PAPER No. 217

EARTHQUAKE RE-CONSTRUCTION IN NORTH BIHAR

By A. St.G. Lyster, I.S.E.

Introductory.

In 1934 the Province of Bihar and Orissa could be described as divided into three parts. (i) Bihar, comprising the Ganges Basin between the eastern limits of the United Provinces of Agra and Oudh and the western border of Bengal, (ii) Chota Nagpur, consisting of a rocky plateau with an elevation of between 1500 feet and 2000 feet above sea level and (iii) Orissa, the coastal area on the Bay of Bengal. The term North Bihar applies generally to that part of Bihar which lies between the Ganges and the foothills of the Himalayas where India marches with the Nepal Frontier.

Effect of the Earthquake.

At about 14.13 hours on the 15th January, 1934, there occurred in North Bihar a destructive earthquake. The severity of the shock in the areas of greatest intensity corresponds with degree X on the Mercalli modification of the Rossi-Forel Scale the detailed description of which is " very disastrous with ruin of many buildings and great loss of life, cracks in the ground, landslips from mountains, etc". Additional criteria : " Sanding intense. Extensive fissuring in alluvial ground. Landslides. Very heavy mortality".

Short of absolute destruction, this degree of severity is awarded the highest place on any comparative scale of earthquake shocks.

Illustrations of the damage done in the 3 to 5 minutes during which the shocks lasted will be found in the Indian Concrete Journal Special Issue 15th October, 1934, Volume 8, No. 10 ; there is also an excellent report with illustrations and maps in Records of the Geological Survey of India, Volume LXVIII, Part 2, 1934 which gives a very clear description of the occurrence. The effects of the shock may be summarized as follows :-

(*a*) Buildings brought to the ground by severe shaking.

This was especially the case where inferior materials had been used and poor workmanship. It accounted for much of the destruction in bazaar areas.

(*b*) Buildings destroyed by fissures in the ground. There were many well built buildings which were literally torn asunder; the two halves remaining standing at different levels, and some inches apart, the standing portions would usually be out of plumb.

Fissures occurred usually along the banks of rivers and lakes due to the forward movement of the unsupported bank. They also occurred at places remote from such banks, in the areas of greatest intensity.

(*c*) Roads and Railways were destroyed by settlement of their embankments, by fissures, and by destruction of their bridges. Bridges usually failed by the abutments being forced towards each other by the forward movement of the banks of the nullah, and the central pier being forced upward by a corresponding movement of the nullah bed. These movements were commonly several inches in extent.

(*d*) The appearance of blow holes which exuded fountains of sand and water. The areas so affected were rendered useless for future building.

(*e*) A general settlement of the countryside with reference to Ordnance Datum. This was of importance in connection with floods. Numerous rivers bring down water from the Himalayas to the Ganges. These cross the North Bihar Area from North West to South East, and are all in the habit of overtopping their banks during the monsoon and inundating very large areas of country. The earthquake reduced the capacity of the river beds by the sliding in of the banks and raising of the beds, and completely disorganized the whole system of Ordnance Survey Bench Marks.

Area affected.

The report by the Geological Survey of India already referred to has been used in preparing the map which accompanies this paper, Plate I. The epicentral tract in which intensity X of the Rossi-Forel scale was experienced extends in a rough ellipse from a point half way between Motihari and Sitamarhi to Darbhanga and there were two small isolated areas at Katmandu in Nepal and Monghyr on the south bank of the Ganges. The total area included in this isoseismal is about 1300 square miles. The boundaries of isoseismals IX and VIII are also shown on the map.

In addition there is marked on the map an area known as the "slump belt". It includes the area of intensity X, but by no means the whole of the area of intensity IX. It is defined in the report of the Geological Survey of India as the area in which buildings were damaged by bodily subsidence or tilting, as distinguished from the area in which buildings were shattered by shaking or by undulations. Fissuring and

emission of sand and water were most marked in the slump belt. Places in the slump belt received vertical rather than oblique shocks and places outside received oblique rather than vertical shocks.

The Slump Belt.

The slump belt coincides very roughly with the area in which the Ordnance Survey Bench Marks were found to have settled by 1 foot or over, but this coincidence is fortuitous ; the definition of the slump belt is as given below. There is considerable difficulty in fixing the extent to which a general settlement of the ground occurred. Since the Earthquake, the Survey of India have re-levelled line 71 Bagaha to Purnea and line 71A Darbhanga to Bagaha. Subsidence is not uniform even in a single town ; in Purnea it varies from 1 to 2·35 feet and at Darbhanga which is not in the slump belt differences recorded were 4·3, 2·5, 1·9 and 1·3 feet. As far as is known these figures represent settlement of the ground, as apart from sinking into the ground, of the structure on which the Bench Mark was recorded as for instance a bridge abutment.

Pre-earthquake Organization.

The organization of the Public Works Department at the time that the earthquake took place is shown in the form of a chart. The Province of Bihar and Orissa had suffered the same financial stringency, accompanied by decreased expenditure and reduced staff, which is familiar to us in the Punjab. In the year 1934 the North Bihar Circle embraced the whole of the Province north of the Ganges, comprising six districts with in addition the District of Monghyr on the south of the Ganges. The duties of the Superintending Engineer included (i) Irrigation (in Champaran District only), (ii) Government Buildings in all seven districts through the official Public Works Department staff, (iii) Inspection of local works which involves supervision duties of the District Engineers (all roads in North Bihar are under District Boards), (iv) Waterways which concerns itself with floods, embankments and flood protection works. There is a great deal of work under this heading.

Expansion to meet the new conditions.

This slender framework required very great strengthening in order to meet earthquake reconstruction requirements. A new Circle was formed called the East Bihar Circle which took over the Districts of Bhagalpur, Purnea and Monghyr and the Inspectorship of local works and subsidiary duties for that area. The North Bihar Circle was thus reduced to the Districts of Saran, Champaran, Muzaffarpur and Darbhanga, but since this included the areas of greatest destruction, the Superintending Engineer was further relieved by the creation of a new Champaran Irrigation Division and a Waterways Division working

directly under Chief Engineer, Irrigation. In addition two Inspectors of local works were created who relieved Superintending Engineer, North Bihar Circle of all District Board and Municipal activities. These inspectors of local works had status as Superintending Engineers and worked directly under the newly created Chief Engineer, Reconstruction.

This re-organization indicates the magnitude of the task with which the Government of Bihar and Orissa were faced. The officers required were found by promotion of officers already serving in the Province, the temporary return to service of Indian Officers who had retired and by borrowing officers from other Provinces. It was in this way that in May 1935, 16 months after the Earthquake had occurred I took charge of the re-organized North Bihar Circle.

The First Task.

The Earthquake destroyed everything in the short space of time it lasted. It produced immediate chaos and a considerable degree of panic. The first task of the survivors was the extraction of the dead and injured from the ruins and the restoration to a working condition of the Hospitals, themselves in ruins, or if necessary the construction of temporary Hospitals. The first tasks then are as follows :-

As soon as possible an organization must be created to take charge of the distribution of food, blankets, etc. and to provide temporary housing, so that the Public Works Department may be able to turn to the tremendous task of reconstruction.

In Bihar a special Relief Officer, a senior civilian, with a staff designated Relief and Supply Officers and under them Town Engineers was appointed. It is essential to include some engineers in this Relief organization as they will have to arrange for temporary housing. In North Bihar this took the form of colonies[1] of barracks or quarters. Bamboo frameworks supporting a C. G. I. Roof with thatch overlay, or thatch only, or thatch and tile, with walls of mud plastered wattle These activities were financed from the Viceroy's Relief Fund[2] and other Relief Funds, which were also used to distribute compensation for losses to private persons and to give easy term loans for rebuilding

[1] One such colony contained 1722 family quarters and cost Rs. 6,26,000/. Average Rs. 364 per quarter.

[2] The Viceroy's Relief Fund allotted certain sums to His Excellency the Governor of the Province. The Provincial Fund so created was administered by a Committee of five of whom three members were officials. The Committee and its operations were not under Government control. The Provincial Committee in turn allotted funds to Local Committees.

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ORGANIZATION OF P. W. D. BIHAR BEFORE THE EARTHQUAKE.

CHIEF ENGINEER	CHIEF ENGINEER
ROADS AND BUILDINGS	IRRIGATION
LOCAL WORKS	WATERWAYS
PUBLIC HEALTH DEPARTMENT	EMBANKMENTS
ELECTRICAL DEPARTMENT	
RAILWAYS	
ESTABLISHMENT	

SUPERINTENDING ENGINEER and Inspector of Local Works, North Bihar Circle.

Executive Engineers.	District Engineers.
CHAMPARAN DIVISION (Champaran District)	CHAMPARAN
BUILDINGS	SARAN
IRRIGATION	MUZAFFARPUR
EMBANKMENTS	DARBHANGA
MUZAFFAR DIVISION (Saran, Muzaffarpur, Darbhanga Districts).	BHAGALPUR
BUILDINGS	PURNEA
EMBANKMENTS	MONGHYR
BHAGALPUR DIVISION	
BUILDINGS	
EMBANKMENTS.	

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ORGANIZATION OF P. W. D. BIHAR BEFORE THE EARTHQUAKE.

