Dedicated

to

people who lost their lives during August 21, 1988 Earthquake

and

the State Government of Bihar

CONTENTS

LIST OF FIGURES

ACKNOWLEDGMENTS

Thanks are due to PWD(Buildings),Bihar and Government of Bihar for helping in the damage survey and providing the survey team all the help and the facilities.

The acknowledgments are also due to the following officials who have very kindly offered unreserved cooperation in making arrangements of the visits and providing informations.

Sri Arun Pathak, Chief Secretary; Sri A.N. Sinha, Joint Secretary; Sri P.M. Mittal, Relief Commissioner; Sri Abhimanyu Singh, Secretary (Buildings); Sri D.C. Jha, Engineer-In-Chief; Sri Bhubneshwar Prasad, Chief Engineer (Buildings), Patna; Sri Jugoshewar Singh, Chief Engineer; Sri S.J. Ahmad, Technical Secretary to Engineer-in-chief; Sri L.P. Ray, Superintending Engineer, Buildings, Patna; Sri Dhaneshwari Prasad, Superintending Engineer, South Bihar Circle; Building Construction Division; Sri R.D. Ram, Executive Engineer, Building Construction Division; Sri Shripati Mishra, Executive Engineer, Buildings Muzaffarpur; Sri Ramanand Prasad, Superintending Engineer, Buildings, Darbhanga; Sri J.N. Singh, Executive Engineer, Buildings, Darbhanga; Sri Ranjit Singh, S.D.O, Buildings I, Darbhanga; Sri Hardwar Prasad, S.D.O., Buildings II, Darbhanga; Sri Birendra Prasad Singh, S.D.O., Buildings, Jhanjharpur, Madhubani; Sri Sitaram Jha, Executive Engineer, Samastipur; Sri Brij Kishore Mehta, Executive Engineer, Munghyer; Sri R.D. Singh, Assistant Engineer, Munghyer; Mr. K.A. Patnaik, General Manager, Barauni Refinery and Sri N.M. Hulyalkar, Senior Maintenance Manager, Barauni Refinery.

Thanks are due to Dr. A.S. Arya, Professor Emeritus, University of Roorkee, Roorkee, for giving several useful suggestions in planning and organising damage survey in Bihar. Thanks are due to Dr. S. Basu, Professor, Earthquake Engineering Department for providing epicentral data of the region. Thanks are due Sri Brijesh Kumar, Earthquake Engineering Department for preparing the Isoseismal map of the affected area and the related writeup. Help and advice given by Dr. D.K. Mukhopadhyay, Lecturer, Earth Sciences Department, University of Roorkee, Roorkee, and Sri A.K.Jethi, STA, Photography Section, CBRI, Roorkee in making black and white prints for this report from colour slides is gratefully acknowledged. Thanks are also to many individuals (official and private personnels) whose names have not appeared above for their invaluable help in carrying out the investigation in the field. Thanks are due to individuals who have replied the questionnaires. Finally, thanks are due to the Head, Earthquake Engineering Department, University of Roorkee, Roorkee for providing the financial support.

1. INTRODUCTION

1.1 Prelude

A strong motion earthquake of Magnitude 6.6 which was felt in two waves of 10-15 sec in the Bihar-Nepal border region on 21 August 1988 at about 4.40 am. The epicenter of this earthquake lies in the vicinity of the epicenters of great earthquakes of 1833 and 1934.

The damage was reported from areas of N.E. region of country, West Bengal, Bhutan and Nepal. The shock was also felt at far off distances such as Tripura, Arunachal Pradesh, Madhya Pradesh, Orissa, West Bengal, Bangladesh, Meghalaya, Manipur, Sikkim, Uttar Pradesh and as far as upto Delhi and Roorkee. The maximum intensity in the epicentral track is estimated to be VII to VIII on the M.M. (Modified Mercalli) scale. This earthquake has caused widespread devastation and loss of life, killing 281 people in Bihar and about 650 people in Nepal. The affected area during Bihar-Nepal Earthquake of August 21, 1988 is shown in Fig. 1.

On receiving the report of damaging earthquake on August 21, 1988 in Bihar-Nepal region on All India Radio and Doordarshan the Department took the initiative to organise at its own cost to send a team to Bihar and carry out damage survey as well as to provide on the spot advice about stability of damaged structures, seismic repair and reconstruction of buildings.

Large scale liquefaction in the Gangetic plain, landslide in the hilly region, dampness due to excessive rain, large number of old masonry brick building and kuchcha houses and by and large the ignorance about the earthquake resistant construction in the region has resulted in wide spread damage due to this earthquake of moderate size.

Since the last major earthquake of 1934 there has been tremendous increase in the knowledge and two Indian Standard codes on earthquake resistant design and construction and ISET manual on non engineering construction have come into practice. The construction practices in this region has not improved significantly so as to resist earthquakes in spite of frequent devastating earthquakes. This report is therefore also intended to bring out the possible reasons of earthquake damages, to generate awareness in the area so as to popularise the earthquake resistant construction. The suggestions for repair, restoration and strengthening are also described for use and finally some recommendations are made. It is hoped that this report will become very useful guide for this region for earthquake resistant measures.

1.2 Socio-Economic Situation, Types of Construction, Materials, Construction Practices, Weather Conditions

Factors contributing to damage are briefly discussed below.

The socio-economic situation in Bihar has not improved so much since the last visit of severe earthquake of 1934 i.e in 54 years time instead the population and poverty both has grown. Most of the area is quite underdeveloped as compared to rest of the country. There are number of existing buildings which had suffered damage during the 1934 earthquake also.

The buildings around the damaged area is on deep Gangetic alluvium. Due to the Monsoon season, the water table in area was high and many places were either water logged or flooded.

The buildings are classified broadly as engineered and non-engineered constructions. The engineered buildings are those buildings which are structurally designed and constructed by qualified architects and engineers. Whereas, the non-engineered buildings are those which are traditionally constructed by the people without any proper design.

Traditionally, the rural buildings are non-engineered and constructed in clayey earth walls with thatched inclined roof. Usually, the naturally available soil is used without any treatment. Generally, the mud houses are of one storey with the wall thickness about 30-35 cm. The construction starts right from the ground level without any foundation. The openings for windows in the wall are usually of small size. The size of the mud houses are generally of 3.5m x 4.0m. There is no interlocking or proper connection between the walls at the corners. The dried brick(adobe) construction was not observed. Many houses are constructed in bricks in mud mortar with the tile roof. The arch construction of door/windows in verandah is quite common.

Recent non-engineering construction in villages and towns are of brick in cement mortar with a band all around at the lintel level.

Traditionally, the urban Government buildings are engineered and constructed of brick in cement mortar and the majority of these range from single to four storeyed buildings with r.c. flat roof. Whereas, many private buildings are non-engineered made of brick in cement mortar. The cement mortar used in the Government buildings consist of 1:10 cement sand ratio.

Burnt brick construction in cement mortar as a building material is very popular and can be seen all over. Wooden and stone masonry buildings were not observed as such.

This area has high percentage of very old (100 years or more) brick buildings constructed in lime mortar, including the school building some of which have survived the great earthquake of 1934. These buildings have several arches at the opening and the inclined tile roof resting on rafters. The height of the roof is generally very high approximately 6.5m.

Recent construction include very few r.c. frame structure with brick in cement mortar as infill and the storey height increased to four to five but the mortar quality (1:10) is very poor.

It is unfortunate, that the lessons learnt in the previous devastating earthquake of 1934 have not upgraded the type of construction in this highly seismic area except in the new construction, band in lintel level is seen to have been provided. Most of the buildings are very vulnerable from seismic consideration. There is a lack of awareness about the methods available for earthquake resistant design and construction. Since the last major earthquake of 1934 there has been sea change in the knowledge of earthquake resistant design and construction and two Indian Standard codes have come into practice. Except few Government constructions, there are many constructions under way with complete disregard to the two codes of practice i.e. IS Code 1893 and IS Code 4326.

The damaged area experienced very heavy rains and most of the area was under water. The Indian Army was alerted in Katihar district as the river Koshi was rising alarmingly all along the course.

1.3 Visits to Damaged Area

Department of Earthquake Engg., University of Roorkee have been conducting damage surveys of Indian earthquakes and a list is given in Annexure A. Visiting a damaged area for study purposes are not always simple and demands lot of sacrifices and hardship. The study of the damaged area is considered important from several point of view. This is also clear from the international interest shown by the institutions from USA and Japan. Two separate damage survey teams from Japan also visited the area. The first team consisted of two Japanese scientists, Dr. Sato Nobuhiko from Institute of Industrial Science, University of Tokyo and Dr. Fukui Toshio from Laboratory of Urban Safety Planning, Tokyo accompanied by an Indian research scholar, Mr. Rajeev Duggal who have been sent by Dr. Katayama, Professor, University of Tokyo, and Secretary General, International Association for Earthquake Engineering. The second team consisted of four expert members Dr. Teizo Fujiwara, Leader of the team and Professor, Kyoto University, Dr. Tadanobu Sato, Associate Professor, Kyoto University, Dr. Tetsuo Kubo, Associate Professor, Nagoya Institute of Technology and Dr.(Mrs) Hitomi Murakami, Instructor, Hokkaido University. Other teams include the Bihar Public Works Department, Central Public Work Department (team leader, Dr. Thiruvengadam, Supt. Engr.) and the Indian Institute of Technology, Kanpur (team leader, Dr. S.K. Jain).

The damaged area was so extensive that it was not practically possible to visit all the damaged areas and the damaged structures in the short time. The following places were visited for damage survey: Patna, Muzaffarpur, Darbhanga, Madhubani, Dalsing Sarai, Samastipur, Barauni, Munghyer, Jamalpur, Hassanpur village, Nalanda and Rajgir. The other important places where the team could not visit were Purnea, Begusarai, Saharsa, Sitamarhi, Bhagalpur, Gaya, Madhepura, Sikkim, Bhutan and Nepal. The severely affected districts reported were Darbhanga, Madhubani, Samastipur, Munghyer, Saharsa and Begusarai.

The following staff members who accomplished the work are stated as:

A five member team consisting of Prof. B.V.K. Lavania, Professor and Head, Dr. S.K. Thakkar, Professor, Dr. D.K. Paul Professor, Mr. Shyamal Mukerjee, Reader and Dr. S.Bandyopadhyay, Reader reached Patna on August 30, 1988 evening. The team visited Barauni Refinery on Aug. 31, 1988 and came back to Patna on the same day evening. Sri Puranmal Mittal, Relief Commissioner, Sri A.K. Sinha, Joint Secretary were contacted on September 1, 1988. The team met Sri D.C.Jha, Engineer-in-chief, Sri Abhimanyu Singh,Commissioner and Secretary, Sri Bhubneshwar Prasad, Chief Engineer who assisted in planning the visit to earthquake affected area. The team met Sri Arun Pathak, Chief Secretary on September 2, 1988 to apprise him the objective of the mission. The team visited some Government buildings affected by Earthquake in Patna on Sept. 1, and 2 1988. Professor B.V.K. Lavania returned to Roorkee on Sept. 2, evening. The remaining team completed the damage survey until Sept. 9, 1988 in the areas of North Bihar and returned to Roorkee on September 10, 1988. The following work was carried out.

Damage of Government buildings was studied with the willing help of Bihar PWD engineers.

A village was visited in Munghyer and the behavior of rural houses and their damages were studied.

Assurance to people affected by the earthquake with regards to the safety and structural stability of their damaged building.

The P.W.D. Engineers were advised about the repair, restoration, stability of damaged buildings and seismic strengthening techniques to be adopted for the Government buildings.

On 9th September 1988, a Seminar was arranged by Bihar PWD where the four members of the team delivered lectures on damages and repair and strengthening which was inaugurated by Minister of Housing and attended by state PWD engineers and other engineers from different organizations engaged in repair and strengthening of buildings.

1.4 Objectives and scope of study

The main objectives of the visit to Bihar area may be stated as follows:

To carry out a general examination of the effects of the earthquake on various structures in the region and causes of damage.

For collecting the observations and on the spot detailed informations regarding the structural configurations and types of construction of the damaged and undamaged buildings and residential houses. To analyze the damage and weak and strong aspects of design and construction. To highlight the lessons to be learnt from the failures in this earthquake.

Note: The survey have been conducted to only those buildings which have been partially damaged, leaving out those buildings which either remained intact or were totally destroyed.

To generate an awareness among the masses about the safe design and construction of their residences.

To draw out plans for repair, restoration and strengthening of repairable buildings, and to render technical assistance for the same.

To suggest economical earthquake resistant features for new building construction.

To lay down recommendations for further course of action for future planning and development.

2. SEISMOTECTONICS AND SEISMICITY

2.1 Seismotectonics

The Himalaya is considered to have been formed due to the convergence of Indian and Eurasian plates. For at least 40 million years the

Indian subcontinent has been penetrating deeper and deeper into the rest of Asia and this process resulted in the creation of world's tallest mountain range, the Himalaya [Molnar (1986)]. The study of earthquake data provides clue regarding the physical processes occurring during mountain building. The earthquake activity in the Himalaya is attributed to the Alpine-Himalayan seismicity belt. The Indian plate is moving toward north to northeast at a rate of about 5 cm per year [Le Pichon (1968)]. Various plate tectonic models have been proposed for the evolution of the Himalaya. These models postulate an estimated convergence between Indian and Asia of 2000 to 3000 km [Molnar et.al. (1977)]. About 300 to 500 km of the convergence could be accounted for by shortening along the Himalayan mountain belt. The convergence of India and Eurasia also resulted in the creation of Major boundary thrusts, viz, the Main Boundary Thrust (MBT) and the Main Central Thrust (MCT) whereas the earlier convergence took place along Indus Suture (IS).

In the evolutionary type model [Le Fort,(1975)] the MBT and the MCT are assumed to be similar but successive tectonic boundary thrusts. The southern thrusts (the MBT) becomes the new boundary of the continental convergence zone while the older thrust (the MCT) becomes less active. In the steady state type model [Seeber et.al.(1981)] the MBT and the MCT are contemporaneous features. Central to this model is a master detachment surface (MDS), which underlies the entire Himalaya. Apart from MDS a Basement Thrust (BT) zone is also postulated in the lesser Himalaya where the northerly and relatively steeply dipping MCT merges with the shallow dipping MDS. It is interpreted that most of the medium size thrust type earthquakes occur either along the BT zone or along the downdip projection of the MCT whereas the great Himalayan earthquakes (M>8) occur along the MDS. The geometry of the underthrusting Indian plate beneath the Himalaya was further constrained from the study of fault plane solutions and well determined focal depths of medium sized earthquakes and it is suggested that the great Himalayan earthquakes (M>8) occur along the same detachment surface as defined by the thrust type medium size earthquakes [Ni and Barazangi(1984)].

Apart from the major tectonic features in the Himalaya, the geophysical investigations for oil exploration have brought out that the foredeep is divided into at least four basins separated by subsurface basement ridges running north-south. These ridges are the tectonic continuation from the Indian shield. Most of the faults in the Ganga basin are mapped by aeromagnetic and seismic surveys. They seem to reflect the structural disposition of subsurface ridges or depressions underlying the foredeep [e.g., Agarwal(1977)]. The Moradabad and Patna faults, outline the Sharda and Gandak depressions respectively. It is believed that most of these faults may extend northward across the Himalaya [Valdiya(1976)]. Some of the seismicity in the Himalaya may be associated with these transverse features.

2.2 History of Seismicity

Major portion of the Northern part of the Bihar state forming part of Indo Gangetic plains falls in seismic zone IV. Most of the well located epicenters of events along the Himalaya which are reported after 1961 are concentrated in the narrow zone 50 km wide between the MBT and MCT in the Lesser Himalaya. In last 100 years four great earthquakes have occurred in the Himalaya. The region around Madhubani where the present earthquake has occurred is a seat of one such great 1934 Bihar earthquake (M=8.4) in which 11,000 lives were lost. Hence, the region devastated by present earthquake is having high historic seismicity. The region also falls in seismic zone V of the seismic zoning map of India

which is based on probable intensity IX and more on MM scale.

Map in Fig.2 gives the epicenters of reported earthquakes upto 1983, alongwith the various tectonic features including the transverse lineaments and ridges. From the period 1808 to 1983 in the grid bounded by latitude 24° to 29° and longitude 82° to 89° there are 109 reported small to large earthquakes. Only one great earthquake (M > 8) (i.e., 1934 great Bihar earthquake) has occurred in this region. The entire reported earthquake activity falls in the magnitude range from 3 to 8.4. There are six large magnitude earthquakes (M > 7) and 53 moderate size earthquakes (7.0 > M > 5.0) which have occurred indicating that the region is having considerable moderate magnitude earthquake activity. Remaining activity is confined to the small magnitude ranges (M < 5). For 6 earthquakes the magnitude estimates are not available. Majority of earthquake activity in general follows the trend of the MBT and the MCT but is confined to the north of the MCT. However, the probable epicenter of the great Bihar earthquake is located to the south of the MBT. Some of the reported fault plane solutions are also shown in this Figure which indicate that the focal mechanism associated with the earthquakes is either of strike slip or normal type [Dasgupta et. al.(1987)].

3. EARTHQUAKES AND ISOSEISMAL MAPS

3.1 The Earthquakes:

The region is well recognised seismic zone of the country. This area has witnessed three major earthquakes within 155 years and two major earthquakes in the last 54 years. These earthquakes are briefly described as below:

3.1.1 Bihar-Nepal Earthquake of August 26, 1833

A violent earthquake of Magnitude 7.0-7.5 struck on August 26, 1833 between 5.30 and 6.00 pm (IST), killing 414 people in Nepal and several hundreds in India with severe damages at Kathmandu, Bhatgaon, Khokna and Patan in Nepal, and Munghyer and Purnea district in India. At Bhatgaon a loss of 2000 houses(i.e. 42%) were reported. The maximum intensity reported was IX.

3.1.2 Bihar-Nepal Earthquake of January 15, 1934

This earthquake of Magnitude 8.4 (approx.) occurred at 14h 13m 21s IST on 15th January, 1934 with its epicenter at lat. 26° 21'N, long. 86° 12E and depth of focus 14.8 km. The earth began trembling violently with a rumbling noise. The rumbling deepened into a roar. Buildings were cracking and crumbling on every side with a deafening noise. Suddenly, it became dark and the Sun was hidden by a thick pall of dust. The air became unbreathable, choking and suffocating. Shrieks and moans of the dying were heard all over. It was bitterly cold and a strong cold West wind was blowing. Nearly 10,650 lives were lost (3400 in Nepal and 7250 in India). Most of the buildings were raised to the ground. Its epicenter was North of Darbhanga and Muzaffarpur cities. It was severe in three areas, (i) from Motihari to Madhubani, (ii) near Munghyer city, (iii) near Kathmandu. The isoseismals of the earthquake of Janauary 15, 1934 is shown in Fig. 3.

From Betia to Purnea all the houses either tilted or got buried in the alluvial soil underneath. At many places sand and water fountains suddenly erupted. Fountains of water which gushed out from fissures spread all over the cultivated land to a depth varying from a few inches

to three feet. Masonry buildings, trees, roads, bridges and even railways were engulfed. In some instances men and the cattle disappeared in one moment and then were thrown out once again by the uprush of subsoil water by opening of the surface. All the wells were choked in the worst affected areas creating acute shortage of drinking water. Landslides were triggered in the mountain regions of Kathmandu, Udaipur, Garji and Eastern Nepal and no landslides were noticed in Darjeeling area. The girders of a railway bridge were thrown off the piers. A road bridge became twisted due to the unequal settlement of upstream and downstream edges of the pier. Shocks were felt over an area of about 50,00,000 square kilometers. The communications were completely shattered by the earthquake and for days not much news could come from the outside world. In the towns of North Bihar, there was not a single masonry house which is altogether undamaged, while thousands of houses were completely destroyed with not a wall standing. Sugarcane mills in the area went out of order which created much hardship to the farmers because they could not sell their produce at that time of difficulty and need.

It was the solar ingress as well as the new Moon day. On that day the Sun, Saturn, Mars, Moon and the Rahu were in Capricorn, the natural sign of India (Jain 1983).

3.1.3 Bihar-Nepal Earthquake of August 21, 1988

In early hours, (4.40 a.m.) on August 21, 1988, a strong earthquake measuring 6.6 on Richter scale with its epicenter close to Bihar-Nepal border occurred which shook northern Bihar and Nepal region which lies in seismic Zone IV of India. In the epicentral track the earthquake was accompanied by rumbling noise and felt in two waves of 10 to 15 seconds duration. Peoples were awakened and initial confusion gave way to panic and they rushed out of their houses. The epicenter of this earthquake is shown in Fig.1 and falls in the close proximity of the epicenter of great Bihar earthquake of 1934. The news of death toll injured, damaged and collapsed houses started pouring in since early morning on the same day by All India Radio and Doordarshan. This earthquake caused widespread devastation and loss of life, killing 281 people in Bihar and about 650 people in Nepal. The total number of injured persons are 3767. See Annexure B for townwise detail of deaths and injured.The total number of houses damaged/collapsed are 1,49,334 which include all types of buildings. Annexure C and D give the detail of houses damaged/collapsed during the earthquake under different categories as reported in the Interim Memorandum on Earthquake in Bihar [Memorandum (1988)].

The damages were reported in from some towns of Nepal, such as Dharan, Biratnagar, Dhankuta, Sunsari district, Panchthar, Therathum, Ilam and towns close to Bihar border. In Northern Bihar such as Madhubani, Darbhanga, Muzaffarpur, Munghyer, Barauni, Bhagalpur, Bihar Sherif, Nalanda, Saharsa and Patna. In all, eighteen districts of Bihar state were affected. However, the damage and injury have been severe in six of them. The houses in several villages in North Bihar were reported to be affected. Apparently, there was no severe damage in Madhubani city but the damage in villages were severe. Mudhubani which is approximately 30 km North of Darbhanga has relatively fewer old buildings than Darbhanga. The damage reports, indicated damages much bigger than is usually expected from earthquake of this magnitude. The main reasons for such heavy damage was initially attributed to thickly populated area and the floods in North Bihar which had made the village houses weaker by making them wet. For North Bihar, the two calamities, floods and earthquake occurred together. There were unusual rains this year after an unprecedented floods in the previous year. Initial reports indicated

heavy damage and casualties in Darbhanga and Madhubani region. The damage reports also came from areas of N.E. region of country, West Bengal, Bhutan and Nepal. The shock was also felt at far off distances such as Tripura, Arunachal Pradesh, Madhya Pradesh, Orissa, Bangladesh, Meghalaya, Manipur, Sikkim, Uttar Pradesh and as far as Delhi and Roorkee. The pattern of damage in the epicentral region seems to follow east-west trend and this may be attributed to the preferential energy transmission in a homogeneous rock mass bounded by essentially east-west trending tectonic features including the Main Boundary Thrust (MBT) [Jha and Chauhan(1989)].

The preliminary earthquake parameters as reported by U.S.G.S. (PDE report) are as follows:

(a)	Origin time	23 hrs	09 mins	11.25 sec	GMT
		04 hrs	39 mins	11.25 sec	IST
(b)	Epicenter Coordinates	Latitude		26.775°	N
		Longitude		86.609°	E
(c)	Focal depth	71 km			
(d)	Magnitude, Mb:	6.4			
	Ms:	6.6			

However, estimation of epicenter using near station data falls to the north of MBT near eastern Nepal Himalaya between Udaipur and Dharan. The earthquake was probably caused by thrust movement as indicated by the first motion direction [Rastogi (1989)]. Increase in solar activity was reported when the earthquake occurred.

Many persons who witnessed both the earthquakes of 1934 and 1988 hold the view that the intensity of 1988 earthquake was not less than the 1934 earthquake but lasted much shorter time which was the reason of less damage. The mainshock was followed by number of aftershocks which were felt almost one every hour in all the northern states. This area is heavily instrumented and records have been obtained for which detail can be found in [Ashok Mathur et. al.(1989)].

3.2 Instrumental data of August 21, 1988

Strong motion instruments are installed as a part of Indian National Strong Motion Instruments Network (INSMIN) sponsored by Department of Science and Technology, Government of India. The instrumental records were obtained from five accelerographs and 41 Structural Response Recorders (SRR). A list of places where accelerographs and SRR are located are given in Annexure E and the recorded SRR and accelerograph data is given in Annexure F. he locations of these are plotted in Fig.5. They include the RESA-V version of Accelerograph and Multiple Structural Response Recorders having periods of 0.4, 0.75 and 1.25 sec with two sets of critical damping ratio viz 5% and 10%. Response of SRRs give the information about the response of buildings during an earthquake.

The names of places where these instruments are located are given in Annexure E. Analysis and results in terms of computed spectral accelerations of these records have been documented in Annexure F.

The digitised records from Munghyer, Raxaul, Sitamarhi, and Gorakhpur can be found in Reference [Report EQ-88-17 and Ashok et.el.], Figures 4(a)- (c) shows the records.

3.3 Isoseismal map

The extent of area affected by the earthquake was identified keeping in view the information provided by Doordarshan, All India Radio news bulletin and News paper reports. Macroseismic studies were undertaken to prepare isoseismal map of the earthquake. The data on the effects of the earthquake has
been collected through a questionnaire. A total of 800 questionnaires were dispatched/distributed to all the post offices as well as to the various organizations and, a response from about 30% was received. The questionnaires were obtained only from post offices lying within India. Response from Nepal could not be obtained.

On the basis of the information on earthquake occurrence collected through questionnaires on damage survey, obtained through the Post Masters of the post offices in the affected region and using the instrumental data, i.e. the data of Structural Response Recorders, which was collected by the Scientists of the Deptt. of Earthquake Engg. (DEQ) from various sites in the affected region and reported in [Ashok Mathur et. al.(1989)], the isoseismal were drawn.

Isoseismals VI to VIII on Modified Mercalli scale have been drawn as shown in Fig.5 together with the intensity based on spectral accelerations. Maximum intensity VIII+ was observed at Dharan, Dhankuta, Tehrathum, Udaipur and Ilam in Nepal and at Jogbani in Bihar. Dharan District was the most affected region in Nepal where about 90% buildings were damaged. The intensity VIII was observed in and around Darbhanga district where all Kuchcha houses were severely damaged, many of them almost collapsed, and cracks developed in ground and many retaining walls. The elliptical shape of the isoseismals with its major axis having NE-SW trend coincides with general structural trend of the area. Records of Structural Response Recorders (SRRs) support the views of general public, particularly in and around Darbhanga town.

3.3.1 Questionnaire

Prepared questionnaire for evaluating seismic intensity at site contains 22 items of questions. Several items are for asking the respondent's physical situations of residential house, house type, floor number etc. and the non-physical situations in which state he or she encounters a shock. All items in questionnaire are made with reference to the text in Modified Mercalli scale.

3.3.2 Intensity

The MM intensity in Bihar region was assigned by analysing the questionnaires, which were sent out by the Department of Earthquake Engineering, whereas, the intensity in Nepal region was assigned according to Television and News paper reports.

Intensity VIII+ was assigned where, (i) more than hundred people were reported killed resulting from collapse of large number of buildings (especially in Nepal) and (ii) ground cracks were observed. Intensity VIII was assigned at sites where, considerable damage has occurred in ordinary structures, very heavy damage occurred in poorly built buildings (Kuchcha houses) and some heavy furniture overturned.

The intensity VII was assigned to those points where every one ra outdoors, slight to moderate damage in well built buildings was observe and considerable damage occurred in poorly built buildings.

Intensity VI was assigned to points where the earthquake was felt b all the peoples and where they heard the loud rattling of windows doors, many people were frightened, objects kept on racks and shelve fell down and slight damage occurred in some good brick masonry house and few instances of fallen plasters were observed. The places, where many peoples awakened , dishes, windows broken, unstable objects moved, disturbances of trees were observed, have been kept in the intensity range less than VI.

