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PAST, PRESENT & FUTURE OF ASEISMIC DESIGN AND CONSTRUCTION OF BUILDINGS IN AND AROUND SHILLONG IN MEGHALAYA

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INTRODUCTION

Considerable amount of building activity is going on in and around SHILLONG. With the formation of the new State of MEGHALAYA increase in building activity for Civil construction is also expected. Works are undertaken by MES, State PWD, CPWD, P&T Department and other private agencies. There appears to be a need for a detailed study of the practices followed by different agencies in design and construction of buildings in the past and present and evolve suitable practice for future construction of buildings in this region.

This paper aims at undertaking this study by collectiong and correlating data on the geological features, record of earthquakes and observed damages in the past, on the nature of buildings constructed, the practices followed currently and suggest suitable measures for safe and economical design and construction of buildings This paper covers the following aspects :—

(a) Study of local geological features of the area in brief and the effects of light and heavy earth-quake tremors and necessity for further geological studies of the SHILLONG Plateau from seismic and other considerations.

(b) Study of record of earth-quakes experienced in the past and damage/distress caused to the buildings.

(c) Comparative study of different types of construction, practices adopted in the region and their behaviour during earthquakes with a view to arriving at a rational and economical (construction and design) practice for earthquake resistant structures.

(d) Efforts have been made to recommend the type of design and construction to be adopted, building materials to be used and the various precautions to be observed. The economical aspects of the recommendations have been studied.

In undertaking this study, the authors were faced with considerable difficulty in obtaining authentically recorded data due to paucity of systematic observations and records, mainly because there has not been much organised development in this region in the past. Whatever development has so far been made, is relatively very recent. While the results of study made so far are presented here, it is admitted that this study has to be made a continuing process for quite some time more and the authors will welcome any additional information in this respect from observations and records in this region as well as suggestions from other engineers interested in this subject. Need for further studies has been brought out in the paper.

GEOLOGICAL FEATURES

The Assam Region is characterised by hills, mountains and valleys, prominent

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features being the narrow BRAHMAPUTRA valley with NEFA Himalayas to the North, Mizo and Mishmi hills to the East and North Cachar Hills to the South-East, Mikir, Jaintia, Khasi and Garo Hills to the South. To the South-east of Cachar Hills is the Surma Valley.- Naga Hills extend towards south into Manipur and into the Lushai Hills to the South-east. Thereafter starts the alluvial plain of East Bengal. The Garo and Jaintia Hills of the MEGHALAYA State form a spectacular bluff rising abruptly from the East Bengal Plain. This is known as SHILLONG Plateau and is highly susceptible to frequent earth tremors. These tremors are evidently due to the adjustment that is still going on in the block of peninsula which has been uplifted since the middle Jurassic times. Recent activity of this nature can be quoted as 1897 SHILLONG Plateau earth-quake. Innumerable light and heavy shocks are still being experienced due to the high susceptibility of this plateau. Further detailed geological study is essential with modern methods and techniques available at present for evaluating seismisity of this area which will be certainly of great help to the designers in future.

RECORD OF EARTHQUAKES AND DAMAGE CAUSED

The damage to structures during earthquakes depends mostly on the magnitude of earth tremor vis-a-vis strength of structures to with-stand. In this process not only the major shocks which cause damage but innumerable minor or micro shocks either deep seated or shallow seated also contribute, cumulatively, towards rendering the structures unsafe. SHILLONG city and its surroundings are geographically, politically and strategically important and hence the problem of protection of structures has to be given due importance. Although damage cannot be entirely prevented except at prohibitive costs, it is essential to restrict the same to the minium, commensurate with desired extent of safety. A thorough and detailed study of earth-quakes experienced in the past is essential. All such information has to be collected, analysed so as to arrive at the anticipated effects of future tremors with regard to frequency and magnitude, distress and damages likely to be caused. This will provide the designer basic data for visualising suitable type of constrution and necessary precausions for the safety of structures. Although, the present study is restricted only to a particular area, available record of earthquakes experienced in Assam is given in table No 1.

