly regions.

No seismic zoning of the country has yet been carried out, nor there is any code for earthquake resistant constructions. By comparison to the seismic zoning map of India, Nepal may have only two seismic zones—that with probability of MM Intensity IX or more and the other of MM Intensity VIII. A preliminary seismic zoning map has been attempted by Pradhan* as shown in Fig. 15 but it needs serious reconsideration in view of the observed seismicity.

12.4. Damage in Past Earthquakes

Several earthquakes in Nepal have caused damage to buildings. In the earthquake which occurred in Sept. 1833, about 18000 houses and temples were damaged. But the most widespread damage has been caused in the 1934 earthquake in which in Nepal, 8500 lives were lost, 80900 houses and temples were destroyed, 104000 were heavily damaged and 21800 were damaged. A total of 18700 persons were injured. School buildings in the damage zones were generally completely destroyed due to larger spans.

12.5 Conclusions

From the survey of school buildings and seismic activity in Nepal, it is clearly seen that whereas the seismicity is quite high in the whole of Nepal, the earthquake resistance of buildings is rather negligible. Past experience shows that random rubble masonry in mud or lime mortar is extremely vulnerable and is likely to collapse even in MM VII area. There is an urgent need to improve the materials of construction. Also careful strengthening measures for earthquake resistance will be necessary.

13. Pakistan

13.1 Planning of Space

The basic building for a primary school in rural areas comparises only two class room of size approximately 6.5 m by 4.5 m with or without varandah. For urban areas the number of rooms is increased to provide a separate class room for each grade. Middle schools are also similar but with more rooms added depending on grades and also finances. In some of the newly proposed primary schools, the room sizes are modified to about 6.5 m by 5.8 m. Most of these schools are single or two storeyed structure and have room height of 3.2 m to 3.5 m.

*Seismology and Seismotectonics in Nepal by B.M. Pradhan, Chairman, Department of Geology, Tribuvan University.

13.2 Materials and Techniques of Construction

The usual materials employed in construction of buildings include brick masonry and reinforced concrete. Dry stone masonry with timber runners at regular intervals along the height is also many times employed. The roofs are usually reinforced concrete slabs or in some cases timber frames covered with sheeting. In rural areas most structures for housing are constructed with mud. The foundation of masonry buildings are generally unreinforced strip footings and isolated column footings where necessary.

13.3 Seismicity

Pakistan has a sizeable area under active seismic zones. Baluchistan, Frontier and part of Punjab provinces have experienced strong earthquakes in the past while most of Sind and Southern Punjab are relatively earthquake free. Some of the severe earthquakes experienced in Pakistan area in the present century include Drosh shock of Feb. 1, 1929 (Magnitude 7.1), Mach. Baluchistan shock of Aug. 27, 1931 (Magnitude 7.4), Quetta shock of May 31, 1935 (Magnitude 7.5), Makran, Baluchistan shock of 1945 (Magnitude 8.3) and Pattan shock of Dec. 28, 1974 (Magnitude 6.0).

A study of seismicity of Pakistan shows that such strong earthquakes are associated with West Himalayas, Baluchistan and Mekaran regions. The maximum intensity has exceeded IX on MM intensity scale in many of the earthquakes during the past 70 years or so.

13.4 Damage in Past Earthquakes

Pakistan has suffered earthquake damage like other seismically active countries. During the Mach 1931 shock, while a large number of buildings were totally destroyed, a few buildings with vertical and horizontal rails with half brick (11cm) unreinforced brickwork in 1:3 cement sand mortar did not suffer any damage at all. In Quetta 1935 shock, whose epicenter was nearer to north-east of the city, it was indicated that the nature of ground motion plays vital role in causing damage. During this earthquake many old and poorly constructed compound walls in all directions in the northeast area remained intact while much better compound walls in the southwest fell. Similar feature was noted in the damage to buildings. A building code was introduced soon after the Quetta shock and most official buildings after 1935 were constructed using this code. In 1941 another shock rocked Quetta again and caused cracks in a number of new buildings. Details of such damages are not available. Pattan earthquake of 1974 was, however, covered by a UNESCO study mission which visited the affected area within one month of the disaster. In this earthquake, a few properly constructed single storeyed school buildings in brick masonry suffered damage and developed diagonal cracks at several places. Local construction employing timber runners at regular intervals in vertical direction stood very well. At Jajal, a group of modern buildings were totally destroyed. A two storey school built in 1969 was also destroyed. The main reason appears to be the poor quality of workmanship which led to only clay and sand mixture in place of mortar in many places.

13.5 Norms for Construction

Pakistan does not have an official code of practice for aseismic design and construction. However, Quetta municipal building code which came into being in 1937 after the shock of 19ε5 included some very useful provisions for improved performance during earthquakes. Some heightights of this code are as follows :

(a) (i) For structures of burnt bricks or concrete block masonary reinforced vertically and horizontally, the foundations must be of a continuous frame of reinforced concrete.

(ii) A plinth band in reinforced concrete with 2 bars 16mm in 15 cm thickness and of width equal to masonary walls must be provided all round.

(iii) A continuous band similar to plinth band must be provided at lintel level and also at roof level if roof is not reinforced concrete slab.

(iv) The height of such buildings should not exceed 4.5m from ground floor to top of roof. Rooms should not have length greater than 9m without suitably designed transverse wall. But any wall greater than 6.5m should have additional strengthening elements like steel stranchions, reinforced concrete pillars or reinforced masonry pillasters.

(b) Timber frames with corrugated sheets must have foundation in cement concrete or lime concrete and the superstructure of timber framework. Vertical members of this frame must be in single place and not less than 11cm×7.5cm section and should be connected to horizontal members of same section making a panel not more than 1.2m×1.2m. The lower portion should have 23cm thick masonry walls while upper portion may have corrugated iron sheets. The roof of such a structure must be carried on proper frame trusses. The total height of such buildings must be restricted to 3.6cm.

(c) Two storyed structures are allowed only in steel framed building in which each member is designed to resist a lateral load corresponding to one eighth of dead and live load on it. In such construction, walls should be 1½ brick and one brick in the first and the second storey and the total height of building be limited to 9m.

13.6 Conclusions

Pakistan is an active earthquake country and has suffered considerable damage in the past earthquakes. There is quite an awareness amongst people to build earthquake resistant structures but there is neither seismic zoning nor a seismic code yet. The specifications laid down by Quetta municipality, if adopted, could lead to earthquake resistant construction but are somewhat wasteful. There is an urgent need to properly demarcate seismic zones and the associated seismic coefficients for the country.

14. Philippines

14.1 Planning of Space

The standard class room size in primary and junior secondary schools is 8m×6m and that in higher secondary schools 8m × 7m. Assembly hall size is not specified. The height of a storey is kept 3m and most schools (more than 96 percent) are single storeyed. The trend of the primary school plans is to have one large learning space rather than a number of formal class rooms. Many schools have only two class rooms each. A typical schools plan is shown in Fig. 16.

14.2 Materials and Techniques of Construction

The most common building material for walls of schools in the hollow concrete block 20cm × 40cm in plan area. For partition walls, the width may be made 10 or 15cm. In the new schools and health centre buildings, reinforced concrete columns are used at all junctions of walls and jamps of openings, the former being square or L shaped to fit both the wall thicknesses and the others being 10cm × 20cm. The block walls carry horizontal and vertical reinforcement, the vertical reinforcement being one 12mm diameter bar every two block apart and the horizontal being 2 bars 10mm dia every 30cm height. The horizantal bars are carried into the vertical reinforced concrete posts and the vertical bars are anchored into horizontal reinforced concrete beams at plinth or foundation and lintel levels. Thus a very strong enclosure results. The roof generally consists of mostly timber roof trusses carrying corrugated galvanized iron sheeting. The roof trusses are anchored into the R.C. columns through bolts. The columns have individual footings. The new construction is designed for very high typhoon pressures and suctions effects, these lateral farces being considered more severe than the earthquake forces.

Old school buildings are of Marcos type consisting of double channel light gauge steel posts and similar rafters bolted together and carrying corrugated G.I. sheet roofting on steel purlins. The wall panels were constructed of concrete hollow blocks upto 1.2m height above plinth. In new Marcos type buildings reinforced concrete columns are provided. A reinforced concrete bond beam is provided at eave level all round, having a section of about 40cm × 15cm and reinforced with 4 bars 16mm dia longitudinally and stirrups 10mm dia every 20 cm on centres as web steel.

Four construction types are identified for new schools is as given in Table 3.

14.3 Seismicity

Philippines is a country consisting of more than 7000 islands situated in the great Circum-Pacific seismic belt and has been subjected to a large number of damaging earthquakes. The National Geophysical and Astronomical Office has prepared compile strong and damaging earthquakes in the Philippines upto 1976. In these compilations, the instrumental magnitudes, epicentral locations as well as maximum seismic intensity caused on the Rossei-Forel scale (as adapted in Philippines) are presented for various earthquakes which have caused an intensity VI or more shows that the seismically active regions are those located along the Philippine Trench, Northern and eastern Luzon, and the southeastern Luzon—northeastern Visayas area. Also the area like southern Mindanao is visited by great damaging earthquakes. There are intensity zones VIII, VII, VI and smaller present as indicated in the intensity zone map shown in Fig. 17. The coastal area are also affected and damaged by tsunami waves rising to even more than 5m.

Table 3 Type of Construction and Building Materials

Building Component	Type of Construction: Urban	Rurban	Rural	Modification*
Roofing	RC slab or GI sheets	GI Sheets	Nipa or Cogon	GI sheets
Roof Frame	RC or Steel	Wood or Steel	Wood and/or bamboo	Wood
Floors				
Ground Floor	RC	Plain concrete (Cement or Sulphur)	Natural ground (prepared or unprepared)	Plain Concrete
Upper	RC	RC or Wood	Wood or bamboo	RC or wood
Floor Frame	RC or Prest ressed concrete or steel	RC or Wood	Wood and/or bamboo	RC or wood
Walls				
I Storey	RC or CHB or SB	CHB or SB	None	CHB
Upper	-do-	-do-	Bamboo halves or Nipa	CHB
Columns	-do-	RC	Wood and/or bamboo	RC
Foundation	RC	RC	None (charred ends post buried 1m minimum into ground	RC

* Modification of existing bulidnigs is flexible, to correspond to materials as existing, but to be generally as shown in the Table.

Notes:

RC—Reinforced concrete
GI—Corrugated galvanized iron
SB—Sulphur block, made from sulphur, sand and peak gravel
CHB—Concrete hollow block, made from cement sand mixture
Nipa—Shingles made from leaves of swamp palm
Cogon—A kind of grass

There is a first class seismic station at Manila along with several field stations. Since 1973, an International Seismology Centre for South East Asian region is working at Manila for improving the seismic instruments network. Under this, strong motion instruments are also being located. Eight of these have been installed in Philippines.

