Paper No. 38

BUILDING PRACTICES IN SEISMIC ZONES OF NORTH BIHAR, NORTH BENGAL AND ASSAM

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SYNOPSIS

Buildings which were damaged and which survived the past earthquakes in North Bihar, North Bengal and Assam, along with the recommendations made for improving their aseismicity are described briefly in this paper.

INTRODUCTION

North Bihar, North Bengal and Assam lie in the foot-hills of the Himalayas which form the major part of the Asian Seismic Belt. During the past century and perhaps from times immemorial, these areas have been shaken up violently by earthquakes, many of which have been devastating. Since these seismic paroxysms can neither be predicted nor averted, people in these areas have reconciled themselves to "live" with them. Damage inflicted by strong earthquakes in the past have provided the people engaged in the building trade with invaluable information leading to safer structures. Some of the methods and types of construction that have evolved as a result of these observations came about long before the modern technology of earthquake engineering was rationalised and developed. However, it is not only earthquake resistance that influences the types of construction; other factors like climatic conditions, natural resources, availability of building materials and the economic condition of the people are no less important. At the same time it must be recognised that geology of the site, soil properties, interaction of the structure and the ground and distance from the fault planes also have important bearings on the aseismic property of a building. Nevertheless, a study of the building practices in these areas can be quite revealing and the paper describe briefly the types of structures that are common in North Bihar, North Bengal and Assam.

1. NORTH BIHAR

Important cities that bear witness to the destructive powers of two great Indian earthquakes of August 26, 1833 and January 15, 1934 lie on the flood plains of the River Ganges and Buri-Gandak. Purnea, Motihari, Pusa, Madhubani, Chupra, Muzaffarpur and Darbhanga lie to the north of the Ganges whereas Patna, Jamalpur, Dinapore, Bankipore, Mokameh, Gaya and Monghyr are situated south of this river. In general, the cities are all on a deep bed of alluvium. Monghyr, however, is close to the junction of the alluvium and Archean basement and is known to suffer from more shocks than any other place

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south of the Ganges (1)*. These cities are very hot in summers and cold in winters. There is also a fair amount of rain during the monsoons. Thus, buildings, in such areas have to cope up with the severity of the weather. Moreover, in the early twentieth century, shift of population from villages to towns due to industrialisation resulted in a congeries of buildings, a description of which would be an inordinately difficult task. However, a broad classifications can be made based upon the material of construction.

1.1. "Kutcha" (Temporary) House or the Village Hut :

This has been in the lot of the Indian villager for many centuries and still continues to be the main form of residence. In Bihar, the hut is usually constructed of mud walls. No proper foundation is made and the plinth is raised from the ground level to about 1 ft. in mud itself. Normal practice is to make the walls varying uniformly from about 4 ft. thick at the base to about 2 ft. thick at the roof level. The clayey mud is mixed with local species of straw, ("dhabi", "khar"), wheat or rice husk and pounded well to a paste. Rough prismatic blocks 9"x6"x6" are made by hand, and when still moist, lain one above the other with no set pattern. The walls are then smeared with the same mud-plaster on both the sides. Roof is pitched, consisting of timber ridge and eaves made usually from trunks of palm trees. Bamboo and twig matting is then provided and the roof covered by either thatch or Nurria tiles. Since the walls are often eroded by the weathering action of the rains, villagers who can afford, build in third or fourth class brick masonry in mud mortar upto the plinth level. Village huts get easily damaged during earthquakes of moderate and even low intensity. It was observed in the 1934 earthquake that collapse of tiled roof huts was larger than thatched roof huts (1). Fig. 1 shows a typical village hut near Muzaffarpur. It will be interesting to note that in the 1934 earthquake this was the only hut that was undamaged in the village and it still stands today.

Fig. 1. Village Hut in Bihar.

*Refers to Serial Number of Reference given in the end.

1.1.1. Recommendations made after 1934.

Noting the wide-spread damage to these "Kutcha" buildings it was suggested by Nasu that walls of mud houses should be thick at the base and thin at the top, the inner and outer surfaces having parabolic cross-section (1). The author had an opportunity of visiting some villages around Muzaffarpur and it was found that this has not been adopted and the walls are of the traditional form. Another method which is suggested for strengthening the mud walls against weathering effect and earthquakes is by the provision of bamboo "jaffri" or bamboo-wattle placed at the centre (2).

1.2. "Kutcha-Pucca" (Semi-Permanent) Houses

There are four types of such houses :

(a) Buildings of unburnt bricks or adobe in mud-mortar
(b) Buildings of poor quality class three or four burnt brick masonry in mud-mortar.
(c) Combination of (a) and (b); exterior surface being of burnt bricks and the interior of adobe, both in mud-mortar.
(d) Houses of brick or mud-nogging raised on timber frames, confined mainly in Chupra and Muzaffarpur.

Generally, the brick walls are 1½ or 2 bricks thick. They have a fairly low heat transmission coefficient. Thickers walls were not in practice since they increase the heat capacity of the house. The interior gets heated up quickly during the day and does not cool off quickly enough at night. "kutcha pucca" buildings formed the major proportion of the private buildings in most of the cities of Bihar before the 1934 earthquake due to paucity of materials like cement, steel and good qualty bricks. Most of the "bazaars" had rows of tall two or three storeyed structures, with balconies and "chajjas", built very close together on both sides of narrow winding lanes In most of the cases, these houses also had either tile or thatch roof covering. Buildings with lighter covering were more earthquake resistant.

Type (d) brick or mud nogged houses at Chupra (R F., Isoseimal 8, 1934) were found to be better than ordinary brick built houses. Even though walls were heavily cracked in many instances, the timber frames were found intact. In such cases the walls could be repaired without much difficulty. The best building of this type consists of complete frame-work of timber with the dead-weight of the roof shared by both brick work and timber frame. It was also noticed that verandahs supported by timber up-rights were safer than those raised on brick-nogging.

A two storeyed "kutcha-pucca" house at Muzaffarpur which suffered very minor damage during earthquake wheras hundreds around It collapsed, has outer walls made of second class brick masonry (English bond) in poor lime-sand mortar, 20" thick throughout. Interior walls are of poor quality bricks in mud-mortar. The verandah roof is supported by slender sal timber columns which merely rest on sandstons soling in both the storeys. Top storey columns shifted 3/4" at the base during the earthquake (Fig. 2). The roof is flat and made of sal timber joists covered with brick tiles and earth.