CHIEF ENGINEER	CHIEF ENGINEER
ROADS AND BUILDINGS	IRRIGATION
LOCAL WORKS	WATERWAYS
PUBLIC HEALTH DEPARTMENT	EMBANKMENTS
ELECTRICAL DEPARTMENT	
RAILWAYS	
ESTABLISHMENT	

SUPERINTENDING ENGINEER and Inspector of Local Works, North Bihar Circle.

Executive Engineers.	District Engineers.
CHAMPARAN DIVISION (Champaran District)	CHAMPARAN
BUILDINGS	SARAN
IRRIGATION	MUZAFFARPUR
EMBANKMENTS	DARBHANGA
MUZAFFAR DIVISION (Saran, Muzaffarpur, Darbhanga Districts).	BHAGALPUR
BUILDINGS	PURNEA
EMBANKMENTS	MONGHYR
BHAGALPUR DIVISION	
BUILDINGS	
EMBANKMENTS.	

RE-ORGANIZATION FOR EARTHQUAKE RECONSTRUCTION.

CHIEF ENGINEER
ROADS AND BUILDINGS
ESTABLISHMENT
PUBLIC HEALTH DEPARTMENT
ELECTRICAL DEPARTMENT
RAILWAYS
RECONSTRUCTION DARBHANGA AND EAST BIHAR CIRCLE

CHIEF ENGINEER
IRRIGATION
WATERWAYS
EMBANKMENTS

CHIEF ENGINEER
RECONSTRUCTION
SARAN
CHAMPARAN
MUZAFFARPUR
CHIEF INSPECTOR OF LOCAL WORKS NORTH BIHAR CIRCLE

SUPERINTENDING ENGINEERS (TWO)

INSPECTORS OF LOCAL WORKS NORTH BIHAR CIRCLE (TWO).

NORTH BIHAR CIRCLE

MOTIHARI DIVISION
(BUILDINGS CHAMPARAN District)

MUZAFFAR DIVISION
(BUILDINGS SARAN AND MUZAFFARPUR Districts)

[illegible]BHANGA DIVISION
[illegible]LDINGS DARBHANGA
rict)

EAST BIHAR CIRCLE

CHAMPARAN IRRIGATION DIVISION

WATERWAYS DIVISION

INSPECTOR OF LOCAL WORKS

BHAGALPUR DIVISION
(BUILDINGS EMBANKMENTS BHAGALPUR District)

PURNEA DIVISION
(BUILDINGS EMBANKMENTS PURNEA AND MONGHYR Districts)

DISTRICT ENGINEERS
(BHAGALPUR PURNEA AND MONGHYR Districts)

DISTRICT ENGINEERS
SARAN
CHAMPARAN
MUZAFFARPUR
DARBHANGA

INDEPENDENT OF P. W. D.
SPECIAL RELIEF OFFICER (CIVIL)
RELIEF AND SUPPLY OFFICER
TOWN ENGINEER.

purposes. Of reconstruction work which must commence at once without waiting for the establishment of the relief organization priority must be given to Hospitals, Communications, Treasuries and Jails. Hospitals need no argument to support their claims but the demand on their services in North Bihar was never so great as was expected. Unlike war casualties, the casualties from the earthquake showed a greater number of killed than injured. Communications must receive attention so that relief may be distributed and not concentrated in the large towns. Everyone with whom I discussed the subject spoke with praise of the speed and energy with which the staff of the Bengal and North Western Railway restored to working order their wrecked permanent way. Commencing work from the river bank opposite Patna they announced a further advance of rail head almost daily. Motor omnibus services which are normally non-existent in North Bihar were imported from the south side of the Ganges and used as an extension of rail head as quickly as roads could be made passable. In about a month the railway had restored working over most of their system. A company of Sappers and Miners was of great value in this period. Their special work was the demolition of dangerous structures both with and without explosives, a task in which few members of the Public Works Department had any training and the construction of temporary bridges. Treasuries and Jails take precedence of other activities of Government, because where they have been damaged a number of Police will have been employed to augment their guards. Also it is important to provide the means for money to circulate at a very early date.

Use of Temporary Jail Materials.

During the years 1930-31 the Non-Co-operation Movement was extremely active in the Province of Bihar and Orissa and a very large temporary Jail was erected at Patna. This temporary Jail consisted of C. G. I. Roofing carried on steel trusses of 20 feet span supported on steel uprights, the sheds being generally 85 feet in length. The temporary Jail being unoccupied in 1934 a large number of these sheds were dismantled and sent to North Bihar where they could be erected very quickly with little or no foundation and walls made of 10 inches brickwork and other light materials. Doors and windows were salvaged from the ruins and in a very short time the Collectorate (Kutchery), District Courts and similar offices were housed in this type of accommodation. The steel frame work and C. G. I. sheets were returnable to Patna when no longer required.

Correspondence in Abeyance.

It is evident that during a period of such intense and varied activity the ordinary procedure of a Government office had to be discarded. For the first month after the Earthquake, orders were issued verbally and seldom reduced to writing. Little record remains then of the action taken except three perforated leaf note books used by the Superintending Engineer as Order Books with carbon copies. These

were mostly written up while travelling by aeroplane from one place to another.

The Call for Information.

At this time, when every officer was utilizing his whole energy to get many things done at once, came an insistent call from Government for information. It is imperative that this call for information should be met. Government must be furnished with a fairly accurate estimate of the extent of the calamity. Data must be collected for use when planning the replacement of buildings. (See the Questionnaire and Replies given in Schedule I). Early reports will require modification and amplification and progress of relief work must be watched. The demand on their time and energy was a great strain on the local officers, and in a calamity of this size it might have been better to send out an independent expedition to observe for themselves and to obtain information verbally from local officers and to keep Provincial Headquarters supplied with information. As it is, the only comprehensive account of the earthquake, its nature and effects, which I have found readily accessible is that compiled by just such an independent expedition sent out by the Geological Survey of India. One effect of the earthquake which caused great alarm was the emission of enormous quantities of fine sand from fissures and vents in the ground. This emission continued for 1 to 3 hours after the actual earthquake shock. For example, 3000 cubic feet came up through one portion of a factory floor. In many places fields were covered to a depth of over a foot. It was thought at first that such an overlay had destroyed the ground for cultivation, and compensation was given accordingly but after two monsoons had passed the crops on such ground were not distinguishable in quality from the crops elsewhere.

The Sugar Industry.

North Bihar is an agricultural area which has for its main crop sugar cane. At intervals of about 15 to 20 miles there are established large mills equipped with machinery for crushing the cane and boiling and refining sugar. The whole sugar cane crop is disposed of to these mills which work a 24-hour day for 6 days in the week, from near the end of October to about the beginning of April. During these months the cutting and carting of cane is going on continuously. A good deal of cane is carried to the mills by railway, but the bulk of the crop goes direct from fields to mill by bullock cart. The earthquake threw all the mills completely out of action, wrecking their furnace chimneys, cracking the concrete foundations on which the plant and machinery stood and seriously damaging machinery which was actually running at the time of the shock. The main industry of the countryside was thus brought to an abrupt halt in the period of its greatest activity. Sugar cane is a crop which cannot be stored, any considerable delay between cutting and crushing allows it to dry. Arrangements had

be made to dispose of the cane outside the area of the earthquake, some cane had to be sent as far as the United Provinces ; this traffic alone required the full transporting capacity of the railway, and it was realized that this state of affairs would be repeated to some extent in the cold weather of 1934-35, and therefore the collection of materials for reconstruction work must be organized so as to utilize the railway during the hot weather and be largely independent of it in the following cold weather. The disposal of sugar cane described above was organized by the Commissioner of the Division.

Collection of materials for Reconstruction.

The Public Works Department were not slow to realize how great would be the demand for bricks, and being first in the field were able to buy up existing stocks of serviceable bricks and place contracts for further supplies. Their requirements were limited to government buildings. It was considered that some precautions must be taken to save the general public from artificially raised prices. With this end in view the Relief and Supply Officer in North Bihar was intrusted with the task of obtaining supplies of coal during the hot weather period, so that brick kilns should not be short of fuel during the cold weather when the sugar cane traffic would have first claim on railway transport.

Further he was to contract[1] on behalf of Government for the manufacture of a considerable stock of bricks at each of the principal towns devastated, these stocks to be held by Government and used to control the market price of bricks as and when necessary. The total quantity of coal handled under these arrangements was about 58,000 tons.

The urgency of this work was overestimated. Once they were installed in the temporary housing colonies, the civil population showed no haste to rebuild. Private reconstruction did not show much activity till 1936.

It is however essential that Government should undertake this service of controlling prices for the public, even at the cost of loss incurred in the process, though wastage can be avoided by entrusting the business to experienced officers. In accumulating these supplies, as also those required for government buildings it is of importance to stock the bricks at once near the place where they will be required for use, or if this is impossible ground should be rented for the purpose so as to clear the brick fields for further operations.

[1] It was a condition of these contracts that Goverament would take over certain quantities of bricks only after the contractor had burnt a stipulated quantity and offered them for sale to the public at controlled rates in the season 1934-35. This was effective in keeping down prices which had begun to rise in the hot weather of 1934. Government eventually sold its stocks in lots of 2 to 5 lakhs.