14.4 Damage to Buildings in Past Earthquakes

There have been many very damaging earthquakes in Philippines, the latest one being Aug. 17, 1976 shock in the Maro Gulf having a magnitude of 7.8 to 8.0 on the Richter scale. A maximum intensity VII was reached on land 5m high tidal wave caused on the shore. It left 3564 persons dead, 1502 missing, 8256 injured and more than 12000 families rendered homeless. Greatest cause of loss of life and damage was the sea wave. The lessons learnt from this earthquake regarding buildings could be summarised as follows:

(i) Damage and cracks at the ends of concrete columns indicate insufficient ties there.

(ii) Buildings with no imbalance of stiffness along height and relatively free from torsional effects survived the earthquake.

(iii) Greatest damage to buildings was concentrated in regions of recent alluvial deposits and the backfilled areas.

14.5 Construction Norms

Philippines has a code on lateral forces as a chapter of the National Building Code first drafted in 1969–70. It deals with calculation of seismic forces on buildings of various types and many other details for designing reinforced concrete frames and shear wall buildings. The school buildings as usually constructed fall into the category of non-engineered construction for which detailed lateral force calculations and their effects are seldom worked out. The above seismic code not give any recommendations for strengthening such buildings. Where the building type adopted is amenable to analysis, the code-specifications will be found useful and adequate. The code includes a seismic zoning map as well, as shown in Fig. 18 which divides the country in three seismic zones. Considering the maximum recorded intensities in these zones, these may be termed as zones A+B, C and D respectively.

The following recommendation in the code for masonry or concrete is relevant for the school building. All elements within the structure which are of masonry or concrete shall be reinforced. Principal reinforcement in masonry shall be spaced 1.20 m maximum on centres.

Other importent provisions are those relating to reinforcement details in reinforced concrete for achieving adequate ductility.

14.6 Conclusion

The old Marcos and new Marcos type buildings have appreciable in-built resistance to lateral loads. Buildings being designed for large typhoon pressures also automatically achieve substantial earthquake resistance. Quality of construction by adequate supervision is necessary and detailing of structural members and joints has to be looked into for deriving the best

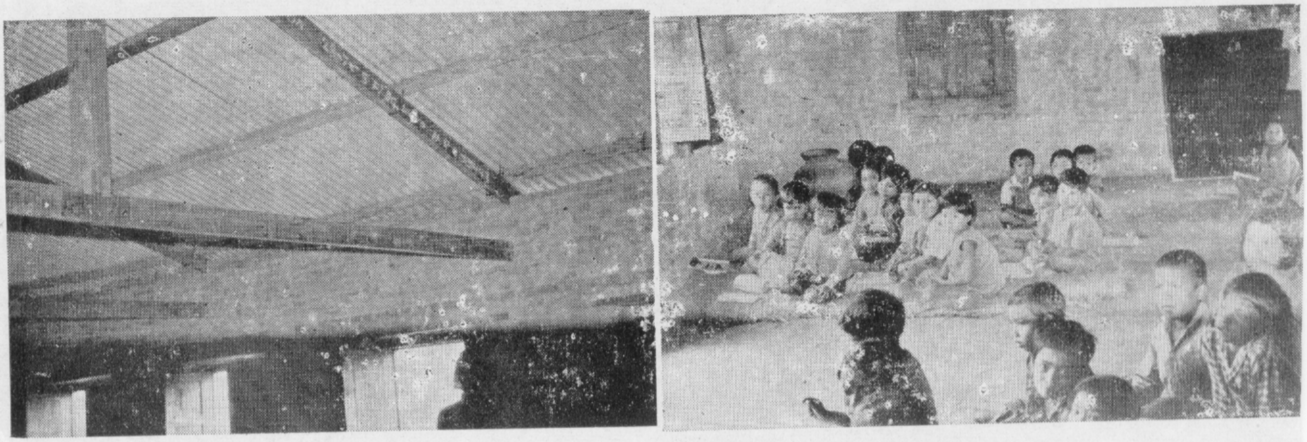


Photo 16, 17 Primary School at Banepa, Nepal. Brick walls steel channel truss, aluminium sheeting, trusses built into wall, on partitions, several classes in same room.

Photo 18. Four storey school construction, Bangkok, Thailand. RC frame building, pile foundations. RC beams at plinth level bothways seen in the photo.

Photo 19. Two storey Teachers' Houses, Bangkok, Thailand. Lower storey, RC posts, brick walls. Upper storey, timber floor joists & planks, timber posts & roofing system.

earthquake resistance by incorporating ductile-deformation capability. The specifications provided in the Philippines lateral force regulations appear to be adequate in this direction.

15. Thailand

15.1 Planning of Space

The schools usually consist of symmetrical rectangular blocks each having a row of class room 6 to 7 m wide with a verandah 2 to 2.5 m wide in front. The class room size in primary schools is 9 m × 6 m and that in junior and higher schools is 9 m × 7 m. Vocational schools have 8 m × 6 m size class rooms. The assembly hall size varies from 32 m × 12 m to 44 m × 21 m. The height of class rooms is usually 3.5 m. The majority of all schools have three or more number of storeys. The approximate percentage of schools having different number of storeys are: primary, single 20 percent, double 20 percent and three 60 percent; secondary, single 10 percent, double 5 percent and three to four 85 percent. But the vocational schools have mostly single storeys, about 50 percent, two storeyed are 35 percent and three storeyed 15 percent. The up-country schools are 2½ storeys in height, the lower half height being used for parking and the upper two storeys for usual functions of the school.

15.2 Materials and Techniques of Construction

The most common building materials are timber, brick and concrete. The school building superstructure almost invariably consists of column—panel construction. A typical plan of structure is shown in Fig. 19. The RCC columns are spaced 3 m apart longitudinally and 7 m apart transversely. RC beams monolithic with the columns span the class rooms 7 m wide. The same arrangement is carried through all the floors. The roof is generally timber truss with tile covering. The verandah floors are made of RC slab monolithic with the framing beams but the class room floors usually consist of timber joists resting on the RC beams and carrying timber plank flooring which is a step higher than the outside verandah slab. The infilling panels between the RC columns are usually in brickwork in good cement sand mortar. The bricks are 15 cm × 7.5 cm × 3.8 cm in size and the panel walls are made 10 cm thick including plaster. Inner partitions are many times made of hard board. Partition wall is strengthened by vertical RC members, 10 cm × 10 cm in section, two in number at a maximum spacing of 2.5 m. The floors and roof are both projected out beyond the outer line of columns by about 1.2 m and louvers are suspended below these cantilevers by about 1 m. Where the soil is good and number of storeys is one or two, open individual footings are used for RC columns. In other cases, individual RC footings rest on timber friction piles whose top is kept below the water table. The wooden piles are driven to the bearing strata at about 20 m depth. The plinth is kept high 50 to 100 cm above ground level to avoid water flooding during rainy season. Plinth level beams are constructed in both directions for connecting the columns with each other and these beams carry the panel walls.

Due to shortage of timber, greater use of reinforced concrete is being made (See Photo 18). For example, it is now used more and more for class room floor construction and for replacing some members of the timber roof truss as in Malaysia. Steel trusses are sometimes used instead of timber trusses. Timber cladding and partitions are sometimes used instead of brick walls in upper floors (See Photo 19).

15.3 Seismicity

Thailand is practically free so far from epicentres of earthquakes having more than Magnitude 4. Only the north western border with Burma is known to have had earthquakes of magnitude upto 5.6. Thus a very small area of Thailand seems to have any earthquake problem. With reference to the seismic zoning map of Burma in Fig. 8, some parts may have Modified Mercalli Intensity VI-VII but not more. According to information from Meteorological Department of Thailand, the intensity has not exceeded VI.

There is no seismic zoning map or seismic code in Thailand as yet. Four seismic stations have recently been established at Chiang Mai, Lampang Bhumibel Dam and Sengkhla.

15.4 Damage in Past Earthquakes

It is understood that there has been minor damage to buildings in the north western border region in past earthquakes but the details could not be obtained.

15.5 Construction Norms

There are no earthquake resistant construction norms for buildings in Thailand as yet.

15.6 Conclusion

The quality and technique of construction of school buildings in Thailand is such as to have inherently good amount of resistance to lateral forces of earthquake or wind. In view of the very low seismicity of the country no special modifications are needed. Only the construction towards west of Chiang Mai will need examination for seismic risk and earthquake resistances.

16. Turkey

16.1 Planning of Space

Class rooms sizes generally adopted for all schools measure approximately 50 m² or 7.2 m×7.2 m and have heights varying from 3.00 to 3.2 m. There are, however, no definite sizes for assembly halls and these are generally on the basis of total number of students in the school which could very considerably. The percentages of scools having single, double and three storeyed buildings are 70, 16, 15 and 20, 40, 40 for primary and secondary schools respectively. A three class room building plan is shown in Fig. 20.

16.2 Materials and Techniques of Construction

Most of the school buildings are made with brick walls, concrete walls, random rubble or dressed stone walls. The foundations are generally unreinforced strip footings and in case of columns isolated footings are used. Lintels are usually in reinforced concrete. Reinforced concrete floors are common and use of timber is almost banned for floors or walls in view of fire hazards. Timber roofs are however permitted. Mostly roofs have reinforced concrete slabs or sloping sheeting which is necessitated by extreme climates. In the modern construction framed construction is being used considerably now although the brick and stone masonry is still invariably employed in rural areas.

16.3 Seismicity

Turkey has had a great seismic history and has about 90 percent of its areas under earthquake zones. According to a report, there have been 45 major shocks ranging between magnitude 5.6 and 7.3 during the past 50 years, which have damaged over 3.74 million buildings in the country. All these shocks caused maximum MM intensities greater than VIII.

There has been considerable thought given to the problem of seismic zoning in this country and the first seismic zoning map was prepared in 1945 in which three zones were suggested as follows :

(a) zones which had experienced destructive earthquakes.

(b) zones which could experience destructive earthquakes.

(c) safe zones.

The data from 1945 to 1963 in respect of seismic events and features led to changes in the seismic zoning map and the revised map divided the country into four zones viz., 1st degree, 2nd degree, 3rd degree and no hazard zone corresponding to MM intensities VIII, VII, VI and V respectively. Later however the map was revised again 1972 due to occurrence of some more destructive earthquakes in some areas which were considered no hazard areas before. The revised map which ironed out some discontinuities in the old map shows five zones now as follows:

(a) First degree hazard zone having MM Intensity IX or more,

(b) Second degree hazard zone having MM Intensity VIII,

(c) Third degree hazard zone having MM Intensity VII,

(d) Fourth degree hazard zone having MM Intensity VI,

(e) No hazard zone having MM Intensity V or less.

The seizmic zoning map of Turkey is given in Fig. 21.