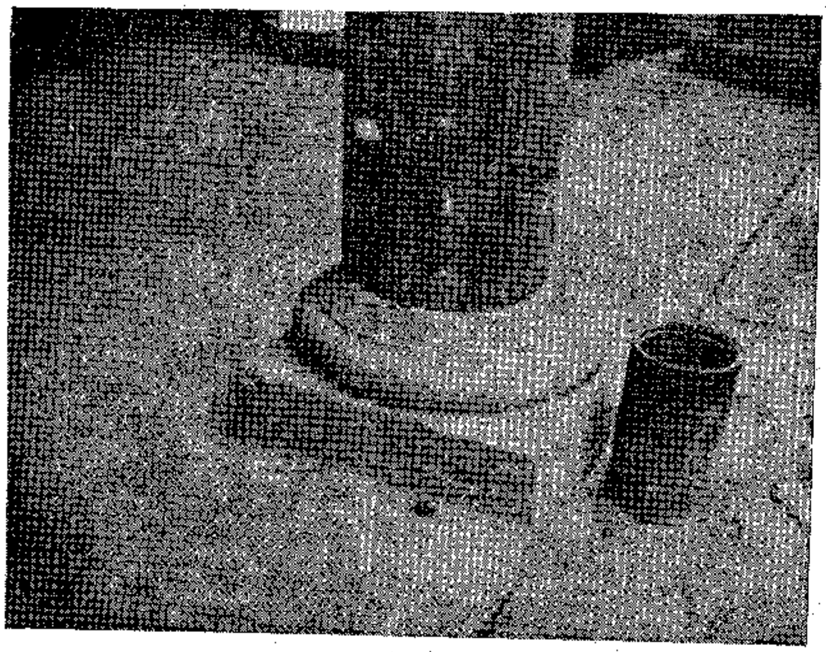


Figure 2 Timber Column on Sandstone Soling.

1.2 1. Recommendations made after 1934 :

Since mostly two or three storeyed buildings collapsed, it was suggested that only single storeyed "kutcha-pucca" houses should be constructed in future. Walls also should not be less than a standard minimum thickness.

The use of timber frames from locally available timber (sal, sisu, jack-fruit and palm) was also recommended. Columns were to be supported on a platform or sole plate, well tied by cross and diagonal beams and firmly attached to the roof. The weight of the roof would thus be shared both by the wall and timber pillars. Thus, instead of every structural element vibrating independently, the building will vibrate as a unit and chances of survival would increase.

In spite of the fact that "kutcha-pucca" houses were damaged more than "pucca" buildings or even mud-huts, such two or three storeyed private buildings are still being constructed in almost all cities of Bihar.

1.3 "Pucca (Permanent) Buildings :

These could be divided into three main types :

(a) One or two storeyed first class brick masonry buildings with lime or cement mortar.

(b) First class brick masonry construction with steel framework.

(c) Reinforced concrete structures.

Most of the Government buildings are of type (a). Type (b) and (c) are generally industrial buildings. Many type (a) buildings collapsed all over Bihar and North Bengal. In the type (b) Tobacco factory at Monghyr (R.F., Isoseismal 9, 1934), the brick-work fractured and the steel frame-work was thrown out of alignment. It would be interesting to note that steel window frames buckled but wooden frames were undamaged in the building. However, reinforced concrete structures escaped damage (1).

In general, type (a) buildings which suffered badly had rich ornamention work, roof balustrades, balconies, chajja, verandahs and porches with series of independent pillars, the roof merely resting on top. Arcuated facade was a common architectural feature then. Roofs were jack-arched or the clumsy roof of beams and rafters with bricks. Ill maintained tiled proved proofs very hazardous.

It will be worth while to describe one such buildidgs in greater detail. The Civil Court Building at Laheria Serai (R.F. Isoseimal 8, 1934), was a two storeyed structure aligned E-W (3).

(i) Foundation and plinth were of first class brick in lime-mortar, resting on a bed of lime-concrete, 18" thick. The top two courses of brick work in plinth were in cement-sand mortar to serve as damp-proof course.

(ii) Superstructure was of first class brick masonry in lime mortar. Ground floor walls were 25" thick and first floor walls 20" thick.

(iii) Ground floor was of 3" Mirzapur stone on 3" lime concrete over a layer of brick flat. First floor was of 2" Mirzapur stone on 2" lime concrete over jack-arches supported on steel joists.

(iv) Roof—In order to prevent echo, the court room ceilings in first floor were of 4" beaten terracing on two layers of flat tiles resting on tee-iron "burghas" and steel joists. Over the other rooms, roof was of 3" beaten terracing on steel joists (Fig 3).

The earthquake cracked the main portico of the building and the N.E. corner of the eastern first floor wing crashed and fell outwards. Roofs of the building proved very susceptible to the shock; they either collapsed or were badly cracked. The verandahs also collapsed and fell outwards.

Hundreds of such buildings were razed to the ground all over Bihar. However, here and there, several, well built structures escaped unscatched.

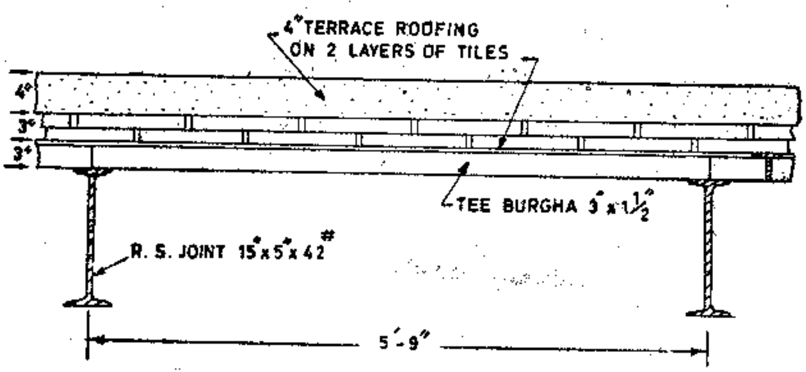


Fig. 3 A. Roof of Court Room, First Floor, Civil Court, Laheria Serai.

Note :—Specification, 1935, for Terrace Roofing.

1. Mix-Dry Volume (Lime 1 : Surkhi 1½ : Brick Khoa ¾" to 1" Gauge 4).
2. Terrace supported by R.C.C., R.B., Tiles (Ribbed or Plain), Dharhara Slates, Stones Slabs or a Layer of Flat Bricks Resting on inverted Steel Tees.
3. ⅜" thick cement mortar (1:3) to be used between tiles and tees.