BRIEF REPORT OF 1897 SHILLONG PLATEAU EARTHQUAKE

Severity of June 1897 SHILLONG Platue earthquake with regard to its magnitude and coverage is briefly stated here :—

(a) The ground moved about 7" to and fro per second.

(b) All stone buildings in SHILLONG, GAUHATI and practically all over ASSAM, fell to the ground.

(c) Fissure of 3' to 4' wide 16 ft deep and 40 miles long was observed.

(d) River BRAHMAPUTRA rose in level by 4' to 5' for a period of 3 Hours; inundating large surrounding areas.

(e) Earth fissures and sand crates were reported from many parts.

(f) In SHILLONG, all masonry buildings were levelled to the ground and not even a stone was left standing over the other. An interesting feature during and after the earthquake was that a few structures most strongly braced together or having high degree of flexibility could sustain the shock with minor damages.

Considerable building activities are going on in and around SHILLONG. The various agencies/deparments engaged in the building industry are ASSAM PWD, CPWD, MES, P&T Dept, ASSAM State Electricity Board and other private agencies. Magnitude of these activities can be seen from the figures of total expenditure of over

10 crores of Rupees a year. Almost all types of structures like, living, office accommodation, recreation centres, public halls, dams, bridges, power house etc have been and are being undertaken by these agencies/depts. The problem of building structures to withstand such earthquake thus needs special consideration. The existing records are by no means comprehensive enough to provide complete guide lines for aseismic design and construction of buildings. It is important that Engineers observe and record the behaviour of structures in a more systematic manner, so that progressive improvement can be made in concepts of planning design and construction of structures safe against earthquake forces. A better system of observation and recording, therefore, needs to be evolved by co-ordination between the various agencies operating in this region. The "SRTEE" or the Institution of Engineers (INDIA) may also take initiative in this direction.

TYPE OF CONSTRUCTION UNDERTAKEN IN AND AROUND SHILLONG BY VARIOUS DEPARTMENTS/AGENCIES

Generally all types of construction have been undertaken and are being planned by various departments/agencies. They can be grouped as :—

(a) Temporary construction.

(b) Semi-Permanent construction.

(c) Permanent constrution.

It is interesting to study the past and present trend of construction work and various practices followed by different Departments/Agencies in SHILLONG. The age old local practice of Assam type construction which although meets many precautionary provisions of Indian Standard Code of practice and Codes of Practices followed in other countries for Aseimic construction, yet deviates from or practically ingnores the provision/stipulations of the IS Codes such asprovision regarding stability of foundation, rigidity of various foundamation pillar units, specified bearing for floor joists, holding down vertical posts and roof members against high winds. However, Enquiries from occupants revealed that except for some feeling of unsafety in staying inside the house during an earthquacke hardly any cases of severe damage or destruction of life and property were reported. Feeling prevails every where during an earthquake in whatever the type of construction it may be.

In other type predominantly observed to be adopted in local construction is to have Masonry (mostly stone) foundation pillars over which the superstructure is built. Some new constructions have been also done on PCC foundation pillars. The results of such constructions are quite satisfactory. Present trend is to provide RCC stilts and erect superstructures on it. Floor joists as well as RCC beams are run between tops of such stilts. But again there is no restriction as to the size and heights of such stilts. Stilt heights vary between 2′—0″ and 15 ft.

A building has been seen constructed on such stilts with size of RCC column of 6″ × 6″ height 12′—0″ and 1:2:4 concrete mix. There columns have not been braced or tied with ties at any level except below the floor level at tops of the stilts/columns. This building is standing for last 4 to 5 years. The design of this building seems to have been based on practical experience rather than the present precautionary measure recommended in the IS Codes (i. e. IS: 1893-1966 and IS-4326-1967).

Fig. 1 shows one of such buildings described above.