16.4 Damage During Past Earthquakes

Earthquakes have caused extensive damage to structures in this country. Among some of the strongest earthquake shocks are one could list Varto shock of Aug. 1966, Adapazasi shock of July 1967, Gediz shock of 1970, Burdur shock of May 1971, Lice shock of Sept. 1976. During Varto earthquake, lot of damage occurred to adobe, dry rubble and other masonry structures. Newly built buildings of a regional school which was in brickwork did not suffer much. A three storeyed school building in concrete block masonry having reinforced concrete tie beams suffered considerable damage. One storey of this building completely disappeared. The one storey building of a recreation hall (RCC gable frame structure) collapsed due to instability of frame and poor material of construction. In 1967 shock, a number of RCC building which were under construction, collapsed. These had waffle slab type of flooring system. The beams were wide and shallow. The columns failed at top and bottom and consecutive floors were thrown laterally and got stacked one over the other. Reinforcing bars generally did not break and were seen connecting the slabs to columns in the collapsed condition.

Gediz earthquake (1970) caused extensive damage to masonry load bearing wall construction. Timber reinforced structures proved very good, although some of these also collapsed but the reason was improper and inadequate diagonal bracing. During 1970 earthquake, Gediz Junior and Senior High School (both two storeyed) buildings got titled towards one side. Gediz Elementary School also got damaged in similar fashion.

16.5 Construction Norms for School Buildings

The Ministry of Reconstruction and Resettlement has laid down very comprehensive specifications for structures to be built in disaster areas. The specifications are being followed all over the country in design and construction of schools. Some of the highlights of these specifications are as follows:

(a) For reinforced concrete framed construction, apart from the seismic forces in various zones, details of various types of reinforcement in beams/columns/shear walls are given. Details are also included for the beam-column joint section to make it efficient.

(b) (i) In case of masonry load bearing walls, it is recommended that analytical methods may be used and reinforcement steel be used both horizontally and vertically. However, the methods of analysis are not suggested in the specification.

(ii) Allowable heights for such structures are upto two storeys in First degree zone, three storeys in Second and third degree zone and four storeys in Fourth degree zone excluding basement. The maximum height of a storey shall not exceed 3.0 m.

(iii) Bearing walls in either direction must be so arranged that stiffness and mass distribution is symmetrical as far as possible.

(iv) Foundation of bearing wall shall be made in concrete, and shall have minimum width equal to thickness of wall plus 15 cm or 20 cm or 30 cm on each side of wall depending on the soil type.

(v) Compressive strength of masonry blocks used in construction should be minimum of 50 kg/cm² for artificial blocks, and 350 kg/cm² for natural block. The mortar to be used in these walls shall be either cement-lime-sand (1 : 2 : 9) or cement-sand (1 : 6 or 1 : 4).

(vi) In all earthquake zones, natural stone masonry and concrete walls are to be used only in basement and ground floor with minimum thickness of 50 cm and 25 cm respectively. Minimum wall thickness is one brick which may increase to 1½ brick for multistoreyed buildings.

(vii) Maximum span of bearing walls is 5·5 m in First degree zone and 7.0 m in other zones for stability of walls. Where not possible, vertical reinforced concrete bond elements shall be provided at 4.0 m apart but total unsupported length of wall should not exceed 15.0 m.

(viii) Openings may be organised in such a way that minimum width af solid wall between corner and opening should be 1.0 m in higher seismic zones and 0.8 m for less severe zones. Also there should be a minimum width of solid wall section between two consecutive openings, equal to 1/4th of width of larger opening on either side or 0.8 m which ever is less. The total length of opening should not exceed 40 percent of the total length of wall.

(ix) Bond beams (20 cm depth) are to be provided under slabs at all floors. These beams should have a 4 bars 10 mm dia longitudinally, and transverse reinforcement of 6 mm ties at 25 cm intervals. In case of random rubble masonry walls, such bond beams are required at every 1.5 m of height.

(c) Timber structures should not be made higher than two storeys. Longitudinal and transverse walls should cross at 4.5 m maximums spacing. For buildings with masonry ground floors bond beams as given in b (ix) must be provided. The foundations for such structures are similar to those for masonry structures.

There is a general awareness amongst engineers and people in general about the importance of having earthquake resistant structures. The government has put up several instructive charts showing the techniques for such construction for the benefit of common man and these do convince.

16.6 Conclusion

In Turkey, there is already a good deal of effort put into making earthquake resistant construction popular. Most of the schools already have been constructed with the aid of anti-seismic specifications. Some of the rural school buildings however are not upto the desirable standards and may not behave well during future shocks. It is felt that if the seismic provisions as envisaged in the latest Turkish regulations are adopted, the buildings for schools would behave well in future earthquakes.

17. Summary of Observations

The information gathered for the various contries under report is abstracted in Table 4 to 10. The seismicity status is presented in Table 4 which gives the information whether an earthquake code for design has been adopted or not; whether seismic zoning has been done and nationally adopted; if so, the area under each zone as percent of the area of the country. The various notes in this table explain the basis of presenting the seismic zones on a comparable basis. In the cases where no zoning has been done at all, the authors have indicated in

Table 4 Seismicity Status of Various Countries

Sl. No.	Name of Country	Earthquake Engg. Code adopted	Seismic Zones			Approximate Area of zone, as percent of country's Area	Reference	Notes
			Adopted	Proposed by group or individual	Likely to be included			
1	2	3	4	5	6	7	8	9
1.	Afganistan	No	A+B			14	1*	* Numbers refer to those listed in Bibliography.
			C			21		
			D			17		
			E			48		
2.	Bangladesh	No		A		26	see Note I	I "Seismic Zoning Map of Bangladesh" by Bangladesh Meteorological Dept.
				B		26		
				C		30		
				D		18		
3.	Burma	No		A		21	see Note II	II Gorshkov G.P. "Intensity Map of Burma", Problems of Seismotectonic and seismicity zoning of the Territory of Burma.
				B		30		
				C		29		
				D		20		
4.	India	Yes	A			12	2*	*Definition of Zones*
			B			17		
			C			25		
			D			20		
			E			26		A—Destruction risk zone (MM IX or more)

1	2	3	4	5	6	7	8	9
5.	Indonesia	Yes	A+B			33	*	B—Heavy damage risk zone (MM VIII area)
			C+D			27		C—Moderate damage risk zone (MM VII area)
			B			40		
6.	Iran	Yes	A+B			100	2*	D—Slight damage risk zone (MM VI area)
7.	Iraq	No			B			E—No damage risk zone (MM V or smaller)
					C			
					D			*Definition of degree of damage*
					E			
8.	Malaysia	No			D, E	100		The 'damage' degree terms are related to ordinary brick buildings, buildings of large block construction, half timbered structures and buildings in natural hew stone and are defined below:
9.	Nepal	No		A		22	4*	
				B		65		
				C		13		
10.	Pakistan	No		A		2	5*	
				B		21	*	*Destruction*—Gaps in walls; parts of building collapsed; inner walls collapsed; total collapse of building.
				C		58		
				D		19		
11.	Philippines	Yes	A+B			77	2*	
			C			15		*Heavy Damage*—Large and deep cracks in walls; fall of chimneys.
			D			8		
12.	Thailand	No			C			*Moderate Damage*—Small cracks in walls; fall of fairly large pieces of plaster; slipping of pentiles; cracks in chimneys; parts of chimneys fall.
					D			
13.	Turkey	Yes	A			19	6*	
			B			28		
			C			15		*Slight Damage*—Fine cracks in plaster; fall of small pieces of plaster.
			D			22		
			E			16		

col. (6) of the table, the zones that will be likely to occur considering the observed seismic events. This table gives at a glance the relative magnitude of seismic problem in various countries. The seismic zoning maps as available have been reduced to a common basis of zones A, B, C, D and E as defined in the table and reproduced in the figures presented countrywise in earlier sections.

Tables 5—7 present the standard dimensions related to primary, junior secondary and higher secondary schools respectively. The items included are class rooms, assembly halls or multipurpose rooms, storey heights and number of storeys. The length and height of walls are important parameters for examining earthquake resistance.

The usual construction materials and types are listed in Tables 8—10 for the three categories of schools. It is seen that the materials and construction techniques vary widely in various countries; load bearing system varies from random rubble masonry walls to reinforced concrete and steel frames; the cladding panels vary from bamboo matting to reinforced brickwork; the roofs vary from rafter purlins with slates or clay tiles to those having steel trusses with corrugated galvanized iron sheeting or those built in reinforced concrete; and the foundations vary from isolated unreinforced footings to reinforced concrete piles; the weights of the structures vary from very heavy to very light; the stiffness varies from very rigid to quite flexible, and the tensile strength of bearing members varies from almost nil to large value as for steel. The details as well as quality of construction are also variable not only among countries but in the same country as well from region to region. Naturally the earthquake resistance and behaviour would show large variation. Consequently for bringing them to adequate safety level in different seismic zones, treatment of varying degrees will naturally be called for.

18. Conclusions

The information as available for various countries under study regarding seismic activity. grade of construction of school buildings and their damageability is abstracted in Table 11 The third column of the table gives the information regarding the seismic status of the country in terms of percentage area of the country where damage as defined by MM VII or more may occur in future. This area was characterised by zones A, B and C in Table 4. The fourth column lists the quality of school buildings in various countries and the fifth column presents the performance that is likely to occur in the event of an earthquake causing the seismic intensity according to zone classification. The quality of buildings and their performance are best stated in terms of gradings as defined in MSK Scale of Intensities of which short notes are given under Table 11. The damage grading will naturally be higher in higher intensity zones. The strengthening of buildings should be such that damage grade 4 Destruction and grade 5 Total Damage are eliminated. For achieving this level of safety, certain actions need urgently be taken by the various countries. These include seismic macro-zoning, making an earthquake resistant construction code of practice, and implementation of the same. It is unfortunate that even where the codes have been made, implementation in actual school construction is not taking place in majority of cases. Another action, which is important for further developments in future, is the improvement of existing seismological observatory network and addition of such stations in the whole region. In this respect, international and regional cooperation wilt be most useful.