3.3.3 Isoseismals

Figure 5 represents the delineation of isoseismals as per Modified Mercalli scale. Isoseismals VI to VIII were determined by plotting the points where the intensity was estimated, and then modified according to the spectral acceleration values. However, intermediate isoseismals may also be fitted if sufficient data are available. Isoseismal for intensity VIII+ could not be drawn due to insufficient number of points bearing the intensity VIII+. However, study of isoseismals reveals north of Ganges as the region where the maximum intensity was reached. Isoseismals below VI are not shown, since they can not be adequately differentiated.

The intensity VIII+ was observed at Dharan, Dhankuta, Tehrathum, Ilam, Udaipur and Jogbani where maximum damage occurred. Quoting Hindustan Times report, dated August 22, 1988, in Vivjipur area of Dharan town 90% of buildings were damaged and over 150 people lost their lives'.

Isoseismal VIII encloses the region of Darbhanga, Madhubani, Samastipur, Saharsa Madhepura, Purnea and the places where the value of spectral acceleration was 0.37g and more for a structure of period 0.4 sec and damping 5% of critical. In Darbhanga, roads have cracked at many places with sand and water gushing out. The shape of isoseismal indicating intensity VIII is more or less elliptical in shape.

The area bounded by isoseismal VII marks the places with spectral acceleration less than 0.37g and more than 0.165g and the regions of Sitamarhi, Muzaffarpur, Vaishali, Begusarai, Khagaria, Madhepura, Munghyer and Purnea. About 15,000 houses were damaged in Munghyer, while in Begusarai the swollen river flooded nearly 50 villages. Vast areas in the district were also water logged following land breaches at several places.

In the area bounded by Isoseismal VI, Munghyer, Nalanda, Patna, Saran, Nalanda and Champaran etc. are the important regions where damage has been considerable. The places with spectral acceleration value 0.165g and less have also been included in this isoseismal.

The intensity below VI covers the regions Bhagalpur, Bhojpur, Nawada, Gaya and Giridih etc.

3.3.4 Remarks

The area of high intensity occurs where the thickness of alluvium is quite high (more than 1000 m) and it decreases towards the shallower

basement. It is also to be noted that as soon as we go beyond the boundaries (Munghyer-Saharsa ridge) of negative anomaly the intensity decreases.

The shape of isoseismals follow the general structural trend in the region.

The enhancement of intensity (VIII+) at various places in Nepal may be interpreted as the effect of topography, caused by amplification of ground motion on top of the hill as well as on the hill slopes.

If we extend the Patna fault towards Nepal side it seems that the epicenter lies in the vicinity of the fault.

4. PUBLIC EXPERIENCE AND MEDIA COVERAGE

To have a feel of the national calamity and the human response and the related social problem during this damaging earthquake, a few public experience and news paper reports are reported here.

4.1 Public experience

Due to the violent shaking people were roused from their sleep. In panic they rushed out from their houses. Many people found that they could not open the lock because of violent shaking (with roaring sound of locomotive) prevented them to get out fast. Some people found that due to vibration the doors were jammed and could not be opened. The people were living in fear of after shock in tents while it was raining. Inconvenience was also caused by the flood.

4.2 News Paper Reports

Both the press and the television toned very high initially in their reporting on this earthquake and later on toned down the reports as facts started pouring in. Some of the news paper cuttings are included in this report (see Annexure G). A good coverage was given districtwise, some of them are summarised here.

At Darbhanga and Laheriasarai roads had cracked at many places with sand and water gushing out. Power supply and the telecommunication services collapsed completely and the town remained cut off for many hours. At Munghyer several places ground caved in and water sprouted out. The area near the Nilam water tank sank about 3 m. For every dead and injured Rs 500 and Rs 250 were given for immediate relief from Chief minister Relief fund.The help from IAF helicopters were sought after 48 hours to evacuate the injured persons and to reach the inaccessible area.The prime minister, Mr. Rajiv Gandhi, Home minister, Mr. Buta Singh, the minister for Urban Development, Mrs. Mohsina Kidwai, and the Health minister, Mr. Moti Lal Vohra visited the worst affected area. A high level Government of India Committee also visited the area for evaluating and to suggest relief measures.

basement. It is also to be noted that as soon as we go beyond the boundaries (Munghyer-Saharsa ridge) of negative anomaly the intensity decreases.

The shape of isoseismals follow the general structural trend in the region.

The enhancement of intensity (VIII+) at various places in Nepal may be interpreted as the effect of topography, caused by amplification of ground motion on top of the hill as well as on the hill slopes.

If we extend the Patna fault towards Nepal side it seems that the epicenter lies in the vicinity of the fault.

4. PUBLIC EXPERIENCE AND MEDIA COVERAGE

To have a feel of the national calamity and the human response and the related social problem during this damaging earthquake, a few public experience and news paper reports are reported here.

4.1 Public experience

Due to the violent shaking people were roused from their sleep. In panic they rushed out from their houses. Many people found that they could not open the lock because of violent shaking (with roaring sound of locomotive) prevented them to get out fast. Some people found that due to vibration the doors were jammed and could not be opened. The people were living in fear of after shock in tents while it was raining. Inconvenience was also caused by the flood.

4.2 News Paper Reports

Both the press and the television toned very high initially in their reporting on this earthquake and later on toned down the reports as facts started pouring in. Some of the news paper cuttings are included in this report (see Annexure G). A good coverage was given districtwise, some of them are summarised here.

At Darbhanga and Laheriasarai roads had cracked at many places with sand and water gushing out. Power supply and the telecommunication services collapsed completely and the town remained cut off for many hours. At Munghyer several places ground caved in and water sprouted out. The area near the Nilam water tank sank about 3 m. For every dead and injured Rs 500 and Rs 250 were given for immediate relief from Chief minister Relief fund.The help from IAF helicopters were sought after 48 hours to evacuate the injured persons and to reach the inaccessible area.The prime minister, Mr. Rajiv Gandhi, Home minister, Mr. Buta Singh, the minister for Urban Development, Mrs. Mohsina Kidwai, and the Health minister, Mr. Moti Lal Vohra visited the worst affected area. A high level Government of India Committee also visited the area for evaluating and to suggest relief measures.

This earthquake occurred in the early hours of August 21, 1988, and had its epicenter close to the Bihar-Nepal border. Extensive evidence of liquefaction was reported from areas near Darbhanga, Laheriasarai, Madhubani and Jhanjharpur. There was no reported liquefaction in other areas like Muzaffarpur, Sitamarhi, Purnea etc. where liquefaction took place in the earthquake of 1934. As this earthquake was of a smaller magnitude so also the extent of liquefaction. In the Munghyer area, which lies at the junction of the alluvial Gangetic basin with the Archaean quartzite rocks, no liquefaction was reported. In the 1934 earthquake also no liquefaction was reported in Munghyer though there was extensive structural damage.

In the belt covering Darbhanga, Laheriasarai, Madhubani and Jhanjharpur; sand water geysers rising to a height of about 1 m were reported. Sand and water vents were seen in open areas and floors of buildings cracked with water and sand oozing out of the cracks, building foundations and long boundary walls sank and cracked. The boundary walls of the Darbhanga Raj complex developed cracks at many places and so did the thick walls of the Darbhanga Jail complex.In both Darbhanga and Laheriasarai roads are reported to have cracked at many places with sand and water gushing out. In the nearby villages of Taralahi, Bishanpur and Keoragach a layer of sand was reported to have been deposited following the earthquake. Much of the telltale evidences of liquefaction in these areas were lost due to the floods which followed the earthquake.

As in the previous earthquakes of 1897 and 1934, it was observed that the spewing of sand and water took place after the earthquake shock and continued for hours afterwards. Sand was reported to have oozed out in the Fulwara distribution system and silted up a length of about 30 to 40 m. Most of the wells at Rajbiraj, Nepal were reported to have dried up due to chocking caused by sanding.

Thermal Springs

The hot springs situated at Sitakund, 10 km from Munghyer, issue from alluvium close to an outcrop of quartzite. Another set of hot springs are located at Rajgir, near Nalanda. In the 1934 earthquake no noticeable changes in behavior of these springs were observed as a result of the earthquake but following the earthquake of August 1988, it was reported that the hot water coming out of the spring turned blood red. This red colored water oozed out for about 10 to 12 hours after the earthquake. No red colored sediment was observed in the tanks at the springs after this behavior.

Remarks

This densely populated area, which lies predominantly on an alluvial bed a few thousand meters thick, has in the past experienced a number of earthquakes and is likely to continue to be subjected to future earthquakes. The evidence of damages to life and property in the past due to liquefaction is all too evident. It is therefore felt that a detailed zoning of the area, particularly to the north of the Ganges, be carried out and areas more prone to liquefaction be identified.

3.4 Village Houses (Mud Houses)

The major loss of life was in villages occurred due to collapse of mud houses and brick houses laid in mud mortar.

Hassanpur Village, Murgiachak

This village is on very soft brown clay and the water table was around 6 m below the ground level. Nearly 90 percent of village houses were damaged which were constructed in mud. Some houses were constructed in burnt brick using mud mortar. These constructions are weak in tension, shear and compression. Thus, the separation of walls at the corners and junction took place easily under ground shaking. Afterwards, the wall fail either due to bending or shear combined with compressive loads. Finally, the whole house would crash down. Photo 1 shows typical damage in village houses in Hassanpur.

Madhubani Village

Photo 2 shows typical houses in a village near Madhubani. The cracks in the wall can be seen in one photograph.

5.5 Brick Buildings in Lime Mortar (Old Buildings)

These are generally old masonry brick buildings constructed in lime-mortar and with inclined tile roof on rafter. The use of arches at window, door and verandah opening are very common.The roofs are generally at much higher level.

Land Mortgage Building,Darbhanga: (Photo 3)

It is about 100 years old brick building with arches constructed in lime-mortar. The front arches failed and as a consequence the building was severely damaged. The debris damaged a jeep parked in front of the building. The Finance Ministry buildings adjacent to this building was not damaged.

Circuit House, Darbhanga: (Photo 4)

The circuit house building is one storey old brick structure having gable roofs. The building developed cracks in exterior and interior walls. The significant damage was observed at eaves level. The chimney was damaged badly, tiles on the roof were dislodged.

Civil Surgeon House, Darbhanga: (Photo 5)

This is an old brick building in lime mortar. This was severely damaged and the building was abandoned. The masonry arch at the entrance developed severe diagonal cracks. The roofs also badly damaged and in one room the roof collapsed because it was supporting a water tank over it.

Jail Barracks,Madhubani

The barracks in front of Madhubani jail consists of several rooms with front verandah. The verandah in the front showed damage. The arches in the verandah showed cracks at the crown. The cracks were also developed at the joint where the cross walls and the longitudinal walls meet.

Samanalaya or Land Registry Record Room, Madhubani

This is an old brick building in lime mortar. The record room showed crack at the walls at the points where the channels were embedded. Buildings, adjacent to record room also showed cracks.

Reason:

The land registry files were stored in several open steel almarah's. These almarah's were connected by an angle iron at the top and embedded into the walls on either side for reason of better stability. The inertia force, developed due to the combined weight of almarah and files was partly transferred to the embedded support of the angle iron and caused the damage of the wall.

Remedy:

It is good idea to connect the almarah's at the top by an angle iron for reasons of better stability in an event of earthquake but they should not be extended into the walls on either side.

DSP Residence, Samastipur

This is old brick lime mortar building constructed in 1910. The building was badly damaged. A portion of roof fell down.

Munsif Magistrate Quarter, Samastipur

This was constructed approximately in 1980. This was severely damaged in the E-W direction and declared dangerous. Severe diagonal cracks were observed in the masonry shear walls.

D.M.'s Residence, Munghyer: (Photo 6)

This was constructed before 1934. There was no apparent damage in the 1934 earthquake. This is load bearing construction of brick masonry with lime mortar.

The arches in one direction showed crack at the crown. The walls showed diagonal crack in the other direction. The steel almarah with two big cup trophy in it fell down. The almarah was filled with the files.

Collectorate Record Room, Munghyer

The building suffered slight damage showing cracks in the arches at the crown.

Town Hall, Munghyer: (Photo 7)

This town hall was constructed in 1916 using brick with lime mortar. Wide spread cracks in brick arches was observed. The walls, ornamental portion in roof below parapet showed cracks.

Sangam Hotel, Munghyer: (Photo 8)

This 3 storeyed building was constructed in brick lime mortar before the 1934 earthquake. During the 1934 earthquake second and third floor damaged completely. The building was restored after the 1934 earthquake and built upto first floor only and it was used as medical store. It was renovated and it was being used as hotel.

The walls are very thick and consequently suffered heavy damage. The arches also developed crack. The new first floor construction of brick cement mortar also got damaged. Horizontal crack developed on wall at the supporting level of roof.

Clock Tower, Munghyer: (Photo 9)

The clock tower was damaged during 1934 earthquake. During this earthquake cracks were observed in the smaller arches while the big arch did not show any crack. Crack was also observed in the middle of the column.

Dilip Dharamshala, Munghyer: (Photo 10)

This is an old brick lime mortar construction consisting of arches in verandah. The arches failed causing failure of the left portion of the Sarai. The right portion was on the verge of failure.

5.6 Brick Buildings in Cement Mortar

Ashoka Patiliputra Hotel, Patna

This is newly constructed brick building. It developed cracks in the walls and around the staircase.

S.D.O. Building, Darbhanga: (Photo 11)

This is one storey old residential building constructed in brick with lime mortar. The building was constructed before 1934. The building got severely damaged from inside although no damage was seen on the outside. The diagonal cracks propagated upward from short span lintel over openings. The load bearing walls developed wide diagonal cracks. There were cracks observed in the floor as well as in the roof. Tilting of inner walls was also observed.

Residence of Jail employee, Darbhanga

The two room single storeyed brick building with verandah was severely damaged. The arches of the building showed cracks, wedge of brick got separated in one of the arches. The residents, in panic, constructed a prop to support the falling wedge from the arch and spoiled the aesthetic appearance of the building.

Doctor's residence near Jail building, Darbhanga

The building developed minor cracks. The liquefaction was observed inside the building at some places.

Collectorate Building, Madhubani: (Photo 12)

This is a three storeyed brick masonry structure constructed in 1972. In a room, at N-W corner of the building block, 3 horizontal (plinth, mid and near roof) cracks were observed on the wall. No damage was found in the stair case block. Cracks appeared on one of the extreme block probably due to torsion in the unsymmetric building.

C - Type Residential Building, Samastipur: (Photo 13)

There are several load bearing two storey blocks constructed of conventional type in brick with cement mortar. These were constructed in 1980. The mortar quality seemed to be very poor (1:8 or even less). Due to dampness in the monsoon, the strength of mortar was further reduced. Due to this reason one block showed severe horizontal shear cracks to the walls in the E-W direction.

Collectorate Building, Samastipur: (Photo 14)

This is a new three storeyed frame construction (1974) and of same design as in Madhubani. The lintel level band was provided. The brick walls are 25 cm thick.

The damage was observed in the corridor. The cross wall showed cracks. The cracks propagated in E-W direction. Diagonal cracks were observed60 cm below the roof level and horizontal crack was observed 15 cm above the floor level. The cracks were also observed on the stair wall over the beam in the corridor. The walls showed heavy cracking over the lintel. Horizontal cracks were observed in 12.5 cm thick panel walls and diagonal cracks in plaster were observed in 25 cm thick walls. The building was tilted on one side. The inspection of the building did not corroborate that the building tilted during this earthquake. The building might have been tilted already. Though the collectorate building in Madhubani and in Samastipur are of same type but the damage in Samastipur was worse.

Police Residence, Samastipur

These are three storeyed police officers residential building. Horizontal shear cracks were observed at the bottom storey. No damage was observed in the upper storey.

The quality of the mortar was very poor and could not withstand the large shear force at the base, generated by the earthquake.

Nurses Hostel, Darbhanga

This is a three storeyed brick building with the conventional construction in cement-mortar. The cracks were seen in the mumty of staircase at the roof level.

Military Sainik barracks, Jamalpur: (Photo 15)

This is a three storeyed load bearing brick masonry building constructed in 1984 with cement mortar having r.c.c. roof/floor slabs. One side of the stair case in the ground floor, is used as garage and other side is used as residential flats. Heavy damage, observed in the garage, was due to the poor cement mortar used in the construction.

The cross walls in the rooms developed wide cracks. The cracks were not observed in the longitudinal wall which also form the corridor walls. This may be due to the fact that three concrete slabs(shelves) casted in this wall offered additional strength. The rooms are very long (may be upto 50m). The planning of this building was poor. Heavy damage to the building may be attributed to the torsion caused by the unsymmetry of building and poor quality mortar. The lintel bands were not provided.

5.7 Reinforced Concrete Frame Structures

The reinforced concrete civil buildings are relatively few and almost all of them are of recent construction.

Residential Buildings of Military Police, Jamalpur: (Photos 15 e,f,g)

The three storeyed newly constructed (1979) r.c.c. beam column framed residential brick building with 60x30 cm columns and 30x40 cm beam which

was damaged heavily and abandoned. The building also had r.c.c. floor and roof. The partition walls were shattered. No cracks in beam and columns were observed. Top portion including parapets of the building were very badly damaged. The cement mortar used was of the order of 1:10 which reflects weak cement mortar ratio.

The International Yogashram Building, Munghyer

This is a seven storeyed r.c.c. framed building construction in 1985 having large rooms. This building is well designed and have good quality construction. The building did not suffer any damage which is mainly attributed to its good quality of design and construction.

Cycle Stand Cum Canteen R.C.Str., ITI, Darbhanga and Munghyer:(Photo 16)

The cycle stand cum canteen structure was constructed for ITI, Darbhanga in 1968. The 2 storeyed structure was supported on 2 rows of 5 columns, 50 cm dia, two and half meters high without brick infill. The beams were 30 cm in depth and 50 cm wide. The lower portion was used as cycle stand and the first floor was used as canteen. This structure was totally collapsed. There was no continuity of the main steel from column to beam. Stirrup spacing in column was not adequate. The bottom storey was much flexible. The top and bottom of column, at roof level, seems to have developed hinge condition resulting into formation of mechanism which then collapsed. This failure may be attributed to the poor detailing of the reinforcement and improper anchorage of reinforcement bars at beam column junctions.

A structure of similar design was also constructed in Munghyer. That structure did develop cracks at the top of column but was still standing in damaged condition. This is relatively much away from the epicenter as compared to the Darbhanga which have resulted into less intensity of ground shaking.

Telegraph Office, Munghyer: (Photo 17)

This is a three storeyed r.c. frame building constructed in 1984. The ground floor was damaged much more than the first and second floors. The walls got cracked badly between lintel and plinth. There was practically no damage to r.c. beams and columns constituting the resisting structural frame. The 3.5 m high outside and inside walls are 25 cm and 12.5 cm thick respectively. Twelve and half centimeter thick partition walls were cracked badly.

5.8 Historical and Monumental Buildings

There are many old buildings which often have an important architectural, cultural, historical and monumental value. These buildings must be preserved at all cost even at much higher cost of repair and strengthening. Because these represent our heritage and should be passed on safely to our next generation. Most of the old historical buildings are in British architecture. There are many historical and monumental buildings that got damaged. The Munghyer historical fort which was damaged in 1934 earthquake was further damaged during this earthquake. The historical Naulakha temple of Rajnagar (Madhubani) has collapsed. Eleven Buddhist monasteries of historical importance in Sikkim were damaged and three of them were severely damaged. The other damages to this type of buildings are as follows:

Governor's Residence, Raj Bhawan, Patna: (Photo 18)

The massive masonry three storeyed structure was constructed during 1916-1918. The structure was built with burnt brick in lime-surkhi mortar. It consist of load bearing masonry arches. This structure withstood the 1934 Bihar Earthquake which had cracked the dining hall on first floor in N-S direction. In the dining hall, first floor, east side, new cracks were developed near window top. This earthquake did not produce any cracks in N-S direction in the masonry arches. Nearly, all verandah arches, about 10 m span on all floors oriented in approximately E-W direction suffered damage. The damage was in the form of fine cracks at the crown. The 15m span arch in the western side of the building developed a large horizontal shear crack on one side just above the crown. The diagonal cracks were also observed above the opening in N-S direction wall. The cracks are fine in general. The cracks also appeared on the reinforced brick roof/floor in the corridor. The top of Darbar hall showed horizontal cracks in the arches in the E-W direction. The cracks also occurred in roof slab/false ceiling in front of Prime Minister's suit.

High Court Building, Patna: (Photo 19)

This is a massive two storeyed brick masonry structure constructed in 1917-1918 having 50 cm brick wall with lime mortar. The cracking occurred on the outer surface of dome. The cracking also occurred on outside walls. The false roof is made of expanded metal plastered with cement mortar. It consists of reinforced brick floors and sloping clay tile roof and the false roof is suspended from the roof truss. The damage occurred in false roof all along the wall junction. The separation of walls occurred at the corners. The separation between roof and wall was also observed. There are separation of two walls at one end of Bar association room (first floor) and crack in the false roof plaster. Cracking was also observed in the walls of court room no. 20. Horizontal and diagonal cracks are visible in the central marble hall.

Old Sachivalaya, Patna: (Photo 20)

This is a massive two storeyed brick masonry structure in lime mortar constructed in 1916-18. The building consists of three main blocks connected with arch corridors. The building has a clock tower in the central block. The clock tower was damaged in 1934 earthquake, subsequently the height of the tower was reduced during reconstruction. The tie rods were used at the top during reconstruction. The clock tower did not show any major damage as such during this earthquake but there was a slight crack in the wall where the girder was resting just above the clock at the top of the tower. The cracks occurred in the corner of registrar supply room in Northern wing. The vertical cracks occurred near the crown of the arches in both NS and EW direction. In Room no. 117 horizontal cracks occurred over the lintel at two different levels. The cracks were also seen in false ceiling of Room no. 117.

Nalanda Archaeological Remain: (Photo 21)

This archaeological remain of Buddhist education center, Nalanda University is in very bad shape which has developed cracks in the massive brick structure due to seepage of water. However, because of earthquake no damage was reported.

5.9 Religious Buildings

Many religious buildings were damaged such as the historic Naulakha temple of Rajnagar(Madhubani) and the Saraswati Shishu Mandir of Madhubani collapsed. Several Buddhist monasteries were severely damaged in Sikkim. Damage to some other religious buildings are described hereunder.

Shiva Temple, Darbhanga: (Photo 22)

The arches of Shiva temple (200 yrs old) developed cracks constructed in brick mortar. The 20 m dome of the building was also cracked. The separation was observed at the corner between verandah and the temple walls. There was a clear vertical crack in the corner. This temple was also damaged in 1934 earthquake.

Jama Masjiid, Darbhanga: (Photo 23)

This Jama Masjiid was constructed in the year of 1963. It got severely damaged. One of the Mehrab at the top was dislocated and hanging in a very dangerous manner on eight 15 cm hexagonal columns. A horizontal shift of 7.5 cm had taken place at the supporting level of dome on columns. The Indian army from Bareilly were busy in restoring it by jacking the damaged dome and repairing it again. The minarets were also damaged.

Shahi Masjiid, Quila Ghat, Madhubani

This Masjiid is very close to the Madarsa Hamedia. In this Masjiid, the minarets and mehrabs showed damage in the form of cracks.

Sita Kund, Munghyer

In Sita Kund, the hot spring became red due to red mud started flowing from underneath with the water.

Hot Spring Temple, Rajgir

In the hot spring, red mud came out with the water for hours. The Rajgir temple showed crack in the arches and the temple walls.

5.10 Educational Institutions

There had been wide spread damages caused ,to educational institutions during the earthquake which have indicated the vulnerability of the school buildings. Extensive damage has been observed to institution in Madhubani, Darbhanga, Samastipur, Munghyer, Begusarai, Khagaria districts. Besides general educational buildings most of the Madarsa and Sanskrit school buildings which are mostly situated in Darbhanga and Madhubani districts have collapsed. The number of casualties would have been much more, if this earthquake had struck during the school hours.

The school buildings are special structures from earthquake point of view since there is a trend to make longer rooms with longer unsupported wall length. The school has also large assembly rooms with long span and taller walls than the class rooms.

Zila School, Muzaffarpur

It is a two storeyed building of brick masonry constructed in 1890 almost 100 years ago. It survived but weakened by the 1934 earthquake. Some of the repairs undertaken after the 1934 earthquake is still visible. This building had front verandah with arches. The building was connected with the assembly hall at the center by a corridor. All the arches of verandah developed fine diagonal cracks near the crown. The rafters of the gable roof with tiles had shown spreading, causing separation of longitudinal walls with the cross walls near the top. Extensive wall cracking and wall separation was observed at several places. The damage was mostly on the second floor. The reason for this damage was that there was no band provided at the eaves level. The diagonal cracks were seen on the black board in the class rooms. In the assembly hall (brick wall with truss roof, 10x20 m) there were some vertical cracks observed at the top of the columns supporting 20m span arches. There was no damage observed in the arches. Heavy wooden staging had moved from its original position with the wall during earthquake.

Medical College old Hostel, Darbhanga: (Photo 24)

This is a two storeyed brick masonry building constructed in lime-mortar built in 1927. There were 22 rooms on either side of stair case with jack arch roof. Front verandah consist of brick masonry arches supported on brick pillars. there were about 180 students at that time. However, luckily only three got injured. The damage in the second floor was much severe than that in the first floor. The common wall between the staircase and verandah got severely damaged. One corner block of the building collapsed totally due to the failure of corner arch. The damage to the other corner was also severe but did not collapse. The verandah arches had cracked badly near the crown.

Most of the walls along transverse direction of building showed diagonal wide cracks and in most cases the roof fell down. In other places, there was wide separation of walls at roof level. The roof consists of three small arches 2m span approximately and 30 cm high resting on iron girders. There were some tie bars also in some of the spans. The verandah also showed severe damage all along, specially at the crown of arches. The ground floor walls did not suffer so much damage. The arches on ground floor cracked badly in transverse direction whereas some arches in longitudinal direction were not damaged at all. As a whole the damage was severe and the building was declared unsafe by the authorities. The main reason of damage was due to failure of corner arches because of lateral thrust and torsion of building.

Temporary Hostel, Darbhanga

Single storeyed barrack typed hostel showed cracks on the cross wall. The quality of construction of this hostel was very poor. The cement-mortar used was 1:10 or even less. Mostly lime concrete was used. It showed crack at the column and junction. Separation of false ceiling from wall, all along, was also observed.

L.R. Girls High School, Darbhanga: (Photo 25)

This is a single storeyed building in brick lime mortar approximately 70 to 80 years old. The school was damaged badly and was abandoned. The arches of the class room failed and there were extensive damages to the wall. The boundary wall was also badly damaged and collapsed at some portions.

High School, Madhubani

The school building suffered damage due to this earthquake.

Madarsa Hamedia, Qila Ghat, Darbhanga: (Photo 26)

This old single storey building is in L shape, consisting of fourteen class rooms (height 4.5 m with 60 cm brick wall) on either wing of 6.5x6.5 m size (approximately) was constructed in 1927. This was a load bearing brick masonry construction in lime mortar. In the front of the class room there was verandah corridor consisting of brick masonry arches resting on brick pillars. The roof of the class room consist of four small brick arches resting over iron girders. The arches (span 3.0 m) of the verandah got damaged, completely, in one wing and the rooms were damaged beyond repair. The ties came out from the arches. The cross and longitudinal wall got separated at the corners. Eight persons died and nine injured. This earthquake did not spare the respected principal Mr. S. Molibber Rasool Quadri and his two sons. The main reason of damage was due to the failure of verandah arch at one end due to lateral thrust and torsion of building which triggered a sequential failure of arches.