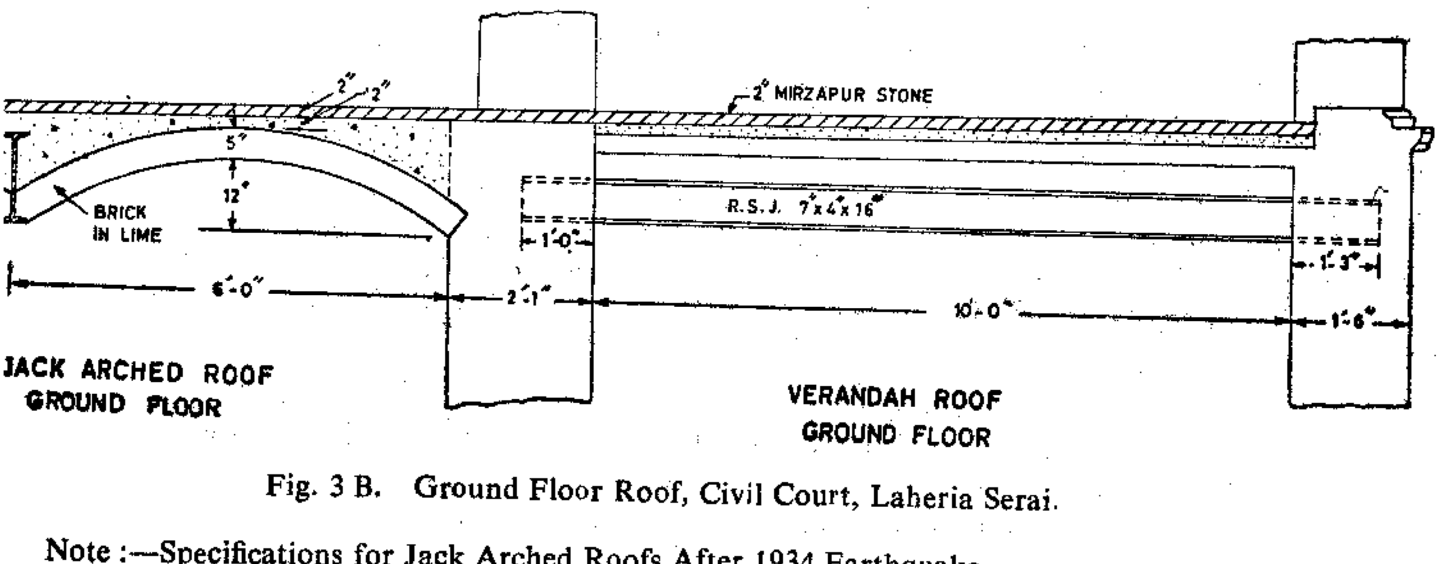


Fig. 3 B. Ground Floor Roof, Civil Court, Laheria Serai.

Note :—Specifications for Jack Arched Roofs After 1934 Earthquake.

1. Not to be used in North Bihar except for replacement of damaged roofs.
2. Cement mortar (1:3) to be used around supporting R.S. Joists.
3. Jack arches should be sprung from the top flange whenever possible.
4. Arches to be in first class bricks, 5" thick set in fine lime mortar (1 lime : 3 Surkhi)
5. Rise = 1" per foot of span.

The two storeyed "pucca" brick masonry Zilla School building constructed in 1910 as per the spcifications of the P.W.D , North Bihar Circle, presents an interesting study. Ground floor of the two storeyed class room block has an arcuated facade with excellent herring bond (dove-tailed) brick masonry filling over the arches. First floor has a trabeated facade with an R.S. joist running right along the length of the building over brick masonry piers supporting the roof over an arched corridor Walls are of first class brick masonry 30″ thick in lime-sand mortar (1:2). The hall is situated centrally and at right angles to this block. It has a narrow gallery at the first floor level supported by a collonade of circular brick columns. Roofs over both the blocks are pitched and covered by Nurria tiles. The passage (Fig. 4) between the two blocks at the first storey level collapsed during the earthquake Besides some minor cracks in the wall and slippage of tiles from the roof, this building did not suffer appreciably. The two blocks, because of their dissimilarity, had different periods of vibration but the damage was safely concentrated in the passage, a lighter and more fragile structure. Rear view of the building (Fig 5)

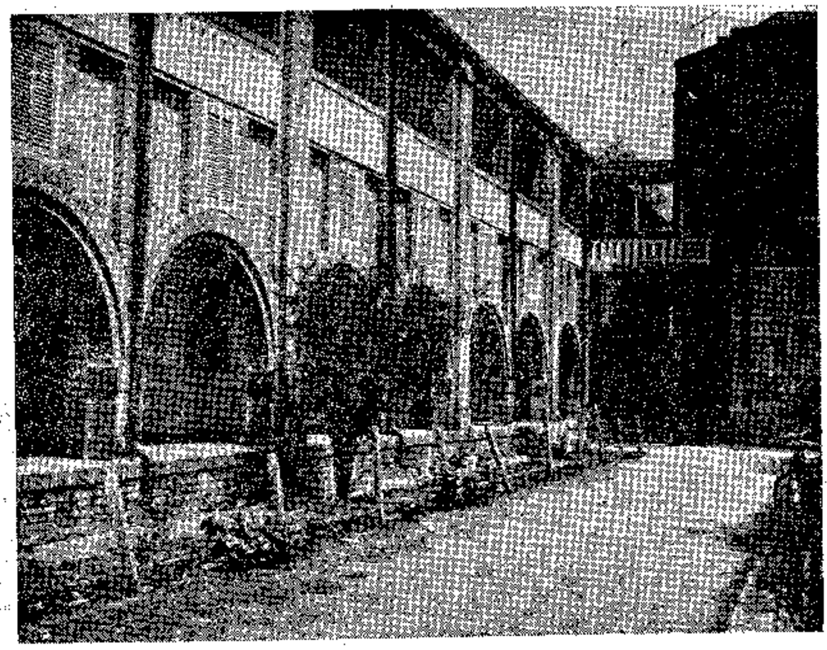


Fig. 4 Passage between Classroom Block and Hall, Zilla School, Muzaffarpur.

shows the exposed R.S. joists at the roof level of the ground floor. Specifications of N. Bihar Circle, 1935, however, indicate that a 3″ cut-brick in cement mortar is to be provided beyond the 3/4″ expansion gap at the end of R.S. joist resting on bed stone or R B. lintel at the top of wall (4).

It will be interesting to note that brick "Jali-work" (Fig. 6) at L.S. College,

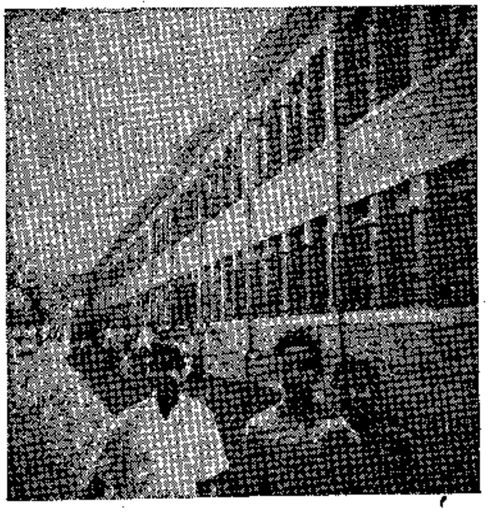


Fig. 5 Rear View of Zilla School, Muzaffarpur: Note the exposed steel joists.

Muzaffarpur was not affected at all. Another instance of the survival of "Jali-work" in lime-mortar can be found in the Muzaffarpur Club Swimming Pool (Fig 7) constructed in 1885. This is 90'x30' structure, 30' high with a 20 gauge G.I. roof supported on M.S. russes Joints are bolted and ends anchored to the walls in the usual manner.