Table 5 Standard Dimensions of Primary Schools

Sl. No.	Country	Class Room Size (m×m)	Assembly Hall Size (m×m)	Height of Room (m)	Approximated percent of Schools having Storeys: One	Two	More than two
1	Afghanistan	6.5×4.3	9.0×8.0	2.80	100	—	
2	Bangladesh	6.1×6.1	18.3×6.1	2.09	99	1	
3	Burma	8.2×6.7	18.3×12.2	3.65	100	—	
4	India*	7.6×6.1 6.1×4.9	11.4×8.2 12.2×6.1	3.50 3.30	Most	Few	Few
5	Indonesia*	8.0×7.0 7.0×6.0	16.0×15.0 18.0×10.0	3.50 3.30	94	5	1
6	Iran	7.0×6.0	180 (Area 36 in m²)	4.20** 2.80	80	20	
7	Iraq	7.2×6.0	24.0×18.0	3.00	Most	Few	
8	Malaysia	9.1×7.6	3×(9.1×7.6)	3.00	—	100	
9	Nepal	5.9×5.5	5.5×any	2.44	90	—	10
10	Philippines	8.0×6.0	—	3.00	98	2	
11	Thailand	9.0×6.0	32.0×12.0	5.00	20	20	60
12	Turkey	7.2×7.2	—	3.00	70	15	15

* Dimensions in two rows show range of variation
** Height according to climate

Table 6 Standard Dimensions of Junior Secondary School

Sl. No.	Country	Class Room Size (m×m)	Assembly Hall Size (m×m)	Height of Room (m)	Approximate percent of Schools having Storeys		
					One	Two	More than two
1	Afghanistan	—	—	—	—	—	—
2	Bangladesh	6.1×6.1	3×(6.1×6.1)	2.09	98	2	—
3	Burma	9.1×6.7	30.0×12.3	3.00	—	Most	Few
4	India*	7.6×6.1 6.0×6.0	11.4×8.2	3.5	Most	Few	—
5	Indonesia*	8.0×7.0	20.0×12.0 17.5×10.5	3.50 3.00	75	23	2
6	Iran*	7.0×6.8	216 (Area 162 in m²)	4.20** 2.80	30	50	20
7	Iraq	7.2×6.0	24.0×18.0	—	—	—	—
8	Malaysia	9.1×7.6	37.3×12.2	3.65	100	—	—
9	Nepal	7.3×5.9	5.9×any	2.44	67	22	11
10	Philippines	8.0×6.0	—	3.00	98	2	—
11	Thailand	9.0×7.0	36.0×21.0	5.00	10	5	85
12	Turkey	7.2×7.2	—	3.20	20	40	40

* Dimension in two rows show range of variation

** Height according to climate

Table 7 Standard Dimensions of Higher Secondary Schools

Sl. No.	Country	Class Room Size (m×m)	Assembly Hall Size (m×m)	Height of Room (m)	Approximate percent of Schools having storeys: One	Two	More than two
1	Afghanistan	8.6×5.1	20.0×10.0	3.20	50	50	—
2	Bangladesh	6.1×6.1	22.9×9.1	3.20	77	18	5
3	Burma	12.2×6.7	30.0×15.0	3.65	18	80	2
4	India*	7.6×6.1 6.1×4.9	11.4×8.2	3.50 3.00	—	100	—
5	Indonesia*	8.0×8.0 9.0×7.0	20.0×18.0 24.0×10.0	3.5 3.0	92	5	3
6	Iran*	8.0×6.8	252 (Area 189 in m²)	4.2** 2.8	—	60	40
7	Iraq	7.2×6.0	24.0×18.0	3.00	50	50	—
8	Malaysia	9.1×7.6	37.2×12.2	3.00	—	Most	Few
9	Nepal	7.3×5.9	5.9×any	3.35	61	35	4
10	Philippines	8.0×7.0	—	3.00	96	3	1
11	Thailand*	9.0×7.0 8.0×6.0	44.0×21.0 30.0×14.0	3.50	30	20	50
12	Turkey	—	—	—	—	—	—

* Dimension in two rows show range of variation

** Height according to climate

Table 8 : Usual Construction Types for Primary Schools

Sl. No.	Country	Walls	Foundation	Lintel	Floor/Roofs
1	Afghanistan	BW, RM	US	TP, RC	PT, BD, RS
2	Bangladesh	BW, TL	US, IC	TP, AR, RC, RB	TJT, PS, RC
3	Burma	BW, RM, TB	US	AR, RC	TJT, PS, RC
4	India	BW, PC, RM, DM, CB	IC, US	RB, RC	RC, TJT, PS
5	Indonesia	BW, RM, TL, TW	IC, US	TP, RC, RB, AR, TP	TJT, PS, RC, TJP
6	Iran	BW, RM	US, IC, RS, RIC, ICP	RC, RB, AR, TP	TJT, SJA PS, RC, RB
7	Iraq	BW, RM, CB	US	TP, AR	TJP, SJA
8	Malaysia	BW	ICP	RC	PS
9	Nepal	BW, RM, TB	US	TP, RC	PS, SJA
10	Philippines	DM, PC, TW	IC	TP, RC	PS, RC
11	Thailand	BW, RM, DM, CB, PC, RC, T, TL, TW	IC	RC	RC
12	Turkey	BW, RM, DM, CB, PC, RC	US	RC	RC

Symbols

- AR—Flat or segmental Arch
- BD—Brick Dome
- BW—Brickwork
- CB—Concrete Block
- DM—Dressed Stone Masonry
- IC—Isolated Column
- ICP—Isolated Column Piles
- PC—Plain Concrete
- PS—Pitched with Sheeting
- PT—Pitched with Tiles
- RB—Reinforced Brickwork
- RC—Reinforced Concrete
- RIC—RC Isolated Column
- RM—Random Rubble Masonry
- SJA—Steel Joist and Arches
- TB—Timber Frame, Brick infill
- TJP—Timber Poles or Joists with Planks and Earth
- TJT—Timber Poles or Joists with Tiles
- TL—Timber Frame, light Cladding
- TP—Timber Plank or Poles
- TW—Timber Wall

Table 8 : Usual Construction Types (in Junior Secondary School)

Sl. No.	Country	Walls	Foundation	Lintel	Floor/ Roofs
1	Afghanistan	—	—	—	—
2	Bangladesh	BW, TL	US, IC	—	—
3	Burma	BW, RM, TB	US, IC	AR	TJT, PS, RC
4	India	BW, RC, RM	IC, US	RC	TJT, RC
5	Indonesia	BW, RC, RM, DM, CB, PC, TB, TL, TW	US, IC	RC, RB, AR, TP	TJT, PS, RC
6	Iran	BW, RM	US, IC, RC, RIC, ICP	RC, RB, AR, TP	TJT, SJA, PS, RC, RB
7	Iraq	BW, RM	US	AR, TP	RB, RC
8	Malaysia	BW	ICP	RC	PS
9	Nepal	BW, RM, DM	US	RC, RB	PS, TJT, SJA
10	Philippines	DM, RC, TW	—	TP, RC	PS, RC
11	Thailand	—	IC	RC	RC
12	Turkey	—	US, IC	RC	RC

Symbols

AR—Flat or Segment Arches
BD—Brick Dome
BW—Brickwork
CB—Concrete Block
DM—Dressed Stone Masonry
IC—Isolated Column
ICP—Isolated Column Piles
PC—Plain Concrete
PS—Pitched with Sheeting
PT—Pitched with Tiles
RB—Reinforced Brickwork
RC—Reinforced Concrete
RIC—Reinforced Isolated column
RM—Random Rubble Stone Masonry
SJA—Flat or Jack Arches on Steel Joists
TB—Timber Frame with Brick infill
TJP—Timber Piles or Joists with Planks and Earth
TJT—Timber Piles or Joists with Tiles
TL—Timber Frame with Light Cladding
TP—Timber Plank or Piles
TW—Timber wall

Table 10 Usual Construction Types for Higher Secondry Schools

Sl. No.	Country	Walls	Foundation	Lintel	Floor/Roofs
1	Afganistan	BW, RM	US, IC	RC	PS
2	Bangladesh	BW, TL	US, IC	TP, AR, RC, RB	TJT, PS, RC
3	Burma	BW, RM, TB	US, IC	AR	TJT, PS, RC
4	India	BW, RC, RM	IC, US	RC	RC, TJT
5	Indonesia	BW, RC, RM, DM, CB, PC, TB, TL, TW	US, IC	RC, RB, AR, TP	TJT, PS, RC, TJP, SJA, RB, PT
6	Iran	BW, RM	US, IC RS, RIC, ICP	RC, RB, AR, TP	TJT, SJA, PS, RC, RB
7	Iraq	BW, CB	US	AR	RC, RB
8	Malaysia	BW	ICP	RC	PS
9	Nepal	BW, RM, DM	US	RB, RC	PS, SJA, TJT
10	Philippines	DM, RC, TW	—	TP, RC	PS, RC,
11	Thailand	DM, TL, BW, RM, CB, PC, RC	IC, ICP	TP, RC RB	TJT, PS, RC
12	Turkey	BW, RM, DM, CB, PC, RC	US, IC	RC	RC

Symbols

AR—Flate or Segmental Arches
BD—Brick Dome
BW—Brickwork
CB—Concrete Block
DM—Dressed Stone Masonry
IC—Isolated Column
ICP—Isolate Column Piles
PC—Plain Concrete
PS—Pitched with sheeting
PT—Pitched with Tiles
RB—Reinforced Brick-work
RC—Reinforced Concrete
RIC—Reinforced Isolated Column
RM—Random Rubble Stone Masonry
SJA—Flat or Jack Arches on Steel Joists
TB—Timber Frame with Brick infill
TJP—Timber Poles or Joists with Planks and Earth
TJT—Timber Poles or Joists with Tiles
TL—Timber Frame with Light Cladding
TP—Timber Plank or Poles
TW—Timber Wall

Table 11 Seismic Hazards, Action Needed to Mitigate Risk

Sl. No.	Country	Damageable Area. Percent area lying in Seismic Zones A, B, C	Grading of Majority of School Buildings	Likely Grade of Damage in future Earthquake
1	2	3	4	5
1	Afghanistan	35	A, B+	2 to 5
2	Bungladesh	82	B	2 to 5
3	Burma	80	B	2 to 5
4	India	54	B	2 to 5
5	Indonesia	46	B	2 to 5
6	Iran	100	B	2 to 5
7	Iraq	—	B	2 to 3
8	Malaysia	0	C	none
9	Nepal	100	A, B+	2 to 5
10	Pakistan	81	B	2 to 5
11	Philippines	92	B	2 to 4
12	Thailand	Small	C	1 to 2
13	Turkey	62	B	2 to 5

+New schools buildings
For definition of Seismic Zones A, B, C, refer Table 4

Gradings of Buildings

Structure A—Buildings in field stone, adobe and clay
Structure B—Buildings in ordinary brick, large block, half timbered construction
Structure C—Reinforced buildings, well built wooden constructions

Grading of Damage

1. Slight damage —Fine cracks in plaster and fall of small pieces.
2. Moderate damage —Small cracks in walls; fall of fairly large pieces of plaster: pan-tiles slip off; cracks in chimneys and parts fall down.
3. Heavy damage —Large and deep cracks in walls; fall of chimneys.
4. Destruction Damage —Gaps in walls; parts of buildings may collapse; separate parts of the building lose their cohesion; inner walls collapse.
5. Total damage —Total collapse of buildings.