Notre Dam Academy, Munghyer: (Photo 27)

This is a four storeyed school building constructed (1950) in brick with sand cement mortar(load bearing) having r.c.c. floor and roof slab. The building did not have the lintel band. Most of the damage occurred was in the ground floor. The front porch and the class rooms were damaged. The school authorities have marked the cracks and were monitoring the cracks by putting glass pieces across the crack in order to find out whether the cracks were widening or not. Some of the glass pieces broke indicating slight widening of the cracks. The main reason for damage of building was due to large size rooms with large window opening without the lintel band.

Baijnath Girls High School, Munghyer

This old building was constructed in 1928 using brick lime mortar. Arches developed crack at the crown and walls showed diagonal cracks. At the roof, the small dome supported by columns showed cracks and spalling of plaster at the dome column support.

5.11 Health Care Units

Health care units are the emergency centers which render their service to all classes of people and are usually occupied for 24 hours a day at full capacity. These are also the post earthquake important structures. Large number of primary health centers, additional primary health centers, health sub-centers, state dispensaries, referral hospital, subdivisional hospitals, district hospitals, and medical college hospitals have suffered serious damages during the earthquake. Some of the damages are described below:

Medical College Building, Darbhanga

It is a single storey old brick structure constructed in lime mortar in 1927. It survived but it was already weakened by the 1934 earthquake. The repairs of arches by filling the gap over the door frame and arches by brickwork can still be seen. The failure have been observed in several arches of 3.0 to 3.5 m span. The arches generally cracked at the

crown. The damage in the key stone was also observed in some cases. In one of the arches a wedge of masonry near quaterpoint was almost separated. The damage was also seen at the false ceiling of the lecture theatre. The boundary wall fell down at some places, the wall also developed cracks and got tilted at other places.

Surgical Ward of DCHS, Darbhanga: (Photo 28)

It is a three storeyed reinforced concrete structure constructed in early 70's. The earthquake victims were treated mainly in this hospital. The type of construction is very poor. The following types of damages were observed.

(i) The reinforced concrete columns developed diagonal cracks in the ground floor.

(ii) In one of the columns, the rusted reinforcement was exposed due to spalling of concrete. The spacing of ties was quite apart.

(iii) One of the columns had substantial vertical crack near the bottom. A temporary support was provided by two brick columns, one on either side of the reinforced concrete column.

(iv) Cracks were also observed in concrete on the face of the column, concealing the pipes.

(v) There were horizontal and diagonal cracks on the cross wall in the first and second floor.

The main cause of damage was dampness in the building causing corrosion in reinforcement, poor quality mortar and the poor maintenance of the building.

Sakri District Dispensary, Madhubani

The load bearing one storey old brick buildings (1904) with jack arch roof constructed in mud mortar utilised as residence and dispensary got badly damaged, with collapse of jack arch roof. The walls and the roof were badly cracked. The cracks were wide.

5.12 Museums

The Patna museum is a three storey building which was slightly damaged and many precious statues and objects fell down and got damaged. The damage to other museums are described as follows:

Sri Maharajadhiraj Laxmi Singh Museum, Laheriasarai: (Photo 29)

The two storeyed old brick building consisting of arches, is situated over a small hillock. The building showed crack over arches and at the joint of the cross and longitudinal walls. There were too many ventilations and windows and as a result they showed crack around the openings.

Many statue and display items overturned and fell down and got damaged as a result of violent shaking due to earthquake. A proper holding and support arrangement of statues and display items can prevent the damage of these valuable items.

5.13 Jail Buildings

Jail building, Darbhanga: (Photo 30 a-e)

This is an old structure constructed before 1934. This building was damaged in 1934 earthquake also. The Jail boundary wall was cracked and bulged at several places. The wall approximately 3.5 m high, was approximately 200 m square in shape. The boundary wall was strengthened by providing buttresses at an interval of approximately 6.5 m after the 1934 earthquake. The construction was in mud mortar with cement mortar tipping.

The buildings inside the Jail, prison cells were also cracked. The security tower also developed cracks. The liquefaction was observed outside and inside of the Jail. The sand fountain rising to a height of about 2 to 3 m was observed half an hour after earthquake inside the Jail complex. The sand deposit could be seen after the earthquake. Ice cold water continued to flow for about 12 hrs.

Sub Jail, Madhubani

It is a very old construction of 1904. The boundary wall showed minor cracks.

5.14 Water Supply and Sewerage Systems

The districts of Darbhanga, Madhubani, Munghyer, Khagaria, Samastipur, Saharsa, Muzaffarpur, Sitamarhi and Madhepura indicate damage to water supply installations and their ancillaries. These reports indicate that large number of hand tube wells have choked due to this earthquake which damaged both water pipe lines and sewerage pipes except the sewer pipes near Darbhanga Medical College Hospital started leaking. No major dislocation in sewerage system has been reported. Damages to 4,418 hand tube wells in rural areas and 511 in urban areas have been reported from various districts, as mentioned above.

The pump house near the Darbhanga jail was approximately of 4m high brick structure. It developed cracks all around and above the plinth level. The walls also developed cracks.

5.15 Water Tanks

Water tank of 1.0 lakh gallon capacity at Khagaria has been extensively damaged. The 6.5 m staging was badly damaged and demolished. Water tanks at Munghyer (Photo 31a) and Sitamarhi have been partially damaged. The area near the Nilam Talkies water tank, Munghyer sank about 3 m and developed minor cracks at the column and bracing joints. The damage to other water tanks are described as follows:

Water Tank, Darbhanga: (Photo 31b)

This structure is of post earthquake importance. The circular water tank 6.5 m in diameter and 17 m high near Darbhanga jail is resting on circular raft of 50 cm thick, brick construction in lean cement mortar. The water tank showed apparently no damage. The shaft showed circumferential cracks all around the base passing through door and windows showing a formation of hinge. The liquefaction near the tank seems to have occurred but due to flood water it could not be ascertained. The structure appeared to have been tilted on one side (towards west).

5.16 Roads and Bridges

Since the substructure of most of the bridges were under water, it was not possible to assess the damage caused to the portion under water. However, the portions above the water were inspected in few cases, and extent of damage has been assessed.

There were many bridges of simple spanned steel beam supported on piers of steel pipes. Such bridges seemed to have behaved very well. The maximum number of bridge structures were damaged in Darbhanga, Munghyer, Madhubani and Saharsa districts. The reinforced concrete bridge of nearly 5.6 km over the Ganges river connecting north country did not show any apparent damage. Some other bridge structures have also been damaged in Muzaffarpur, Madhepura and Bhagalpur. Damaged roads and bridges were reported from Nepal, Sikkim and Darjeeling also. The bearing of the Railway girder bridge over river Gandhak at Samastipur got Damaged. Sinking of railway tracks was also reported from Saharsa-Madhepura section due to the subsedence of ground. Two bridges near Forbesganj were reported to be damaged.

A one kilometer portion of the Mahendra highway(Nepal) at Lahan heaved up 60 cm above the land level. Many hill slopes suffered failures causing damage to roads and bridges. The problem was compounded by incessant rains before and after the earthquake. In Sikkim three major bridges were damaged. All the damage to bridges was due to failure of hill slopes. As such earthquake vibration have not caused any damage. In Sikkim a number of massive landslides also caused damage to several roads and many routes had to be closed for several months. In Darjeeling district of West Bengal, roads subsided at several places of the order of 2-4 meters.

The damages in the rural roads were in the shape of subsedence of roads crust and its embankment. Wide cracks in the roads embankments were also observed. The earthquake caused cracks in the piers, abutments, wing walls, r.c. deck slab etc. At places due to subsedence in the embankment, hume pipe, culverts have also been damaged.

5.17 Embankments and Irrigation Systems

A brief note on damages to embankments and irrigation system as reported in Bihar Government Memorandum [18] is described as below:

(i) Kamla Balan Embankment

This embankment is located on Kamla river and approximately 35 km from the Darbhanga. This embankment is 6 m high and 6 m wide at top having 1:2 slope on riverside and 1:3 slope on countryside with brick pitching on both slopes. This embankment was constructed last year after a breach which has washed away the old embankment in August 1987. Longitudinal cracks on the top of the embankment have been noticed in nearly 7.15 km out of the total length of 180.50 km. The worst affected portion was at 47.5, 57.00, 65.80 and 67.00 km of the left Kamla Balan embankment where top and side slope subsided by 1.25 to 2.5 m thereby causing great threat to overtopping of flood water. Other portions where sinking of top and side slopes has been caused are at 51.30, 59.00, 63.50 km of left and 47.5 km of right Kamla Balan embankment. Due to earthquake, the pitching on riverside slope bulged out and that of country side became uneven after subsedence. Liquefaction was also observed on this embankment.

(ii) Bhutani Balan Embankment

Th[illegible] is located on Bhutani Balan river located about 70 [illegible] ea[illegible] Darbhanga. This embankment starts from Indo-Nepal Boarder having [illegible] river side with brick pitching over 15 cm filter material and [illegible] slope on country side without pitching. Longitudinal cracks developed in the top of embankment. The cracks are 7.5 to 15 cm wide. Out of the total length of 50 km of the embankment, nearly 26 km has been badly affected. Shrinking of top and side slopes has occurred in a length of about 37 m. Liquefaction seems to have occurred on both sides of embankment.

Besides above, the river action has changed. It started attacking the right embankment at Rajpur, Narainpur and left embankment at Hanuman Nagar eroding the embankment in length of about 1000m.

(iii) Bagmati Embankment

Tremor caused sinking of tail and portion of the Sormarhat-Hayaghat embankment i.e. between 16.38 km to 16.40 km. This portion was serving as a link road to Hayaghat.

(iv) Kothauri Embankment

Countryside slope of filled up breach portion (a length of 85 m) at 10 km near Balua has slided. At Garara tola top of embankment subsided by 15 to 40 cm in a length of 200' and longitudinal cracks found in 270 m in Muradpur.

(v) Gupta-lakhmina Embankment

Cracks developed longitudinally in the earthen portion of the spur and launching of apron.

(vi) Kosi Embankment

Longitudinal cracks developed in the embankment spurs. The river action has changed, attacking the Western Afflux Bundh and Western Kosi embankment. Nirmati Marguna low bundh-cum road breached at four places, slope eroded away and badly damaged. Similarly, the Sikarhatta Majhari low bundh-cum-road was badly damaged.

(vii) Irrigation System

It has also caused damage to canal system of Kosi water and sand oozed out in its Fulwara distribution and silted up in a length of 35 m. The eastern and western approach to Kosi Barrage developed,many cracks.

.18 Electrical Generation and Distribution Systems

The three Thermal Power Stations (two units at Barauni, two units t Muzaffarpur and one unit at Patratu) had to be stopped immediately ue to severe vibrations resulting from earthquake. There was no damage o the Thermal Power Stations. There were severe damages to Kosi Hydel ower house and the colony.

The earthquake affected the transmission systems of five districts North Bihar namely Madhubani, Purnea, Saharsa, Muzaffarpur and otihari, and three districts of South Bihar, namely, Munghyer, agalpur and Patna. There was extensive damage to the transmission nes between Purnea to Koshi Hydel Power Station and Jamalpur to

Sultanganj. One of the transformers installed at the Pandaul Grid sub-station was completely damaged resulting in complete dislocation of power supply in the districts of Darbhanga and Madhubani. The tower at semi permanent river crossing at Kasela were damaged resulting in complete dislocation of power received from Chukka Hydel System. There had been serious damage in the civil works such as sub-stations foundations, cable trenches and central rooms and in the colony of five sub-stations namely, Pandaul, Jamalpur, Ganga, Hathidah etc. Due to damage of the foundation, the lightning arrestors at Jamalpur and circuit breakers and Sultanganj and Hathidah were seriously damaged.

The damages in the distribution sector resulted into complete dislocation of the power supply in the 15 districts. There had been a total damage in the infrastructure laid for giving the transformers and other inter related structures.

4.19 Telecommunication Systems

The telecommunication system was severely damaged and remained out of order for quite some time which made the relief and rescue work difficult. More details of damages of its facilities could not be obtained.

4.20 Industrial Structures

There are large number of industries in Bihar specially in the South of Ganges where the intensity of earthquake was low. Generally, an industrial structure houses many people together at a time continuously and damage in monetary term could be substantial. The damage may also include machinery and material. Damage to such type of structures may lead to sometimes a serious calamity such as in Bhopal. The indirect damage could be substantial due to payment of compensation in an event of death to the relatives of its employee and the loss of an economic productivity for reason of closure.

The Barauni Refinery is located 10-15 km from the Ganges. Here, underground Ganges is also flowing. Even 24 hours pumping of water , the water table does not go down. The soil is mainly silty sand. The deep foundation were provided under the various structure. The r.c.c. raft foundation were also provided. The codal provisions were not made in the various structure. There were minor damages to various structures in the Barauni refinery such as the Horton Sphere, LPG storage tank and the Coke Calcination plant chimney (50 m high, 6 m at base) whose foundation seems to have shown cracks. The Horton Sphere LPG storage tank which was carrying 500 MT and 300 MT during the earthquake is supported on eight braced 20 m high columns. Spalling of fire resistant concrete at the diagonal bracing column junctions at few locations (the northern side) were observed in one of the two closely located Horton sphere. The damage is also seen at the joint of the columns and the tank junctions. Any damage to Horton Sphere LPG tank could lead to serious consequences of fire hazard. Minor cracks were also observed at the ICCP new office building. Cracks were also observed in various building structures in the refinery complex which are of repairable nature. Damages were observed in Munghyer, Darbhanga and Barauni milk dairy. Repeated heavy damage to industry may lead to shift of resources from the area as in case of agriculture institute, Pusa road, New Delhi, which was shifted from its original location in Pusa near Samastipur. This further denied the development of the area.

6. CONCLUSIONS

6.1 General

A moderate size earthquake (M=6.6) was felt in the Bihar-Nepal border region on August 21, 1988 at about 4.40 am with epicenter in close proximity to the epicenter of great earthquake of 1934. This earthquake caused wide spread damage to property and about 1000 people lost their lives (281 in Bihar and nearly 650 in Nepal). The maximum intensity of VIII+ was observed at Darbhanga (D = 90 km), Munghyer (D = 142 km) in Bihar and Dharan in Nepal. These three places are located quite apart as shown in Fig.1. The reason for high intensity at Darbhanga is mainly attributed to the soft alluvial soil and liquefaction resulting in large scale subsidence of soil whereas in Dharan the high intensity is attributed to amplification of ground acceleration due to hill and hill slope. The Munghyer is quite far from the epicenter still it experienced high intensity. Similar observation was made during the 1934 earthquake [Memoir GSI, 1934]. This is attributed to local amplification of ground motion due to convergence of seismic waves from the rock outcrop (Satpura hills).

The damage survey of various structures with respect to seismicity, socio-economic condition, type of construction, material of construction and construction practices of the region has been reported. The isoseismal map of the earthquake is drawn. The alluvial soil of the Gangetic plain makes the region very vulnerable to liquefaction under earthquake excitation. The recent r.c.c. construction with codal provision have shown better performance while old and poorly built load bearing unreinforced masonry brick buildings performed badly. Many of the school buildings, student hostels and dispensaries are housed in old buildings some of them have experienced and weakened by the 1934 earthquake. Such building should not be used for such purposes since it may have resulted in severe consequences had the earthquake was of slightly higher magnitude.

Seismic history and geotectonics of this Himalayan region indicate that earthquake will occur there in the future also. Thus it is important that we should improve the existing construction by incorporating the latest techniques in earthquake resistant analysis, design and construction and strengthening of old buildings. Awareness among the masses, specially in villages, should be created to provide the earthquake resistant measures through printed information given as handouts, short film through television and radio broadcast.

If proper construction practices are not followed,the earthquake hazard can become a large scale disaster. The disastrous affects of earthquakes can well be avoided or mitigated if the knowledge regarding earthquake resistant measures are properly implemented. The disastrous effect on buildings and other structures depend not only on the intensity but also on the strength and construction quality of the buildings/structures.

The instrumental data obtained from the Structural Response Recorder and Accelerograph installed and maintained by the Department of Earthquake Engineering, University of Roorkee will be very useful in further analysis and design of structures in this region.

6.2 General damage observations

Large scale liquefaction of ground was observed in the Gangetic plane resulting in ground subsidence.

Mud houses and brick houses laid in mud mortar were affected most in villages.

Severe damage to old masonry buildings having jack arch construction were observed. Those masonry buildings which have survived the 1934 earthquake have damaged beyond repair. The new construction have also shown severe damages because the use of poor quality mortar and lack of proper knowledge about earthquake resistant design and construction.

The framed construction have shown better performance than the load bearing construction. The concrete frame structures have also failed where the earthquake resistant design consideration and the reinforcement detailing were not incorporated.

The damage survey have pointed out very specifically that Government buildings constructed by engineers as per the recommendations contained in IS 4326- 1976 have performed very well.

6.3 Main causes of damage and remedial measures

The common reasons of damages which were observed during this earthquake are as follows: (i) spreading of roof rafter causing separation at corner of wall and separation of false ceiling; (ii) a vertical cracking of brick masonry arches near the crown, wedge action; (iii) aging of buildings; (iv) failure at the corners of opening (v) horizontal shear cracks due to poor strength of cement sand ratio (vi) poor mortar quality and poor quality of construction (vii) poor drainage; (viii) absence of horizontal band in the mud and the brick houses caused most of the damages; (ix) a serious weakness of the reinforced concrete columns was lack of lateral ties or large spacing of the ties, (x) failure due to liquefaction and (xi) inadequate detailing of reinforcement.

Many damages of structures were associated with the liquefaction of soil. Proper design of the foundation is very important against possible liquefaction. It is advisable to compact the foundation soil or use pile or raft foundation. Many embankment have been damaged because of improper compaction or no compaction. Therefore, it is recommended that proper compaction must be carried out to avoid such damages. Insitu soil test should be carried out in order to determine liquefaction potential of the affected region.

The buildings having brick masonry arches and the old buildings including those buildings which have survived the 1934 earthquake were worst hit by the earthquake. The old buildings have deteriorated in their strength due to aging. These are the old brick buildings which constitute most of the irrepairable damage. In future earthquakes, it will cause even more damage since the old buildings will become even more older and weaker. The masonry arch has proved to be a weaker construction. The masonry arch construction in new buildings should be abandoned. The old arches must be strengthened wherever possible.

The movement of objects resting on platforms without proper holding caused damage to precious objects in Museum and elsewhere. These precious display objects should be properly restrained or placed on

isolators so that these do not get damaged during violent shaking due to earthquake.

The code of practice for earthquake resistant construction have come into action in 1967, even then most of the buildings in urban area have been constructed with total disregard to the codal practices. This ignorance has resulted in wide spread damage to the residential buildings. By and large, the Government agencies are following the codal practices while private and public construction are still ignorant about the codal practices.

7. RECOMMENDATIONS

7.1 Short term recommendations:

A Workshop on "Lessons learnt from Bihar Earthquake of August 21, 1988" be held in Patna at the earliest. The objectives of this Workshop should be (i) to create awareness while the affects of earthquake is fresh in their mind (ii) to highlight the lessons learnt and to advice very common methods of repairs and restoration of buildings and (iii) preparedness for future in improving earthquake resistant construction practices.

The ISET manuals(1981) and IAEE Guidelines (1980) for non engineered construction, repairs and restoration should be made available to the engineers and the affected people. A brief description of repair, restoration and strengthening of structures are given in Annexure H.

Assurance to affected people in the earthquake affected area with regard to the safety and structural stability of their damaged building should be extended by qualified engineers. Where possible, on the spot technical advice should be rendered for repair and strengthening of buildings.

An effective way of dissemination of knowledge can be carried out by constructing urban and rural building models demonstrating earthquake resistant design and construction features from where the masons could see and learn the new method of construction. An exhibition displaying such features should be organised.

7.2 Long term recommendations:

Special one/two weeks short term courses on following subjects should be organised to educate local engineers, (i) Earthquake resistant design and construction of buildings, (ii) Earthquake resistant design and construction of bridges, (iii) Methods of repair, restoration and strengthening of buildings and bridges damaged in earthquakes.

The knowledge of the earthquake resistant analysis, design and construction concepts be spread in the state with speed by means of technical teaching at all levels by holding Workshop/ Seminars.

Educating the people on earthquake hazard awareness and preparedness using the mass media such as television and radio broadcast. Video films with titles like: How to react in an earthquake, be prepared and screened to masses.

The guidelines for non-engineered construction as given in [IAEE Guidelines(1980) and ISET Manual(1989)] should be adopted. The use of IS: 1893-1988, IS: 4326-1976 and National Building codes should be made mandatory in all the Government departments and private builders in this seismic region. The building Bye laws in the region should be modified or introduced to incorporate the earthquake resistant features in design and construction. Finally, the methods should be evolved so that the Bye laws are enforced properly.

Effective details for earthquake resistant rural houses are to be worked out to suit the traditional construction.

Adequate annual maintenance of buildings should be carried out so that it remains in good condition.

A survey should be undertaken to identify those structures which require retrofitting.

Studies of soil for liquefaction potential should be carried out.

Accelerogaphs and the Structural Response Recorder should be installed in important buildings so as to obtain scientific data for use in future analysis and design. Seismic Alarm and Tripping Device should be installed in Power Houses and Industrial structures so as to save the equipment from the possible damage.

8. REFERENCES

1. Agarwal, R.K. (1977), Structure and tectonics of Indo Gangetic plains, In:V.L.S. Bhimsain Karan and V.K. Gaur (Editors). Geophysical case histories of India, AEG Seminar, Hyderabad, India, Vol. I, 29-46.

2. Ashok Kumar, S. Basu, M.K. Bansal, Shikha Mathur and Brijesh Chandra, Strong Motion Data From Bihar-Nepal Earthquake of August 21, 1988, Workshop on Bihar Earthquake of August 21, 1988 at IIT Kanpur, December 28-29, 1988.

3. Arya, A.S., Protection of Educational Buildings Against Earthquakes, UNESCO Educational Building Report 13, Bangkok, Thailand.

4. Arya, A.S., L.S. Srivastava and S.P. Gupta, Damages during Dharmar earthquake of Dec. 13, 1982 in Yemen Arab Republic, Bull. ISET, 21, 4, Dec. 1984, pp.11-162.

5. Auden, J.B. and A.M.N. Ghosh (1934), Preliminary Account of the Earthquake of the 15th January 1934, in Bihar and Nepal. In Records of the Geological Survey of India, Vol. LXVIII, part 2, pp.177-239.

6. Dasgupta, S. M. Mukhopadhyay, and D.R. Nandy (1987), Active transverse features in the central portion of the Himalaya, Tectonophysics 136, 255-264.

7. Gosain, N.(1966), Building Practices in Seismic Zones of North Bihar, North Bengal and Assam, Proc. Third Symposium on Earthquake Engg., Univ. of Roorkee, Nov.

8. Gupta, S.K., S.Kumar, P.M.Jalota, R.B.Sharan and A.K.Relan (1986). A Macroseismic Study of Dharamshala Earthquake of 26th April 1986. (8th Symposium on Earthquake Engg., Roorkee, Dec. 29-31, Vol. I, pp. 31-38).

9. IAEE Guidelines(1980), Guidelines for Earthquake Resistant Non-Engineered Construction, Basic Concept of Seismic Codes, Vol.1, Part 2, IAEE, Tokyo, Oct.

10. IS:4326 (1977), Code of Practice for Earthquake Resistant Construction of Buildings, Bureau of Indian Standards, New Delhi.

11. IS:1893 (1988), Code of Practice for Earthquake Resistant Design of Structures, Bureau of Indian Standards, New Delhi.

12. ISET Manual(1989), A manual of Earthquake Resistant Non-Engineered Construction, Indian Society of Earthquake Technology, Roorkee.

13. Jain, N.K.(1983), Bihar Nepal Earthquake -1934, Disaster Management, 3, 1, Jan.-March, 29.

14. Jha, P.C. and R.K.S. Chauhan, Investigation Into August 21, 1988 Bihar-Nepal Earthquake, Workshop on Bihar-Nepal Earthquake of August 21, 1988, IIT Kanpur, December 28-29, 1988.

15. Karunakaran, C and A.Ranga Rao (1976). Himalayan Geology Seminar, New Delhi, 1976 (In Misc.pub., Geol. Surv. Ind., 41, Pt. V, pp. 1-66).

16. Kumar. S., S.K.Gupta and P.M.Jalota (1981). A Macroseismic Study of 14th July 1978 Dharamshala Earthquake, Himachal Pradesh. Rec. Geol. Surv. Ind., Vol. 112, Pt. VIII, pp. 84-88.

17. Lefort, P. (1975), Himalayas the collided range: present knowledge of the continental arc. Am. J.Sci. 275A, 1-44.

18. Memoirs GSI (1934), Report on the Bihar-Nepal Earthquake of 1934, Memoirs of the Geological Survey of India, Vol. 73.

19. Memoir GSI (1897), Report on the Great Earthquake of 12 June 1897 - Memoirs of the Geological Survey of India; Vol. 29

20. Memorandum Bihar Govt.(1988), Interim Memorandum on Earthquake in Bihar, 1988, Relief and Rehabilitation Department, Government of Bihar, Patna.

21. Molnar, Peter (1986). The Geological History and Structure of the Himalaya, American Scientist 74, 144-154.

22. Molnar, P., W.P. Chen, T.J. Fitch, P. Tapponnier, W.E.K. Warsi, and F.T. Wu (1977), Structure and Tectonics of the Himalaya: a brief summary of relevant geophysical observations, td. C.N. R.S., 268-294.

23. Ni, J. and M. Barazangi (1984), Seismotectonics of the Himalayan Collision Zone: Geometry of the Underthrusting Indian plate beneath the Himalaya, J. Geophys. Res. 89, 1147-1163.

24. Pichon, Le, (1968), Sea-floor spreading and continental drift, J. Geophys. R. 73, 3661-3697.

25. Rastogi, B.K.(1988), Some Reflections on Intensity and Source Parameters Study of Bihar-Nepal Earthquake of Magnitude 6.4 on August 21, 1988, Workshop on Bihar-Nepal Earthquake of August 21, 1988, IIT Kanpur, Dec. 28-29.

26. Report EQ-88-17 (1988), Performance of Strong Motion Instruments in Bihar-Nepal Earthquake of August 21, 1988, Report of Earthquake Engineering Department, UOR, Roorkee, Oct.

27. Richter C.F., (1958), Elementary Seismology.

28. Seeber, L., J. Armbruster, and R. Guiltmeyer (1981), Seismicity and continental subduction in the Himalayan arc, In:H.K. Gupta and F.M. Delany (Editors), Hindu Kush Himalaya: Geodynamic Evolution, Geodyn. Ser. Am. Geophys. Union 3: 215-242.

29. Valdiya, K.S. (1976), Himalaya transverse faults and folds and their parallelism with subsurface structures of North Indian plains, Tectonophysics 32, 353-386.

30. Wadia, D.N. and Auden, J.B., (1939), Relation Between Geological Structure And Earthquakes. In Memoirs of Geological Survey of India, Vol. 73, pp. 143-158.