Third and most common type of construction being preferred and adopted in local construction practice is RCC framed structures with filler walls. In this type of structures also it was observed that all external walls were filler walls with cement concrete hollow blocks, while inside partition walls were of brick on edge. These walls were

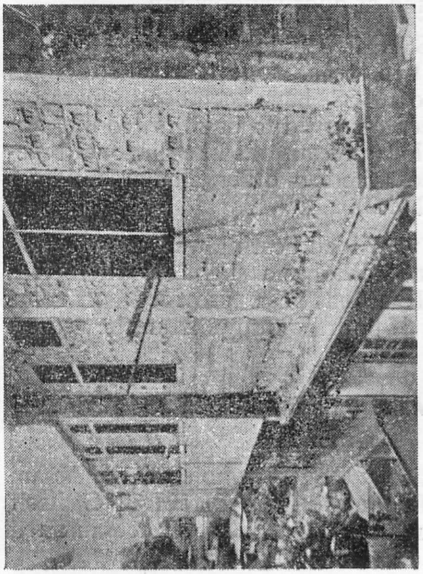

Fig. 2. Half Brick reinforced external walls without sufficients bands in the wall panels. Internal partition walls are without reinforcement at any course.

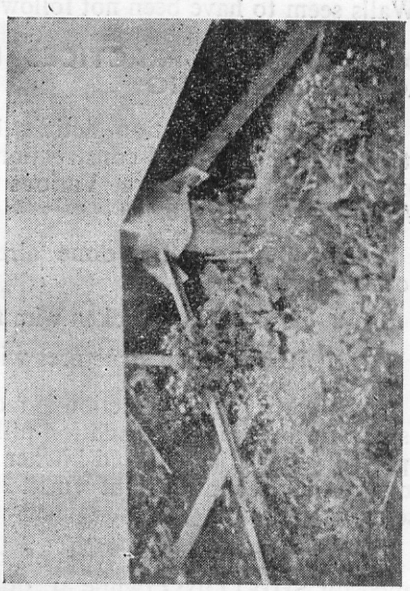

Fig. 3. Diagonal Bracing to the columns—Strengthening Measure.

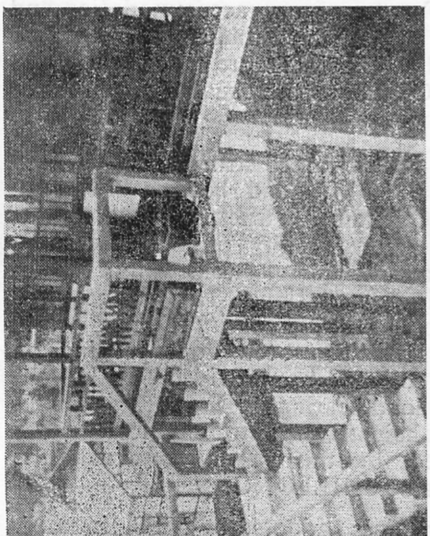

Fig. 1. Building Constructed with Slender columns and without ties at footing or at any other level.

constructed off the PCC floor to the under side of the RCC slab without any reinforcement in any layer or without any continuous lintel band at door/window top.

Construction by ASSAM PWD, CPWD (ASSAM) Circle and ASSAM State Electricity Board etc. seem to have been mainly of two types viz (a) framed structures (b) Assam type construction (construction activities of MES have been dealt separately in the subsequent para). Different practices have been observed to be followed by various departments. In some buildings, it is observed that precautions like diagonal bracings in the columns below plinth have been provided whereas other similar buildings are constructed without this provision. (See Figure No 2)

Although it is out of the scope of the paper to view load bearing wall construction outside SHILLONG, it may be mentioned that, Assam PWD has a slight deviation from the code provision i. e. "No plinth band at plinth level has been provided" in some buildings. Similarly, minimum distance at the jambs of doors/windows from the nearest X Walls seem to have been not followed strictly.

CONSTRUCTION PRACTICES FOLLOWED/ADOPTED BY MES IN AND AROUND SHILLONG

Building construction activity by MES practically covers whole of the Assam State. Our planning and construction programme for buildings in SHILLONG itself is of very much wide nature. Various types of construction is done for works connnected to Army and Air Force.

Type of construction done already and planned for future are mostly of the following nature :—

(a) Assam type (chicken wire mesh in wall panels)

(b) RCC framed structures with hollow block filler walls (Double storeyed.)