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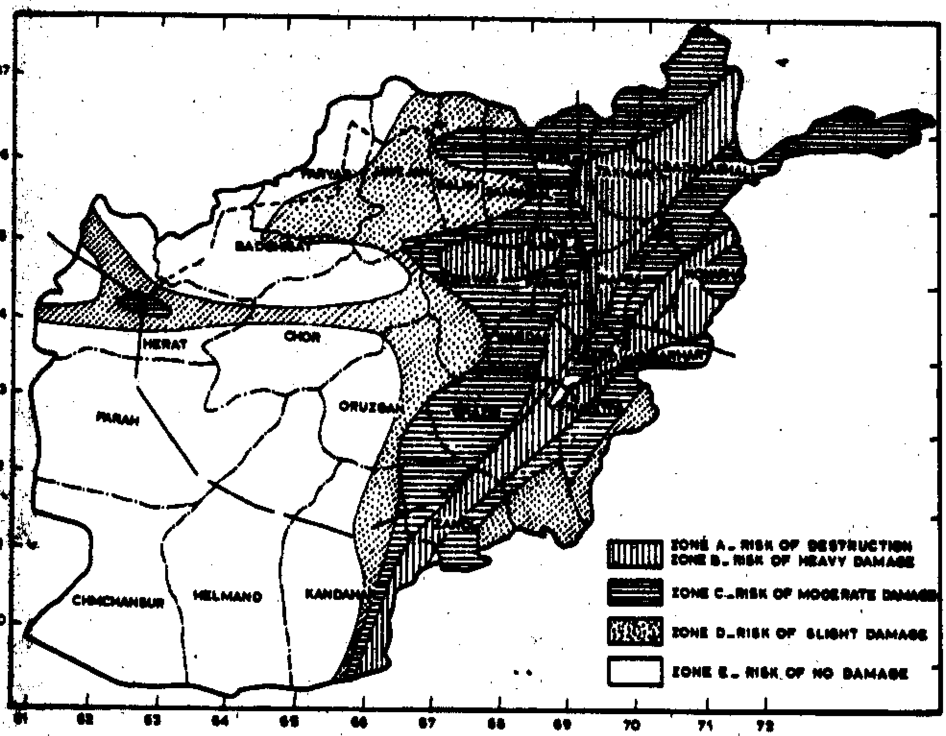

FIG. 1 _SEISMIC ZONING MAP OF AFGHANISTAN

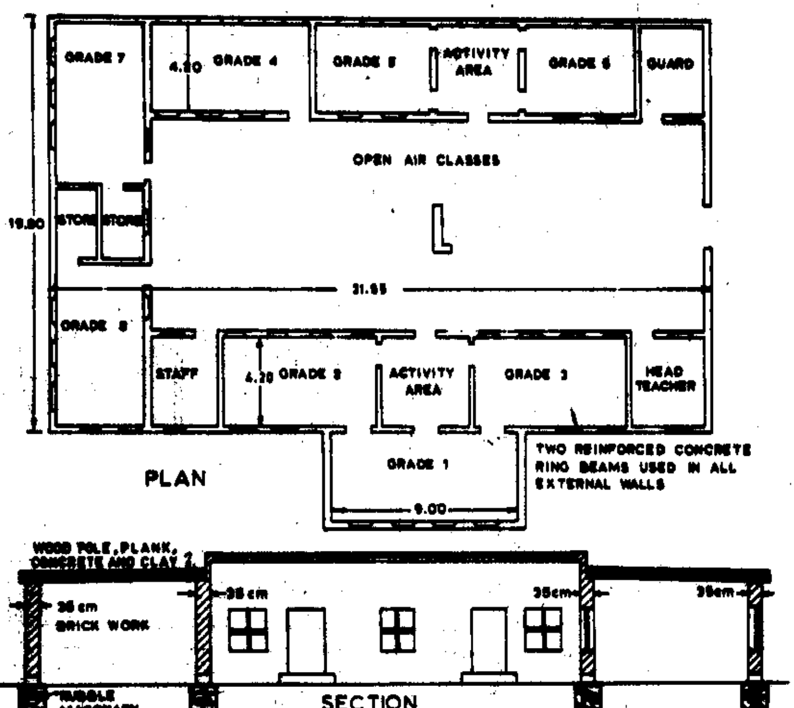

FIG. 2 _PRIMARY SCHOOL IN AFGHNISTAN (new construction)