For government work stocks were also collected of steel rods for reinforced concrete, and corrugated iron sheets. Small stocks of surkhi and sand were collected as soon as building sites were fixed, but only sufficient quantity to enable a quick start when building contracts were let.

Office Staff.

The Public Works Department were thus set free to devote their energies to the reconstruction of shattered government buildings. The extent of this task in the reduced North Bihar Circle is shown by the Statement of Expenditure. (Schedule II).

New Circles and Divisions were brought into existence as already described. Sub-Divisions were created as need arose and I have not thought it necessary to trace out all their vicissitudes in this Paper. Ministerial staffs were largely augmented by the addition of temporary posts, and special assistance given in the form of an additional Accountant or Accounts officer attached as Personal Assistant to the Executive Engineer or Superintending Engineer. M affarpur Divisional staff was increased from 23 to 31 correspond e and accounts clerks. The source of supply for additional clerks as by advertisement, and there was very strong feeling against any bu domiciled natives of the Province being employed. The quality obt able in this way was no good and was only partly compensated for by numbers. In order to obtain a proportion of experienced and capable clerks in the new units, a certain number of permanent posts with their incumbents were transferred to them, the vacancies so caused in the original units were made good by the creation of temporary posts on similar scales of pay against those vacancies. These temporary posts were in many cases held by permanent clerks temporarily promoted from the lower substantive grades. Draughtsmen and Estimators are separate cadres in Bihar; there was real difficulty in obtaining additional men with sufficient knowledge and training to be useful, and I do not think that the North Bihar Circle and its Divisions were ever quite adequately equipped in this respect.

Outdoor Staff.

As with indoor staff so outdoor staff also were obtained by advertisement and there was objection raised to any but domiciled natives of the Province being so taken. The first to be accepted were those brought under reduction during the years of retrenchment, and again numbers had to make up for lack of quality.

In the first rush of work after the catastrophe a number of third year students were taken from the Engineering Colleges and employed for 6 months, it being stipulated that they should resume their studies without detriment to their prospects in sitting for their final examinations.

These young men were given small charges and definite tasks and showed great keenness and energy in carrying them out.

Abandonment of Old Building Sites.

Within the slump belt it was usually the case that the sites on which Government Offices and residences had stood, were no longer in a fit state to support a building of any size. The decision was taken therefore to acquire an area sufficient for a complete District Head Quarters at Luathaha outside Motihari and for the head quarters of the Civil Sub-Division of Sitamarhi at Dumra (about 2 miles distant). This transplantation roused strong opposition in the Provincial Council so much so that only half the Civil Sub-Division of Madhubani has been removed to a fresh site, the remainder being reconstructed on the old ground. In Muzaffarpur and Darbhanga outside the slump belt reconstruction was on the old site or at least within the same Municipal limits.

In the case of Motihari, local bodies such as Municipality, District Board and School Committees came forward with requests that they might be given the land abandoned by Government on nominal rents. But the land which is unfit for a Government office cannot be considered suitable for a school. Where land in private ownership had been badly shattered, there was no way of preventing the owner rebuilding a more or less unsuitable type of building. This matter of declaring land unfit for use as building sites requires early attention before the public commence rebuilding, and the loss of value to the owner might be made good to some extent from relief funds. Such cases were generally confined to the Slump Belt. Land no longer required by Government was to be disposed of in the open market, and the sale proceeds credited to Provincial Revenues.

The Position in May, 1935.

The position in May 1935 when I took over charge of the North Bihar Circle from Captain G. F. Hall, M. C., C.I. E. was that :—

The circle had been reduced in area and duties, new units created and scales of enlarged establishment sanctioned (most of these had been engaged).

Abandonment of sites and selection of new sites had been decided in all important cases.

Specifications had been drawn up by a conference, and approved by Chief Engineer for the earthquake resisting features to be incorporated in the new buildings.

A number of schemes had passed through the process of administrative approval and detailed estimates were in hand.

A large drawing office had been got together in the Secretariat to relieve the local officers of the designing and estimating of the larger projects.

In a few cases construction had started. In brief the initial difficulties had been overcome, and though the heavy programme to be worked to meant high pressure for all concerned the Department had organized itself to meet the conditions, and the normal process of working had been restored.

Specification to resist Earthquake Shock.

It is not my intention to discuss the merits or demerits of the various types of residential and other buildings as suited to their purpose. To do so would take too much space and is outside the scope of this Paper. The climate of Bihar is very different to that of the Punjab and the type approved in one Province would not be found advantageous in the other.

The specifications for earthquake re ing buildings both outside and inside the slump belt are giv in Schedule III. The specifications were evolved from a caref study of the replies to the Questionnaire (Schedule I). No calculations of the strength of buildings so reinforced against earthquake shock is given or was ever made. Japanese and American designers have adopted the principle that buildings subject to earthquake shocks should be designed to withstand an acceleration of 3 feet per sec. per sec. This figure was arrived at by measurement of the oscillations of many storied buildings. It may be stated in another way. Tall buildings must be designed as cantilevers capable of resisting a force equal to one-tenth the weight of the building applied horizontally at the centre of gravity. No doubt this formula gives satisfactory results in the case of tall buildings subject to swaying due to undulationary movement of the ground. A study of the different types of failure in North Bihar, showed that with single storied buildings a compact building made with good materials and workmanship would withstand severe shaking without collapse ; that if the ground is fissured under the building, the building will be torn asunder ; no calculation can give the measurement of this force and the most that can be hoped for is that the different portions of the building will stand without collapse. Subsidence under one part of the building produces the same effect as fissures. The construction of buildings capable of remaining intact when a considerable part of the foundation is without support is too costly to be contemplated.

The main features aimed at in the specifications are compact buildings well braced together with cross walls. Where long buildings were unavoidable they were divided into lengths of about 100 feet by articulation joints, where long rooms were unavoidable the long walls were strengthened with R. C. C. columns springing from the R. C. C.

foundation and intimately connected with the horizontal reinforced brick bands. Foundation pressures were equalized and kept low, and the ceiling and roof divided into independent units both of a type which will not readily collapse and bury the occupants. Corners, lintels and the R. B. bands are all in cement mortar. Articulation joints were always given in buildings with projecting wings.

Articulation joints. These joints varied from $\frac{1}{2}$" to 3" in width and were a complete separation through the foundation, plinth and superstructure, see detail on Plate III. Lintels were cantilevered out from either side and a gap left in the middle. Ceiling slabs of reinforced brick, which spanned these joints, were given a sand bearing at one side to permit of movement. External and internal plaster covered the joints though it was found advisable to leave a fine joint in the plaster as in nearly all cases sufficient movement occurred to cause the plaster to crack. Purlins and C. G. I. sheet roofs were carried straight across the joints without special precautions. The best position for an articulation joint is along a cross passage.

Foundations, and Plinth.—Importance was attached to equalizing pressures all over the foundation and the low limit of 0·5 ton per square foot (0·3 tons per square foot in the Slump Belt Type) was fixed. Foundations are of the R. C. C. cantilever type, (Plates II, III and IV) with longitudinal reinforcement added and a band of re-inforced brick just above the concrete forming an inverted T-beam. In the case of very long verandahs such as occur in hospital wards and court buildings the main wall and verandah plinth were connected by dwarf stiffening walls. These had no foundations.

Superstructure.—The arrangement of the R. B. bands and the vertical columns of R. C. C. are clearly shown in Plate II, also in sectional elevations, Plates III and IV. These columns were given in walls which had a greater length than 26 feet without cross walls or other stiffener. Cement mortar was used for corners and jambs.

Roof.—The ceiling and the roof are independent of each other, (Plates III and IV) and ventilation between the two is provided. The steel trusses were connected in pairs by cross bracing and in large roofs, groups of three trusses were so connected. Spans varied from about 17 to 40 feet. The *nurria* tiles are provided for coolness. No gables were allowed except in small buildings of less than 10 feet height and small span. Ceilings were given bearing on the full width of the walls.

Arched openings.—These were avoided and horizontal lintels in brick or concrete substituted.

Verandahs.—Verandah roofs in the standard type were R. B. slab and lime concrete terracing. The R. B. slab was given bearing on the full width of the main wall. Pillars were of substantial size and in

long verandahs special lintels were inserted at intervals to connect the verandah pillars to the main wall.

Double storied buildings were not constructed. Chimneys were placed to avoid excessive height.

Slump Belt Type.—(Plates V and VI). Actually this type was constructed only in the area shown as the epicentral tract (isoseismal X, plate I) and also for all Police Buildings in any part of the four Districts. The entire roof load is carried on a steel frame work to which the brick walls, only 10 inches thick, act as panelling. This type is capable of severe deformation due to fissures or subsidence without actual collapse. In this type the ceiling which is of cement asbestos sheets is not independent of the roof.

Materials : Anti-corrosive Copper-bearing steel rods.—These are a standard product of English manufacture and are advertised to have a copper content of 0·35 to 0·50 per cent. It is claimed that they will resist corrosion due to contact with lime or mineral salts. Mineral salts are known to occur in brickwork in Bihar, either from the clay of which the bricks are made or from soaking the bricks in well water. No direct evidence of the extent to which these rods resist corrosion was available, but they were used for all reinforced brick work, which, in addition, was specified to have joints of ample width so as to secure a surround of cement mortar for the rods.