ASSAM type construction is mostly planned for temporary accommodation and consists of provision of foundation pillars PCC (1: 3: 6) on which timber floor joists are supported. In bath, WC and kitchen, PCC/PCC solid block walls are constructed from foundation to a certain height (max 200 cm) and PCC floors are usually provided for these units.

In case of permanent type of constructions, RCC framed structures have been planned for SHILLONG (while at other places in ASSAM" Load bearing brick wall construction has been adopted). Adoption of RCC framed structures with hollow cement concrete block" filler walls is mainly due to nonavailability of good bricks and sloping ground. Sloping ground would involved excess heights of bricks wall in foundations, weakening them resulting in instability of such walls on slopes. This also required increased thickness of walls below plinth resulting in increased quantity of brick work. In some of the cases composite type of construction has also been done judging on merits of the individuale cases. In such cases RCC columns are provided to take concentrated loads i. e. under the trusses or beams and load bearing brick/block wall construction is done between these columns to a certain height i. e. upto lintel level. This has one advantage that plinth beams can be omitted, but this type of construction is recommended for few constructions and that too outside SHILLONG.

In all types of these above construction practices adopted by MES in north Eastern Zone, the designs are based on relevant IS Codes of Practice (i. e. IS-1893-66 and IS-4326-1967). Practically all the provisions for seismic consideration recommended by IS Code of Practice are being strictly followed, irrespective of increased cost considerations. However, some recommendations are not clear. These are mentioned subsequently,

OBSERVATIONS ON DISTRESS/DAMAGES CAUSED TO STRUCTURES DURING AND AFTER THE EARTHQUAKE

When a survey was carried out in SHILLONG by the authors on available records of damage/distresses caused to various structures during earthquake shocks in the past, such records were not available, unfortunately with any of the Department/Agency. In fact this is an very important aspect and has been neglected on wide scale. Another interesting aspect observed was that even adequately qualified staff on execution of works appeared to be ignorant and not interested in the knowledge and technical reasons for various provisions recommended in IS Code of Practice for Aseismic design of structures. General feeling was that they are responsible for only execution of work based on designs and drawing supplied to them by higher authority/Design office and they never felt a need to go into the pros & cons of the various precautionery measures for which they were actually supervising. It is conceivable that any structure, though designed as earthquake resistant will still suffer increasing distress due to successive earthquake shocks affecting stability. There is a great need therefore, of observing the same structures after successive earthquakes and recording such distress/damage as these records will warn designers, as to what necessary precautions need to be taken to nullify even small effects in future. It is recommended that maintenance of such records is undertaken by all the Government Departments and other construction agencies, so that record of damages/ distresses (small scale or large scale with probable reasons) is available for future guidance. These records will help in determining the deficiencies in the past and current design and construction practice and enable modifications for future.

Damages generally observed in various types of construction in SHILLONG were of the followiog nature.

(a) In ASSAM type construction, generally it was seen that the structures have stood sound during and after sufficiently severe earthquake shocks also. However, cracks were especially seen along the vertical continuous posts of door/windows frames as shown in fig. 4.