Annexure A - List of earthquakes

No.	Name	Date	Magnitude
1.	Badgam Earthquake	Sept. 2, 1963	5.5
2.	Anantnag Earthquake	Feb. 20, 1967	5.7
3.	Koyna Earthquake	Dec. 11, 1967	6.3
4.	Broach Earthquake	March 23, 1970	6.7
5.	Kinnaur Earthquake	Jan. 19, 1975	6.8
6.	Roorkee Earthquake	Nov. 6, 1975	4.7
7.	Indo-Nepal Earthquake	May 21, 1979	5.8
8.	Western Nepal-India Border Earthquake	July 29, 1980	6.2
9.	Baddu-Bilawar Earthquake	Aug. 24, 1980	5.2
10.	Great Nicobar Island Earthquake	Jan. 20, 1982	5.6
11.	Cachar Earthquake	Dec. 31, 1984	5.6
12.	Assam Earthquake	Aug. 6, 1988	7.0

Note: Among the above earthquakes, very special studies of isoforce determination by using sliding and overturning of objects were carried out for the Koyna earthquake and the Broach earthquake. Also, the Koyna dam was thoroughly studied through dynamic response and model tests on the shake table and the strengthening scheme was finalised for not only repair and restoration of the cracked dam but also for its seismic strengthening for future earthquake shocks. During the Broach Earthquake, the major railway bridge across Narmada river was damaged at some bridge supports and the same was successfully investigated by this Department.

Annexure B - Table showing deaths and injured
(information received upto 8th September 1988)

Sl.no.	District	D (Km)	Injured	Deaths
1	Samastipur	122.2	158	21
2	Khagaria	127.0	238	9
3	Saharsa	85.7	435	21
4	Munghyer	141.8	932	16
5	Darbhanga	90.0	992	83
6	Muzaffarpur	134.4	19	5
7	Madhubani	63.5	660	98
8	Nalanda	193.1	20	1
9	Purnea	128.0	17	3
10	Madhepura	83.6	30	9
11	Gopalganj	215.9	3	-
12	Bhagalpur	158.7	24	3
13	Sitamarhi	113.2	75	6
14	Jahanabad	227.0	-	1
15	Begusarai	145.0	155	4
16	Sahebganj	172.0	5	-
17	Giridih	271.4	1	1
18	Saran	208.5	3	-
	Total		3767	281

Note: total deaths of 650 were reported in Nepal.

D = Distance in Km from the epicenter to the district town

Ref. Interim memorandum on Earthquake in Bihar, 1988, Relief and Rehabilitation Department, Government of Bihar.

Annexure C - Table showing number of damaged/collapsed houses in different categories.

Sl No.	Categories	Damaged	Collapsed	Total
1	SCs	-	-	18415
2	EWS	45955	9346	55301
3	LIG	24334	12228	36557
4	MIG	15103	10232	25335
5	HIG	-	-	13726

The district wise detail of houses collapsed/damaged are given in table below.

Note: SC - Scheduled caste; EWS - Economically weaker section; LIG - Low income group; MIG - Middle income group; HIG - High income group.

Annexure D - Table showing the number of houses damaged/collapsed during the earthquake under different category

Sl.no.	District	D(Km)	S.C.	E.W.S.	L.I.G.	M.I.G.	H.I.G	Total
1	Darbhanga	90.0	7554	17969	13373	10050	3938	52884
2	Madhubani	63.5	4286	11740	7630	7695	6882	38433
3	Munghyer	141.8	3430	16412	7789	746	63	28440
4	Saharsa	85.7	1823	5379	4734	4251	2135	18322
5	Samastipur	121.2	456	1397	1360	1847	405	5465
6	Sitamarhi	113.2	251	840	450	191	67	1799
7	Khagaria	127.0	278	797	380	73	-	1528
8	Purnea	128.0	170	384	290	218	98	1160
9	Begusarai	145.0	93	183	154	121	65	616
10	Madhepura	83.6	44	119	137	95	55	450
11	Muzaffarpur	134.4	14	34	28	25	11	112
12	Nalanda	193.1	12	33	25	18	6	94
13	Bhagalpur	158.7	4	12	7	5	1	29
14	Giridih	271.4	-	1	-	-	-	1
15	Sahebganj	172.0	-	1	-	-	-	1
	Total		18415	55301	36557	25335	13726	149334

Government extended soft loans to build and repair the damaged houses.

ANNEXURE-E

LIST OF STRONG MOTION STATIONS FOR RETREIVAL OF DATA OF BIHAR EARTHQUAKE OF AUG. 21, 1988

S.N.	STATION	STATE	LONG	LAT	LOCATION
1	LAURIYA	BHR	8414	2659	C.K. HIGH SCHOOL
2	SIWAN	BHR	8422	2614	GEOPHY.DEP.DAV COLLEGE
3	BETTIAH	BHR	8428	2647	RAJ HIGH SCHOOL
4	CHAPRA	BHR	8444	2548	JAGDAMBA COLLEGE
5	SAGAULI	BHR	8445	2646	GOVT.NAND.HIGH SCHOOL
6	KESARIYA	BHR	8452	2622	GOVT.HIGH SCHOOL
7	SHIKARPUR	BHR	8455	2637	VERMA DEGREE COLLEGE
8	RAXAUL **	BHR	8456	2659	HAR.SC [illegible]
9	SONPUR	BHR	8511	2542	P.RLY.DEG.CO[illegible]
10	LALGANJ	BHR	8512	2551	B.D.O.OFFICE
11	JOGBANI	BHR	8513	2624	EMPLOYEE BUILDING
12	BAIRAGANIA	BHR	8515	2639	R.B.P.BAIRAGANIA COLLEGE
13	MUZZAFARPUR	BHR	8523	2607	INSTITUTE OF TECH.
14	MOTIPUR	BHR	8524	2622	JEEWACHH COLLEGE
15	SITAMARHI **	BHR	8530	2636	S.R.K.GOEN. COLLEGE
16	SAMASTIPUR	BHR	8547	2552	SAMASTIPUR COLLEGE
17	DARBHANGA	BHR	8554	2610	EX. ENGG. R&B PWD
17	DARBHANGA **	BHR	8554	2610	CM SCIENCE COLLEGE
18	BARAUNI	BHR	8559	2530	A.P.S.M. COLLEGE
19	MADHUBANI	BHR	8605	2632	D.M.OFFICE
20	JAYNAGAR	BHR	8610	2635	B.D.O. OFFICE
21	MUNGER **	BHR	8629	2524	OFF WIRELESS STATION
22	NIRMALI	BHR	8634	2622	B.D.O. OFFICE
23	SUPAUL	BHR	8635	2607	AGRI.PRD.MRT.COMM.
24	SAHRASA	BHR	8636	2554	SASHRSA COLLEGE
25	BIHARIGANJ	BHR	8649	2546	INS.BUNG.IRR
26	MURLIGANJ	BHR	8700	2552	IRR.INSP.BUNGLOW
27	ARARHIA	BHR	8721	2607	ARARHIA DEG. COLLEGE
28	PURNEA **	BHR	8728	2544	DEGREE COLLEGE
29	KATIHAR	BHR	8735	2534	E.E.IRRGATION DIV.
30	BAHADURGANJ	BHR	8749	2616	RUCESEL HIGH SCHOOL
31	KISHANGANJ	BHR	8809	2605	SDO KISHANGANJ
32	GORAKHPUR **	UP	8323	2645	MMM ENGG. COLELGE
33	NAUTANWA	UP	8325	2726	MUNI.BULDG.
34	NICHLAUL	UP	8347	2715	B.D.O.OFFICE
35	RAIGANJ	WB	8810	2538	RAIGANJ COLELGE
36	KURSEONG	WB	8814	2647	DARJ.POLYTECHNIC
37	ENGLISH MALDA BAZAR	WB	8816	2500	GOVT.TEACHER PRG COLLEGE
38	KALIMPONG	WB	8826	2704	S.D.O. OFFICE
39	SILIGURI	WB	8830	2642	I.T.I.SEVOK ROAD
40	BELAKOBA	WB	8835	2633	JUNIOR BASIC TRANG.INST.
41	HALDIBARI	WB	8844	2614	B.D.O. OFFICE
42	JALPAIGURI	WB	8850	2630	CIVIL ENG. DEPT.
43	RAMSHAI	WB	8954	2644	RUL.TRG.D.CENTRE
44	MADARIHAT	WB	8920	2651	B.D.O. OFFICE
45	ALIPURDWAR **	WB	8938	2629	SDO CIVIL OFFICE

NOTE: 1. ACCELEROGRAPH STATION ARE DENOTED BY **
2. AT DARBHANGA (SN 17) ACCELEROGRAPH AND SRR ARE INSTALLED AT DIFFERENT PLACES

ANNEXURE F

RECORDED STRUCTURAL RESPONSE RECORDER AND ACCELEROGRAH DATA

STRUCTURAL RESPONSE RECORDER AND ACCELEROGRAPH DATA FROM SELECTED LOCATIONS OBTAINED DURING BIHAR-NEPAL EARTHQUAKE OF AUG.21,1988
(A total of 41 records were obtained)

A. STRUCTURAL RESPONSE RECORDER

STATION	EPICENTRAL DISTANCE (km)	HYPOCENTRAL DISTANCE (km)	SPECTRAL ACCELERATION Sa (%g) Damping 5% Period(sec)			Damping 10% Period(sec)		
			0.40	0.75	1.25	0.40	0.75	1.25
1.JAYNAGAR	53.24	88.74	36.20	24.80	12.62	29.45	14.73	6.84
2.MADHUBANI	63.65	95.08	35.80	28.41	14.16	28.41	16.51	12.65
3.NIRMALI	63.80	95.45	36.85	56.30	31.77	38.18	46.67	24.15
4.SUPAUL	63.92	95.53	47.71	49.30	20.90	42.54	40.00	15.64
5.JOGBANI	75.80	103.85	141.50	69.81	17.34	78.80	48.00	11.64
6.FORBESGANJ	82.65	103.90	58.79	44.98	8.28	33.96	19.07	7.23
7.SAHARSA	84.00	109.98	44.72	15.47	6.16	43.63	14.39	6.35
8.MURLIGANJ	97.97	120.99	32.18	17.45	19.72	29.28	13.75	10.79
9.DARBHANGA	98.38	121.30	74.81	66.21	39.04	58.18	61.18	33.53
10.SITAMARHI	124.24	143.09	31.58	21.29	9.03	22.14	17.99	6.20
11.MOTIPUR	139.98	156.95	12.47	2.20	0.89	12.16	2.00	0.85

B. ACCELEROGRAPHS

		PEAK ACCELERATION(cm/sec²)
(i)	MUNGER	20.50
(ii)	RAXAUL	18.56
(iii)	SITAMARHI	33.83
(iv)	GORAKHPUR	25.38

From: Ref.Ashok Kumar et.al.,Strong Motion Data From Bihar Nepal Earthquake of August 21, 1988.

ANNEXURE – G NEWS PAPER REPORTS

India's largest selling daily newspaper

Lucknow Jaipur Patna Bangalore Ahmedabad Bombay

THE TIMES OF INDIA

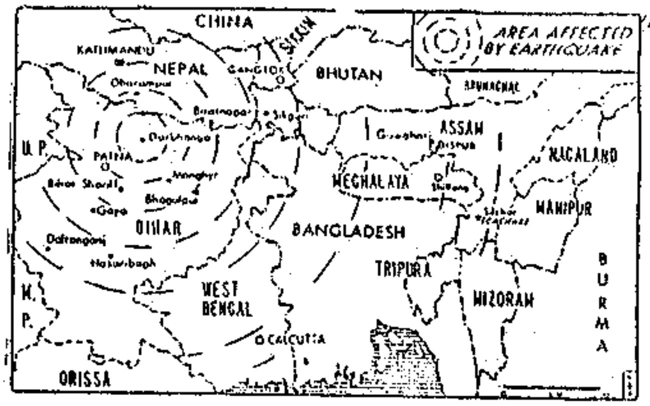
NO. 233, VOL. CLI, CITY 1 NEW DELHI: MONDAY, AUGUST 22, 1988 Rs. 1.20 18 PAGES

650 killed as quake hits Bihar, Nepal

Thousands injured, widespread damage

Tremors all over N. India

NEW DELHI, August 21: OVER 650 people were killed and more than 20,000 injured in a severe earthquake that rocked Bihar and the Himalayan region of Nepal early today, report the Times of India News Service and agencies. According to reports from Patna, over 400 people were killed in Bihar — 200 in Darbhanga district alone. At least 252 people were killed in Nepal, Radio Nepal said this evening. Daran district was the worst-hit.



The toll was expected to be much higher with reports coming in from rural areas of Bihar and remote mountain villages of Nepal.

The tremor at 4.35 a.m. had its epicentre at the Indo-Nepal border, 70 to 80 km northeast of Darbhanga. It measured 6.7 on the Richter scale and lasted about a minute.

The after shocks were felt for almost one hour in all the northeastern states, UP, Madhya Pradesh and West Bengal. Delhi and its adjoining areas were also rocked by a quake of moderate intensity. Experts warned of more after shocks during the next few days.

SECOND DISASTER

BIHAR: Today's earthquake was the second major disaster to strike the state in the last fortnight. On August 6, a steamer capsized in the Ganga off Mansheraghat, drowning 400 people.

The worst-affected districts were Darbhanga, where 200 were feared killed and 10,000 injured, and Munger where the number killed was said to be 125. In the 1934 earthquake also, these two districts suffered the most damage.

People were roused from their sleep by the rumbling noise that accompanied the quake. Initial confusion gave way to panic and they rushed out of their homes.

In Patna, the Raj Bhavan and the old secretariat developed cracks. The governor, Mr G. N. Singh, had to move to the ground floor.

In Darbhanga, 14 children were killed at Quilaghat when their hostel building collapsed. Nearly 100 others were injured.

The quake came in two waves of 10 to 15 seconds, leaving in its wake total devastation. About 50,000 buildings were either completely or partially damaged.

In both Darbhanga and Laheriasarai, roads have cracked at many places with sand and water gushing out. Power supply and the telecommunication system collapsed completely and the town remained cut off for many hours.

The scene at the Darbhanga medical college hospital, where 1,000 persons have been admitted was heart-rending. Unclaimed bodies lay in the verandah of the casualty ward while the other wards were overflowing with injured people.

The chief minister, Mr Bhagwat Jha Azad, rushed to Darbhanga to take stock of the situation and supervise relief and rescue operations. He visited the hospital, the Madarsa and Bara Bazar areas, which were the worst affected areas in the town.

Mr Azad announced an ex-gratia payment of Rs. 500 to the families of the deceased for performing the last rites. He also said that each of the injured would be given Rs. 150.

While 34 persons died at the Madarsa, five deaths were reported from Bara Bazar. In the Bangladesh mohalla the death toll was 15. Sakri, a town 21 km from Darbhanga, reported 14 deaths. The other localities from where deaths were reported in Darbhanga town were Baripur, Ram-nagar, Balbhadrapur, Lalitola, Kanwari, Mirza, Bishnupur and Shaphra.

In the Bangladesh mohalla, an irrigation department engineer, Mr Ashok Agarwal, was killed while a BMP jawan was killed in a wall collapse in Naka number seven area.

MUNGER: The early morning earthquake claimed more than 125 lives and left about 5,000 injured. About 15,000 houses were damaged. Most of the dead included children, women and the aged. The district magistrate

Continued on page 5, col. 1

Earthquake hits Nepal

Continued from page 1, col. 3

admitted that the casualty figure might go up.

At six or seven places, the ground caved in and water sprouted out. The area near the Nilam water tank sank about 10 feet. The Jama Masjid, the P and T building, three barracks of the police lines, the ITC quarters and the district magistrate's residence were damaged.

The badly-hit areas in the town were Murgiachak, Belkapur, Bara Bazar and Dilawarpur. A telecommunication employee, Mr Ramchandra Mandal, died when a telephone pole fell on him.

Ninety-five per cent of the houses collapsed in Hassanpur village under the Mufassil police station, which has a population of about 10,000.

In Jamalpur, three persons were killed and over 100 others injured.

Communication between Munger town and its blocks had been snapped. One injured person was being brought to hospital every two minutes.

Mr Y. P. Verma, district magistrate, said that all government and private doctors had been deployed for round-the-clock medical services and medical shops had been ordered to be opened.

Munger's historical fort, which was damaged in the 1934 earthquake, was further damaged today.

BIHARSHARIF: So far one death was reported in the town and 40 houses, including a hotel, had collapsed. The hot springs in Rajgir had turned red. Fifty persons were injured in Nalanda district.

MADHUBANI: Ten persons are reported to have been killed and 300 injured in Madhubani district. About 2,000 houses were either fully or partially damaged due to the earthquake.

In Jhanjharpur 18 persons are reported to have been killed while 70 have received serious injuries. More than 100 houses have been damaged.

In Khajauli, two persons were killed. Sixteen were killed in Laukaha and Laukahi, four in Jainagar, seven at Rajnagar and one at Madhubani town.

Four constables were seriously injured in a building collapse in the Madhubani police lines.

The historic Naulakha temple of Rajnagar and the Saraswati Shishu Mandir of Madhubani also collapsed. Incidentally, large areas in the district are currently submerged due to flood waters.

BEGUSARAI: More than 150 houses collapsed and a large number of private and government buildings developed cracks in Begusarai town, according to an official spokesman.

An unconfirmed report said six persons were killed in the district. Seventeen were injured in Bhagalpur district.

The Bhootahi Balan river breached an embankment in Madhubani district and inundated vast areas, according to official sources.

The sources said the swollen river flooded nearly 50 villages. Vast areas in the district were also waterlogged following land breaches at several places.

Meanwhile, the army was alerted in Katihar district as the Kosi was rising alarming all along its course.

According to a Central Water Commission report Punpun river was flowing 1.6 metres above the red mark at Sripalpur, Bagmati was flowing 10 cm. above the red mark at Benibad and Kosi was flowing 1.4 cm. above the danger level at Baltara.

TRIPURA: An earthquake of moderate intensity rocked Agartala and nearby areas around 4.30 a.m. It did not however, cause any damage. Reports from other parts of the state are awaited.

ARUNACHAL PRADESH: The state was rocked by a two-minute tremor of moderate intensity at 4.44 a.m.

Hundreds of people came out to streets for safety when doors and window panes started rattling. There was however no report of any loss of life or damage to property. This is the fourth incident in a fortnight in the state.

MADHYA PRADESH: The tremors were also felt in Satna and Chattarpur districts of Madhya Pradesh. No loss of life or damage to property has, however, been reported.

The tremor was also experienced in the steel city of Jamshedpur, Ranchi and Dhanbad.

A "mild tremor" shook Jabalpur city. Panic-stricken people rushed out of their homes. There were no reports of casualty or damage to the property, the police said.

ORISSA: A mild tremor rocked Rourkela and its nearby areas for a few seconds around 4.40 a.m. No loss of life or property has been reported so far.

WEST BENGAL: A high-intensity earthquake rocked Calcutta and its suburbs early this morning for the second time in two weeks, jolting people out of their beds.

The Sunday morning calm was shattered as the quake hit the region at 4.40 a.m. creating panic among the people in some parts of this metropolis.

Glass panes vibrated white doors and other wooden structures rattled violently. One person, who was awake at the time of the tremor said he realised a quake was hitting the city only when lights hanging from the ceiling of his balcony started swaying.

The quake was also felt in Malda and Krishnagar areas of the state.

Two policemen and the wife of the Kalimpong sub-divisional officer were injured when an earthquake rocked the three hill sub-divisions for about a minute causing widespread damage.

Official sources said so far there was no report of any death.

They said Mrs Chopra, the wife of SDO, Mr Sanjeev Chopra, was injured while she was coming out of her bungalow which was extensively damaged. The two policemen, injured near the police line, were removed to hospital.

Massive landslides were reported from Tindharia, under Kurseong subdivision where many houses were either collapsed or extensively damaged in the tremor. Roads were blocked at several points.

While the collector's office here was severely damaged, the administrative building of the junior basic training college collapsed. Its staff quarters also suffered an extensive damage.

The Singamari border outpost could not withstand the impact of the quake and collapsed. Alubari and Ghutia bustees here, the army telephone building at Jaldapara and the house of the station commandant were damaged. The new building of the post and telegraphs here also developed cracks.

MEGHALAYA: A tremor, lasting one minute 20 seconds, rocked Shillong and its neighbouring areas at 4 a.m. with no report of casualty or damage.

MANIPUR: Mild tremor rocked the state. There was, however, no report of any damage to property, official sources said.

SIKKIM: Several buildings in Gangtok were damaged. People ran out into the streets in panic as objects tumbled from shelves and tables.

While the initial tremor lasted one minute, several after-shocks were felt until 6 a.m.

UTTAR PRADESH: Several parts of U.P. were rocked by a moderate earthquake early today, reports received here said.

In Varanasi, people ran out into the streets in panic as the earthquake jolted the city at 4.40 a.m.

The reports said the people woke up as their beds shook and articles fell to the grounds. No casualty or damage have been reported from the city so far, police said.

Gorakhpur, Kanpur, Lucknow and some other cities were also rocked.

NEPAL: At least 252 people were killed in Nepal in the devastating earthquake, which hit the eastern and central parts of the kingdom, Radio Nepal said this evening.

Quoting Nepalese home ministry sources, the radio monitored here said that over 900 people were injured and over 300 houses damaged.

The earthquake with an epicentre at Udaypur about 240 km east of Kathmandu hit the kingdom at 4.40 a.m.

In the worst affected eastern district of Dharan, 150 people were killed and over 800 injured, home ministry sources quoted residents as saying but added that official confirmation of the figure was being awaited.

Five deaths were reported from Dhankuta, eight from Biratnagar, one from Rajbiraj and Cyinnamastta in Saptari district, three deaths from Taplejung and 12 from Panchathar — all in eastern Nepal.

Six deaths were reported from Bhaktapur in central Nepal, near Kathmandu.

Unofficial sources said the death roll in the quake, the worst since the great devastation of 1934, could not be less than 200.

Rajiv expresses anguish

The Times of India News Service

NEW DELHI, August 21.

THE Prime Minister, Mr Rajiv Gandhi, has expressed his deep sorrow and anguish at the number of lives lost in the earthquake in Bihar and parts of West Bengal.

He has asked the agriculture and home ministry to keep a close watch on the situation.

Tomorrow, the Prime Minister will be visiting the areas seriously affected by the earthquake, including Darbhanga and Munger for an on-the-spot assessment of the situation. He will be accompanied by Mrs Mohsina Kidwai, minister for urban development, Mr Bhajan Lal, Union minister for agriculture and Mr Moti Lal Vora, health minister, and some MPs.

Mr Gandhi had a meeting with Mr Vora and senior officers of the ministry. A team of eight orthopaedic doctors and medicines are being flown to the earthquake affected areas in Bihar.

Agencies add: The Bihar chief minister, Mr Bhagwat Jha Azad, also expressed shock and grief over the deaths in the tremor which rocked several parts of the state.

The former Bihar chief minister, Dr Jagannath Mishra, has urged the Prime Minister to take "personal interest" in the rescue and rehabilitation of the people affected by the quake.

Dr Mishra said the state and central governments must come out in a big way to help the affected people. He demanded that defence personnel should be pressed into service immediately to rescue people in Darbhanga and Munger.

The Jammu and Kashmir chief minister, Dr Farooq Abdullah, has also expressed grief over the large number of deaths.

Capital rocked by earthquake

By A Staff Reporter

NEW DELHI, August 21: A moderate magnitude earthquake rocked the Capital and its neighbouring areas early in the morning today. It did not cause any damage to either property or life, it was officially stated.

According to Dr H. N. Srivastava, director of the seismology department, the epic centre of the earthquake was 900 kms away near Nepal-Bihar border where hundreds of people were reported to have been killed due to strong quake.

Dr Srivastava said the deadly earthquake near Nepal-Bihar border was recorded at 6.5 on the Richter scale. The same region had experienced a worse earthquake at 8 degree on richter scale in 1934 when thousands of people had died and massive damage was done to the buildings.

'Himalayan Belt On Rocks In Motion'

NEW DELHI, August 22. (UNI).

THE Himalayan belt, particularly the northeastern region, is said to be perched on a layer of rocks in motion.

The zone is part of one of the two main seismic belts where large and destructive earthquakes are likely to originate.

Since the time earthquakes were recorded from the early 18th century, there have been 15 major quakes in India since 1819 including the ones in Assam in 1819, 1897, 1935, and 1950.

The last major earthquake in Bihar was in 1934 in which more than 10,700 persons died.

Other major quakes in India were in Maharashtra in 1967 and in Himachal Pradesh in 1905, 1975 and in 1987.

The worst quake took place in Calcutta on October 11, 1737. The toll then was over 300,000 and the world's highest in earthquakes.

According to experts, about a million tremors occur every year. Over 95 per cent of these are detectable by scientists on their recording machines.

In March last year, more than 4000 died in a series of quakes in Ecuador.

Earthquakes in the 20th century have killed nearly two million people and damaged property worth Rs. 10,000 crore.

The last major earthquake in India took place in Assam on the Independence day in 1950 killing 1530 persons.

The earthquake which hit north Bihar and parts of eastern Nepal was predicted more than three years ago by Pune-based seismologist, Mr Arun Bapat.

He had communicated his observation, based on a new method of earthquake prediction developed by him known as "seismic grid method" to the International Centre for Integrated Mountain Development (ICIMOD) in October, 1985.

Scientists at the centre for scientific and industrial research's regional research laboratory at Jorhat, Assam had also predicted the probability of a major earthquake ripping through the northeastern region.

Experts say the entire Indian sub continent, including the Indian peninsula, is earthquake prone. "The after shocks of the quakes could continue for another month, highly placed officials at the seismology directorate in the department of meterology said.

BASIC APPROACHES

There are two basic approaches to earthquake prediction.

The first is to study exactly what is going on within the earth — the new science of plate tectonics, or the movement of the earth's major crustal plates — make calculations and come up with a deterministic prediction.

The other approach is to search for things that occur before earthquakes — smaller earthquakes, changes in the magnetic field of the earth or electrical currents or water levels — and make a statistical relationship that can be used to predict the probability of an earthquake.

"But very few scientists are willing to predict when accurate quakes prediction will be a reality," the experts said.

Army out to aid quake-hit

The Times of India News Service

PATNA, August 22.

THE Bihar government today sought the help of the army in conducting rescue and relief operations in the quake-ravaged districts of the state.

The army is expected to begin operations from tomorrow, 48 hours after the state was hit by the worst earthquake in 30 years.

The exact extent of the damage is yet to be ascertained as full reports are yet to reach the state capital from the interior areas of north Bihar. According to official estimates, 164 people have died.

The state government today sent teams of doctors and engineers to the affected districts. Funds have also been released for these districts — Darbhanga (Rs. 10 lakhs), Madhubani (Rs. 10 lakhs), Munger (Rs. 5 lakhs), and Rs. 2 lakhs each for Saharsa and Khagaria.

Reports reaching Patna indicate that panic continues in all the affected districts. At Madhubani, the hospital authorities are finding it impossible to cope with the large number of patients.

TOLL REPORTS

While officially 86 have died in Madhubani, a TOINS report from the district puts the death figure at 175.

While more than a thousand patients arrived for treatment at a referral hospital at Madhubani, doctors could administer medication to only 83 due to acute shortage of medicines. The position is no better in many hospitals elsewhere in the district.

Madhubani, incidentally, is the constituency of the former chief minister, Dr Jagannath Mishra. Today he claimed that 300 people had died in the district. He also alleged that correct information had not been given to the Prime Minister.

The chaos in which the administration found itself in the wake of the earthquake deepened further today with the Prime Minister visiting the state. While wounded people continued to come to Bhagalpur, five senior doctors from the government hospital there were sent to Munger as Mr Rajiv Gandhi was to visit the district. Six other medical officers from different blocks of Bhagalpur were also rushed to Munger.

Meanwhile, people with serious injuries kept pouring into the Bhagalpur hospital. Many cases were from rural areas where the devastation was much greater than in urban areas.

According to one report from Darbhanga, relief operations had not started even 36 hours after the quake.

Agencies add from New Delhi: Offers of donations from state governments, political parties, industrialists and film personalities poured in as massive relief operations were underway.