Nurria Tiles.—A half round tile of local manufacture about 1 foot in length tapered so that it can be laid overlapping. Very flimsy and absorbent when wet, adds materially to the weight of the roof. Used with the intention of making the C. G. I. roofs cool.

Koa.—This is *jhama* brick ballast. Difficulty was experienced in btaining a proper bond between dry rammed *koa* and the 1 inch thick artificial stone surface. I would prefer 3 inches of lime concrete. The cost would be the same.

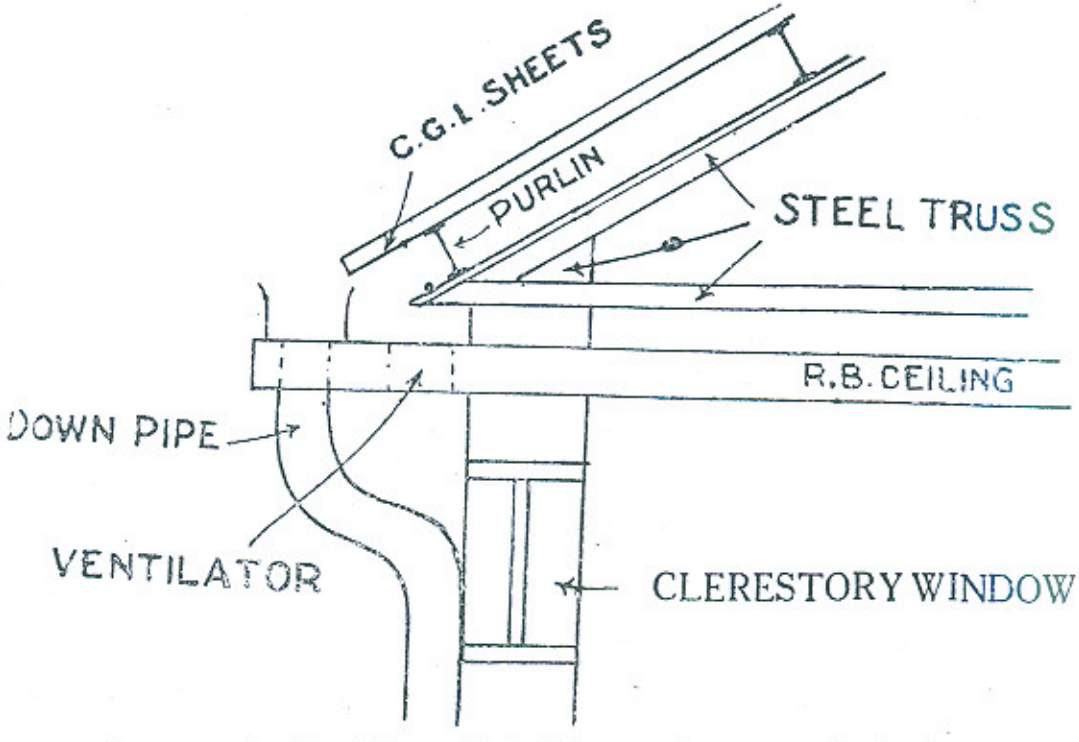
Lime sand plaster.—Except for plinth-filling, all sand was obtained from the Sone River, a large tributary to the Ganges on the south side above Patna.

This sand was admirable for cement concrete work but gave a rather rough surface when used in plaster. It is standard practice in Bihar to plaster the outside of a building. External plaster is usually self coloured by the addition of a small quantity of surkhi. Such surfaces require rubbing down to clean off damp stains every four years.

Oil finish to wood work.—It is standard practice to finish teakwood doors and windows with raw linseed oil. Woodwork exposed to weather is painted.

Slump Belt Type.—Plates V and VI.—A difficulty was experienced in this type. The longitudinal L-iron runners at plinth level and lintel level interfered with the reduction of the plinth by 1 inch (for verandah drainage) and in the construction of R. B. lintels. These runners were accordingly fixed at 6 inches below plinth level, and 6 inches above lintel level.

In the Author's opinion the two types are very suitable to their purpose. The Author would discard the use of *nurria* tiles, at least in buildings which have a R. B. ceiling. These tiles are not fastened down except by their own weight, which is not sufficient to keep them from being disturbed by a high wind. Their absorption of rain may result in deterioration of the C. G. I sheets, which will not readily be detected. A well ventilated roof will be cool whatever the material. Cement asbestos sheets were used in certain buildings, but their use was restricted pending experience of their resistance to hailstones. The parapets in the standard type of building (Plates III and IV) were not satisfactory. They are seriously weakened by the footings of the roof trusses, and by the ventilation openings. The gutters being placed inside the main walls may give trouble in the future. In the P. W. D. office buildings at Motihari the Executive Engineer made the *chajja* horizontal and strong enough to carry the gutter at its outer edge. The roof was prolonged to drain into the gutter, and the main walls were thus covered and parapets avoided. Ventilation to the roof was given through the *chajja*. This type is in my opinion an improvement.



As regards the Slump Belt Type, for economical design the plan of the building must be arranged to suit the roof. The addition

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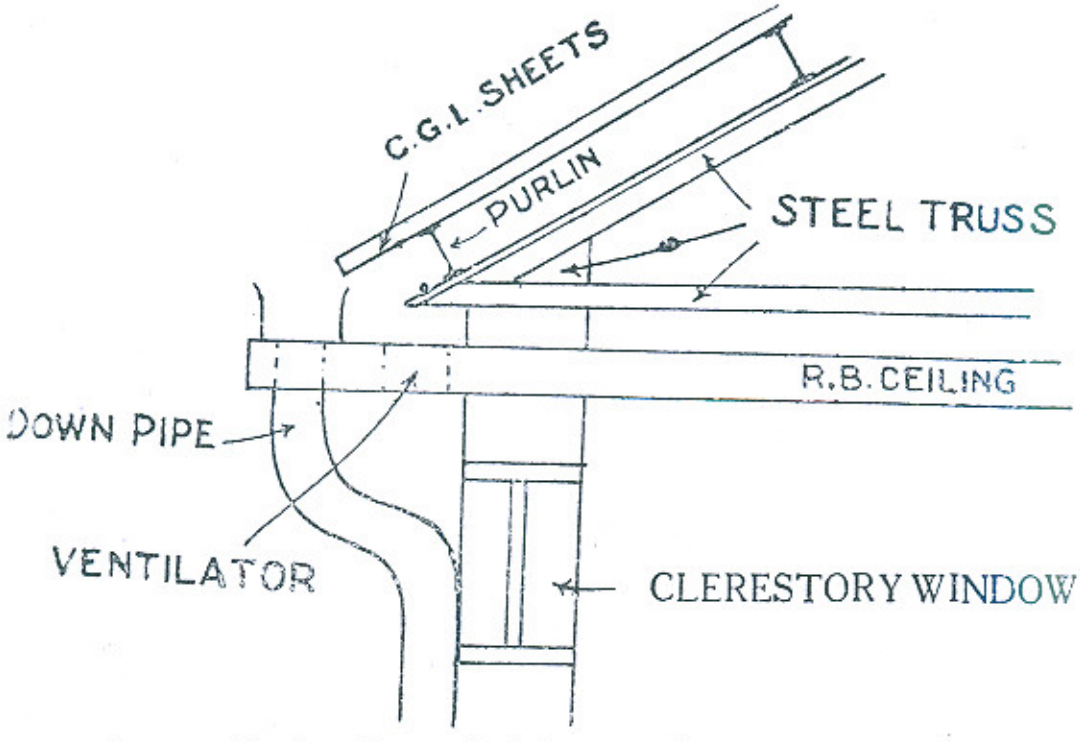


As regards the Slump Belt Type, for economical design the plan of the building must be arranged to suit the roof. The addition

of uprights and a trussed roof to a building planned originally for a flat roof, may result in avoidable expenditure on material and labour.

Plate	Cost.	Total estimated Cost.	Cost per sq. ft. of plinth area.
III	Judge's Court, Muzafarpur ..	Rs. 1,22,989	@ Rs. 4-11-6
IV	Collector's residence ..	Rs. 36,544	,, Rs. 5-2-8
V	Executive Engineer's residence ..	Rs. 25,291	,, Rs, 5-2-3
VI	Sub-Div : Officer's Court, Slump Type	Rs. 62,860	,, Rs. 5-7-3
VII	S. D. O.'S residence, Slump Type ..	Rs. 18,780	,, Rs 5-10-11

The increase of cost due to earthquake resisting features is considered to be from 10 to 15 per cent.

Plans of the 5 buildings for which plinth area rates are given above are shown in Plates III, IV, V, VI and VII.

A list of projects put in hand in the North Bihar Circle during the period May, 1936, to November, 1936, inclusive is given as Schedule II. The estimated cost is shown against each project costing more than Rs. 20,000 while less expensive projects are shown in groups. Other Circles had proportionately heavy expenditure. This expenditure was financed in part by the Government of India, who undertook to contribute 50 per cent of the cost of reconstructing government buildings in charge of the Public Works Department and the whole cost of roads and buildings in charge of local bodies.