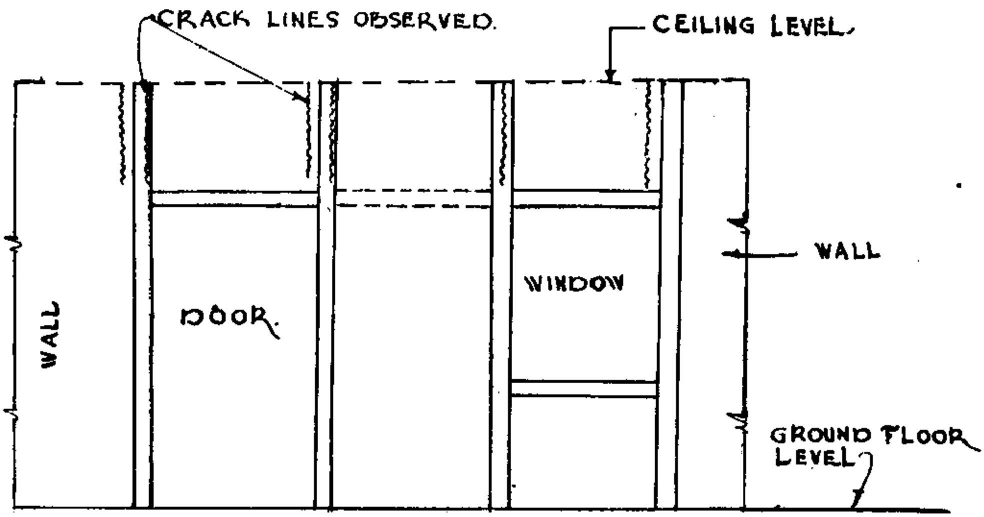

Fig. 4.

In some cases, where timber trusses are supported on vertical timberposts (size 15 cm × 15 cm) and embedded in the wall were seen got deflected (by @ 2″) towards one side causing undue stresses and distortion in the whole wall panel.

(b) In framed structures construction at some places diagonal crack were seen in the 1/2 hollow block filler wall with door/window openings the reason may be :—

(a) Faulty construction.

(b) No provision of steel reinforcement in 1/2 thick hollow block wall.

(c) Use of substandard hollow blocks.

(c) At present it is observed in SHILLONG, that in a framed construction practically all inside walls have been constructed of 3" thick reinforced brick work, off the PCC floor. As this is a new practice of the recent origin in SHILLONG. No records or otherwise any on the spot information is avoidable about behaviour at present (see figure No. 4)

STUDY OF SOME OF THE RECOMMENDATIONS OF INDIAN STANDARD CODE OF PRACTICE FOR EARTHQUAKE RESISTANT STRUCTURES

As pointed out earlier, the clause 3·5 of IS 4326—1967 refers to provisions of crumple section. Separation of adjoining structures or parts of the same structure is required to avoid damage due to collision when they have different total heights.

On this subject of providing crumple section; it is seen that every designer has got his own judgement in providing or otherwise the crumple section in a building Again it is not clear from the above clause as from what height difference onwards crumple section is required. For example if the difference in adjoining floor heights is say less than one metre, some design engineers may provide crumple sections, due to the existing wording of this clause, although the general opinion appears to be that for such small differences in height crumple sections could be avoided. This clause may therefore need to be reexamined.

The horizontal seismic coefficient given in IS-1893-1966 (clauses 3·4) has been specified as per the type of soil (viz type I, II & III). In our opinion the coefficients would also depend on the type of construction and frequency of earthquake shocks in the region of construction. These aspects need consideration and modification of the clause.

LOCAL BUILDING MATERIALS

Regarding availability of local materials and their suitability for incorporating in the works it is hard to say that these materials meet the full requirements towards quality and strength.

Aggregate are derived mostly from NONGTHUMAI & MOWLAI stone quarries. This is a sand stone variety. These stones are used for road metal and aggregates for concrete works. Sand is derived from MILLIUM river and used widely in all the concrete works.

Timber required to be used in all wood work except in special cases is obtained locally. Red & white pines are the varieties of timber available. Out of these two, red pine wood is better. However, seasoning as well as anti-termite treatment is also required when this timber is used in permanent buildings.

Bricks of good quality are not available because of poor soil. Similarly, to procoure bricks from outside of SHILLONG is costly affair as the transportation cost is high. Hence, walling is generally in hollow concrete blocks in framed construction.

Lime : source is at CHERAPUNJI and lime is mostly used in EKRA wall panels in local construction practice.

RECOMMENDATIONS FOR SUITABLE PERMANENT TYPE OF CONSTRUCTION FOR THIS REGION

In following plan four various types of constructions are taken for example to have cost comparison. While recommending the final, economical type of construction certain things like availability of building materials ease in construction and life of the structures have been taken in consideration to the maximum possible extent.

The four types of construction are briefly described below :—

Type I—Framed structure with hollow block filler walls. External walls 20 cm thick. Internal walls 10/20 cm thick RCC slab for roof.

Type II—Framed structure with brick filler walls external walls of 1 brick thickness internal walls of 1/2 brick thickness RCC slab roof.