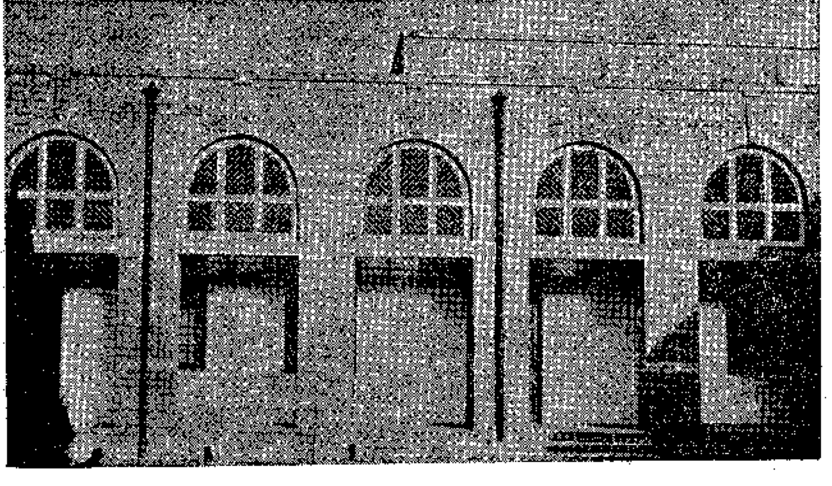
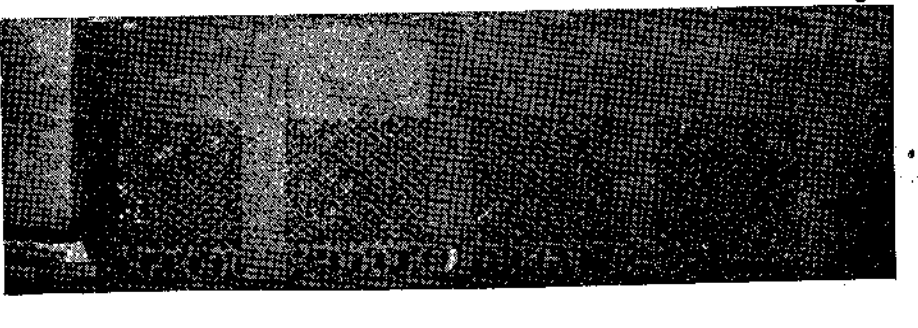


Fig. 6 Brick "Jali-work" in L.S. College, Muzaffarpur.



1.3.1. Recommendations made after 1934 :

After studying the performance of different types of buildings and constructions, certain recommendations were made for rebuilding. The necessity of tying the foundations by means of tie beams in order to make the structure vibrate as a whole and prevent it from spreading, was emphasised. This should serve well for the single storeyed structure. Raft foundation was suggested for public buildings and buidings greater than one storey.

Another type of foundation, the "Salvus Foundation", was suggested in 1935 by R.W. de Montalk, a New Zealand architect, for the seismically active places in India (5). This consists of a thick bed of shingle called severer, kept in position by a strong rim of concrete forming part of the foundation. On top of the shingle is a sole-plate, namely, a R.C. slab occupying the whole area of the building and forming a unit with it. The building accordingly "floats" upon the shingle. When an earthquake occurs, it is claimed that the foundation will take the shock and that the shingle will absorb it, although the shingle itself, being comparatively "fluid" will move underneath the sole-plate and very little of the shock will be transferred to the building.

Windows should be kept away from the outer corners of buildings as far as possible. Wide window areas should be compensated by strong intervelling walls. However, the present specifications impose no such restriction. Reinforced lintels are to be preferred over door and window openings. Where possible, they should be at the same height in a floor and carried around the walls as a single band, but this has also been omitted in the current specifications.

Roofs should be light since during large vibrations, the inertia of heavy roofs break the walls on which they rest. Necessity of tying the roofs with the wall was also felt. Gable ends should also be avoided and hip-roof construction preferred.

For heavy important structures and industrial buildings, steel or R.C. framework with brick or cement concrete panelling was suggested.

2. NORTH BENGAL

North Bengal has also been severely shaken by many earthquakes in the past (Assam 1897, Bihar 1935, Dhubri 1930, Assam 1930). Important towns are Jalpaiguri, Siliguri, Bagdogra and Cooch Bihar in the plains and Darjeeling, Kalimpong and Kurseong in the hills. A large number of tea estates are also scattered all over North Bengal.

2.1. "Kutcha" and "Kutcha-Pucca" Construction :

Buildings and houses constructed in this area could also be classified into three types mentioned earlier. Villagers and tea-pickers in the valleys have the usual mud-walled huts but thatch roofing is more common. Due to availability of bamboo in large quantities, bamboo-wattles plastered with a thin layer of mud are often used as walls. These are usually very thin and light. In higher altitudes where timber is abundant, log cabins are also constructed. These have walls made of timber planks. Roof usually consists of ridge and eave pieces covered with G.I. sheeting or thatch. A bricknogged building of the type shown in Fig. 8 (Darjeeling) could be classified as "kutcha-pucca" construction.

Fig. 8 Brick-nogged Building in Darjeeling.

2.2. "Pucca" Buildings :

Stone being available locally, stone masonry buildings are very common in Darjeeling, Kurseong and Kalimpong. Some of the structures which suffered badly during the 1934 Bihar earthquake were rather old and constr cted of heavy undressed stone masonry, set in mud or poor quality mortar, with foundations on loosely aggregated subsoils. Oberoi Hotel Mt. Everest with its heavily buttressed walls (Fig. 9) and light top floor suffered very little damage. Fig. 10 shows a three storeyed house, bottom two storeys are in rubble masonry and top floor is of metal lath-plaster with steel bracings. (Metal lath sheeting is usually from coal-tar drums. Holes are perforated in the sheets and placed within timber or steel framework. These are then plastered on both the sides giving a wall about 2" thick).

In the area of maximum damage (1934, even in the midst of fallen houses, R.C. structures stood almost unharmed as also did well constructed new buildings of brick or dressed stone.