During 1936, negotiations were in progress to fix a total for the contributions from the Government of India. It was a condition of the 50 per cent contribution, that it should only apply to the replacement of what had been destroyed, and that any increase in accommodation or improvement in the quality of the building (other than additions which were purely protective against earthquake) should be paid for *in toto* by the Provincial Government. This led to constant queries from the Accountant General and in some cases to a minute sub division of the cost. Once the total amount of contribution from the

Government of India was fixed, this classification of accounts would no longer be necessary.

Contracts.—All building contracts were lump sum contracts. There were no lack of contractors ready to tender for the work. They varied from well known Calcutta firms under European management to local contractors with no known resources who had come into the market since the earthquake. After eliminating these latter it was usually possible to accept a bid at about 10 per cent below the estimated rates. Tenders up to Rs. 50,000/- were accepted by the Executive Engineer ; if an Executive Engineer wished to accept a tender which was not the lowest, he was required to record his reasons in writing, and to get the approval of the Superintending Engineer. The reasons so recorded were then placed in the confidential record, and produced on demand for the inspection of the audit officers at the annual office inspection ; after that they were destroyed.

In the course of this business it became apparent that tenders submitted by European firms varied a good deal in comparison with the estimates, while the tenders of Indian firms were much more consistent. This point was discussed with one of the European firms who replied that his firm and others of the same standing maintained a drawing office staff capable of making a complete detailed estimate on which the firm's tender would be based. Indian firms even of considerable standing, it was alleged, do not do this but tender at a percentage below the Public Works Department estimate, relying on the accuracy of this to secure them from loss and reaping the advantage of reduced overhead expenses. The manager of the European firm further stated that the apparent variation in this firm's tenders was in reality a variation in the accuracy of the P. W. D. estimates. The preparation of some of the larger estimates in the Secretariat offered an opportunity for a completely independent check and scrutiny in the Divisional office concerned. In more than one instance the results supported the allegation of inaccuracy in the P. W. D. estimate. It is evident that when calling for tenders on a lump sum basis, accuracy in the description of the work is of even more importance than in rate tenders. The specifications in particular must be as accurate as possible. The specifications shown in Schedule III are not sufficient for the purpose ; it is necessary to re-write a full specification for the particular work. An integral and important part of the specification is a list of items included in the contract. Any errors in the drawing may result in additional cost to government.

Steel Work Contracts.

The large amount of steel work in these buildings introduced some problems which were new to the contractor. In the case of the outlying Police Buildings scattered over the districts, before the Author's

arrival in May, 1935, a contract had been let to a firm under English management which had a workshop at Muzaffarpur for the manufacture and erection of the steel frames and roof trusses and the C. G. I. roofing, (this contract included foundation to the stanchions). After the frame and the C. G. I. roof had been completed, individual contracts were let to local contractors for the completion of the buildings, including foundation of the walls, brickwork, plaster and woodwork. Most of the buildings were small and grouped in twos and threes in remote localities, and I do not think that any better method could have been devised. Later when the original contract for this steelwork had expired, the same firm was unwilling to extend the contract on the same lines and tenders were invited for the manufacture and delivery of steel work at the nearest railway station to the work. Erection and all other parts of the building were completed by local contract.

It was desired to ensure that no steel of less quality than "Tata's tested" was used. In the case of the firm with a workshop at Muzaffarpur, inspection by P. W. D. Officers of work under Government contract was welcomed at any time, and test certificates were produced for comparison with heat numbers. In the case of contracts allotted to local contractors, it was always specified that all steel work must be designed, manufactured and erected by a firm approved by the Superintending Engineer. The list of approved firms included the local firm and three or four of the best known firms in Calcutta. These firms worked under a sub-contract with the contractor for the building. The terms of such sub-contracts were never disclosed to me, but I believe that in many cases there was no formal signed contract between the two parties. In the case of the Calcutta firms, they were always unwilling to allow their designs to pass into the hands of local Superintending Engineer. In special cases they would send up a representative with a number of plans which could then be scrutinized together, and detail alterations decided on with great saving of time and correspondence. There were one or two instances of the completion of the building being delayed by late delivery of the steel roof trusses, but generally the arrangement worked smoothly. It was impossible to check the quality of steel used in a Calcutta workshop and reliance had to be placed on the assurance of the firm concerned. It was this consideration which kept the list of approved firms so limited.

Where there were a sufficient number of steel framed buildings in one place as at Sitamarhi and Madhobani, it was found advantageous to let the contracts for the whole building work to one or other of the firms approved for steel manufacture. The scrutiny and acceptance of steel work designs threw a good deal of work on to the Superintending Engineer, as draughtsmen could only be relied on for a tabulated statement of differences between the P. W. D. drawings and the design submitted. There appeared at one time to be cases where the building

work had been let as a lump sum contract, and the approved firm for steel had entered into a sub contract on a rate per cwt. basis but this was not known for certain. In such a case there might be a temptation to the steel manufacture to add weight to the trusses which was not strictly necessary. Anything of this kind was constantly watched for when designs were submitted. A building contractor who had been awarded a contract at 10 per cent below the P. W. D. estimate, and who has still to let a substantial contract for steel work, is at a disadvantage as he may be unable to get terms from any of the approved firms which do not absorb a large part of the profits on his contract. The remedy for this state of affairs is for the P. W. D. to deal direct with the steel manufacture, taking responsibility of any delay to the whole work due to late delivery of steel and if the same circumstances arose again I would certainly give this system a trial.

The New Building in use.

The only complaints in the case of court buildings and offices was that some rooms were dark. This is a fault in planning and was found to be due to enclosing the verandahs. Complaint was also made of the absence of venetian shutters to court and office rooms. The omission of these was intentional. When fixed on the same *chowkat* as glazed and panelled doors it is necessary to use long " parliamentary hinges" which enable the venetian shutters to fold back against the verandah wall. These hinges are weak and soon sag and the effect is unsightly. It was also argued that the glazed doors alone offered insufficient security at night. Venetian shutters are unknown in the Punjab and the points is of only passing interest. In the residential buildings, some detailed improvements in planning were suggested and better protection from weather to the windows of servants quarters and cook houses is badly needed. A lean-to for heating bath water was added to the back of the cook house and in some cases additional servants quarters were added. The Slump Belt Type had not been long enough in use to form an opinion on.

Earthquakes since 1934.

During the author's residence in Bihar three sharply perceptible earthquake shocks occurred. None of these was destructive or exceeded intensity III to IV on the Rossi-Forel Scale. In one case the shock consisted of undulations moving East to West. I was at the time of its occurrence sitting at a table on a verandah talking business with a man from Calcutta. I was facing South and he was facing East. When the shock occurred I was acutely aware of a sideways movement but he did not notice anything until I drew his attention to a repetition of it a few seconds later.

The first of these three shocks led to an inspection of the newly completed court buildings in Muzaffarpur. It was then noticed that

fine cracks had occurred in the R. B. ceilings parallel to the main reinforcement. This caused some concern at the time, but I observed as time went on that such cracks occurred in all R. B. ceilings, which led me to the conclusion that they were due to contraction, and that such ceilings require cross reinforcement in every case. I do not think that the earthquake was in any way responsible for these cracks.

The Situation in November, 1936.

At the time when I left Bihar, most of the works listed in Schedule II had been completed and the buildings brought into use. In Saran District all works were completed. In Muzaffarpur district all works were completed. One Sub Division had been closed. In Champaran District all works were completed except the District Jail and the Superintendent of Police's residence which were nearing completion. A plinth area estimate for a new Hospital had received administrative approval, and the detailed estimate was under preparation. The 1st April, 1937, had been fixed for re-absorbing the Champaran Irrigation Division into the Motihari Division and closing one Sub Division. In Darbhanga District the District Jail was in progress, and the Medical School Hospital was up to about roof level while at Madhubani the Sub Jail was nearly complete and some small buildings remained to be put in hand when the old Sub Jail and temporary courts were demolished. It was expected that all works at Dharbhanga would be complete about the end of 1937 and the Division would then be re-absorbed into the Muzaffarpur Division. This event might be regarded as completing earthquake reconstruction in the North Bihar Circle.

The temporary East Bihar Circle would also complete its work by the end of the financial year 1937-38. A return to the pre-earthquake organization of one Circle covering seven civil districts in April, 1938, was under consideration when I left. I would not wish to close this paper without paying a tribute to the great assistance which I received from all officials with whom I came in to contact and especially with all those officers of the Public Works Department with whom I came into personal contact in the course of my duties.

Acknowledgements.

The Author wishes to acknowledge his indebtedness to the late N. G. Dunbar, Esquire, C. E., Capt. G. F. Hall, M. C., C. I. E., C.E., Capt. A. E. Green, M.C., S. E., C.A. Browne, Esquire, E.E., J. H. Campbell, Esquire, E. E., R.S. J.N. Bhaduri, E.E. and other officers of the Public Works Department in Bihar for information and assistance in preparing this Paper.

List of Schedules.

List of Plates.

SCHEDULE I.

Earthquake Effects.—Summary of Questionnaire and Answers.