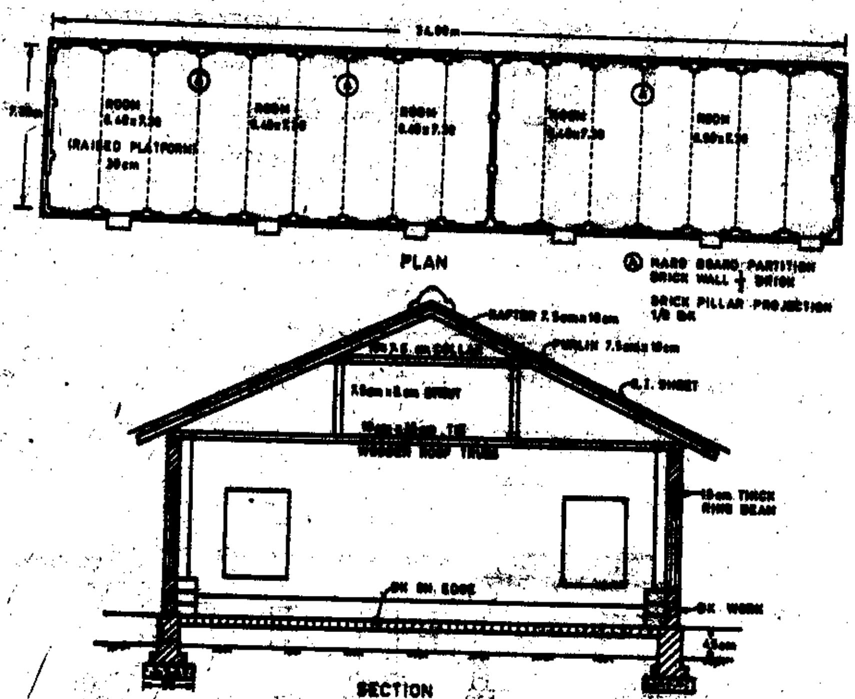

FIG.3 _FIVE ROOMED SCHOOL, BANGLADESH

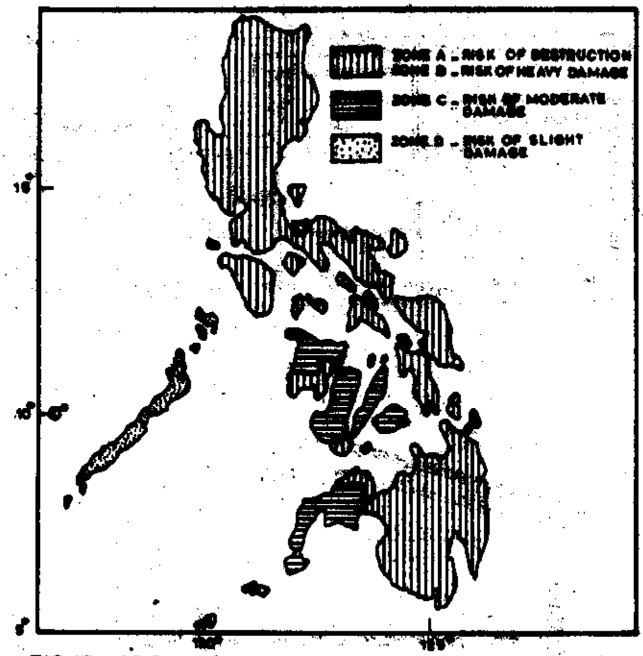

FIG. 18 _ SEISMIC ZONING MAP OF PHILIPPINES

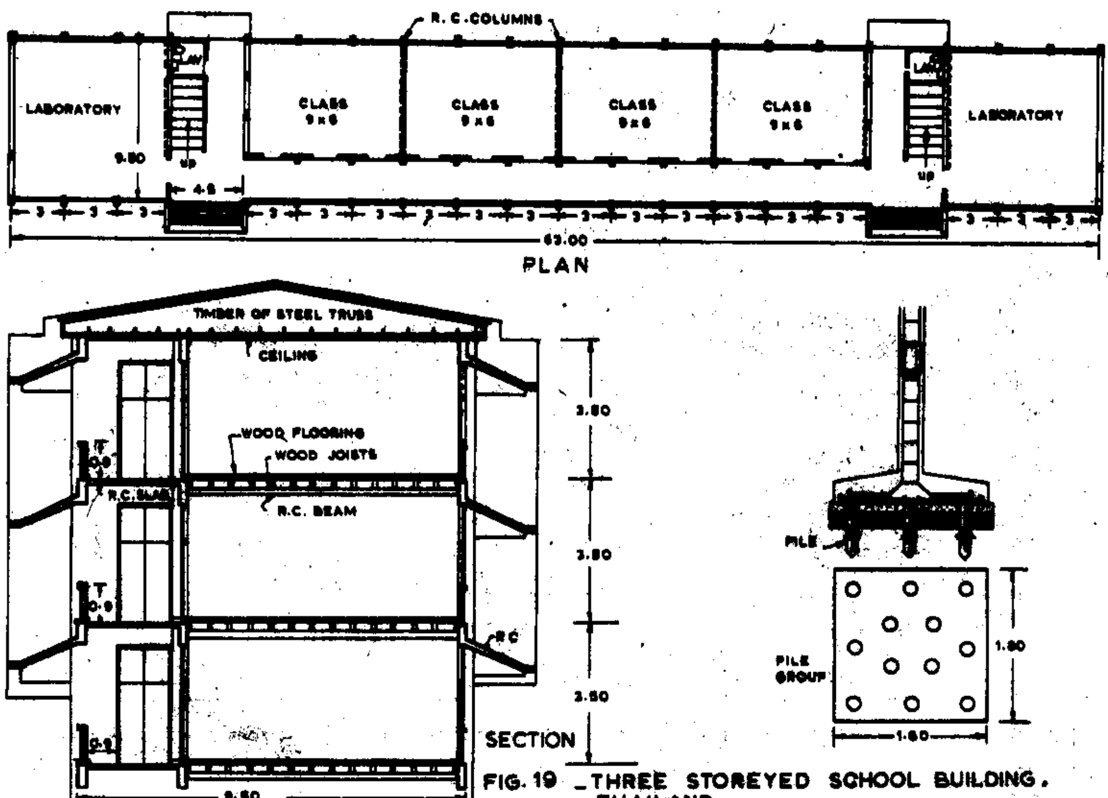

FIG. 19 _ THREE STOREYED SCHOOL BUILDING, THAILAND

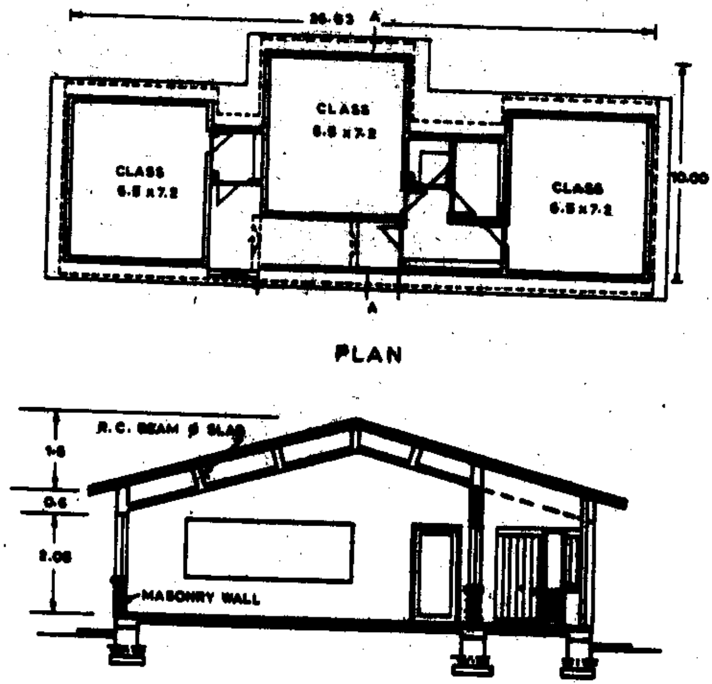

FIG. 20 _THREE ROOM SCHOOL, TURKEY

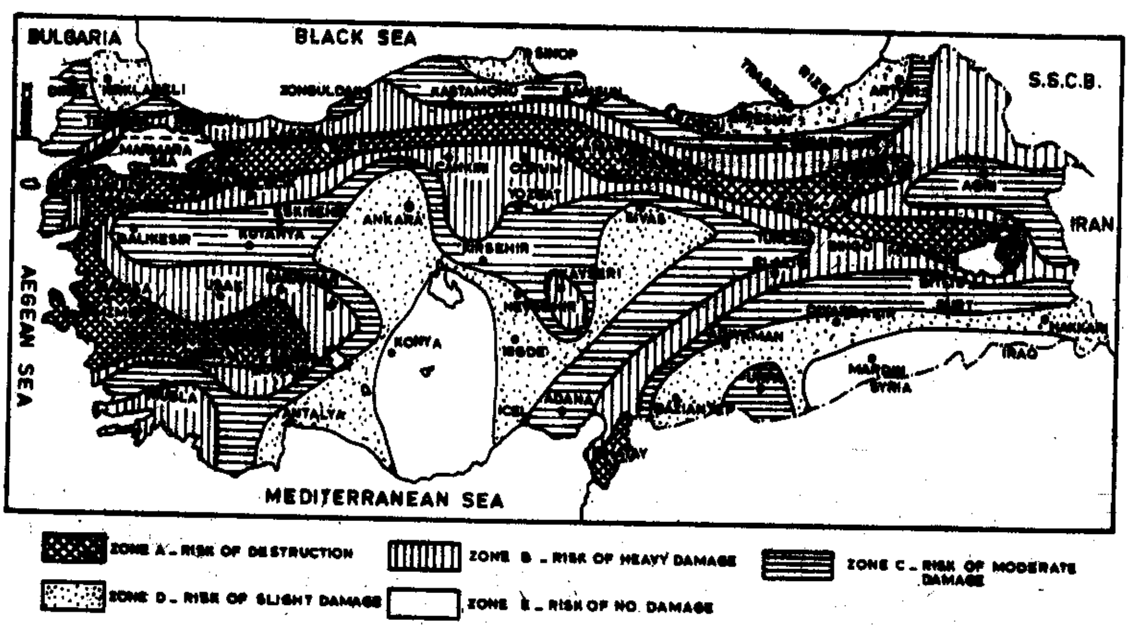

FIG. 21 _ SEISMIC ZONING MAP OF TURKEY

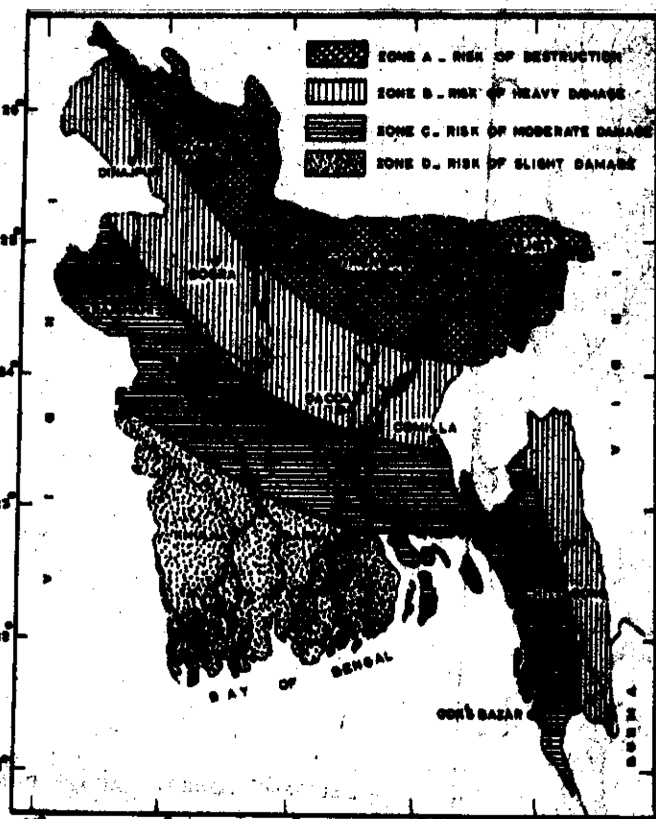

FIG. 4 _ SEISMIC ZONING MAP OF BANGLADESH

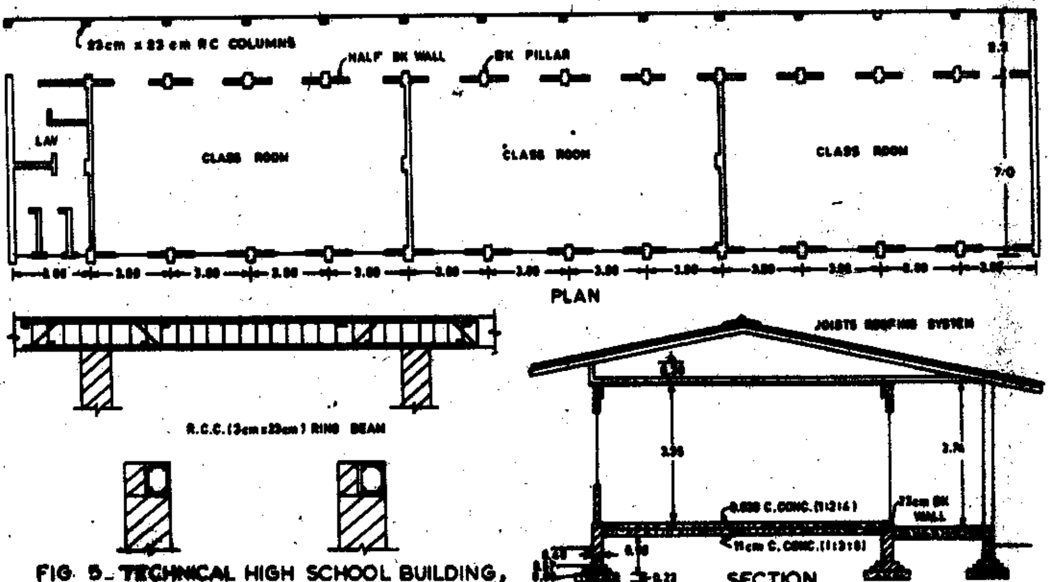