With communication links snapped, the authorities were not in a position to give the exact number of dead. Official reports this afternoon placed the toll at 350.

However, the Munger district magistrate, Mr Y. P. Verma, today expressed surprise at reports of deaths of over 100 persons in the earthquake.

He said that the toll reaching the district administration was only 11 and even allowing for some unconfirmed reports, it was hardly likely to be anywhere near the 100 mark.

IAF helicopters have been pressed into service to rescue the injured from far flung areas to nearest hospitals.

An earthquake relief committee headed by Mrs Aruna Asaf Ali was formed today at a meeting of 15 voluntary organisations and educational institutions convened by the minister of state for woman and child development, Mrs Margaret Alva.

The committee has appealed to all citizens to donate cash and essential items for the victims. The committee will coordinate action for relief measures for the victims.

Aftershock of quake recorded

NEW DELHI, August 22 (UNI): An aftershock of the earthquake that struck Bihar and Nepal yesterday was recorded at the seismograph here today.

PM grants Rs. 30 lakhs for relief

PATNA, August 22 (PTI): The Prime Minister, Mr Rajiv Gandhi, today announced a grant of Rs. 30 lakh from his relief-fund to pay Rs. 10,000 to the dependents of each killed in yesterday's earthquake.

The amount left after such a payment would be used for providing relief to the injured. The Bihar chief minister, Mr Bhagwat Jha Azad, who was present when the Prime Minister made the announcement at a press conference here, said that so far the government had reports of only 160-odd deaths in the state.

Mr Gandhi said that the extent of damage was fairly large, but the projection in the media appeared to be rather exaggerated. He said that houses had collapsed in 'ones' and 'twos' in different areas, but there had been no extensive collapse in any pocket.

When a newsman probed the possibility that the government might not have had full reports from the far-flung rural areas yet, Mr Azad intervened to say that the administration had compiled information from such areas too. In fact, he said that most of the 80-odd deaths reported in the Madhubani district were from the rural areas.

Nepal quake toll rises to 450

KATHMANDU, August 22.

THE death roll in yesterday's devastating earthquake in eastern and central parts of Nepal has gone up to 450, the home minister, Mr Niranjan Thapa, announced here this afternoon, reports PTI.

Mr Thapa told a crowded press conference that the toll may rise further with the recovery of more bodies. He said over 687 people were injured in house collapses of whom 106 were in critical condition. Initial reports yesterday had put the number of injured at 900.

The largest number of deaths had been reported from Sunsari district, including Dharan where 131 people had died and 300 reported injured so far. In Dhankuta 73 died and 165 were injured. In Panchthar 53 had died, in Therathum 35 and 45 in Ilam, Mr Thapa added.

Mr Thapa said the government was trying to mobilise all its resources to meet the emergency. Various agencies, including the Royal Nepal Army, the police, Rastriya Panchayat members, panchayat and social workers were working round the clock to bring succour to the distressed.

FOREIGNERS' DEATH

He said the government had no information about the death of any foreigner.

Mr Thapa said a high-powered committee, with the assistant home minister, Mr Narbahadur Budathoki, as convenor had been set up at Biratnagar in eastern Nepal to coordinate rescue and relief activities, which were going on a war footing.

Two Indian doctors, attached to the Indian pension office at Dharan had also been deployed for rendering relief to the quake victims.

Mr Thapa said the homeless had been accommodated in schools and dharmashalas. The officials in the affected areas had been asked to furnish details about loss of life and damage to property by August 24.

The minister said the government was concerned at the possibility of an outbreak of epidemic in the affected areas and added that doctors have been put on alert.

The government has also constituted an 11 member relief committee to be stationed in the south east industrial

Continued on page 5, col. 3

You said it

By LAXMAN

No, not at all, sir! I just smelt it. It's far from a killer brew!

Nepal toll rises to 450

Continued from page 1, col. 8

city of Biratnagar to coordinate relief efforts with the Central government's help, he said.

KING'S MESSAGE

In a message to the nation, King Birendra Bir Bikram Shah Dev of Nepal has expressed deep grief at the loss of life and property caused by the earthquake.

He said though the government had been instructed to carry on relief operations in full swing, "it may take some time before we are able to assess the actual damage or loss caused by this tragic mishap. Meanwhile, we have instructed the government to carry out relief operation for the affected victims. In times like these, we expect every Nepali to come forward, as always, with cooperation in the relief being undertaken," he said.

The prime minister, Mr Marich Man Singh Shrestha, yesterday visited the earthquake victims admitted at Bir hospital here.

A one-km portion of the Mahendra highway at Lahan has risen two feet above the land level due to the impact of the earthquake.

Most of the wells at Rajbiraj have dried up as sands accumulated in them. At Rajbiraj the quake caused a sudden flood in the Dhado river.

The government has decided to provide Nepalese Rs. 2,000 for the funeral of each of the deceased and 40 kg of foodgrains for each of the affected families.

According to the health ministry here, although the blood transfusion centre of the Nepal Red Cross society has sufficient quantity of blood in its stock at present, a blood donation drive is being launched. The Biranagar branch of the Red Cross had sent an S. O. S. to Kathmandu for supplying 1,000 units of blood.

Army out to aid quake-hit

The Times of India News Service

PATNA, August 22.

THE Bihar government today sought the help of the army in conducting rescue and relief operations in the quake-ravaged districts of the state.

The army is expected to begin operations from tomorrow, 48 hours after the state was hit by the worst earthquake in 50 years.

The exact extent of the damage is yet to be ascertained as full reports are yet to reach the state capital from the interior areas of north Bihar. According to official estimates, 164 people have died.

The state government today sent teams of doctors and engineers to the affected districts. Funds have also been released for these districts — Darbhanga (Rs. 10 lakhs), Madhubani (Rs. 10 lakhs), Munger (Rs. 5 lakhs), and Rs. 2 lakhs each for Saharsa and Khagaria.

Reports reaching Patna indicate that panic continues in all the affected districts. At Madhubani, the hospital authorities are finding it impossible to cope with the large number of patients.

TOLL REPORTS

While officially 86 have died in Madhubani, a TOINS report from the district puts the death figure at 175.

While more than a thousand patients arrived for treatment at a referral hospital at Madhubani, doctors could administer medication to only 83 due to acute shortage of medicines. The position is no better in many hospitals elsewhere in the district.

Madhubani, incidentally, is the constituency of the former chief minister, Dr Jagannath Mishra.' Today he claimed that 300 people had died in the district. He also alleged that correct information had not been given to the Prime Minister.

The chaos in which the administration found itself in the wake of the earthquake deepened further today with the Prime Minister visiting the state. While wounded people continued to come to Bhagalpur, five senior doctors from the government hospital there were sent to Munger as Mr Rajiv Gandhi was to visit the district. Six other medical officers from different blocks of Bhagalpur were also rushed to Munger.

Meanwhile, people with serious injuries kept pouring into the Bhagalpur hospital. Many cases were from rural areas where the devastation was much greater than in urban areas.

According to one report from Darbhanga, relief operations had not started even 36 hours after the quake.

Agencies add from New Delhi: Offers of donations from state governments, political parties, industrialists and film personalities poured in as massive relief operations were underway.

With communication links snapped, the authorities were not in a position to give the exact number of dead. Official reports this afternoon placed the toll at 350.

However, the Munger district magistrate, Mr Y. P. Verma, today expressed surprise at reports of deaths of over 100 persons in the earthquake.

He said that the toll reaching the district administration was only 11 and even allowing for some unconfirmed reports, it was hardly likely to be anywhere near the 100 mark.

IAF helicopters have been pressed into service to rescue the injured from far flung areas to nearest hospitals.

An earthquake relief committee headed by Mrs Aruna Asaf Ali was formed today at a meeting of 15 voluntary organisations and educational institutions convened by the minister of state for woman and child development, Mrs Margaret Alva.

The committee has appealed to all citizens to donate cash and essential items for the victims. The committee will coordinate action for relief measures for the victims.

Aftershock of quake recorded

NEW DELHI, August 22 (UNI): An aftershock of the earthquake that struck Bihar and Nepal yesterday was recorded at the seismograph here today.

PM grants Rs. 30 lakhs for relief

PATNA, August 22 (PTI): The Prime Minister, Mr Rajiv Gandhi, today announced a grant of Rs. 30 lakh from his relief-fund to pay Rs. 10,000 to the dependents of each killed in yesterday's earthquake.

The amount left after such a payment would be used for providing relief to the injured. The Bihar chief minister, Mr Bhagwat Jha Azad, who was present when the Prime Minister made the announcement at a press conference here, said that so far the government had reports of only 160-odd deaths in the state.

Mr Gandhi said that the extent of damage was fairly large, but the projection in the media appeared to be rather exaggerated. He said that houses had collapsed in 'ones' and 'twos' in different areas, but there had been no extensive collapse in any pocket.

When a newsman probed the possibility that the government might not have had full reports from the far-flung rural areas yet, Mr Azad intervened to say that the administration had compiled information from such areas too. In fact, he said that most of the 80-odd deaths reported in the Madhubani district were from the rural areas.

Nepal quake toll rises to 450

KATHMANDU, August 22.

THE death toll in yesterday's devastating earthquake in eastern and central parts of Nepal has gone up to 450, the home minister, Mr Niranjan Thapa, announced here this afternoon, reports PTI.

Mr Thapa told a crowded press conference that the toll may rise further with the recovery of more bodies. He said over 687 people were injured in house collapses of whom 106 were in critical condition. Initial reports yesterday had put the number of injured at 900.

The largest number of deaths had been reported from Sunsari district, including Dharan where 131 people had died and 300 reported injured so far. In Dhankuta 73 died and 165 were injured. In Panchthar 53 had died, in Therathum 55 and 45 in Ilam, Mr Thapa added.

Mr Thapa said the government was trying to mobilise all its resources to meet the emergency. Various agencies, including the Royal Nepal Army, the police, Rashtriya Panchayat members, panchayat and social workers were working round the clock to bring succour to the distressed.

FOREIGNERS' DEATH

He said the government had no information about the death of any foreigner.

Mr Thapa said a high-powered committee, with the assistant home minister, Mr Narbahadur Budathoki, as convenor had been set up at Biratnagar in eastern Nepal to coordinate rescue and relief activities, which were going on a war footing.

Two Indian doctors, attached to the Indian pension office at Dharan had also been deployed for rendering relief to the quake victims.

Mr Thapa said the homeless had been accommodated in schools and dharmashalas. The officials in the affected areas had been asked to furnish details about loss of life and damage to property by August 24.

The minister said the goverament was concerned at the possibility of an outbreak of epidemic in the affected areas and added that doctors have been put on alert.

The government has also constituted an 11 member relief committee to be stationed in the south east industrial

Continued on page 5, col. 3

You said it

By LAXMAN

No, not at all, sir! I just smelt it. It's far from a killer brew!

Nepal toll rises to 450

Continued from page 1, col. 8

city of Biratnagar to coordinate relief efforts with the Central government's help, he said.

KING'S MESSAGE

In a message to the nation, King Birendra Bir Bikram Shah Dev of Nepal has expressed deep grief at the loss of life and property caused by the earthquake.

He said though the government had been instructed to carry on relief operations in full swing, "it may take some time before we are able to assess the actual damage or loss caused by this tragic mishap. Meanwhile, we have instructed the government to carry out relief operation for the affected victims. In times like these, we expect every Nepali to come forward, as always, with cooperation in the relief being undertaken," he said.

The prime minister, Mr Marich Man Singh Shrestha, yesterday visited the earthquake victims admitted at Bir hospital here.

A one-km portion of the Mahendra highway at Lahan has risen two feet above the land level due to the impact of the earthquake.

Most of the wells at Rajbiraj have dried up as sands accumulated in them. At Rajbiraj the quake caused a sudden flood in the Dhado river.

The government has decided to provide Nepalese Rs. 2,000 for the funeral of each of the deceased and 40 kg of foodgrains for each of the affected families.

According to the health ministry here, although the blood transfusion centre of the Nepal Red Cross society has sufficient quantity of blood in its stock at present, a blood donation drive is being launched. The Biranagar branch of the Red Cross had sent an S. O. S. to Kathmandu for supplying 1,000 units of blood.

LS expresses shock over tragedy

NEW DELHI, August 22.

THE Lok Sabha today expressed its deep shock and distress at the large number of casualties caused in the earthquake in northern India, Nepal and Bangladesh, report PTI, UNI.

The house observed two minutes' silence in memory of those who had lost their lives after the Speaker, Mr Balram Jakhar, made references to the natural calamity.

The Speaker said that the Prime Minister, Mr Rajiv Gandhi, and the home minister, Mr Buta Singh, had gone to the worst-affected areas in Darbhanga in Bihar and the government would make a statement in the House on their return.

Mr Jakhar said "the House has learnt with distress and deep sorrow the large number of casualties in the earthquake."

Mr V. Tulsiram (Telugu Desam) raised the issue of the deaths of a large number of people in Bihar. He was joined by several other members including Prof Madhu Dandavate.

RELIEF DEMAND

Meanwhile, several opposition parties today demanded that immediate and adequate relief be provided to the victims.

In a statement here, the Janata party demanded that the Centre give Rs. 1 lakh to the next of kin of the deceased and Rs. 10,000 each to the injured.

The Janata general secretaries, Mr Ram Vilas Paswan and Mr Harikesh Bahadur, also called upon the Bihar government to provide financial relief and employment to those people whose houses had collapsed.

A team of Janata leaders including Mr Chandra Shekhar, is currently touring the affected areas.

The Haryana chief minister, Mr Devi Lal, today announced a relief of Rs. 5 lakhs. He made this announcement in the state assembly, while expressing his shock and grief at the loss of lives. Mr Devi Lal is currently on a tour of Bihar.

The West Bengal chief minister, Mr Jyoti Basu, said his government would

Continued on page 5, col. 1

THE TIMES OF INDIA

Bihar Relief Fund

The recent earthquake in Bihar has taken a heavy toll of life, caused enormous damage to property and brought untold suffering to a large number of people.

In keeping with its tradition, The Times of India Group of Publications has decided to collect on behalf of The Times of India Relief Fund money to provide help to the victims of the disaster. An initial contribution of Rs. 1,00,000 has been made by The Times of India Relief Fund.

In the past our readers have always responded spontaneously to our appeals for help to the victims of such calamities. We sincerely hope that they will contribute generously to the fund on this occasion as well. All contributions will be eligible for tax-relief under Section 80-G of the Income Tax Act 1961.

Individual contributions of Rs. 100/- and more will be acknowledged in The Times of India. Cheques/drafts drawn in favour of The Times of India Relief Fund or cash contributions may be sent to any of our offices in Patna, Bombay, New Delhi, Ahmedabad, Calcutta, Lucknow, Bangalore, Jaipur, Madras and Pune.

LS shocked at tragedy

Continued from page 1, col. 5

extend all possible help to Bihar to meet the challenges arising out of the "terrible" quake.

Describing the tremor as a major one after 1934, Mr Basu told reporters in Calcutta that the union agriculture minister, Mr Bhajan Lal, had telephonically enquired about the damages in Darjeeling areas.

Mr Gandhi, who was earlier scheduled to visit Darjeeling today, changed his programme after ascertaining the extent of the damage. Mr Gandhi will tour the quake-hit areas of the district soon, Mr Bhajan Lal had told him, Mr Basu said.

Meanwhile, the state government has rushed ministers and engineers for Darjeeling as part of its relief measures. Wherever required, army help would be sought, he added.

The National Front leaders, Mr V. P. Singh and N. T. Rama Rao are also touring Bihar.

Expressing profound sorrow over the large-scale deaths and devastation, the secretariat of the National Front "conveyed its heart-felt sympathies to the victims."

The secretariat in a release also urged the Centre to "extend all the necessary assistance to Bihar in undertaking immediate and adequate relief operations on a war-footing.

The BJP expressed shock over the heavy loss of life and property.

The politbureau of the CPM expressed deep sorrow at the loss of lives in the earthquake. It called upon all its units in Bihar to mount relief-operations and extend help to this effort, a press statement said.

The CPI also expressed its deep sorrow and anguish at the severe earthquake and extended its heartfelt sympathies to the affected people.

The CPI general secretary, Mr C. Rajeswara Rao, is visiting Bihar tomorrow for an on-the-spot study of the situation.

In Bombay film star Shatrughan Sinha said he was ready to offer his services to raise funds for relief.

"I am ready to fly to Patna at the behest of the Bihar chief minister and do whatever is possible to mitigate the sufferings of the people," he said.

The Life Insurance Corporation is to send a team of officials to the earthquake-hit areas, for speedy assessment and disbursal of claims, the corporation chairman, Mr R. Narayanan said in Tiruchirapalli last night.

US relief funds for India

The Times of India News Service

NEW DELHI, August 23: The US has made a voluntary contribution of about Rs. 3.54 lakh to India, following the earthquake in north India on Sunday.

The emergency disaster relief funds were presented today to foreign secretary, Mr K. P. S. Menon, by the U.S. ambassador, Mr John Gunther Dean. The amount would be used by the Prime Minister's national relief fund, according to a USIS release.

Mr Dean said "the American people share India's grief over the tragic loss of so many lives and the widespread destruction caused by the earthquake.

5 die in Bangla boat mishap

DHAKA, August 21 (UNI): Five persons, including two women and two children, were drowned when a boat capsized in southern Bangladesh.

Eyewitnesses said the boat carrying about 40 passengers sank in the River Kumar yesterday near the Faridpur district.

4 THE TIMES OF INDIA, NEW DELHI, TUESDAY, AUGUST 23, 1988

THE TIMES OF INDIA

A Ghastly Toll

Mahatma Gandhi had described the last great earthquake to hit Bihar in 1934 as "a divine chastisement sent by God for our sins". He said, "It is an ennobling thing for me to guess that the Bihar calamity is due to the sin of untouchability ... (but) I do not interpret this chastisement as an exclusive punishment for the sin or untouchability. It is open to others to read in it the divine wrath against many other sins." His linking up divine retribution with a natural calamity disquieted many of his admirers, among them Jawaharlal Nehru, the Kisan Sabha leader, Swami Sahajanand Saraswati and Rabindranath Tagore. The poet wrote to the Mahatma that he was pained by the idea that God's vengeance had been wrought "upon certain parts of Bihar, evidently, specially selected for his desolating displeasure. It is all the more unfortunate, because this kind of unscientific view of phenomena is too readily accepted by a large section of our countrymen ... I keenly feel the indignity of it, when I am compelled to utter a truism in asserting that the physical catastrophes have their inevitable and exclusive origin in certain combination of the physical facts. If we associate ethical principles with the cosmic phenomena, we shall have to admit that human nature is morally much superior to Providence that preaches its lesson in good behaviour in orgies of the worst behaviour possible."

The argument between the Mahatma and the poet will be repeated word for word now that Bihar has been struck by another visitation, only the parties involved in the debate will be punier men. The extent of the calamity will unfold as the days pass. The toll exacted by either a cruel God or equally cruel nature will be totted up. For a while it will seem that somnambulent Bihar has been shaken out of its stupor. There will be a great deal of coming and going and relief will be sought to be organised for the hundreds of thousands who have once again been struck a stunning blow.

The record of the Bihar government in coping with disasters in the past is not such as to inspire confidence. Perhaps it is for that reason that Dr Jagannath Mishra has implored the Prime Minister to take "personal interest" in the rescue and rehabilitation of people affected by the earthquake. In any event there is room for scepticism regarding the competence and efficacy of merely governmental efforts in meeting the relief needs demanded by a disaster of this magnitude. Till now even the figures of those dead are nowhere near definitive and given the appalling communication network in Bihar even in normal times, it is only to be expected that the administration will grope in the dark. At this stage it is not unrealistic to think that if the 1934 earthquake resulted in nearly 11,000 deaths, the toll exacted this time by a tremor of similar intensity, in an area which is among the most densely populated regions in the world and where population and poverty have both grown spectacularly in the last five decades, would be substantially higher than the figures available now. In such a situation, the need for intensive and effective non-government relief effort to supplement and also goad the Bihar administration cannot be overstressed. It took years after 1934 for the region to return to normal and that was achieved largely on account of non-governmental efforts by the Congress under Dr Rajendra Prasad, the Kisan Sabha led by Swami Sahajanand and scores of other voluntary and charitable organisations. Even then however there were reports that the landlords managed to not only corner the bulk of the relief distributed by a relatively efficient albeit colonial administration but that they even used the availability of some ready cash with the peasants to raise levies and tolls and grab scarce money resources at a time when the relatively non-monetised economy of the region was reeling under the impact of the great depression, which had hit the area just a few years earlier. The socio-economic situation in Bihar has not changed so much in the last 50 years for people to be sanguine even in this regard.

Finally, when the dust kicked up by the earthquake settles down, it might also be worthwhile to look at some of its long-term causes and consequences. There is enough scientific evidence now to link tremors with the effect of the construction of large dams and other water-management edifices. Particularly in an area which is located on a geological fault and is therefore naturally quake-prone, such structures can cause havoc in many ways. The unplanned, uncoordinated and ad hoc manner in which the natural and social ecology has been tampered with in Bihar must be checked if a catastrophe is to be prevented. This of course does not mean that the region should be left to languish in under-development, backwardness and poverty. Indeed, after the 1934 earthquake there was a shifting of resources from the area; the agricultural institute now located on a road ironically called Pusa Road in New Delhi was removed from its original location in Pusa near Samastipur. Natural disaster should not serve to provide an alibi for similar denial of appropriate development institutions and infrastructure to the affected people and their descendants. On the contrary, systematic, constructive, well-thought-out development efforts must be intensified in Bihar to prevent nature from periodically exacting a toll which, as disaster studies the world over have pointed out, rises in proportion to the backwardness, poverty and administrative inefficiency of particular regions. If that lesson is learnt, the impact of the visitation of the earthquake might be somewhat mitigated.

Buta's remark draws fire

The Times of India News Service

NEW DELHI, August 23.

OPPOSITION members in the Rajya Sabha criticised the statement of the Union agriculture minister, Mr Bhajan Lal on the earthquake in Bihar for minimising the extent of the tragedy.

Member after member got up to point out the discrepancies between the minister's statement about the casualties and those reported in the press and the government media. However, Mr Bhajan Lal insisted that the information provided by the Bihar government of 184 persons dead and 1209 injured was correct. He said that the government was not interested in hiding the figures from the House.

The agriculture minister said that media reports of the disaster were exaggerated. He assured the House that adequate measures were being taken by the government to provide effective relief to those affected by the earthquake. This, according to him, included the provision of soft loans to build and repair the houses damaged. He said that Bihar had Rs. 35 crores of "margin money", the maximum with any state, which it could use for relief work.

In his statement, Mr Bhajan Lal described in detail the survey of the affected areas undertaken by the Prime Minister along with him, the minister for urban development, Mrs Mohsina Kidwai, and the health minister, Mr Moti Lal Vora. He informed the House that at the instance of the Prime Minister, the health minister had stayed back to supervise medical relief measures.

SPECIAL PLANS

He said the Prime Minister had also instructed the ministry for urban development and the agriculture ministry to formulate special plans to assist those from the economically weaker sections of the population whose houses have been damaged. He informed the members that his ministry had also set up a special committee to coordinate the efforts of all the concerned ministries to help the victims of the earthquake.

While seeking clarifications on the minister's statement, opposition members questioned the validity of the figures of the dead and injured being provided by the government. While calling for a detailed report of the tragedy, they urged the government not to minimise the extent of the tragedy. Mr Yashwant Sinha of the Janata Party said: "Why is the government trying to minimise the death toll? We are not blaming it for the tragedy." He was of the view that such an attempt on part of the government was likely to affect the extent of relief that was likely to reach the state from all over the country.

In a forceful and impassioned speach, Mr Sinha urged the government to think of opening free kitchens in the affected areas and the provision of temporary shelters for the affected population. He also wanted to know whether the government was also thinking of doing something to help those whose houses had been destroyed or damaged but who did not fall in the category of "economically weaker sections". A number of other members joined Mr Sinha in asking for an all party committee to be set up to supervise the relief work. Opposition members, led by Mr Pramod Mahajan of BJP were of the view that the Rs. 10,000 compensation for a

Continued on page 7, col. 5

Buta's remark on quake assailed

Continued from page 1, col. 6

death was too little and should be raised to a lakh rupees.

A number of members from both the treasury benches as well as the opposition benches wanted to know whether the government was aware that the north-east region of the country was an earthquake-prone region and whether any scientific studies wereplanned to study the specific problems that are likely to be faced by the people of the areas. Thus, while Mr Vishwabandhu Gupta wanted the government to formulate long-term plans for this purpose, Mr V. Gopalaswamy wanted the factor of reservoir induced seismicity to be taken into account and Mrs. Pratibha Singh wanted special pamphlets to be printed telling people what to do in case of an earthquake.

Opposition members took exception to the statement of the minister for agriculture that the Prime Minister's visit had helped increase the self-confidence of the people and had given them courage. They accused the government of deliberately politicising the issue. Thus, Mr Yashwant Sinha said, "it is not in the power of the Prime Minister to prevent earthquakes and nor is it within his power to prevent people from running away from their homes in case of an earthquake." He said that considering that the government itself was saying that further shocks were expected, it did not make sense to suggest that the PM's visit had helped in increasing the confidence of the people.

However, Congress members insisted that the Prime Minister's visit had a positive impact on the people of the affected areas. Mrs Pratibha Singh in fact said that she had felt grateful for the visit because it was bound to help in the gearing up of the relief machinery. Mr Ranjan Sahu also shared her views.

Opposition members who sought clarifications from the government included Mr Sukomal Sen of the CPM, Dr Y. Shivaji of the Telugu Desam, Mr G. R. Mattu of National Conference, Mr Ish Dutt Yadav of the Lok Dal and Mr Ram Naresh Yadav and Mr Ram Jethmalani of the Janata Party.

Earlier, the Union agriculture minister was delayed in making his statement as he could provide only the Hindi version of his statement saying that the English version would be available after an hour or so. Opposition members sprang up to object to this and the Janata leader, Mr M. S. Gurpadswamy, wanted to know why the government was not adhering to normal practice of providing the statement in both Hindi and English. He said the minister was unnecessarily dividing the House. Even when the members were engaged in the heated exchange, the copies of the English version arrived.

Fresh tremors in Nepal; toll rises to 501

NEW DELHI, August 23.

OVERCOMING the obstacles created by swollen rivers and damaged bridges and roads, rescue teams reached many remote areas in northern Bihar and Nepal today to give relief to the earthquake affected people, UNI reports.

Relief operations on a massive scale continued for the third day today even as fresh tremors were reported in Nepal and people in many places spent the night in the open fearing after shocks of the strong quake which rocked the areas on Sunday.

The toll in Nepal was officially placed at 501 this evening with authorities discovering more bodies.

In Bihar, officials were unable to give precise figures. The Union agriculture minister, Mr Bhajan Lal, who toured the affected areas yesterday, confirmed in Parliament the death of only 164 people and injuries to 1209.

When opposition members disputed this, he said only these figures had been supplied by the state government.

According to a UNI correspondent who visited Munger, one of the worst affected areas in Bihar, people have not yet come out of their trauma. They came out of their houses thrice last night imagining a fresh tremor.

The quake heavily damaged private and government properties in the district. The trail of destruction in the Murgiachak area resembled the ruins photographed after the massive 1934 quake.

The government deployed more defence personnel and others in the affected areas to render help.

"There are many more remote areas which we are yet to reach," officials said in Patna.

The Sikkim government today said the entire state suffered in the earth quake with extensive damages to roads, bridges and school buildings.

At least 11 Buddhist monasteries of historical importance were damaged and three of them were about to crumble, a state government spokesman said.

With road communication disrupted by the tremor and the incessant rains following it, the state was in the grip of a severe food shortage, he said.