Type III—Framed structure, external walls of 20 cm thick hollow block filler walls. Internal walls with 2″ thick chicken wire mesh type (single)

Type IV—Framed structure External walls of hollow concrete blocks 20 cm thick. Internal walls of double chicken wire mesh type construction.

TABLE NO. 2
COST COMPARISON

Sr. No	Type of construction	Total cost (approx) in Rs.
(a)	(b)	(c)
1.	**Type I**—RCC framed structure, external walls with 20 cm thick cement concrete hollow blocks Internal walls with 10 cm thick hollow blocks.	Rs. 7,750·00
2.	**Type II**—RCC framed structure, 22 cm thick brick external walls, ½ brick thick internal walls.	Rs. 7,300·00
3.	**Type III**—RCC framed structure, external walls with 20 cm thick hollow blocks. Internal walls with single chicken wire mesh	Rs. 6,610·00
4.	**Type IV**—RCC framed structure, 20 cm thick hollow blocks external walls and double chicken wire mesh panels, for internal walls.	Rs. 7,000·00

On examination of Table No 2 it can be seen that the buildings constructed with permanent specifications with four alternative constructions the cheapest alternative is type III i.e., RCC framed structure with external walls of 20 cm thick hollow blocks and internal walls with 5 cm thick chicken wire mesh pannels. This of course, will give plain surface on one side only, for the internal walls. If plain surfaces are required on both the sides "Double chicken wire mesh panel walls" (type IV) construction can be adopted for higher income group. This still will be cheaper than type I and type II construction.

The advantages in type III construction are of the following nature :—

(a) It can be adopted for permanent construction.

(b) Safety is achieved by providing external walls of sufficient thickness.

(c) Total dead load and the resulting mass of the structure can be considerably reduced, which is a need for aseismic design of buildings.

(d) With lightness of internal walls ceiling of safety can be graded for occupants. Also actual damages to the property inside can be negligible even after earthquake.

(e) Best use of locally available building material can be effected.

(f) Considerable economy can be achieved without damaging the safety of the structure.

Apart from the foregoing study, the authors have also undertaken the examination of the following types of construction and determining their suitability and economics.

(a) Load bearing Hollow Cement Concrete Blocks construction.

(b) Load bearing structure above plinth and supported on system of columns and beams below plinth.

(i) Same as above in (b) brick work procured from other places.
(ii) Same as above in (b) with brick work with bricks manufactured locally.
(iii) Same as in (b) above with hollow cement concrete blocks work.

(c) Framed structure to be constructed above stilts for super structure with hollow block panel walls.

(d) Possibility of manufacturing stabilised soil cement load bearing blocks and using them in construction.

While concluding, following recommendations are made for achieving improvement in the existing knowledge and practice of earthquake resistant design and construction of buildings in this region :—

(a) Full and complete geological study of the region and data made available commonly.

(b) A net-work of stations for recording light and heavy earth tremors with modern equipment.

(c) More study on deep seated and micro earth tremors and data analysis.

(d) Setting up of more small scale and large scale Research Laboratories so as to carry out detailed study of the various properties/strength and sources of available building materials, water resources, its suitability in construction, climatic conditions etc.

(e) Govt. department and other construction agencies should undertake to observe and maintain detailed and systematic records of damages to structures in successive earthquakes.

(f) Institution of Engineers through their local centre or a similar organisation should undertake to coordinate engineering thought and practice between the various construction agencies so that consistant design and construction practices are followed.

(g) Setting up a Team of experts to study the local available labour in connection with the skill, workmanship standards (which are found vary poor generally) working conditions and working hours depending on season-climatic conditions and their total output. This has a direct relation to the quality of work which normally is recommended to be of very high standard for seismic regions.