FIG. 5 _ TECHNICAL HIGH SCHOOL BUILDING, BURMA

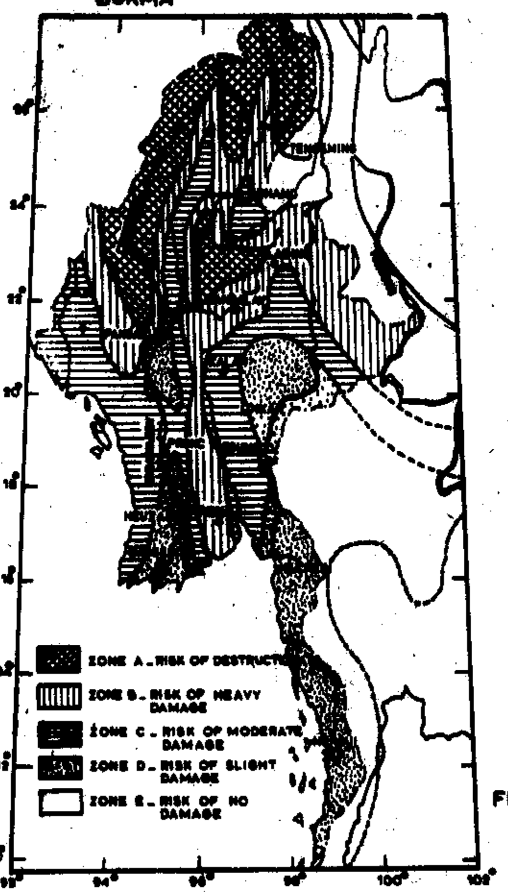

FIG. 6 _ SEISMIC ZONING MAP OF BURMA

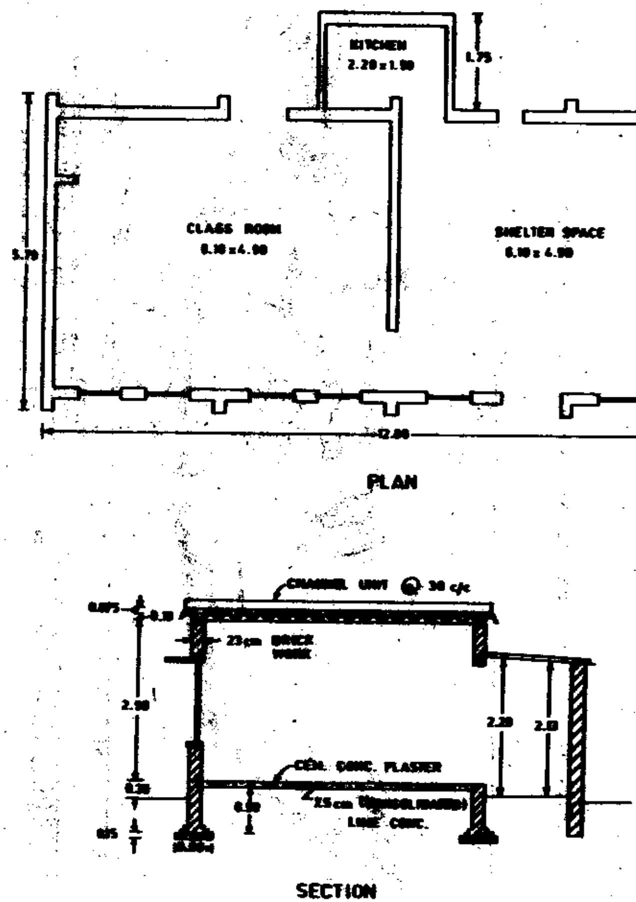

FIG. 7 _ PRIMARY SCHOOL, INDIA

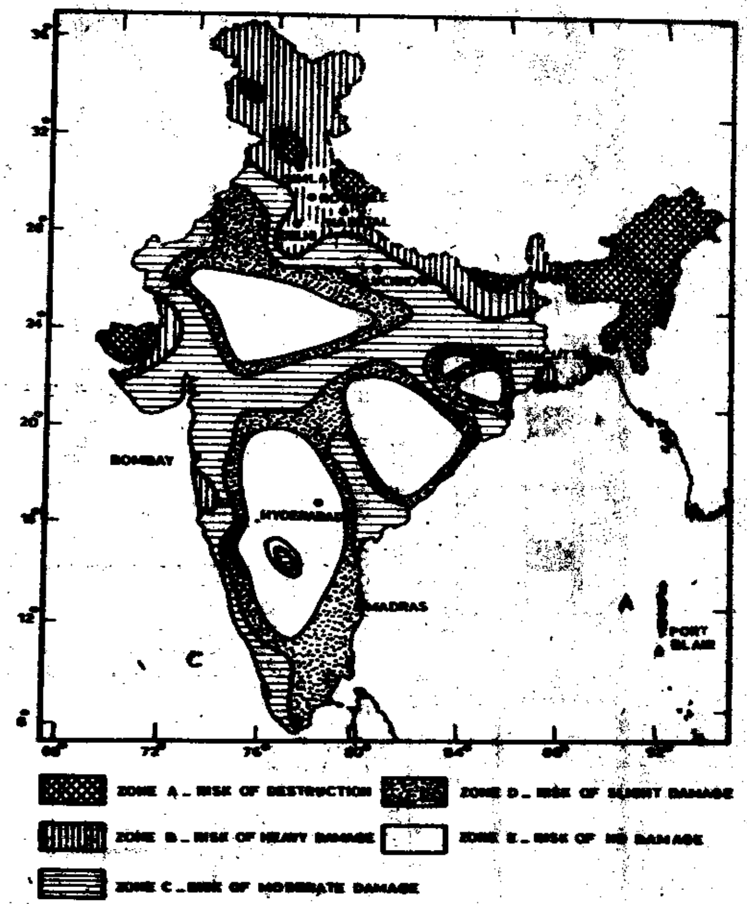

FIG. 8 _ SEISMIC ZONING MAP OF INDIA

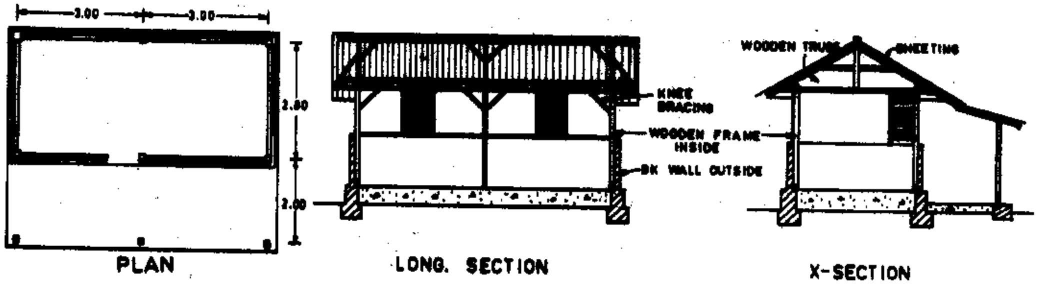

FIG. 9 _ONE ROOM SCHOOL, BALI, INDONESIA

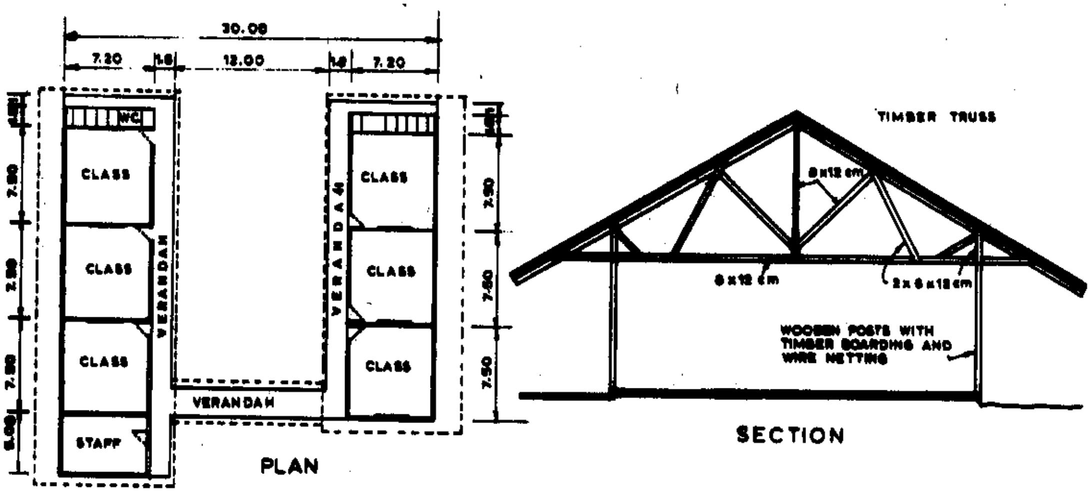

FIG. 10 _SIX CLASS ROOM PRIMARY SCHOOL, INDONESIA

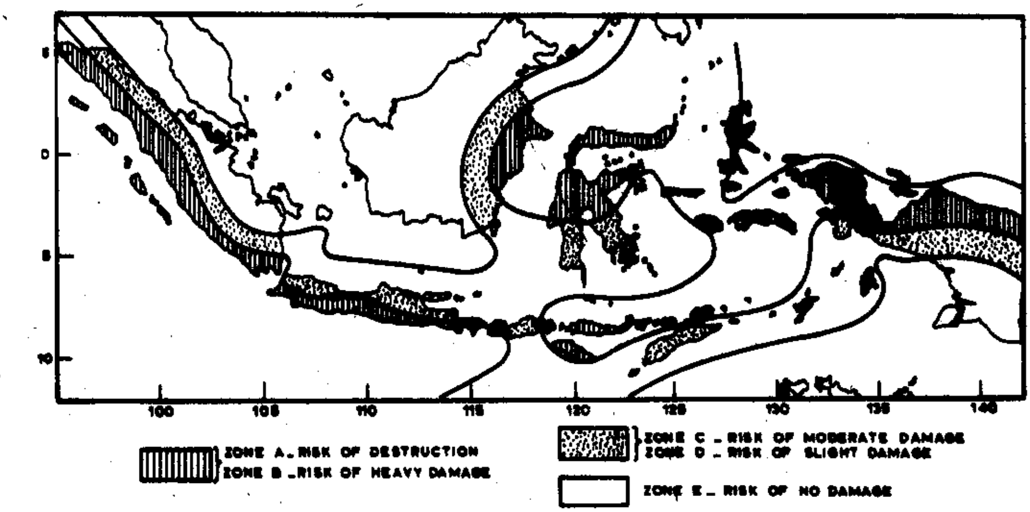

FIG. 11 _SEISMIC ZONING MAP OF INDONESIA