1. Types of building both public and private which have stood the shock.

(*a*) Best.—Single storied buildings, square in plan with adequate cross walls—Galvanized iron sheds such as tent godowns gymnasia, etc.

(*b*) Worst.—Two or more storied—Rectangular with long side three or more times the short side. Rectangular and only one room and a verandah thick. Jack arched.

2. General behaviour of the following types of buildings.

(*a*) Buildings which are long compared to their width

(i)	Length North and South	Mention if known in which direction the Earthquake waves travelled.
(ii)	,, East and West	
(iii)	,, North East-South West	
(iv)	,, North West-South East	

The orientation does not appear to have mattered much and in any case it cannot be taken into consideration for reconstruction, as if another earthquake occurs its epicentre cannot be foretold.

(*b*) Buildings which are more or less compact in shape, approximately square shaped, T-shaped, L-shaped. Compact buildings with small rooms and many cross walls and low ceilings stood best. Square shaped were best. T-and L-shaped buildings were usually badly damaged at the junction.

(*c*) Single storied, two storied and three storied buildings. Single storied buildings stood the best. Others fared badly.

(*d*) Buildings with a good number of cross walls connecting and stiffening the outer walls and buildings without such stiffening.

Buildings stiffened by cross walls stood well.
Buildings without such stiffening fared badly.

(*e*) Long buildings with and without their outer walls supported by buttresses.

Long buildings not good. Value of buttresses is doubtful though the Muzaffarpur church is practically undamaged.

3. Behaviour of various types of foundation, only in cases where the safety of, or damage to, buildings can be directly attributed to the nature of the foundation. Foundations in the North Bihar Circle were all of lime concrete. In towns like Motihari and Purnea where foundation failures were due to fissuring it is doubtful if any foundations except perhaps reinforced concrete rafts could have resisted failure.

4. Behaviour of the various types of superstructure:

(*a*) Walls of sun dried brick in mud mortar—not good. Monolithic mud walls are better than those of sun dried brick.

(*b*) Burnt brick in mud mortar—poor.

(*c*) Burnt brick in lime mortar—showed marked superiority provided that the bricks were well shaped and the mortar good.

(*d*) Steel framing ; a system of stanchions and beams connected together—good.

(*e*) Covering over doors and windows. Reinforced brick or reinforced concrete, arches, architraves, etc.

Reinforced brick failed due to inadequate provision for shear. Arches failed very badly. Architraves stood best.

(*f*) Reinforced brick walls if any—none observed.

5. Behaviour of various systems of roofing.

(*a*) Jack arch—failed hopelessly. In many cases the failure was accentuated by joist corrosion.

(*b*) Tiles and terrace supported on:

(i) wooden battens and beams—collapsed or partially collapsed everywhere.

(ii) Steel T. S. and Joists—did not do badly.
In many cases the rolled steel joists fell but the roof owing to the continuity of the T. S. remained standing. These roofs cracked badly and the type is not recommended for reconstruction owing to its liability to corrosion.

(c) Reinforced Brick and Reinforced concrete roofs:

Reinforced brick roofs even those subsequently condemned stood very well. No observation of reinforced concrete.

(*d*) Precast reinforced concrete slabs—No such roofs in North Bihar.

(*e*) Tiled or thatched roofs supported on:

(i) Steel trusses and purlins—good. Would have been much better if adjacent trusses had been diagonally braced. As it was there was considerable end sway which dislodged the tiles.

(ii) Wooden trusses and purlins—same remarks as for steel trusses.

(iii) Wooden rafters and purlins without trusses—generally failed.

6. Any other general information about buildings which have stood well where their success can be definitely attributed to the causes stated—good bricks and good mortar showed their worth. Reinforced brick proved superior to any other type of roof.

7. State your own ideas as to the lines on which the design of future buildings in your area should be modified in respect of siting, foundations, superstructure, roofs and floors to withstand similar earthshocks.

Siting:—High ground away from any fissures that appeared in the recent earthquake. The proximity of "gushers" need not cause anxiety as they appear to have self filled to near ground level.

Foundations:—Wide rather than deep and even pressure is essential. In many buildings on weak soil the heavy main walls sank to a far greater extent than the verandah and cross walls with the result that the building was torn to pieces. It is probable that with uniform loading of the foundations, the building would have sunk evenly as a whole and would have eventually settled vertically and have been habitable again on the ground becoming stable.

Superstructure:—Should be kept light especially where the subsoil water is high. Should be tied with reinforced brick bands at plinth, door and roof levels. Building to be as square as possible.

Roofs:—For North Bihar—For all important buildings light re-inforced brick with corrugated iron weather protection. Reinforced brick work to have wider joints than used previously and the reinforcement to be placed slightly higher up.

Reinforcement to be tied into the walls. Anti-corrosive steel to be used. For less important buildings, use steel trusses and corrugated iron and tiles with a light ceiling.

SCHEDULE II.

List of Earthquake Reconstruction Works carried out in the North Bihar Circle in 1935 and 1936.

	Estimated Cost.
Saran District.	Rs.
Civil Surgeon's Residence, Chapra	29,975
District Judge's Residence Chapra	42,910
Collector's Residence, Chapra (including cost of land Rs. 20,000) ..	62,543
Other Buildings costing less than Rs. 20,000 each ..	6,180
Outlying Police Buildings in Saran District	52,459
Total for Saran District ..	1,94,067
Muzaffarpur District.	
Collector's Residence, Muzaffarpur	43,731
District Judge's Residence, Muzaffarpur	43,931
Collector's Court, Muzaffarpur	1,30,066
District Judge's Court, Muzaffarpur	1,33,980
Munsiff's Court, Muzaffarpur	72,218
Jail Buildings, Muzaffarpur	59,230
Women's Training School, Muzaffarpur	55,000
District Inspectress of Schools' Residence, Muzaffarpur	20,151

	Estimated Cost
	Rs.
Reserve Police Lines Muzaffarpur	87,334
Other Buildings costing less than Rs. 20,000 each ..	56,177
New Sub Divisional Head Quarters at Sitamarhi.	
Sub Divisional Officer's Court	62,860
Munsiff's Court	39,230
Sub Jail	48,448
Elementary Training School, Hostel, etc.	21,685
Muzaffarpur District Court.	
Sub Divisional Officer's Residence	25,104
Other Buildings costing less than Rs. 20,000 each ..	97,005
Roads and Avenues	13,294
Outlying Police Buildings in Muzaffarpur District ..	1,10,696
Total Muzaffarpur District.	11,20,140
Champaran District.	
Zilla School Buildings at Gopalpur..	1,29,396
Zilla School Hostel at Gopalpur	64,498
Collectorate Building, Motihari	2,17,400
Civil Court Building, Motihari	1,71,273
District Jail, Motihari	3,57,377

	Estimated Cost
	Rs.
Executive Engineer's Office, Motihari	49,946
Registration Office, Motihari	45,488
Collector's Residence, Motihari	47,152
Executive Engineer's Residence, Motihari	32,527
Civil Surgeon's Residence, Motihari	32,527
Superintendent of Police's Residence, Motihari ..	32,527
Circuit House, Motihari	41,757
Four Deputy Magistrates' Residences, Motihari ..	58,636
Approach Roads, level crossings and Avenues ..	1,25,027
Reserve Police Lines, Motihari	1,45,482
Other Police Buildings, Motihari	1,10,165
Other Buildings at Motihari costing less than Rs. 20,000 each	1,17,824
Raising Lake Road and constructing screw pile bridge	23,320
Outlying Police Buildings in Champaran District. ..	97,777
Total Champaran District	19,00,101
Darbhanga District.	
District Jail reconstruction	2,34,024
Medical School Hospital	5,67,424
Registration Office	54,914

	Estimated Cost.
	Rs.
Civil Court Building	98,291
Reconstructing Judge's Court	49,173
Other Buildings at Darbhanga costing less than Rs. 20,000 each	17,348
Police Buildings at Darbhanga	44,717
New Sub Divisional Head Quarters at Madhubani.	
Civil Sub Divisional Officer's Court	71,193
Munsiff's Court	41,615
Civil Sub Divisional Officer's Residence	25,104
Sub Jail	52,432
Hospital	1,00,471
Other Buildings at Madhubani costing less than Rs. 20,000 each	33,714
Other outlying buildings in Darbhanga District ..	29,121
Outlying Police Buildings in Darbhanga District ..	1,65,486
Total for Darbhanga District.	15,86,127
Saran District	1,94,067
Muzaffarpur District	11,20,140
Champaran District	19,00,101
Darbhanga District	15,86,127
	48,00,435

SCHEDULE III.

(a) *Specification—Ordinary Type.*

1. *Foundation*—: To consist of reinforced cement concrete over a brick flat soling the pressure over the foundation bed being limited to 0·5 ton per sq. foot. Not to unduly increase the width, footings in masonry are to be avoided as far as possible and the R. C. footings designed as cantilevers. Provision should also be made for longitudinal reinforcement.

2. *Plinth masonry*:—First class brick work in lime with a 3" continuous band of R. B. just above the concrete and another 6" or 5" band at the top of the plinth masonry according as the wall is an inner or an outer one. The reinforcement in bands to consist of 3" rods of copper bearing steel.