As the magnitude of the devastation was unfolding, help in cash and kind poured in from different parts of the world to India and Nepal.

In Kathmandu, officials released district wise figures of the dead totalling 501. The difficult location of the affected areas in the hilly region had hampered rescue work and the casualty figure would be more, they said.

The worst affected district is Sunsari where 128 people were killed. An emergency meeting of the high power disaster relief central committee headed by the Nepalese home minister, Mr Niranjan Thapa, released Rs. 7.4 million for immediate relief in the 23 affected districts.

Earthquake was predicted

PUNE, August 21 (UNI): The earthquake which hit north Bihar and parts of eastern Nepal was predicted by the Pune-based seismologist, Mr Arun Bapat.

He had communicated his observation, based on a new method of earthquake prediction developed by him, known as "seismic" gird method to the International Centre for Integrated Mountain Development (ICIMOD) in October 1985.

He had informed: "I shall be happy to hear from you, especially in view of the fact that I have predicted an earthquake in Nepal in the area 27-28 N and 85-86 E with probable magnitude around 6.5-.25".

The epicentre and the magnitude are matching properly and the affected areas are covered in Nepal and Bihar. Using the new method the seismologist had been successful in predicting the September 19, 1985 earthquake of magnitude 8.1 in Mexico.

Engineer predicts more quakes

The Times of India News Service

KANPUR, August 22

THE earthquake that shook Bihar, West Bengal and other parts of north India yesterday, killing thousands and injuring hundreds, was part of a series of natural calamities predicted by an Indian civil engineer in April this year.

Mr N. K. Agarwal, the civil engineer who had predicted that starting from May or June this year, earthquakes and other natural calamities would rock different parts of the country up to June 1989, said a number of leading scientists all over the world had now come out in support of his predictions.

He claimed that as predicted by him, earthquakes measuring 6.5 on the Richter scale occurred twice in the month of June this year, confirming the prophesy of the 16th century astrologer Nostradamus. It was just luck that the tremors did not involve substantial loss of life and property.

Mr Agarwal said researches at the U.S. National Oceanic and Atmospheric Administration (NOAA) had indicated that the sun's activity was increasing at the fastest rate since NOAA started recording its observations in 1RP.

Mr Agarwal pointed out that another U.S. scientist, Dr Jim Shirley of California, had also said that the present increase in solar activity could be matched by only two periods earlier during the past 13 centuries — from 1623 to 1633 A.D. and from 1810 to 1812 A.D. On both occasions intense volcanic eruptions had occurred.

Mr Agarwal said Dr Shirley's prediction that the present solar cycle would usher in similar periods of volcanic and climatic extremes on earth was in agreement with his own predictions reported in April.

He endorsed predictions of Dr Shirley and another expert of the U.S. Geological Survey about major earthquakes in the next year or two. Dr Shirley has predicted a steep rise in solar activity over the next 18 months, reaching levels higher than anything seen in this century.

Mr Agarwal said yesterday's quake was second in a series of major earthquakes that would continue to rock vast parts of India, Nepal and Pakistan in the coming months. On August 6 earthquakes of the intensity of more than 6.5 on the Richter scale had rocked north, north-eastern and eastern India. The August 6 quake was the most intense witnessed in India since the devastating Assam earthquake of 1950.

He felt that other countries like the U.S., China, Japan and Chile, falling in the seismic belt, would witness more serious volcanic eruptions and quakes during the coming months.

Quakes may rock 3 more countries

The Times of India News Service

PUNE, August 23: Severe earthquakes are likely to hit Indonesia, the Philippines and Venezuela in the near future, according to Mr Arun Bapat, a Pune seismologist who had correctly predicted the earthquake which hit north Bihar and eastern Nepal on Sunday.

Mr Bapat said the magnitude of the earthquakes would be between 7 and 7.5 on the Richter scale. There would be heavy loss of life and property as these countries are thickly populated.

According to him, other places which would be hit by earthquakes are Mexico, California, and the Alaska peninsula. They would be of almost similar intensity and might take place in about a year.

He said the advanced countries had better facilities of monitoring and, therefore, could take precautions to avoid damage to a considerable extent.

Mr Bapat, who is the head of the earthquake engineering division in the Central Water and Power Research Station (CWPRS) here, which comes under the ministry of water resources, had predicted the earthquake that rocked Assam and its surroundings on August 6. He had also given correctly the magnitude range. However, the earthquake occurred about 70 km away from the place he had predicted.

Mr Bapat's predictions are based on a method—known as seismic grid method—developed by him. In this, the seismological parameters are divided in a particular fashion and the available seismic data is examined.

The area is divided into grids of ten degrees latitude by ten degrees longitude. The earthquake magnitude is divided into four categories: (a) between 1 and 4.9, (b) five to 5.9, (c) six to 6.9 and (d) seven to above. The time of observation selected is one decade.

The seismic grid method consists of observing the number of earthquakes per grid, per magnitude range and per decade. These observations are supported by a seismic model which involves various stages of activity.

While making the prediction, the first stage is called establishment stage in which the seismic gap is established as a result of two major-magnitude seismic events.

The next stage is the development stage, during which a few medium-intensity earthquakes occur. The next stage is the maturity stage of the gap, during which small-magnitude earthquakes occur around the gap. Once a seismic gap reaches maturity level, the area could be positively identified as a highly-vulnerably seismic region which may experience an earthquake in the near future, that is within 500 to 1,000 days.

The seismic grid area, which is about 10,000 sq km, could be examined in terms of geo-physical, seismological and meteorological parameters and the epicentre of occurrance reasonably foretold. It is somewhat difficult to tell the exact time of occurrance, according to Mr Bapat.

Using this method, it was possible to predict the Mexico earthquake of September 19, 1985. This method has been described in a paper jointly written by Mr Bapat and Mr R. C. Kulkarni and presented at the eighth world conference on earthquake engineering held at San Francisco in July 1984.

Mr Bapat said the work done by distinguished seismologists in India, China, the U.S., the Soviet Union, Japan and other seismically-active countries had raised hopes that predic-

Continued on page 8, col. 1

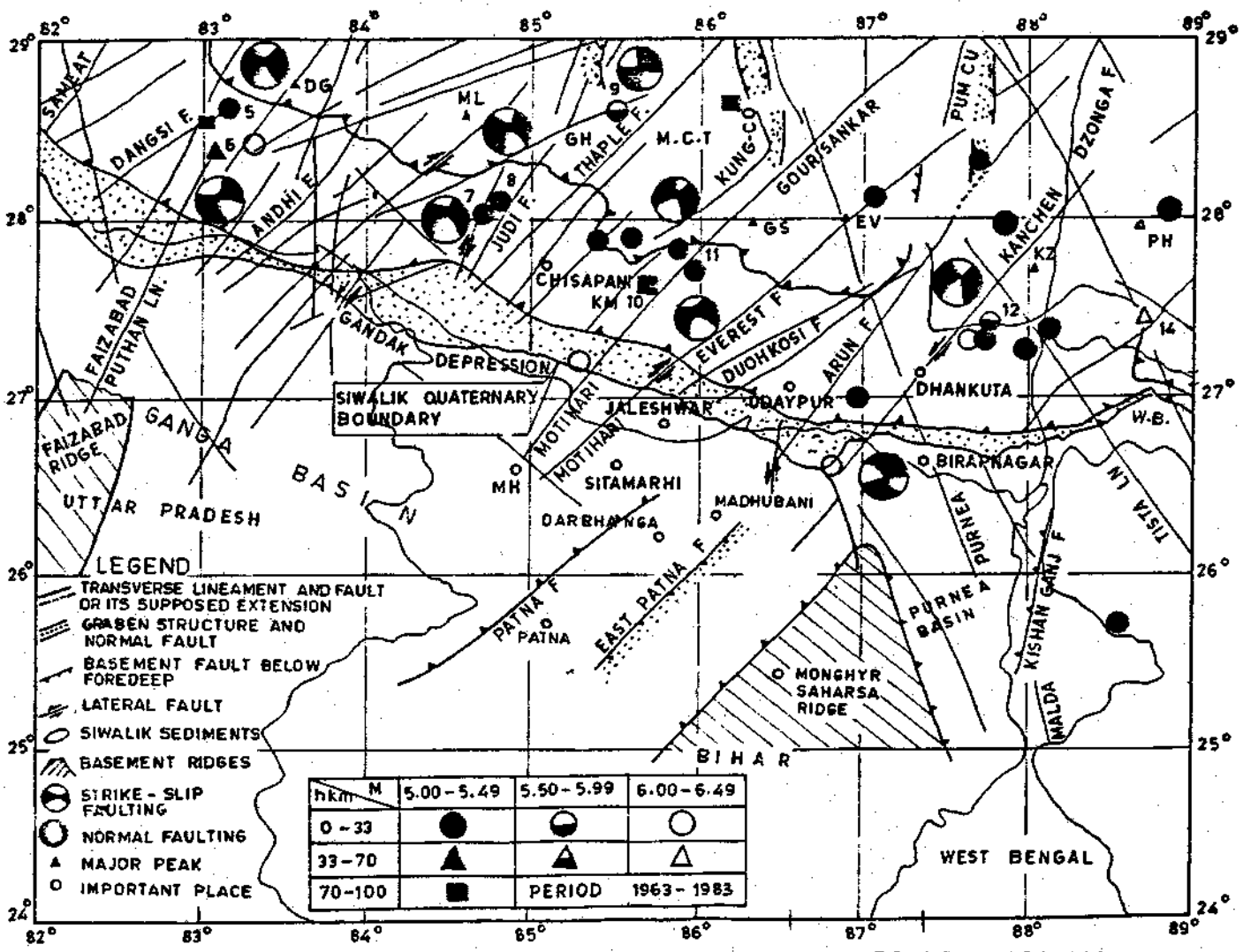
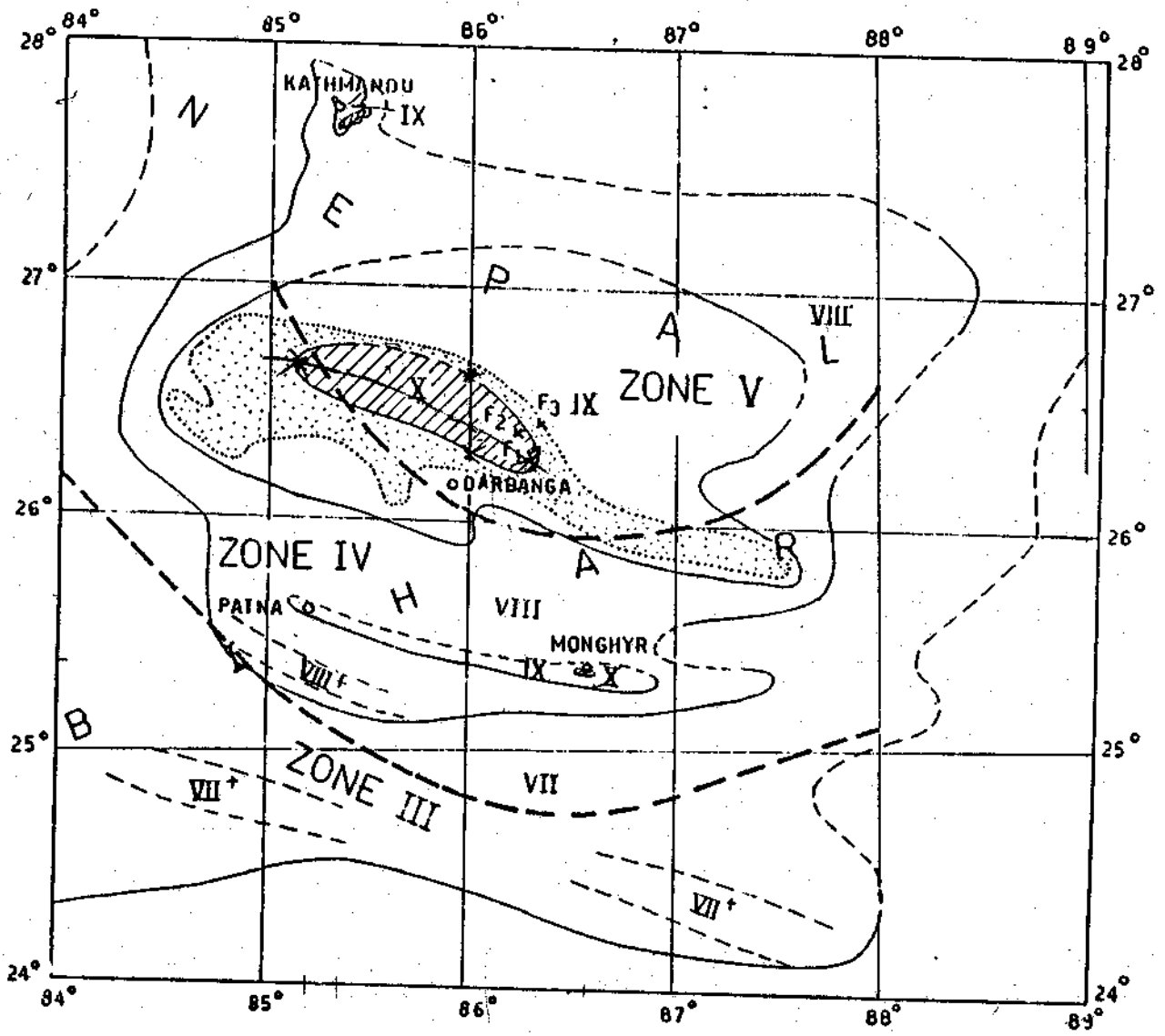


FIG-2_ EPICENTRAL MAP OF BIHAR SCALE_1: 2500000



INDEX

ISOSEISMAL X

SLUMP BELT

THE ISOSEISMAL LINES ARE BASED ON THE MERCALLI SCALE.

F_1 - FOCUS OF INITIAL FAILURE, MAIN SHOCK

F_2 - FOCUS OF MAJOR FAILURE MAIN SHOCK

F_3 - AFTER SHOCK OF JANUARY, 19th 1934

FIG. 3 - THE HIGHER ISOSEISMALS OF THE EARTHQUAKE OF THE 15th JANUARY, 1934

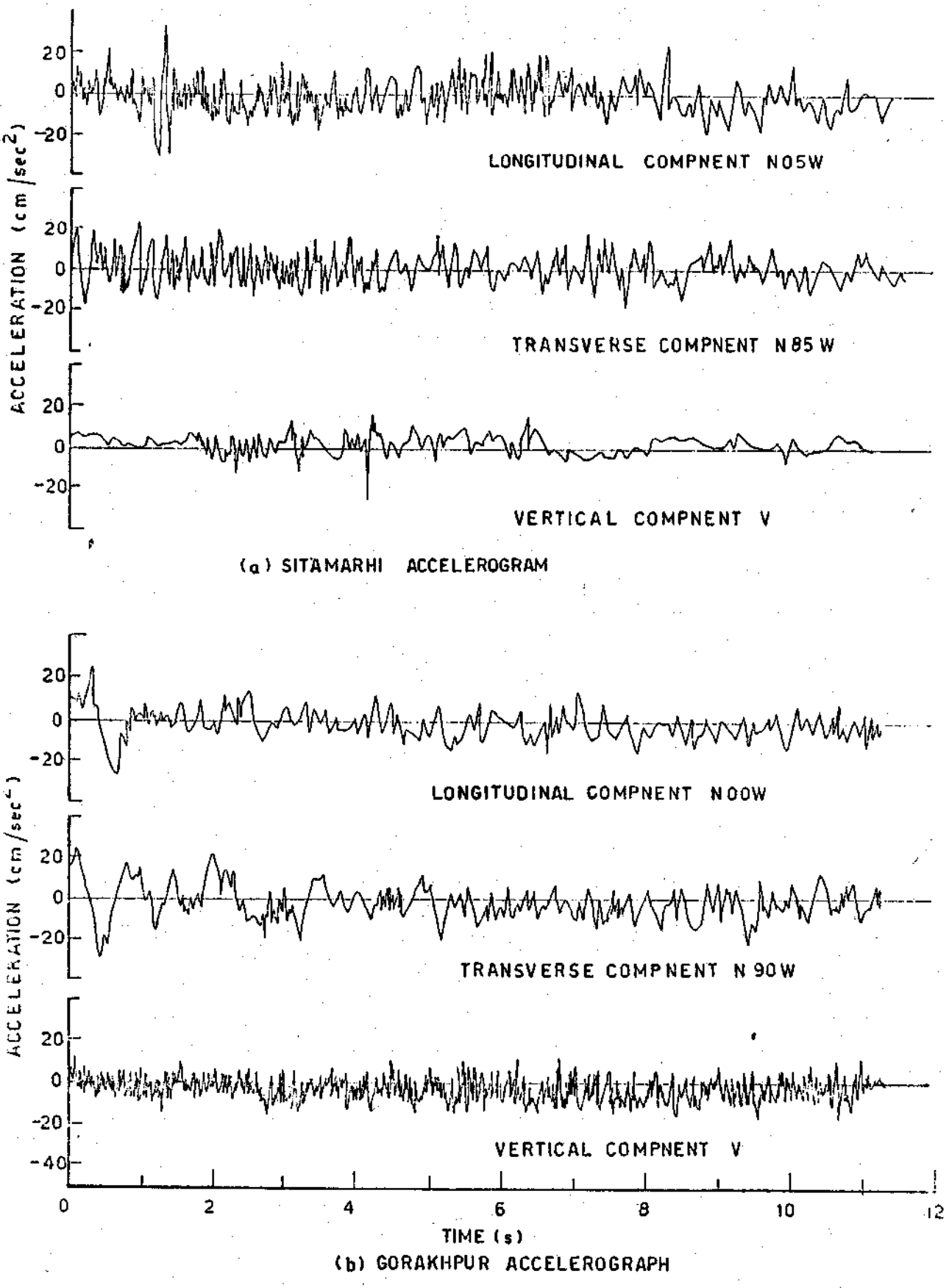
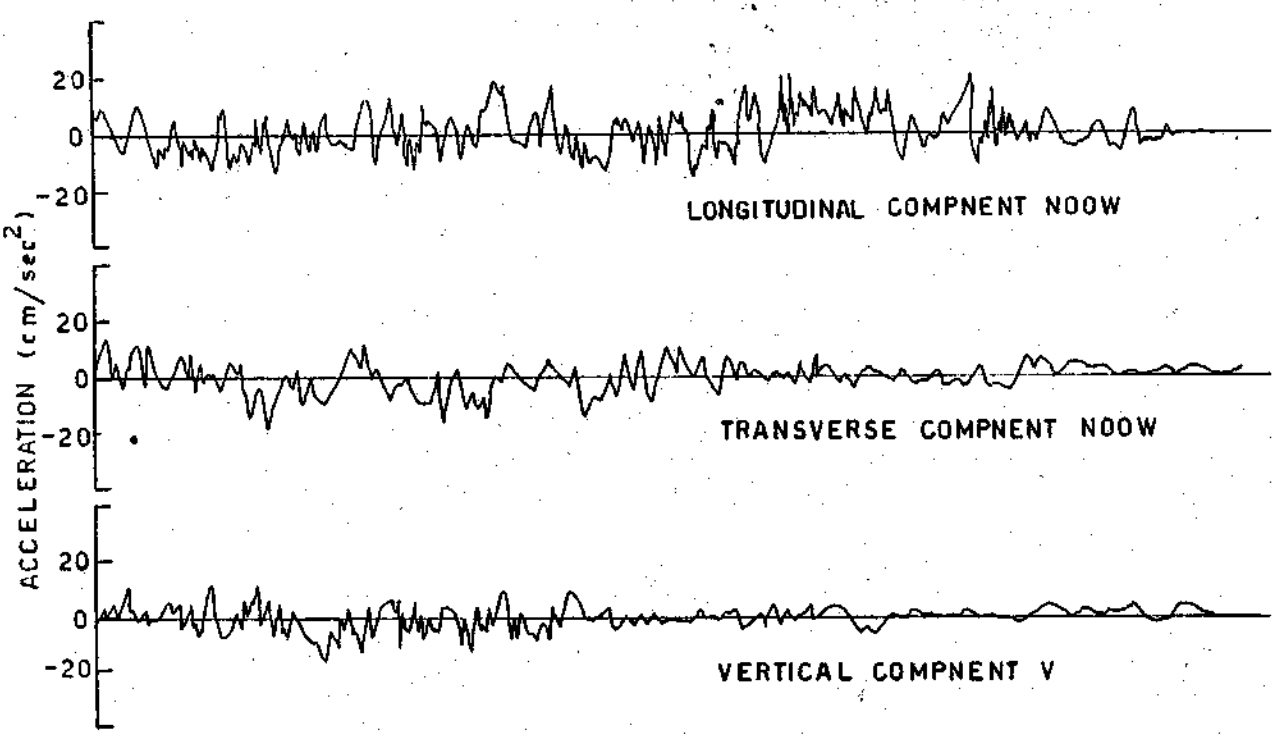
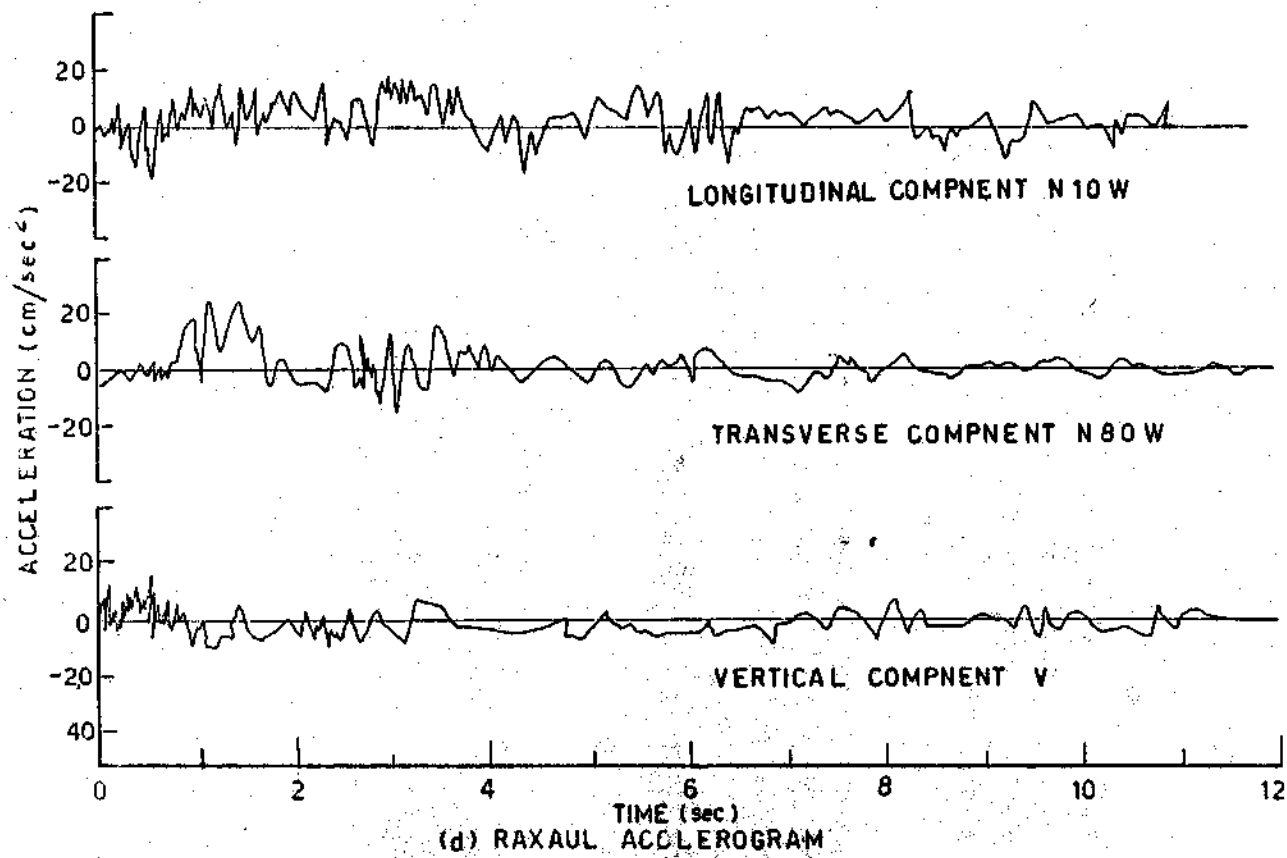