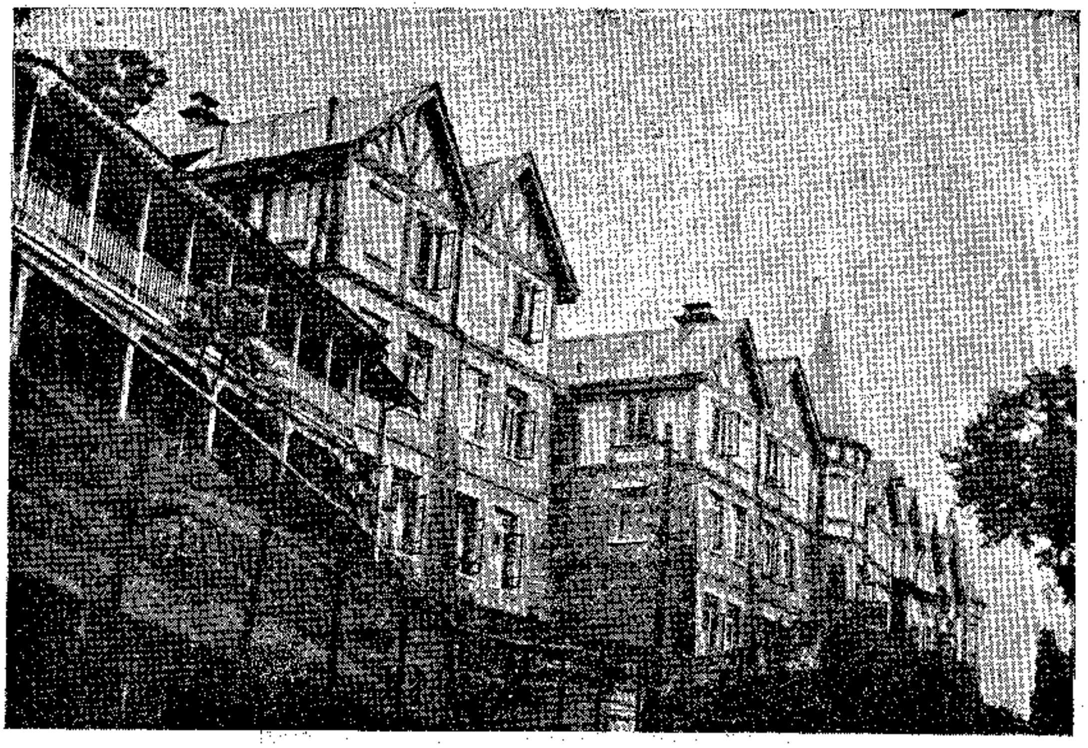


Fig. 9 Stone Masonry Buttressed Walls of Mt. Everest Hotel, Darjeeling

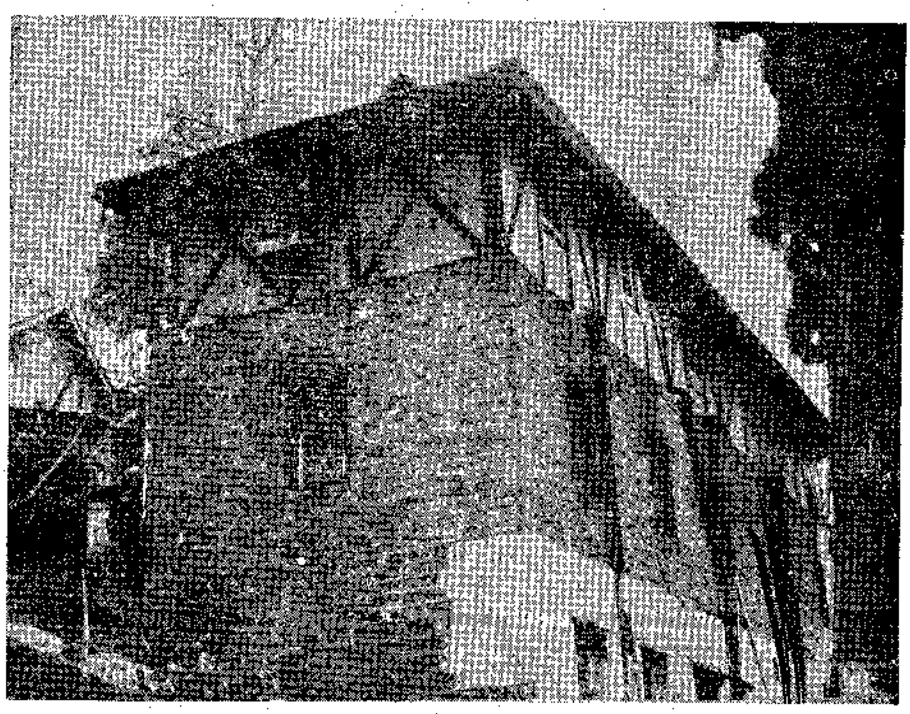


Fig. 10 Stone Masonry and Metal Lath-Plaster Construction, Darjeeling.

Exerescences like chimneys caused a lot of damage. These were usually of heavy masonry which crashed through the roofs and upper floors.

2.3. Recent Construction :

Lessons learnt from past damages appear to have been applied to some extent in Darjeeling. The new Office and Suptd. Quarter in the Himalayan Zoological Park is a two storey coursed rubble masonry building with R.C.C. roof slab. The coursed rubble masonry walls, in cement mortar (1:3), are 15″ thick in both the storeys. Size of stone is 10″×7″×5″. A continuous lintel band (Fig. 11), 9″ thick above openings and 6″ thick in wall is provided in both the storeys. Walls have the usual wall type step foundation, 3′—3″ deep with 1:3:6 c.c. (6″ thick) over 6″ thick rubble soking 3′—6″ wide. Floor surface will comprise of wooden planks over 3″×3″ timber joists placed on cement floors.

The new Tourists Lodge opened in April 1966 is a three storeyed reinforced concrete framed structure (Fig. 12) on R.C. raft foundation. R.C. walls are 4″ thick throughout with horizontal reinforcement $\frac{1}{4}''\phi$ bars at 9″ c.c. and vertical reinforcement $\frac{3}{8}''\phi$ bars at 6″ c.c. Roof is a sloping R.C. slab with edge beams.

Fig. 11 Continuous Lintel Band in Stone Masonry Wall.

A private two-storeyed Buddhist School Building under construction is also of reinforced concrete (Fig. 13). On account of heavy rains and winter snow, pitched roof with G.I. sheets is very common. These are normally carried in timber trusses, the common timbers being bola (kimbu), suji (dhupei) and champ (champa).

Jalpaiguri, Silguri and Cooch Behar have buildings similar to those in the cities of Bihar. Cooch Bihar suffered badly during the 1930 Dhubri earthquake (6). Fortunately, other places were far from the epicentral tracts of past earthquakes and escaped with minor damages.

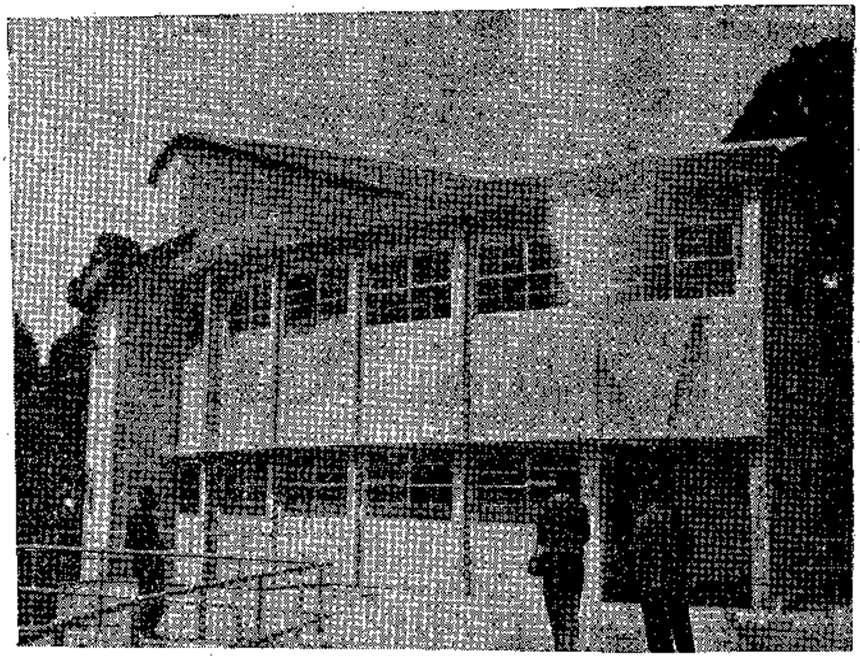


Fig. 12 Tourist's Lodge, Darjeeling, R.C.C. Framed Structure with R.C.C. Walls

3. ASSAM

Assam is literally known as the home of earthquakes and is the most unstable region in India. It lies along the main boundary fault line on the foot-hills of the Himalayas and the Eastern Assam Ranges, and has been the scene of nearly a dozen earthquakes during the last century. These include the Assam earthquake of 1897, Dhubri earthquake of 1930, earthquakes of 1943 and 1947 and the Upper Assam earthquake of 1950.