3. *Superstructure*:—1st class brick in lime with 6" R.B. bands at lintel level and at ceiling level R. C. or R. B. stiffening cols., to be provided in otherwise unstiffened walls. The doors and window openings to be covered by lintels monolithic with the R. B. band. The reinforcement of the bands to continue right through the vertical cols. The lintels in outer verandahs may be substituted where necessary for strength by boxed joists but the rods also should be made continuous through the boxing. All verandah pillars, outer corners in walls to a distance of 2'-6" on each side and jambs of opening to a width of 1'-3" on each side to be in cement brick work.

Jaffri work and louvres to consist of reinforced concrete of a suitable design the reinforecment being efficiently anchored into the masonry.

4. *Roof*:—The main room will consist of *nurria* tiles over C.I. sheets supported on purlins carried over trusses of a special design as shown in plans. The trusses will be anchored to the walls. The end trusses will carry hip rafters of a special triangulated design so that the slope and the arrangements of the roof are not altered. The hip rafters shall be efficiently connected to the main trusses by bracing in addition to the ordinary purlins. The end two trusses in every line of roof will also be braced together by a diagonal bracing at two points. The roof over the verandahs and the side rooms will consist of 6" R. B. slab supported on walls or over walls and M. S. joists as may be required and will be finished with an average thickness of 5" of lime concrete terrace. The slope in the terrace to be not less than 1:40 R. B. slabs to have full bearings into the walls for the sake of stability.

5. *Ceilings* :—These are only required under the G. I. roofs and will consist of 5″ reinforced brick slabs supported on walls or on walls and M.S. Joists. The 5″ ceiling slab is to have no connection with the trusses and will be entirely independently supported.

6. *Floor* :—1″ 1st class cement concrete artificial stone over dry *koa* rammed to 4″ final thickness. Sills and steps will require 1″ artificial stone only. Steps may be cement plastered. The verandah floors should have a slope of about 1″ outwards. Bath rooms should have a slope of 2″ towards the outlet which is to consist of a C. I. pipe. A sunk space with 3″ parapet should be provided for the bath.

7. *Surfaces* :—Exterior sand and lime plastered, interior walls $\frac{1}{2}$″ sand and lime plastered in all places but sills of windows may be given cement plaster also dados in bath rooms, etc., up to a height of 3 feet. Ceilings to be $\frac{1}{2}$″ 4:1 cement plaster. Interior plaster to be finished with 3 coats of whitewash. Interior corners in plaster to be rounded in all places.

Doors and windows to be given two coats of raw linseed oil thoroughly rubbed in. Steel work to be given two coats of paint over a coat of priming. Red oxide may be used for trusses and roof framing. Joists where not fixed or boxed may be painted white and down pipes to have paint to match the sand plaster.

8. *Doors and Windows. Chowkats* to consist of first-class Burmah teak scantlings at least 5″ x 3″ for doors and windows with double shutters, 4″ x 3″ for single shutters and 3″ x 3″ for clerestories. Shutters to consist of $1\frac{1}{2}$″ teak but in doors of 8″ or more in height $1\frac{3}{4}$″ should be used.

9. *Cornices and Decorations* :—Projecting *chajjas* and sun-shades may be constructed in cement concrete thoroughly well anchored into the walls, supported also where necessary by suitable brackets. Cornices and bands to be finished true to template in brick and plaster, and the plaster of the main cornices to be provided with a clear drip.

10. *Drainage* :—The main roof will be drained by means of gutters and down pipes the former supported by brackets or straps connected to roof members. The joints in the gutters should be made thoroughly water tight by efficient soldering. The drainage from the verandah roof to the ground level to be by means of 4″ diameter C. I. down pipes of which a sufficient number should be provided to carry away all rain water without permitting soaking. A *pakka* cement plaster surface drain will be provided round the building to carry away all drainage. A *pakka* outfall will also be provided.

The ground all round the building to be suitably dressed so as to prevent any collection of water near the building.

11. *Ventilation* :—Clerestory windows to be centre hung and fixed flush with the inner side of the walls complete with ropes and cleat hooks. The space between the C. I. roofs and the ceilings will be ventilated by means of R. C. louvres inserted just under the eaves. Louvres to be designed according to the principle of venetian shutters with wire netting of small mesh on the inside, or moulded with the louvres. Ridge ventilators are also to be given at the top of the roof according to plan.

12. *Fixture* :—Wall cup-boards to consist of teak, shelves in the pantry, etc., to consist of 1½″ R. C. slabs supported on angle iron brackets where necessary.

13. *Fire Places* :—To be provided with flues not less than 10″×10″ finished with a special fire proof plaster inside. The design of the mantlepiece to be a plain and neat one in masonry and plaster. The fire place is also to be fitted with Minton tiles and provided with a suitable design of grate.

(*b*) *Specification—Slump Area.*

[(*i*) Buildings—10 feet and over from floor to ceiling.]

The building to be of the framed structure type in which the roof is carried on steel trusses the weight of which is transmitted direct to the foundations by steel stanchions embedded in the walls.

Foundation:—R. C. concrete foundations will be provided throughout under the steel stanchions as well as the walls and will be in the form of reinforced grid. The pressure on the foundation is not to exceed 0·3 ton per square foot or as little as possible above this. The depth of the foundation will be 2′-6″ maximum including the R. C. concrete. No foundation is necessary under the cross walls in plinth which are given merely as stiffeners for walls of rooms more than 20 feet in length.

Plinth:—The plinth will not be more than 2 feet high above ground level. The walls in plinth as well as in foundation will be of 10″ brick-work in cement and sand mortar in the proportion of 1:4. At plinth level there will be a horizontal angle iron bolted to each stanchion. These angle irons will be carried also along the brick work of all the cross walls including the stiffening cross walls if any.

Superstructure. The weight of the roof will be carried on steel stanchions which will be spaced not more than 10 feet apart. The panel walls between the stanchions will be of brickwork in cement and sand mortar in the proportion of 1:4 and will be 10″ thick throughout. The maximum height of room to ceiling level will be 16 feet and the door openings will be 7′-6″. The walls will be reinforced every fourth course with horizontal rods or Exmet reinforcement which will be securely anchored to the stanchions on either side. Besides these, horizontal angle irons will be provided connecting stanchions at lintel and ceiling level.

Surfaces:—Sand and lime plaster outside and inside with the inside white-washed. Cement plaster 1:3 in sills and in dadoes of bath rooms, kitchens, etc. Joists and other iron work to be painted; wood work to be oiled.

Roof:—Corrugated iron sheeting, with a layer of *nurria* tiles over or Red Trafford sheeting resting on M. S. trusses which will be properly braced and stiffened so as to form one compact whole. The M. S. trusses will be directly connected to the stanchions with a rigid connection of at least 50 per cent over minimum strength. The verandah rafters will also be connected directly to the stanchion with similarly strong and rigid connections. The verandah roof will be at a lower level than the main roof so as to allow of clerestory windows being fixed in the walls of the main rooms. The upper roof will project 3 feet beyond the wall to protect it from the sun's rays. The steel stanchions supporting the roofs of verandahs, bath rooms, etc., and also roofs of the main rooms, will, where necessary, be boxed with cement concrete. The main rooms will have a ceiling of asbestos cement sheets or some such light material to aid in keeping the rooms cool. The main verandahs will have a sloping ceiling of similar material to the main room, as will also the bath rooms and other small rooms. Ridge ventilators will be provided in the main roof. Stout wire netting or XPM of small mesh to be provided at the ridge ventilators or all other gaps so as to prevent birds, etc., entering the open spaces between the ceilings and roofs.

Floor:—1″ artificial stone floor over dry *koa* rammed to 4″ thickness. The verandah floors to slope 1″ outward and bath room floor to slope $1\frac{1}{2}$″ towards the pipe outlets. The bath space to be sunk and provided with a 3″ high wall around.

Doors and Windows:—Teak shutters hung on *sal chowkats* fixed to steel clamps let into the masonry. Fittings to be of brass.

General:—All reinforcing rods to be of 3/8″ diameter or other suitable section but not less than $\frac{1}{4}$″ diameter in any case, and of anti-corrosive copper bearing steel with a copper content of 0·35 to 0·5 per cent.

The General specification of the North Bihar Circle (19 Edition) will apply to all materials and workmanship.

[(*ii*) Buildings less than 10 feet from floor to top of wa measured inside, such as servants' quarters, etc.]

Foundation. Lime concrete, width and depth according to pla pressure not to exceed 0·5 ton per square feet.

Plinth. Brick in cement, strengthened with 2 nos. 3/8" diamete rods on top of concrete and at plinth level. The rods should be anti corrosive, copper content of 0·35 to 0·5 ton per cent.

Superstructure. Brick in cement with 2 nos. 3/8" diameter rod at lintel and ceiling level, the reinforcement being of anti-corrosiv steel.

Surface. Sand and lime plaster inside and outside, only inside white washed.

Roof. Nurria tile roof over C. I. sheets. Roofs of kitchens shoul consist of corrugated asbestos sheets over timber or R. C. framing.