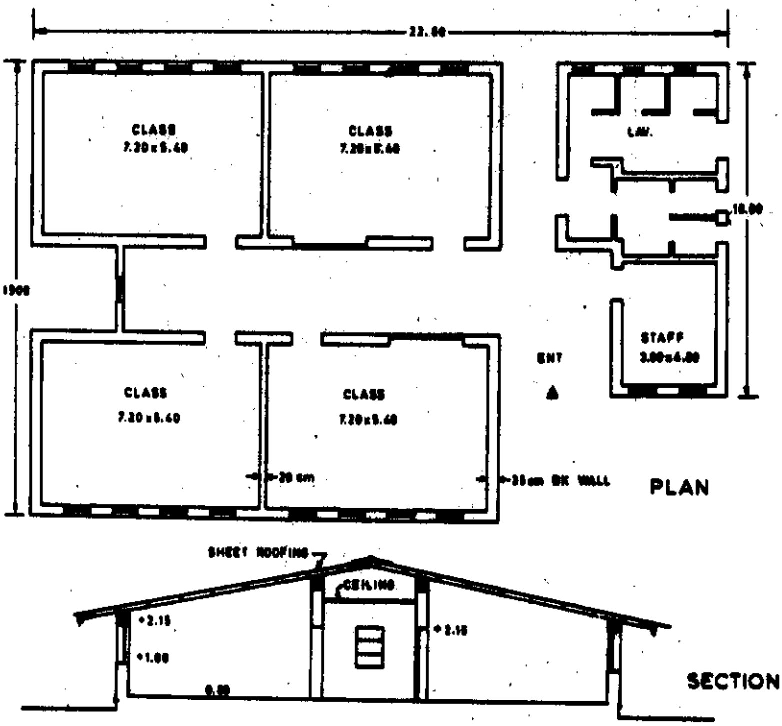

FIG.12 _ FOUR CLASS ROOM PRIMARY SCHOOL, IRAN

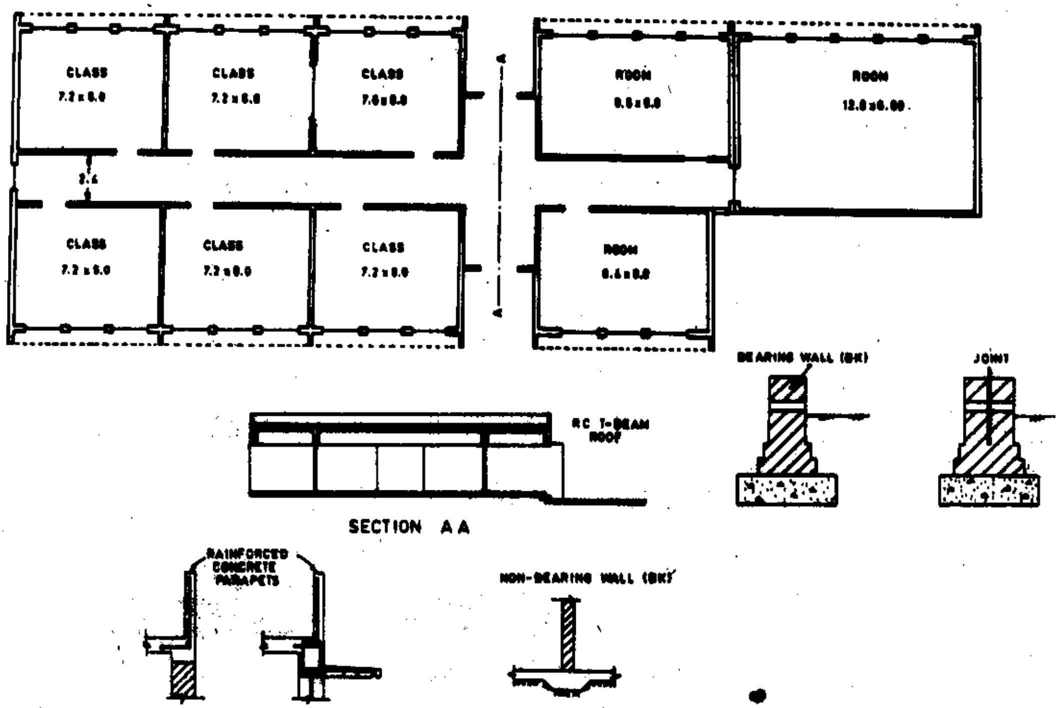

FIG 13 _ SEVEN CLASS ROOM PRIMARY SCHOOL, IRAQ

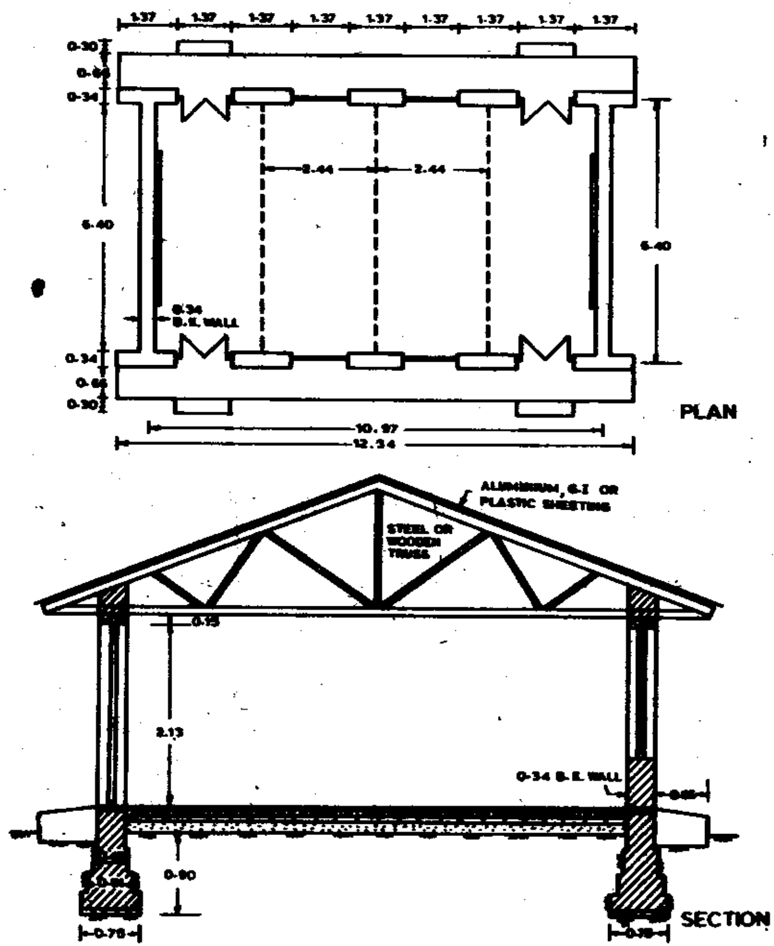

FIG. 14 _ ONE ROOM PRIMARY SCHOOL, NEPAL

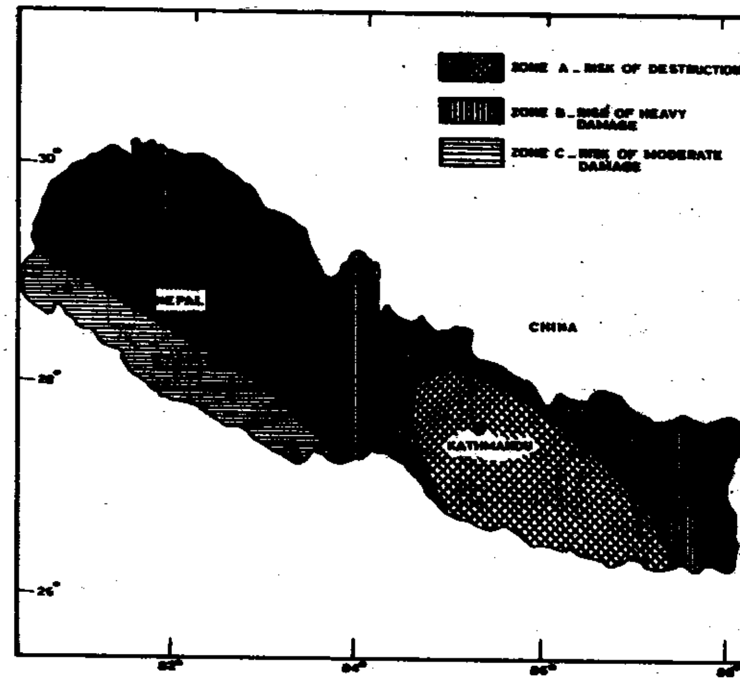

FIG. 15 _ SEISMIC ZONING MAP OF NEPAL

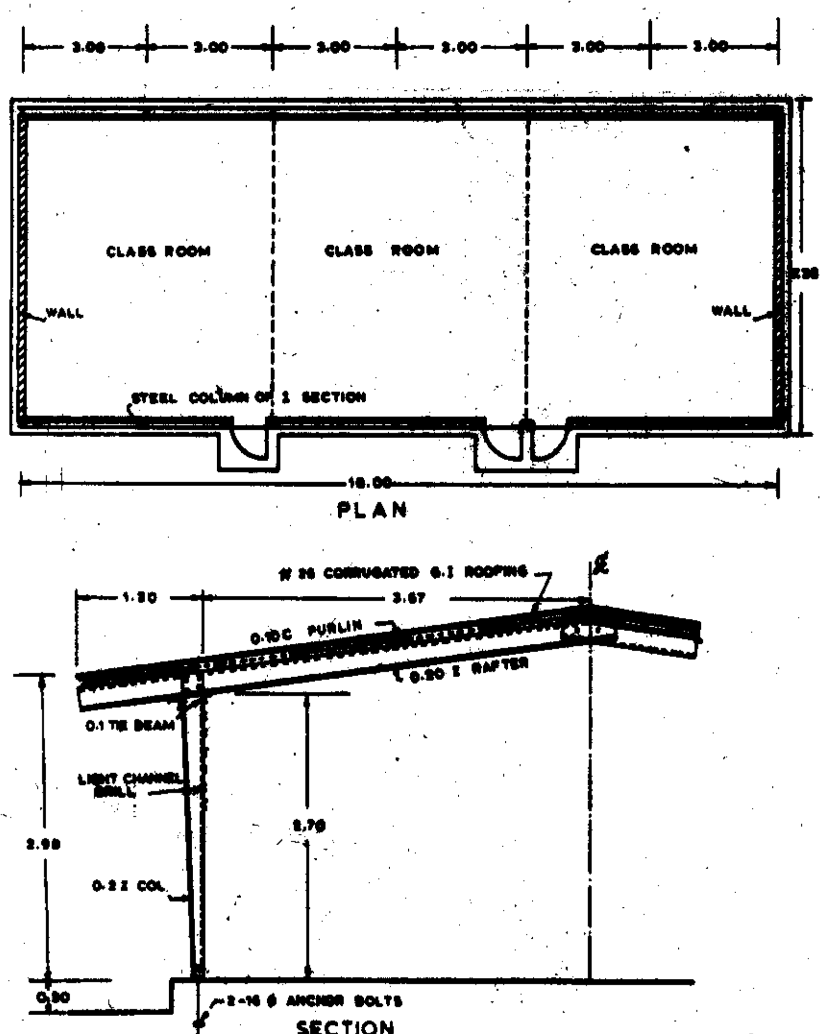

FIG. 16 _MARCOS TYPE PRE-FAB SCHOOL BUILDING, PHILIPPINES

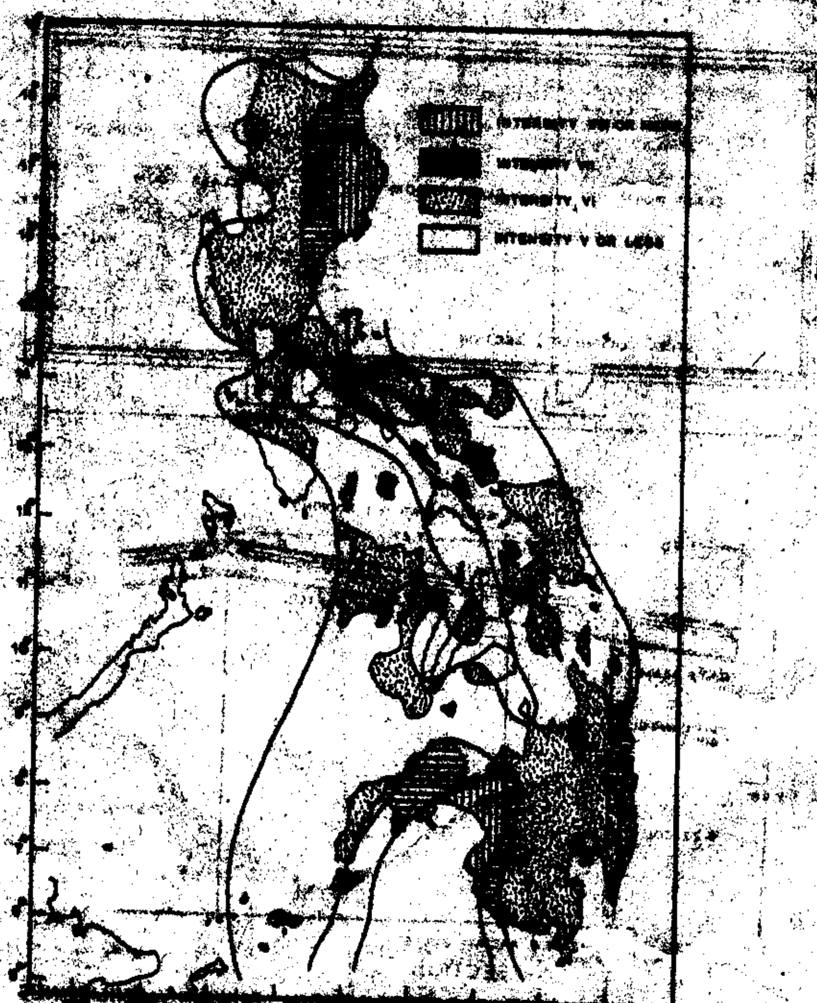

FIG. 17. OBSERVED INTENSITY MAP OF PHILIPPINES