The principal towns situated in the broad alluvial valley of the Brahmputra and its tributaries, the Luhit, Dibang, Subansiri, Noa Dihing and Burhi Dihing Rivers are Dhubri, Gauhati, Nowgong, Tezpur, Silghat, Jorhat, Mariani, Sibsagar, Dibrugarh and the oil cities of Tinsukia, Digboi and Nahorkatiya. South of the Brahamaputra is a great block of uplands, a plateau comprising of various hill ranges known as the Assam Hills. Tura lies in the jungle clad uphills of the Garo Hills, Shillong (Capital of Assam), Cherrapunji and Jowai in the Khasi and Jaintia Hills, Nizam Ghat, Dennings and Sadiya in the Mishmi Hills. These hills are cooler but subjected to heavy rains during the monsoons. Timber is found in abundance. Good building stone is also available in plenty in the hilly regions. A variety of reed, locally known as "ikra" or "sarkanda" grows profusely throughout Assam and has been used widely at a good advantage by the people.

3.1. "Kutcha" and "Kutcha-Pucca" Construction :

The huts of villagers and labourers engaged in the industry are similar to those in North Bengal. Walls of matted "ikra" with mud plaster are commonly used in the hilly tracts. In the lower regions of the Brahmputra valley, one and two storeyed conventional brick masonry houses are to be found. These are largely made of poorly burnt sandy bricks with thick exceedingly heavy thatched roofs. They fare badly during earthquakes. Tea gardens, factories and certain bungalows have steel girder frames with brick filling in poor lime mortar which normally shatter badly duridg moderate and severe shocks.

3.2 Stone Masonry Buildings :

Before 1897 a large number of buildings in Shillong were of stone masonry with conventional foundation and G.I. sheet roof covering. All these were absolutely levelled to the ground by the 12th June, 1897 earthquakes (7). Buxa Fort had many houses constructed of roughly hewn blocks of white and grey quartzite weakly bonded with sandy mortar. These were all heavily damaged in both 1897 and 1930 earthquakes. In Cherrapunji too, untrimmed stone masonry houses in mud-mortar collapsed (1930) but well constructed stone masonry buildings were undamaged.

3.3 "Ikra-Plaster" Construction.

Lighter construction with walls of wood, "ikra", and bamboo behaved admirably both in Shillong (1897) and Buxa Fort (1930), most of the damage to this type being due to collapse of heavy stone masonry chimneys. Walls of these buildings have a timber batten framework, panels being generally 9 to 12 sft. An "ikra" matting is placed centrally in the framework (Fig. 14). This is then coated on both sides by either mud, lime or cement plaster, thickness of the walls being barely 2". There are three methods of supporting this superstructure.

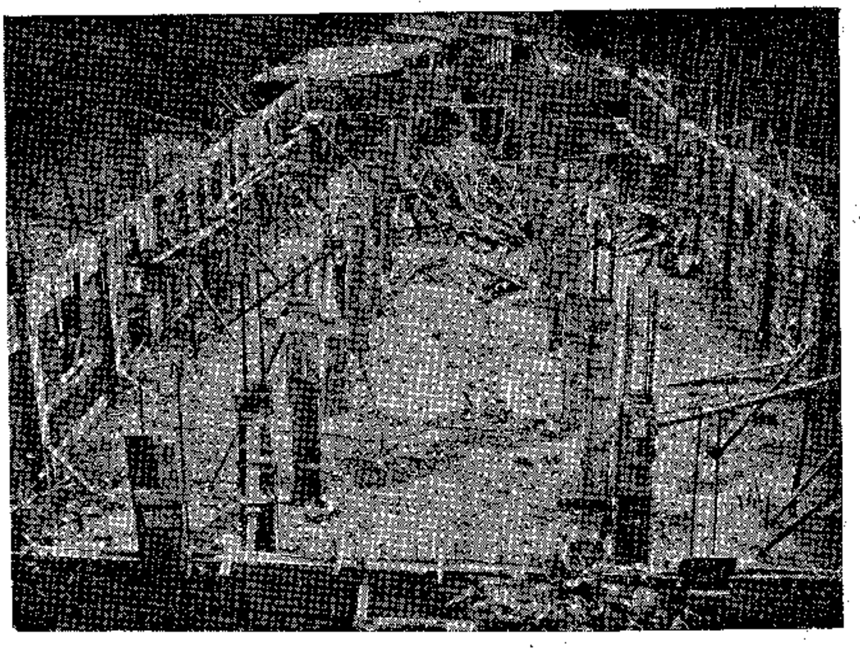


Fig. 13. Budhist School Building under Construction, Darjeeling.

(a) Houses supported on wooden piles, 10″ to 20″ diameter, driven several feet into the ground. These piles continue upto the roof level.

(b) Timber posts of wooden framework are either driven into the masonry plinth or attached to the plinth in mortar cups or they are fixed to m.s. tee or other esections embedded in masonry.

(c) The "ikra" house merely rests on short piers of stone or brick masonry or concrete 3′ to 4′ in height and about 6′ centre to centre, such that the superstruture is free to move as a whole(Fig 15). Such structures are usually known as "Shillong-Pattern" Buildings.

Fig. 14 " Ikra-Plaster " Walls.

in type (a), plinth is of two types :-

(i) Timber flooring raised above the ground floor.

(ii) Stone masonry plinth in either lime or mud-mortar with a cement facing over 6″ to 9″ mass concrete.

Flooring of type (c) house is invariably of timber raised above the ground level. These houses have a pitched roof convered with either thatch or G.I. Sheets.

In Tura, buildings of type (a)—(i) supporting system were damaged in 1887 earthquake by sinking of piles from a few inches to a foot deeper into the earth(7). In Dhubri (1930), piles in several bungalows belonging to the Forest Department subsided 4′ to 5′.

In general, damage to types (a)—(ii) and (b) was due to the tendency of different parts of the structure to tear away from one another on account of the irregular oscillations set up within the building.

Type (c) proved to be the best. This was demostrated by the American Mission Buildings at Tura(6). These light superstructures, of a pattern similar to the badly affected Government buildings (of "ikra", split-bamboo, wood etc.) are mainly supported 3 to 4 ft. above the ground on large blocks of stone placed on thick wooden posts. The earthquake shock (Dhubri 1930) was fortunately of insufficient intensity to throw the buildings bodily off these boulder supports, though in one or two instances, they moved to the extent of several inches. The superstructures thus vibrated as a whole irrespective of the oscillation of the ground below, and as a result comparatively little damage was caused. The Forest Department Bungalows being fixed to the ground by supporting piles and situated on the same valley were, however, seriously affected.

Subsequent shocks and the earthquake of 1950 bore testimony to the fine performance of "Shillong-Pattern" structures and most of the places in Assam have adopted this method of aseismic construction.