TABLE—I

RECORD OF MAJOR EARTHQUAKES ORIGINATING FROM ASSAM AND ITS SURROUNDING REGIONS

Sl. No.	Date of occurrence	Probable Epicentre	Description Remarks
1	2 Apr 1762	Arakan region of BURMA	The shock was very severe over Arakan coast in BURMA and over parts of BENGAL.
2	3 Apr 1822	Indo-Burma Border Region	Felt over Bengal and parts of Bihar was severe in East Bengal.
3	8 Jun 1828	Southern Border of Khasi Garo hills.	Large number of shocks were felt most severe Mymensingh in East Bengal.
4	23 Mar 1839	Upper Burma	Destructive over North Burma.
5	11 Nov 1842	Bengal-Burma Border	Felt widly over Bengal, Assam and parts of Bihar. This had a deep seated epicentre.
6	6 Apr 1843	Upper Assam	A number of shocks at least one of which was violent over upper Assam.
7	16 Jun 1843	Upper Assam	A very violent shock over Upper Assam.
8	6 Aug 1845	Khasi Hills Regions.	Destructive at Sylhet, Gauhati, a large train of aftershocks followed, few at these were violent.
9	24 Aug 1858	Upper Burma	A very severe and destructive earthquake affecting North Burma, Burma, including Prom, Akyab Kyakpya.
10	18 Dec 1869	Burma-Bengal Border	Severe over East Bengal.
11	10 Jan 1869	Cachar (North Eastern side of the Shillong plateau)	This was felt over an area of 250,000 Sq Miles Earth fissures and sand creles were very abundant.
12	22 Apr 1870	Bengal Assam Border	Felt over whole of East Bengal.
13	13 Oct 1882	Epicentre not correctly known	Felt over Assam evidences insufficient.
14	14 Jul 1885	Assam-Bengal Border	Felt over East and middle Bengal.
15	24 Jul 1885	Bengal Burma Border.	Felt over East Bengal.
16	10 Oct 1885	Burma	Felt over Burma.
17	23 Dec 188	Epicentre not known	Felt over South Bengal.
18	17 Jun 1891	—do—	Felt over Bengal.
19	12 Jun 1897	Shillong Plateau Khasi, Garo hill region.	R. D. Oldham described this earthquake as the severest during the historic times. This was felt over an area of 1750000 Sq miles. Destruction of adobe building was almost universal

Sl. No.	Date of occurrence	Probable Epicentre	Description Remarks
			in Shillong, Goalpara, Gauhati, Nowgong and Sylhet, Calcutta was seriously affected about 1600 lives were lost. This was followed by large number of aftershocks continuing for 10 years.
20	12 Jul 1908	17°N, 97°E	Magnitude 7·5.
21	12 Jul 1918	Near 24½°N 92°E Srimangal	Magnitude 7·6 This was felt over an area of 80,000 Sq miles. Sympathetic shocks were felt at Madras and Arakan coast.
22	28 Jul 1930	Lat 25°·8 N Long 90°·2E Near Dhubru	Magnitude 7·1. This shock was felt over an area of about 350000 Sq miles. No loss of life was recorded.
23	9 Sep 1923	Lat 25½°N 90°·2E	Magnitude 7·1. This shock was felt over Assam, Bengal, East Bihar and Chota Nagpur. Some damage was caused too destructive near epicentre over West Assam and East Bengal.
24	14 Aug 1932	Lat 25°·8N Long 95°·7E (Near Burma)	This shock was felt over Assam, Bengal, North Bihar. Semi destructive near the epicentre region and some damage over Eastern parts of NE Assam was recorded
25	21 Jan 1941	Lat 27°·5N Long 92°·5E North Assam	The shock was felt near Assam and North East Bengal. Some damage near epicentre was reported.
26	23 Oct 1943	Lat 27°·5N Long 93°·5E	The shock was felt over Assam, Bengal and major parts of Bihar and North East Orissa. Destruction was caused over Northern parts of Assam.
27	29 Jul 1947	Lat 28°·5N Long 94°5E (100 miles N W of Dibrugarh)	The shock was felt over Assam, in Bengal up to Calcutta and in Bihar up to Patna. Some damage to buildings was reported to parts of North East Assam.
28	15 Aug 1950	RIMA	One of the biggest Earthquakes of the world. Similarly, shocks experienced on 29 Jul. and 24 Aug. 70 were also of quite high magnitude although felt for a short duration.