FIG. 4 – ACCELEROGRAPH RECORD OF EARTHQUAKE OF AUG. 21, 1988



(c) MUNGHYER ACCELEROGRAM



(d) RAXAUL ACCLEROGRAM

FIG. 4 – ACCELEROGRAPH RECORD OF EARTHQUAKE OF AUGUST 21, 1988

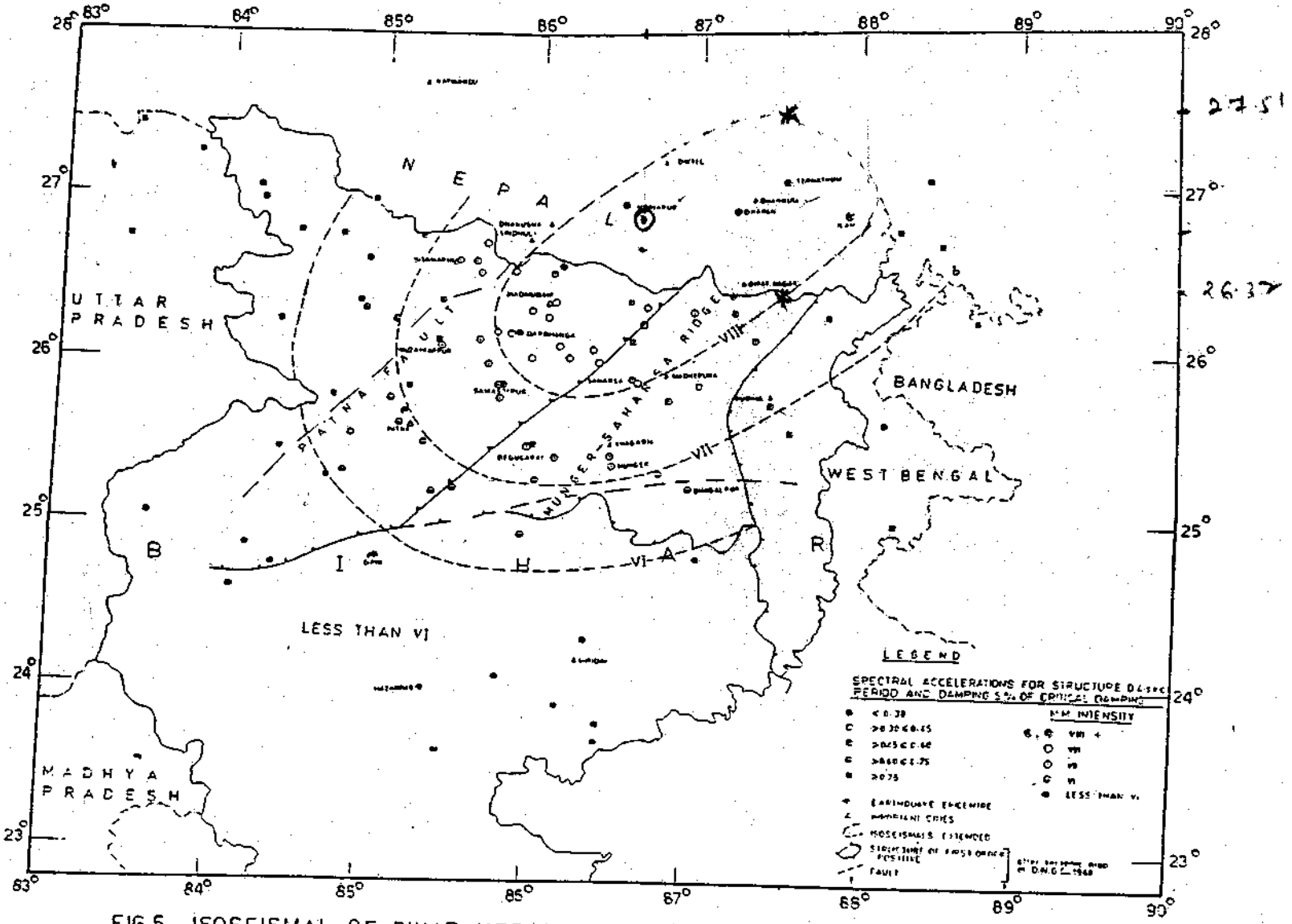


FIG.5 _ ISOSEISMAL OF BIHAR-NEPAL EARTHQUAKE OF AUGUST 21, 1988

Photo 1(a) Splitting of wall at junction in Hassanpur village

Photo 1(b) Cracking in a mud house in Hassanpur village

Photo 1(c) Wide cracks at arch crown in Hassanpur village

Photo 1(d) Damage in roof and walls

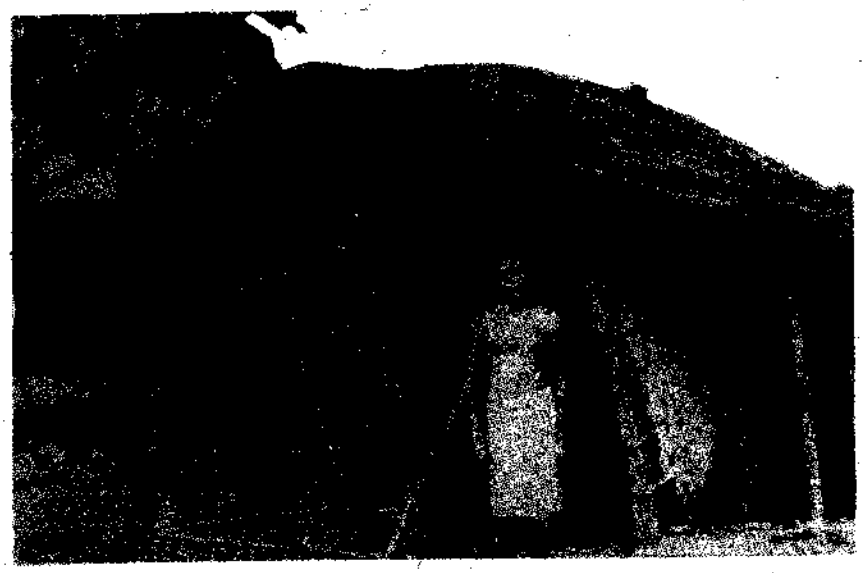


Photo 2(a) Tilted village house, Madhubani

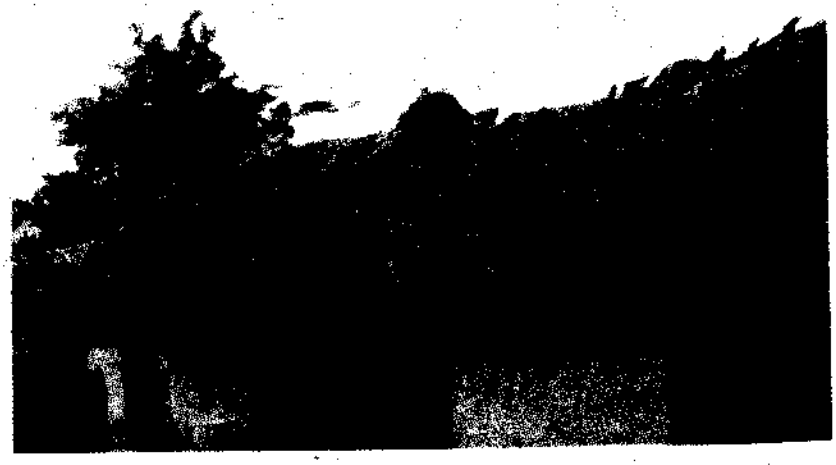


Photo 2(b) A village house, Madhubani
(cracking of walls, falling of plaster)

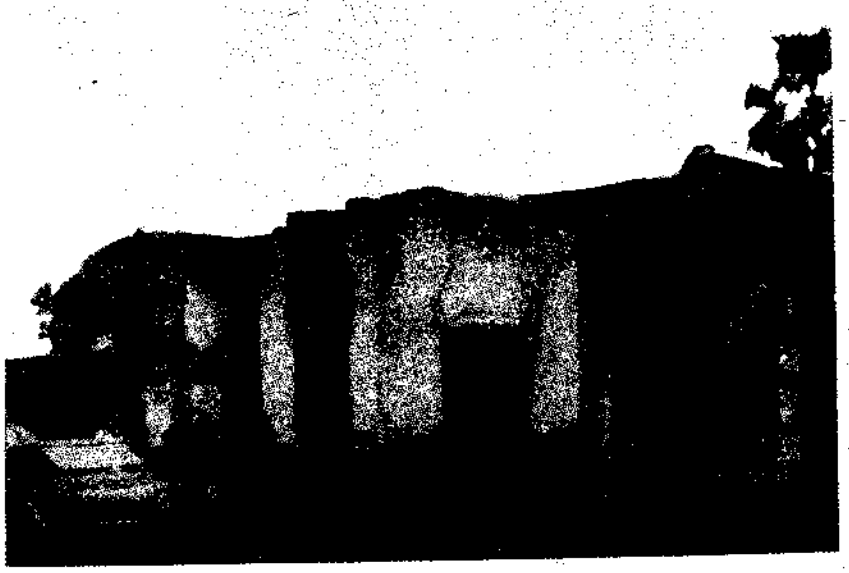


Photo 3 Land mortgage building, Darbhanga
(failure of front arches, walls and roof)

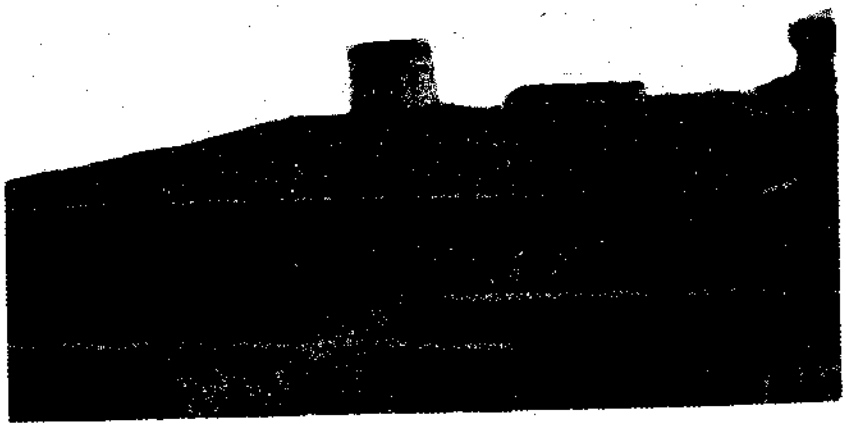


Photo 4(a) Circuit house, Darbhanga (cracks at eaves level)

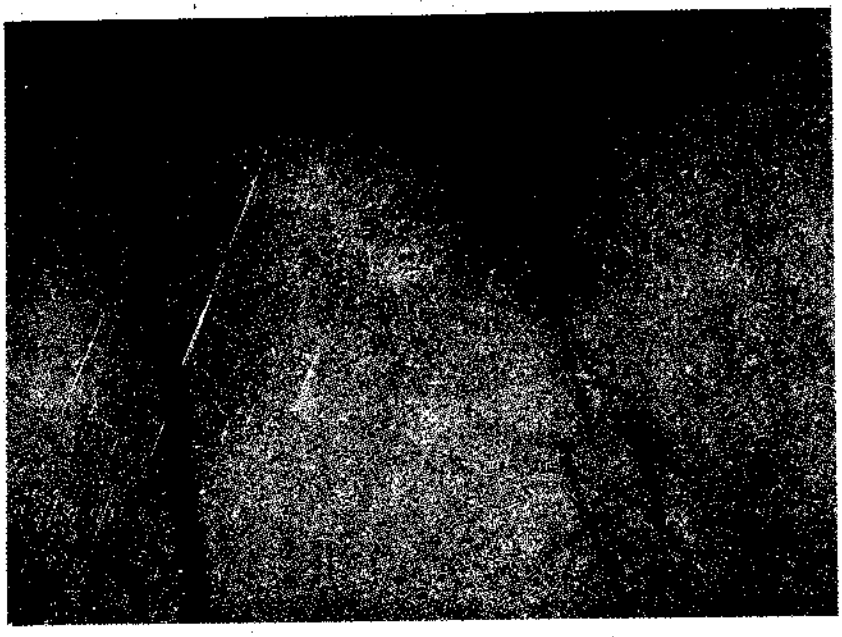


Photo 4(b) Circuit house, Darbhanga
(wide cracks in walls separation)

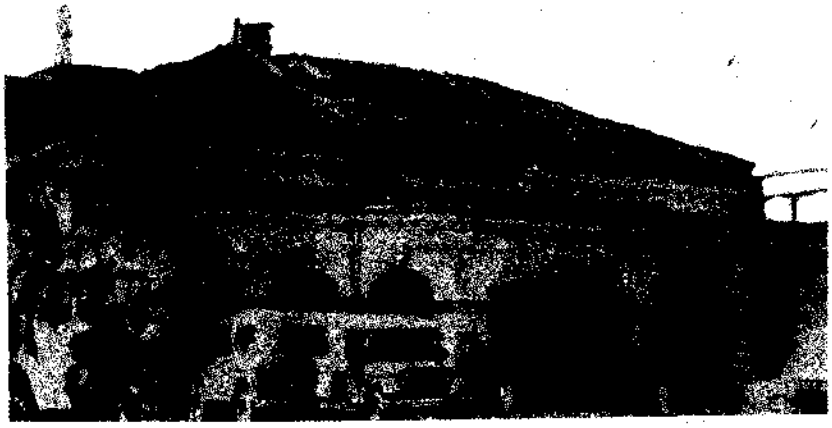


Photo 5 Civil surgeons house, Darbhanga
(severely damaged, building abandoned)

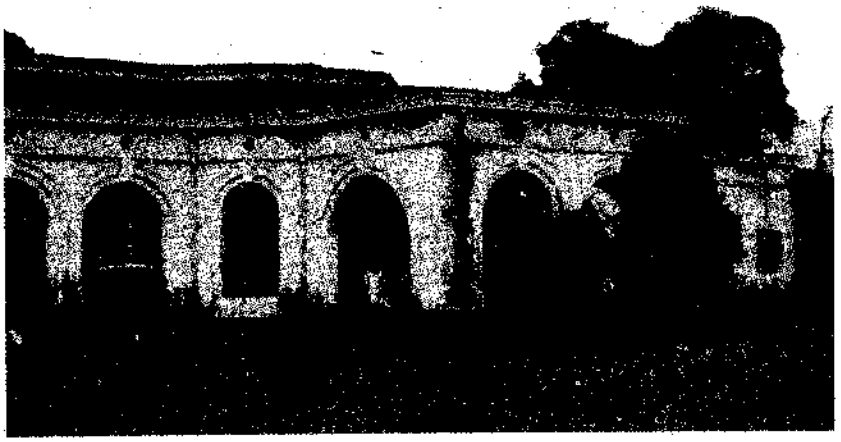


Photo 6(a) D.M.'s residence, Munghyer
(arches cracked)

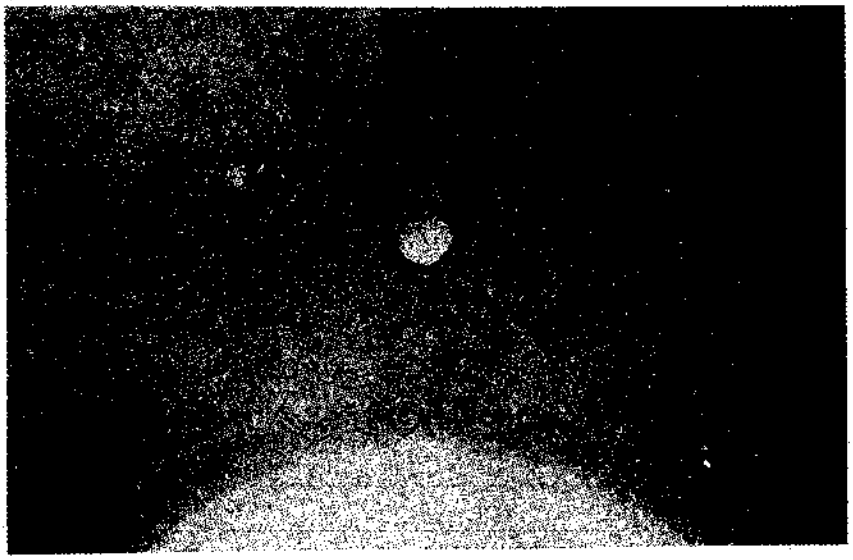


Photo 6(b) D.M.'s residence, Munghyer
(cracks near crown in the arch)

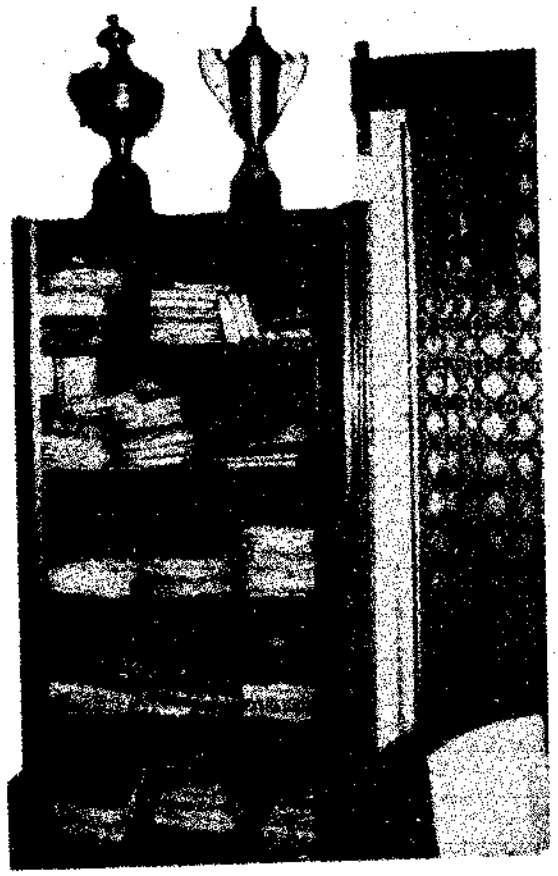


Photo 6(c) D.M.'s residence, Munghyer
(this cupboard overturned)

Photo 7(a) Town hall, Munghyer (1916)
(wide spread cracks in the building)

Photo 7(b) Town hall, Munghyer (1916)
(cracks outside of the building)

Photo 7(c) Town hall, Munghyer (1916)
(cracks in the roof and the arch)

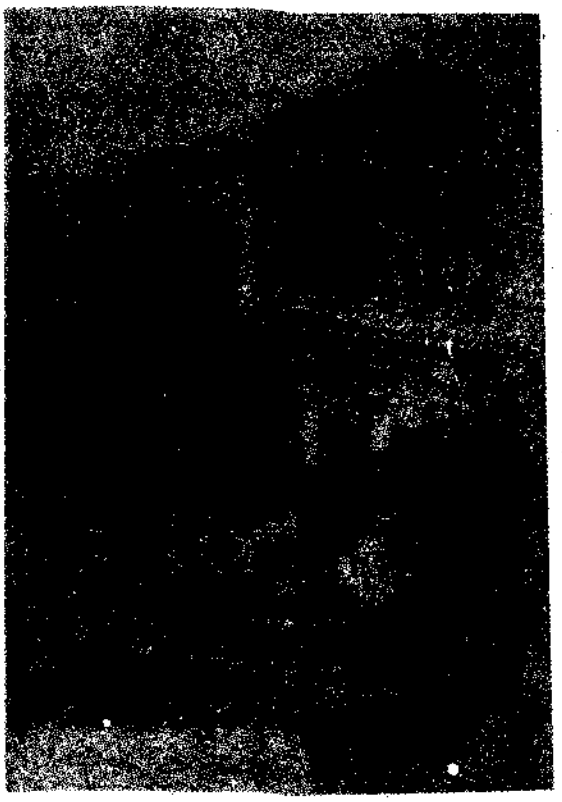


Photo 8(a) Sangam hotel, Munghyer prior to 1934 earthquake
(2nd and 3rd floor damaged in 1934 earthquake)

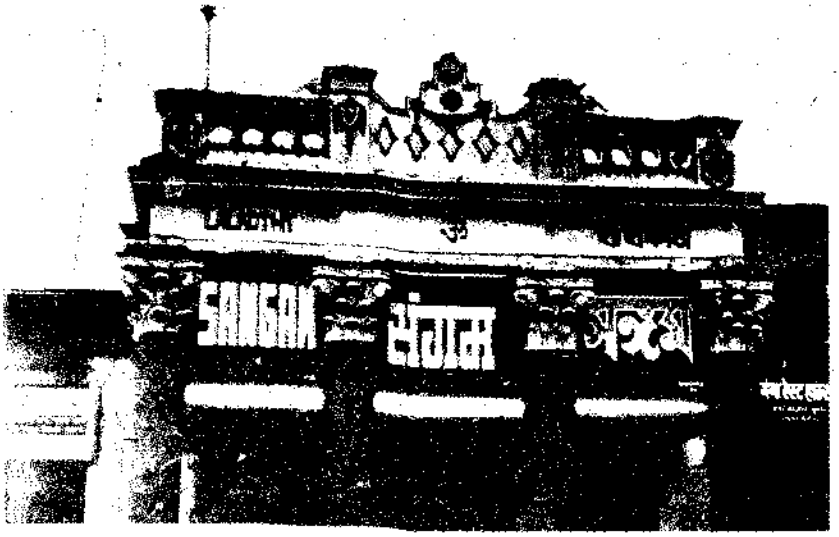


Photo 8(b) Sangam hotel, Munghyer (after 1988 earthquake)
(suffered heavy damage in walls and arches)

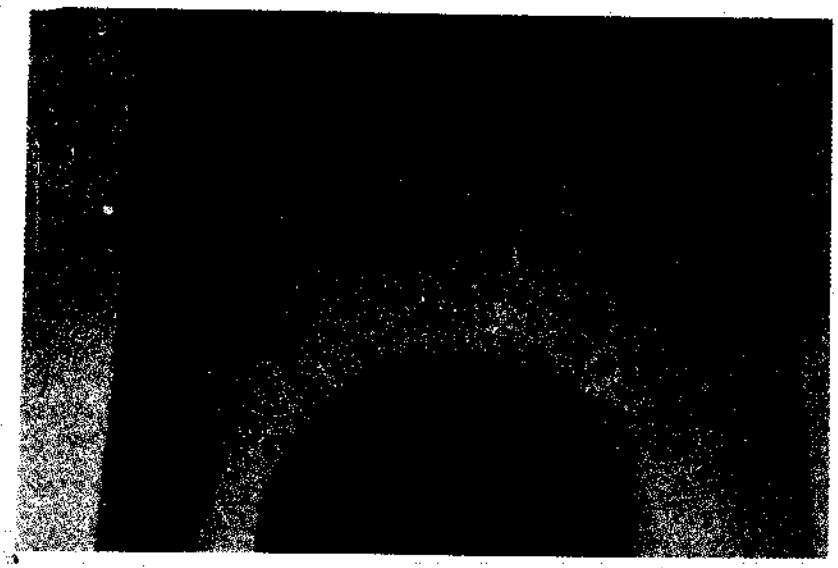
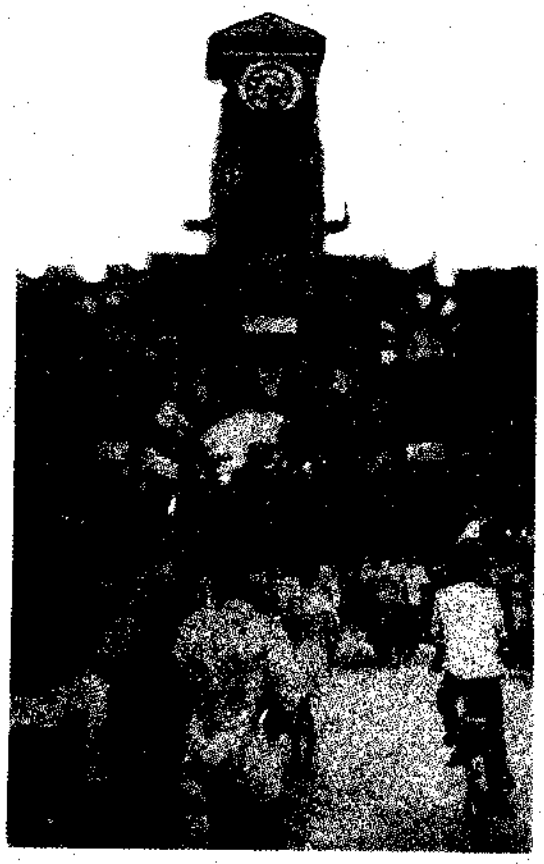


Photo 9(a) Clock tower, Munghyer (cracking of arches)



Phot0 9(b) Clock tower, Munghyer (cracks in smaller arches)

Photo 10(a) Dilip dharamshala, Munghyer
(badly damaged in earthquake)

Photo 10(b) Dilip dharamshala, Munghyer
(failure of arches, columns, roof)

Photo 10(c) Dilip dharamshala, Munghyer
(right portion in the state of mechanism)

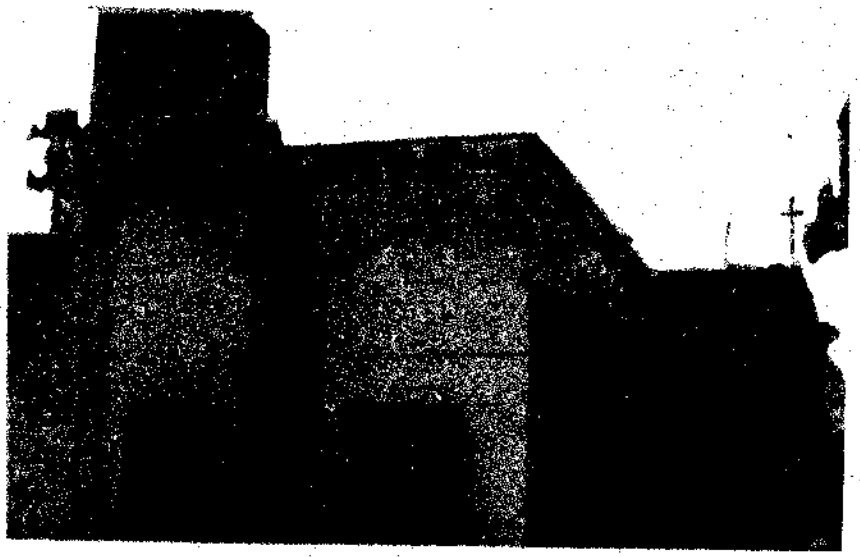


Photo 11(a) S.D.O. house, Darbhanga (severely damaged)

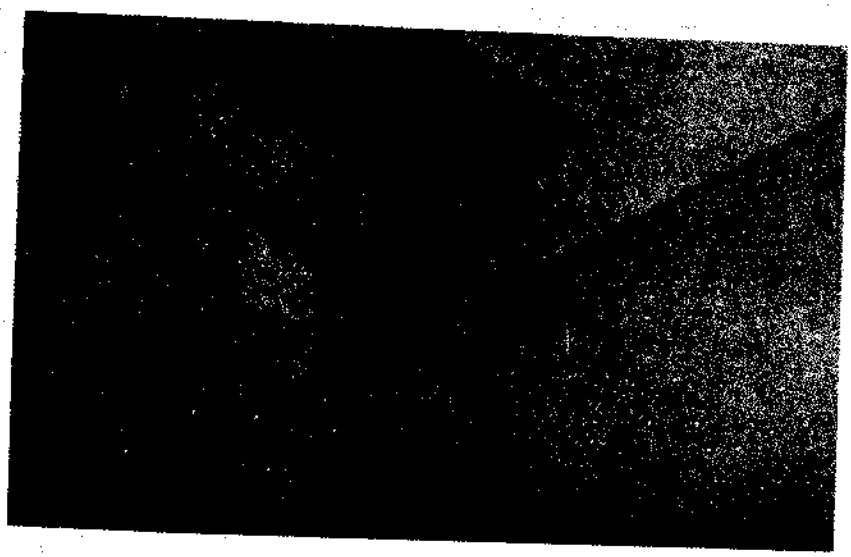


Photo 11(b) S.D.O. house, Darbhanga
(cracks in roof-wall junction)

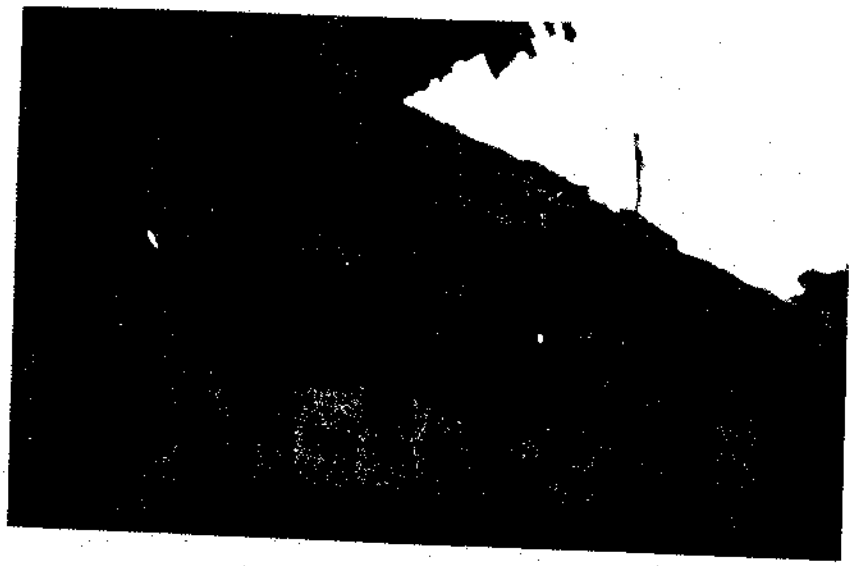


Photo 12 Collectorate building, Madhubani
(cracks in N-W corner of building)

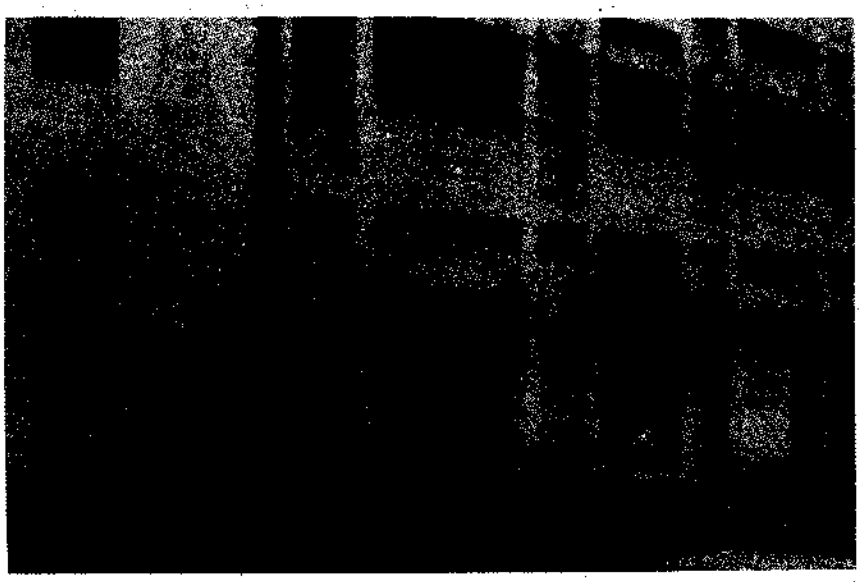


Photo 13(a) Residential building, Samastipur
(building cracked due to poor mortar quality)