3.4. "Semi-Pucca" Construction :

Another type of structure that is common in the Brahmaputra Valley is the "Semi-pucca" structure (Fig. 16). Lower three to four feet are brick masonry walls and upper

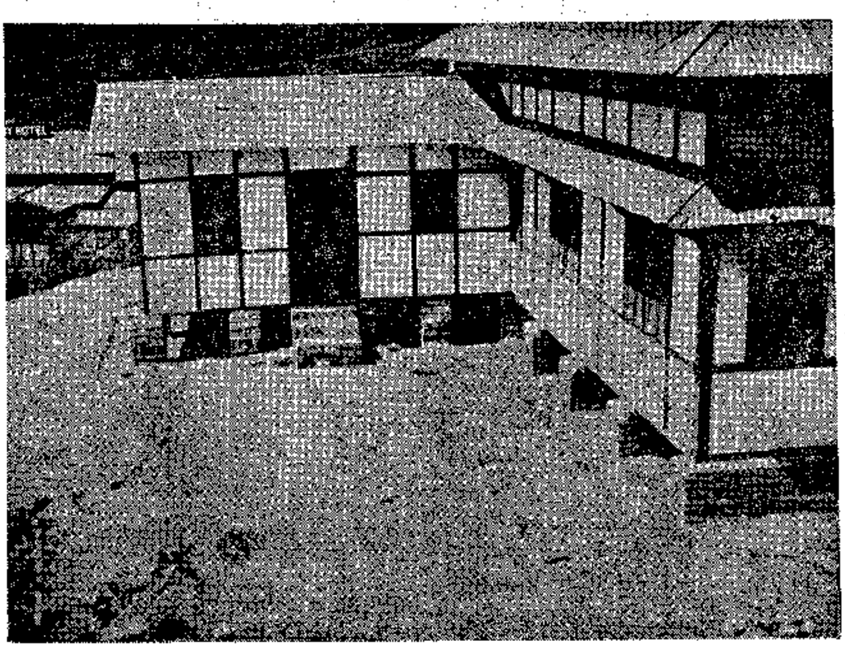


Fig. 15 Shillong Pattern Building

portion of plastered "ikra" or bamboo within timber panels. Roof covering is again of light G I. sheeting. They either have the conventional foundation or the "Shillong-pattern" supposting system. In the earthquakes of 1930 and 1950 a number of these were more or less severly damaged.

3.5. "Chung" Bungalows and Hyrib Construction :

Other types of structures that are not very common but nevertheless patronised by tea estates and railways are "Chung" type bungalows (6), with panels of brick nogging instead of "ikra". There are very few instances of this type of quarter which totally escaped damage due to the case with which the bricks are dislodged from the panels. In Digboi there are several Hy-rib lath-plaster bungalows belonging to the Assam Oil Company. Damage to these was less than in other types of buildings (8). Hy-rib walls are just 4" thick. Walls of bungalows are made completely of Hy-rib or partly in brick masonry and partly in Hy-rib. The company's houses usually have steel trusses anchored to the walls by rag bolts and covered with 22 gauge G.I. sheet roofing, (fig. 17). The

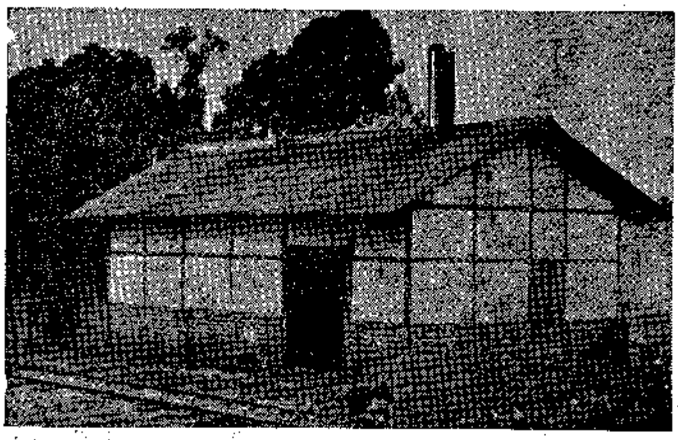


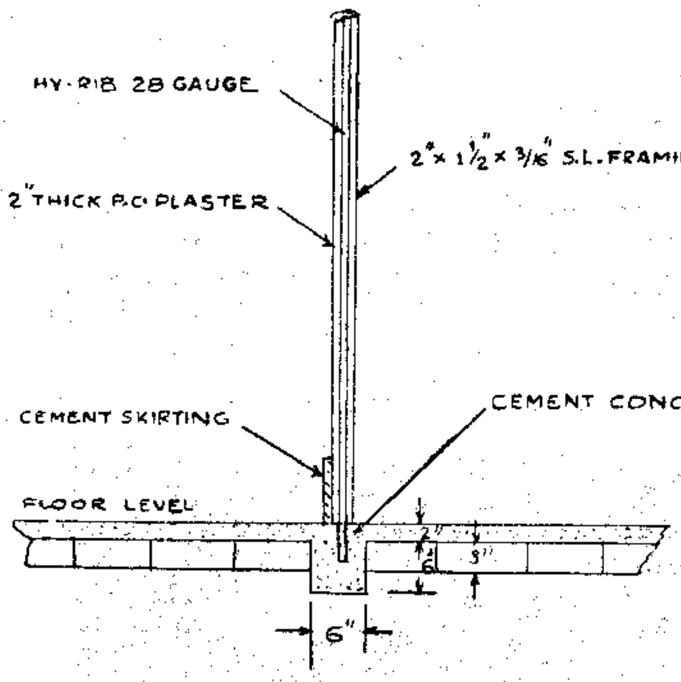
Fig. 16 "Semi-Pucca" Construction, Assam.

verandah is supported on steel angle columns. Pump houses and other single storeyed structures housing various refinery works are of framed construction, the steel beam and column sections being encased in concrete.

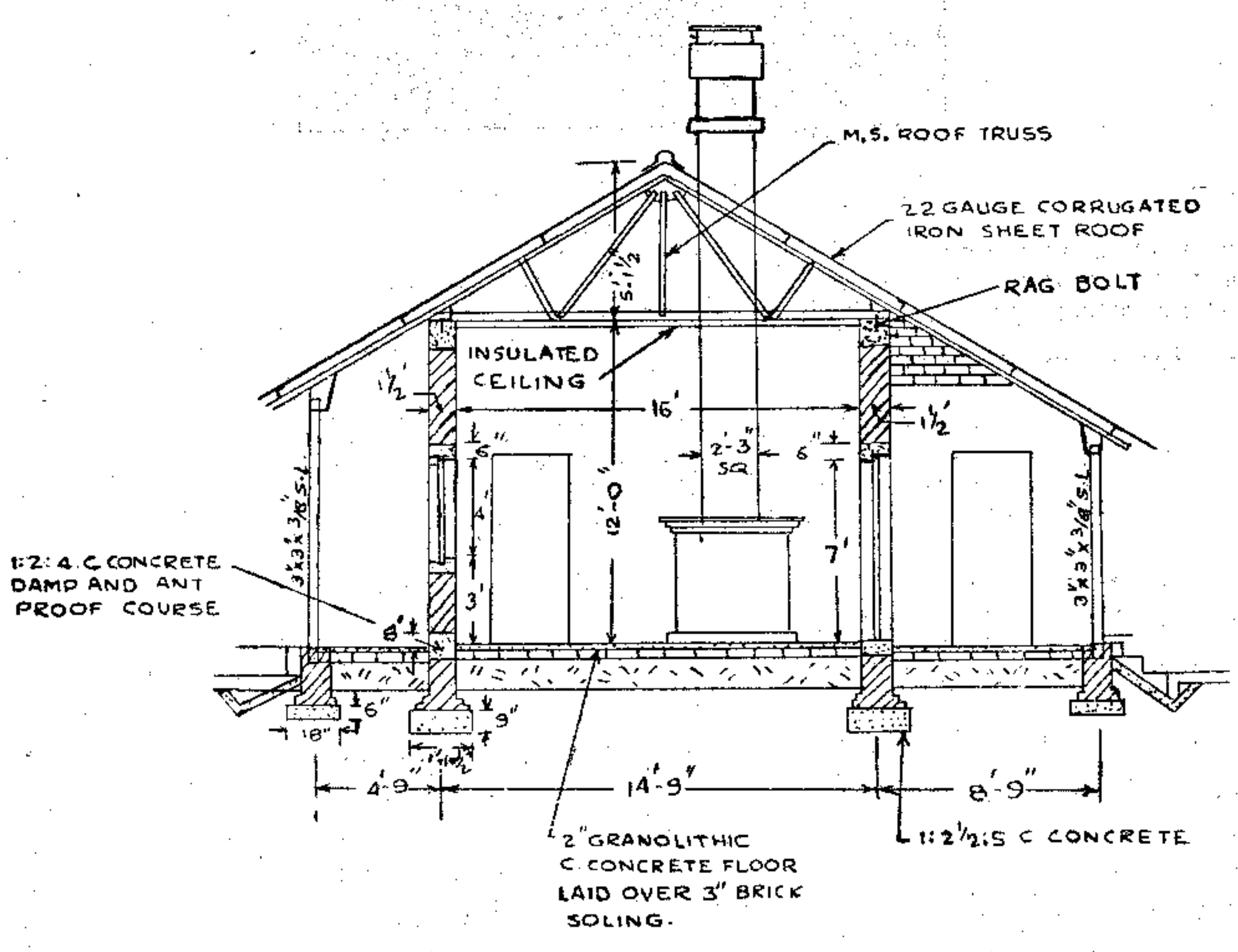
5. Recent-Construction :