Floor. 1" artificial stone floor over 4" dry rammed *koa.*

Doors and Windows. Teak shutters hung on *sal chowkats* fixe into masonry by steel clamps. Fittings to be of iron.

The general specification of the North Bihar Circle (1935 edition will apply to all materials and workmanship.

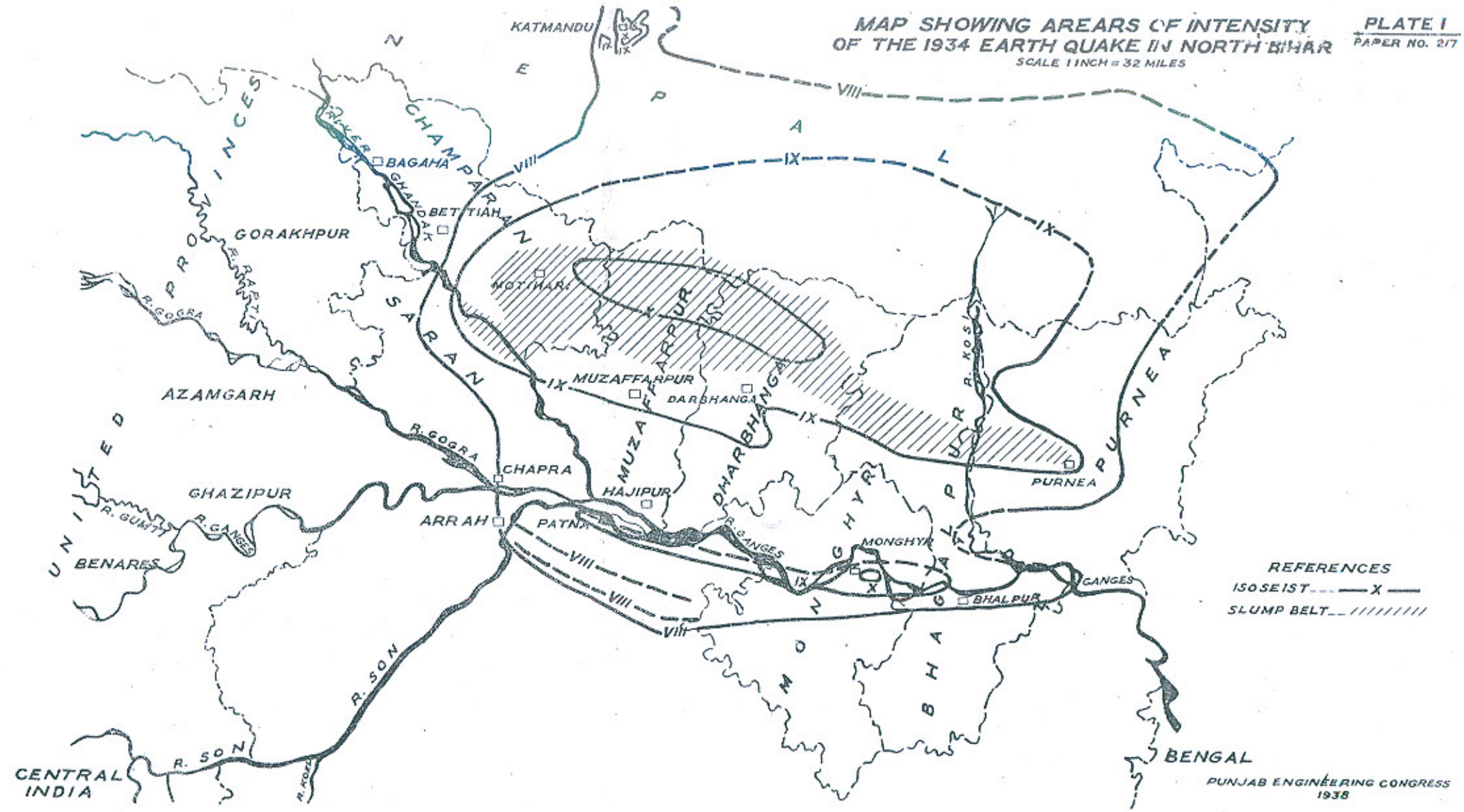
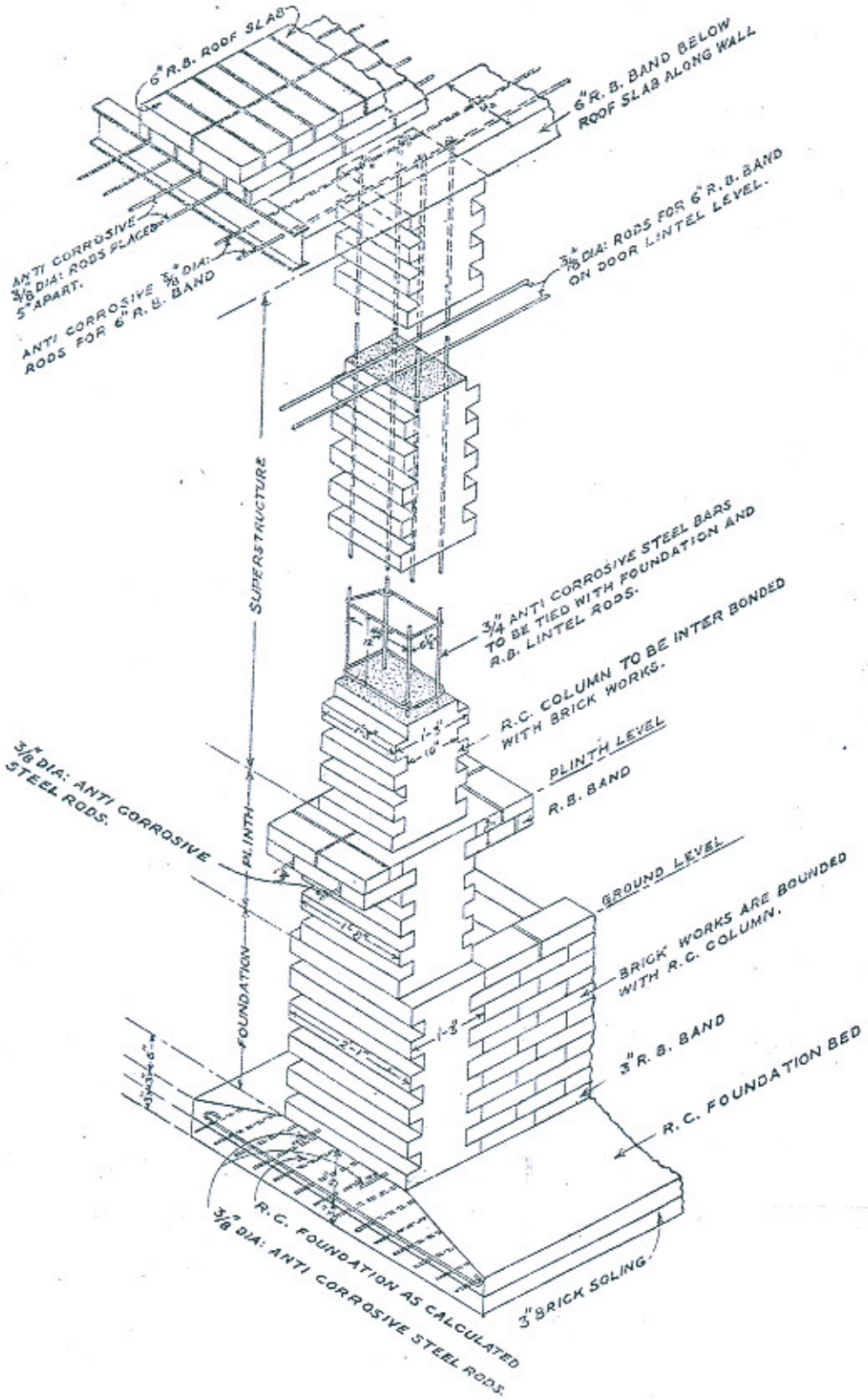

MAP SHOWING AREARS OF INTENSITY
OF THE 1934 EARTH QUAKE IN NORTH BIHAR
SCALE 1 INCH = 32 MILES
PLATE I
PAPER NO. 217
KATMANDU
NEPAL
CHAMPARAN
BAGAHA
BETTIAH
GHANDAK
GORAKHPUR
MOTIHARI
MUZAFFARPUR
DARBHANGA
DHARBHANGA
MUZAFFARPUR
SARAN
CHAPRA
HAJIPUR
PATNA
ARRAH
GHAZIPUR
AZAMGARH
BENARES
PURNEA
PURNEA
MONGHYR
MONGHYR
BHAGALPUR
BHAGALPUR
GANGES
BENGAL
CENTRAL INDIA
UNITED PROVINCES
R. GOGRA
R. GUMTI
R. GANGES
R. SON
R. KOSI
R. KOSI
VIII
IX
X
REFERENCES
ISOSEIST
SLUMP BELT
PUNJAB ENGINEERING CONGRESS
1938

PLATE II
PAPER NO. 217

DETAIL OF REINFORCED CONCRETE COLUMN
USED TO GUARD AGAINST SHOCK OF EARTHQUAKE
SCALE 1" = 2 FEET



PUNJAB ENGINEERING CONGRESS
1938