Recent masonry construction in Assam employs good bricks bonded with either lime or cement mortar. R.C.C. piers are used at the corners and in between door and window openings. Besides these, a continuous lintel band is also incorporated in the design. Fig. 18 shows a first class brick masonry structure under construction near Jorhat.

With the setting up of a cement factory at Cherrapunji, R.C.C. framed structures have been given preference to "Shillong-Pattern" houses for most of the Government buildings. (Maintenance cost of "Shillong-Patrern" building is rather high. Generally, a small gap develops between the "ikra-plastered" panel and the timber framing due to shrinkage and distortion of the materials. The timber battens are thicker than the wall panels and the projecting portions inside the room trap a lot of dust. Moreover, since it is largely of timber, there is always the fire hazard). Walls of these framed structures are either of R.C.C. 4" thick (as in Darjeeling), or of hollow concrete blocks. Bricks are used where they are available cheaply. R.C.C. columns have 2 No. $\frac{1}{4}''\,\phi$ reinforcement bars projecting outside for about 9" at a regular interval along the entire length of the columns



Section through B B



Section through A A

Fig. 17 Section of an Assam Oil Company's House at Digboi.

for embedding in the masonry work. A diamond shaped wire meshing is tied to these and stretched over the concrete blocks or bricks at every third course (9). The mesh is not cut at the end but taken up continuously for the next three courses (Fig. 19).

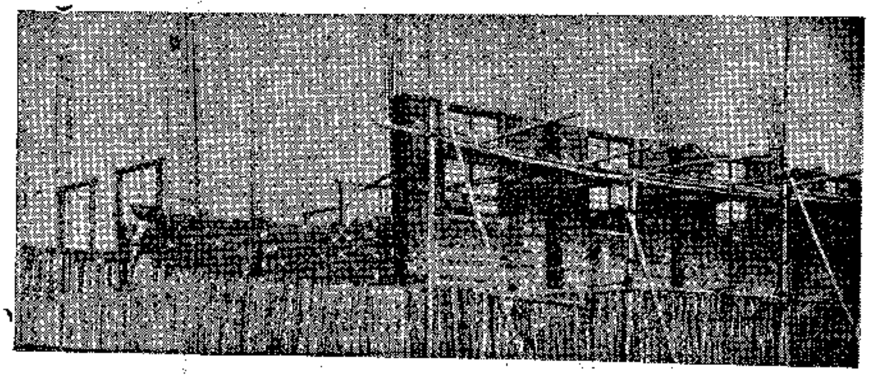


Fig. 18 Brick Masonry Construction Strengthened with Steel

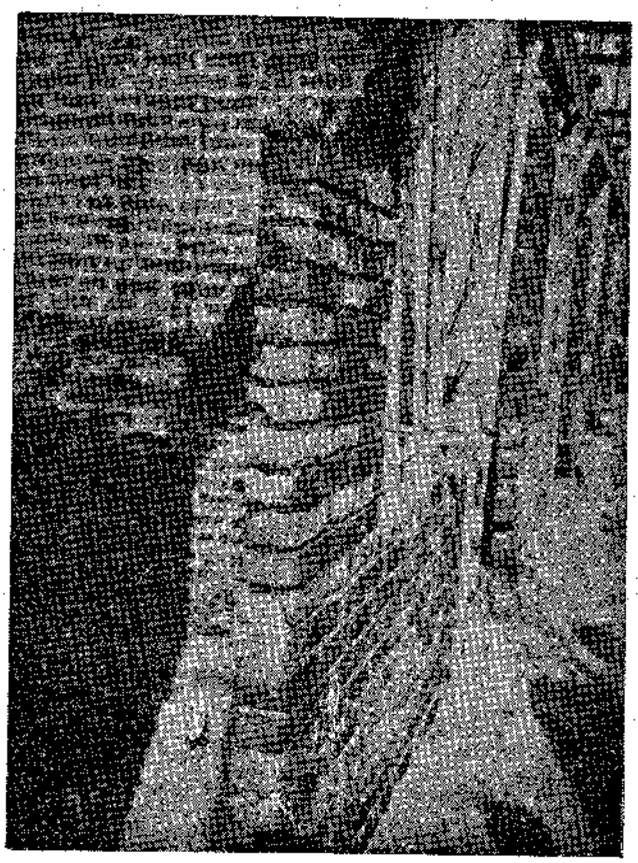


Fig. 19 Wire Meshing in Brick Masonry.

All new important buildings have either a raft foundation or the various columns are tied to each other by tie beams. Fig. 20 shows the tie beam in the foundation of the Additional Secretariat, Shillong. Simillar tie beams have also been provided in the four storeyed R.C.C. Constables Quarters under construction at Dhubri.

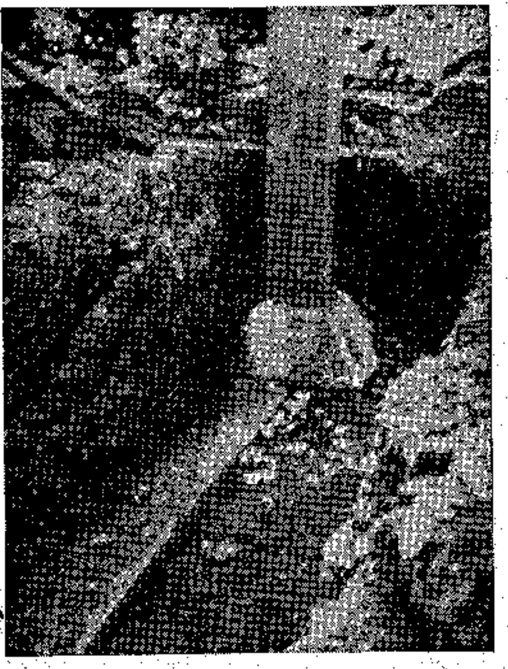


Fig. 20 Foundation Tie-Beam.

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