Photo 13(b) Residential building, Samastipur
(diagonal cracks in the building)

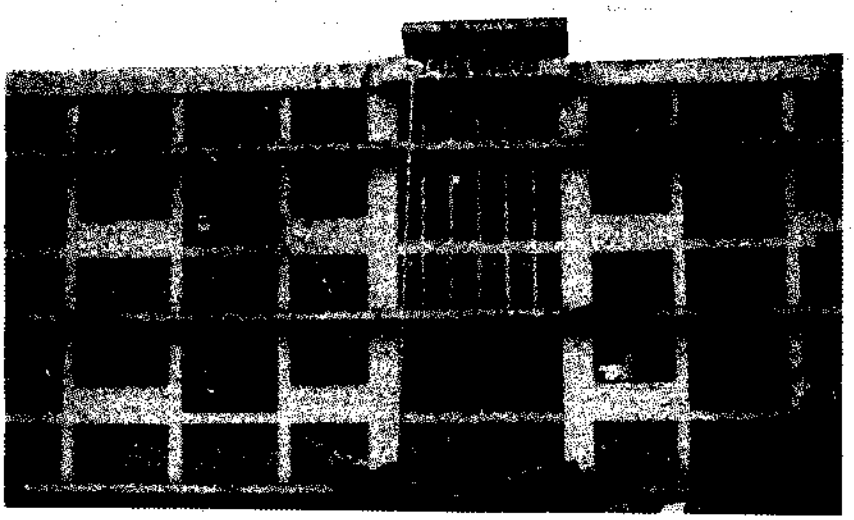


Photo 14 Collectorate building, Samastipur
(walls showed heavy cracks)

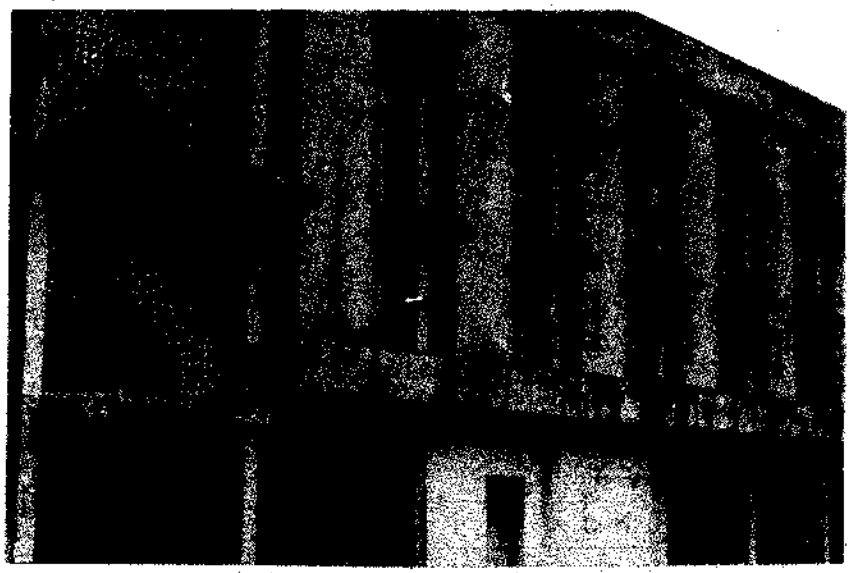


Photo 15(a) Sainik barracks, Jamalpur
(wide spread cracks, jali failure)

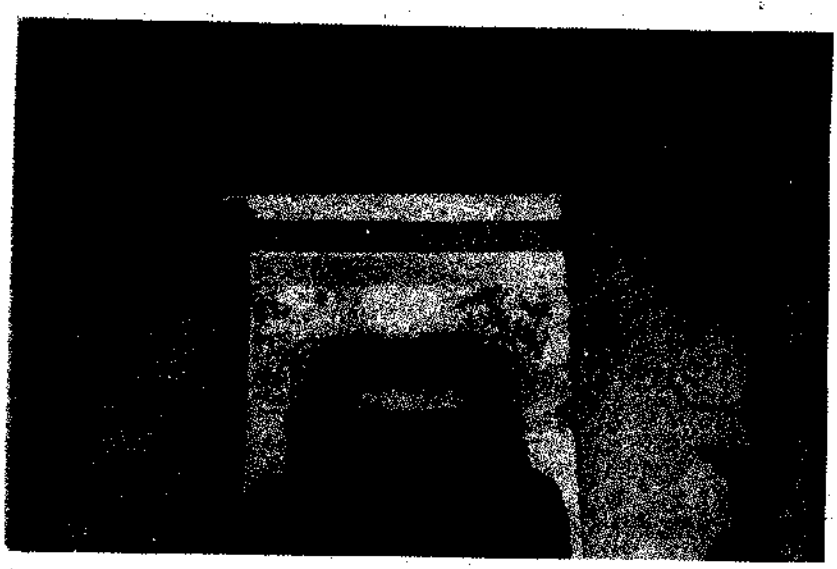


Photo 15(b) Sainik barracks, Jamalpur
(cracks in the garage)

Photo 15(c) Sainik barracks, Jamalpur
(diagonal cracks in cross walls)

Photo 15(d) Sainik barracks, Jamalpur
(horizontal/diagonal cracks in walls)

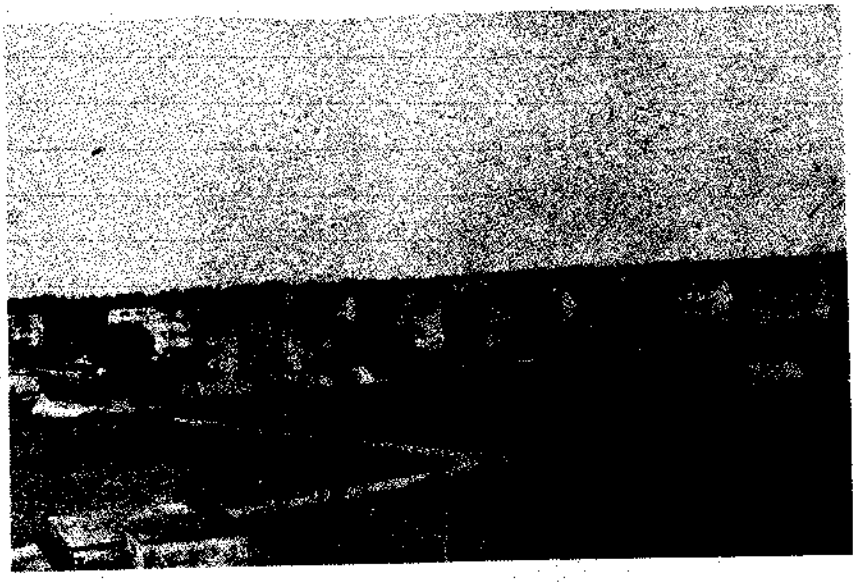


Photo 15(e) Police quarters, Jamalpur
(wide spread cracks in walls)

Photo 15(f) Police quarters, Jamalpur
(diagonal cracks in walls around stair case)

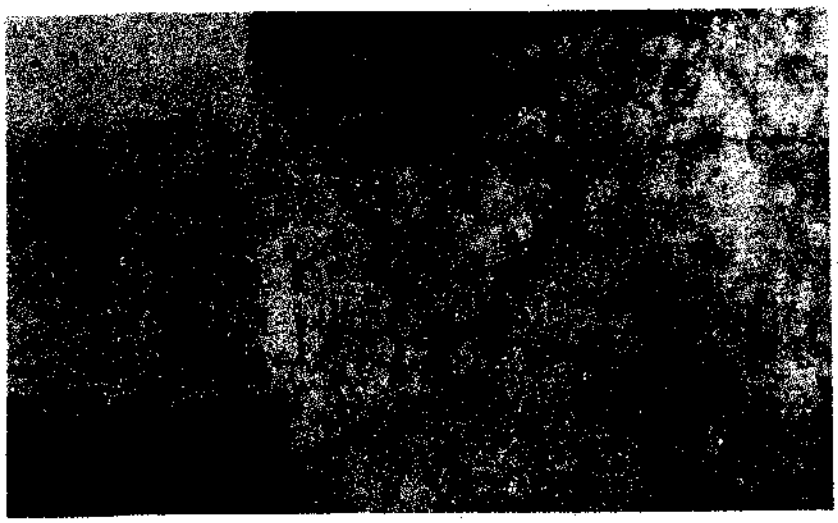


Photo 15(g) Police quarters, Jamalpur (diagonal cracks in walls)

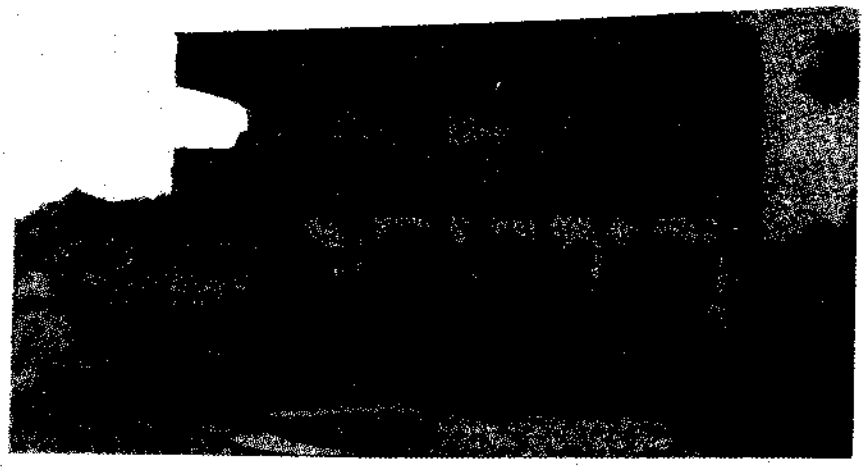


Photo 16(a) Cyclestand cum canteen r.c. structure, Munghyer

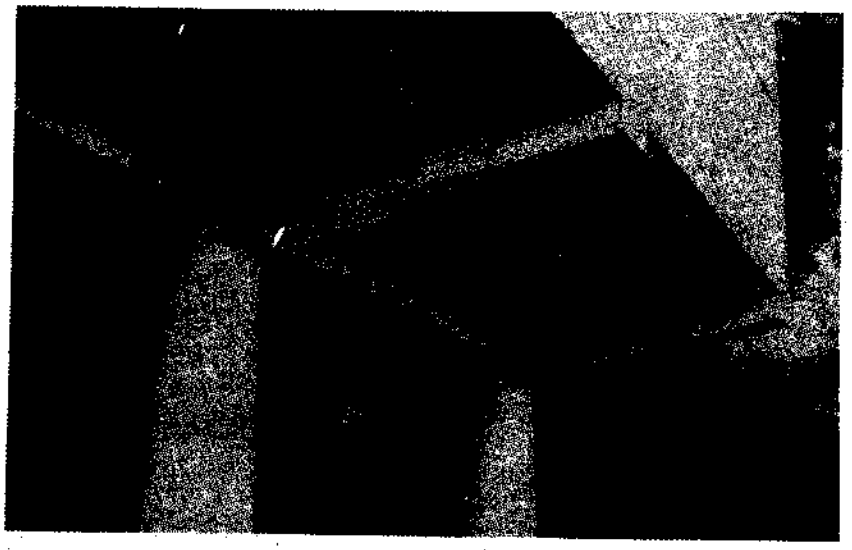


Photo 16(b) Cracks at top of columns, Munghyer

Photo 16(c) Collapsed cycle stand cum canteen structure, Darbhanga

Photo 16(d) View of collapsed structure, Darbhanga

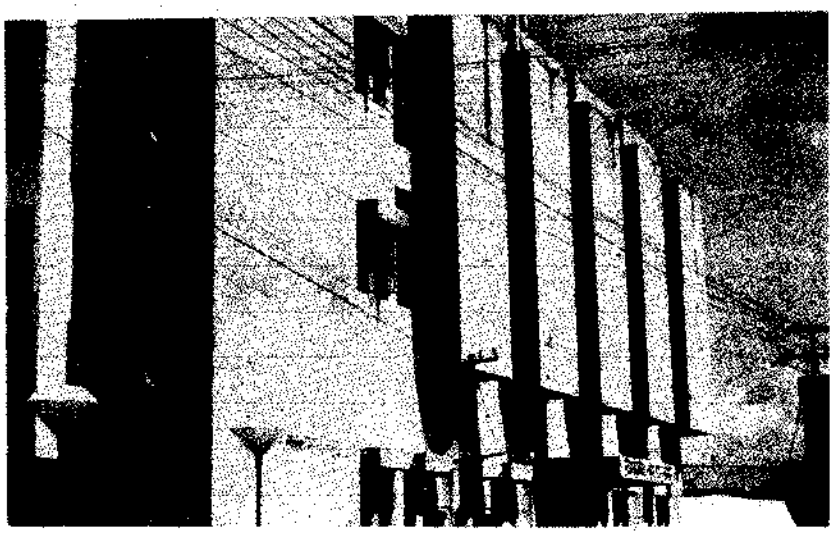


Photo 17(a) Telegraph office, Munghyer (outer view)

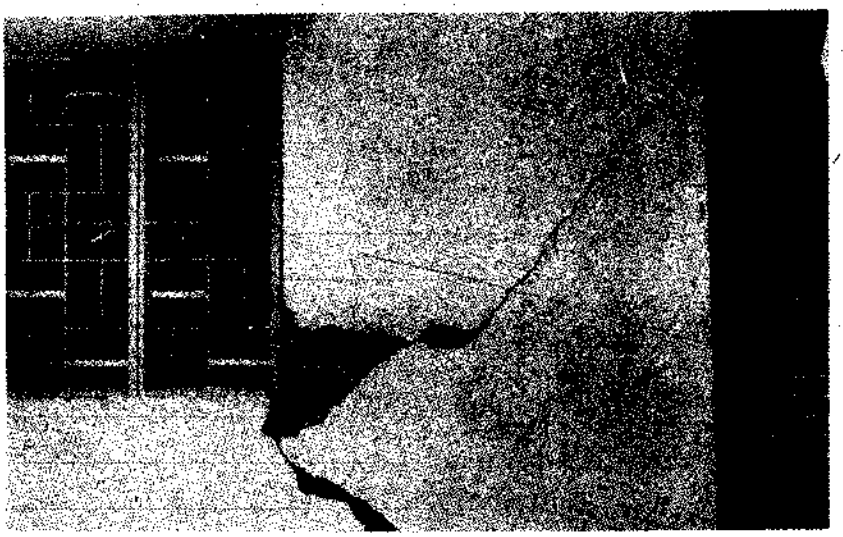


Photo 17(b) Telegraph office, Munghyer
(wide spread cracks in inner walls)

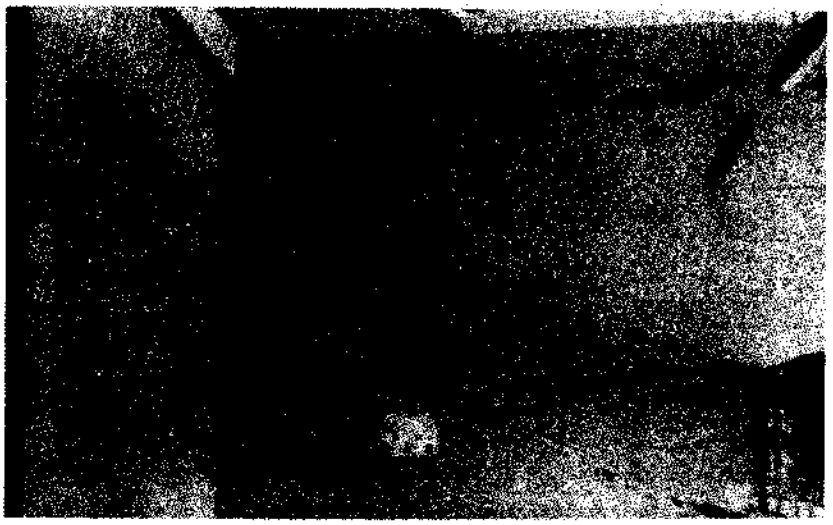


Photo 17(c) Telegraph office, Munghyer
(diagonal/horizontal cracks in inner walls)

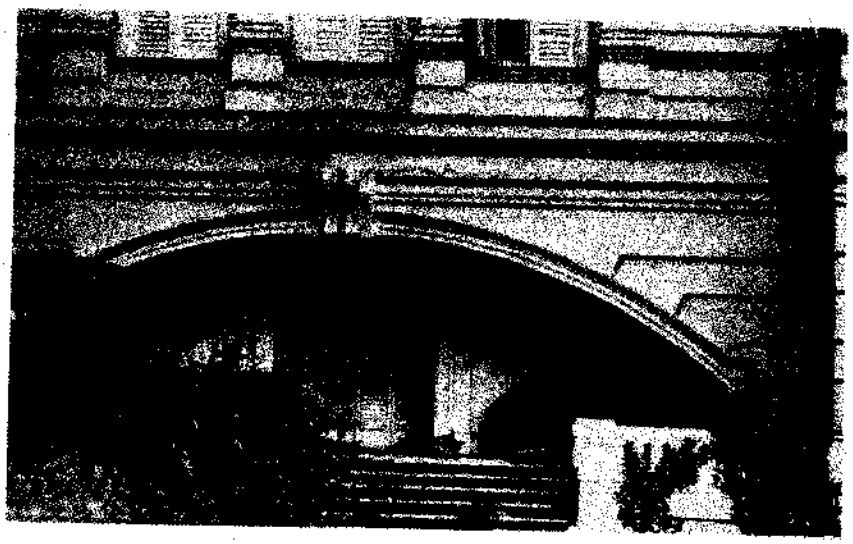


Photo 18(a) Raj bhawan, Patna (Horizontal
crack over the arch in right half)

Photo 18(b) Raj bhawan, Patna (cracking of smaller arches)

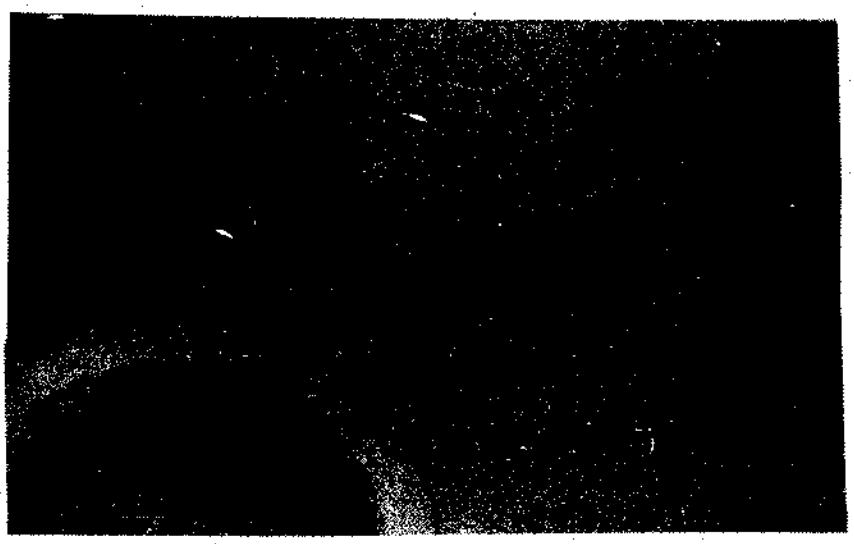


Photo 18(c) Raj bhawan, Patna cracking of arches, roof)

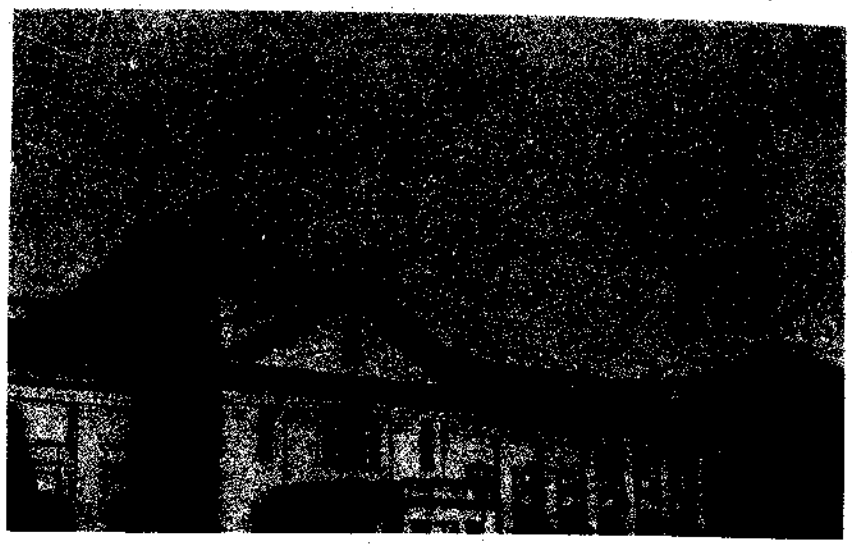


Photo 19(a) High court building, Patna
(cracking of dome, walls, roof)

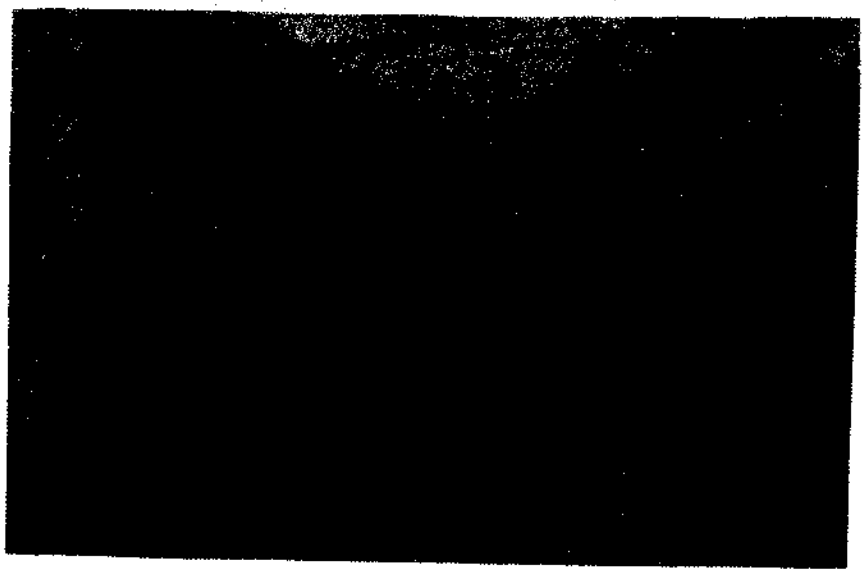


Photo 19(b) High court building, Patna
(cracking of walls, roof)

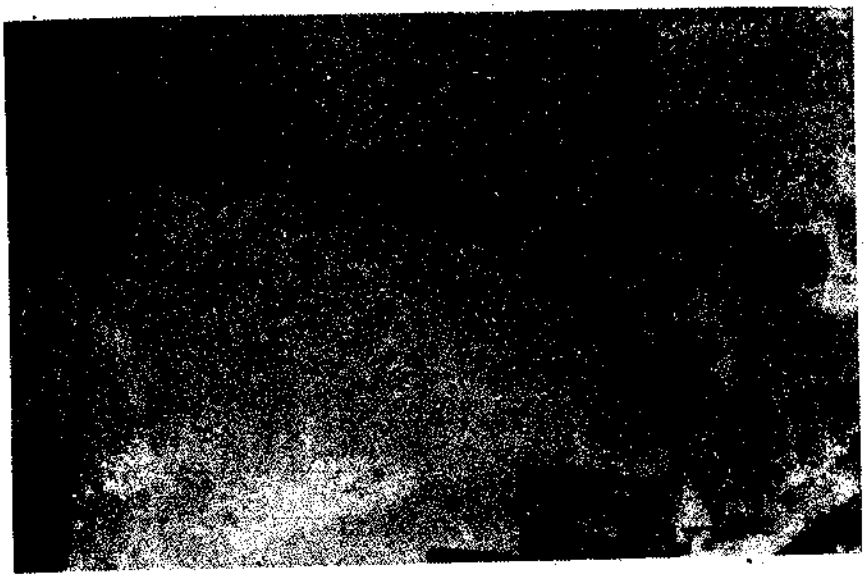


Photo 19(c) High court building, Patna
(cracking of roof-wall junction)

Photo 19(d) High court building, Patna
(vertical crack at wall junction)

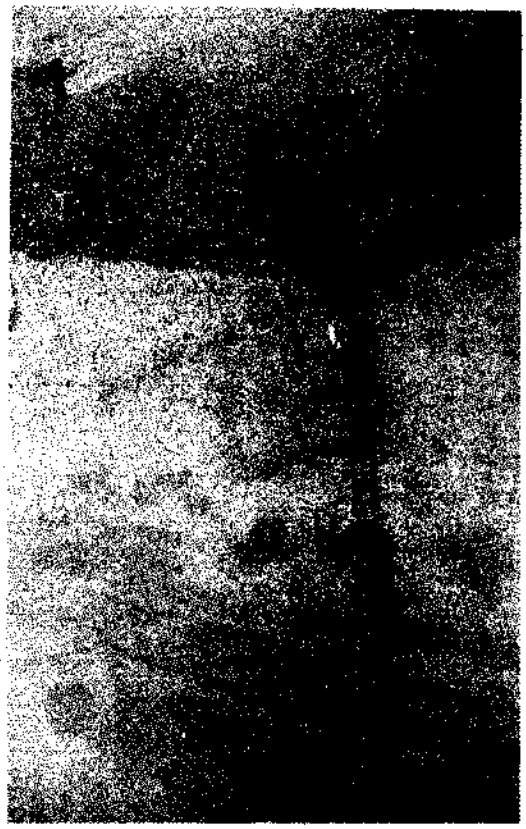


Photo 19(e) High court building, Patna
(separation of walls at corner)

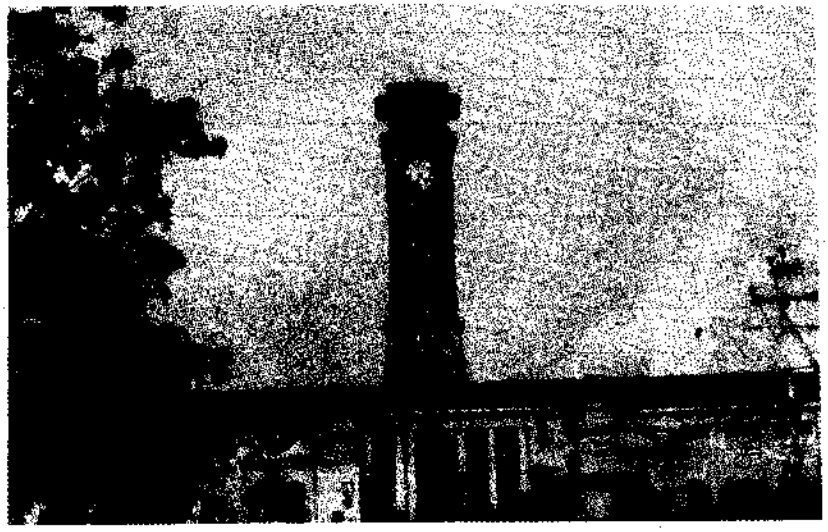


Photo 20 Old sachivalaya, Patna
(walls and roof of left block was cracked)

Photo 21(a) Nalanda archaeological remain (undamaged)

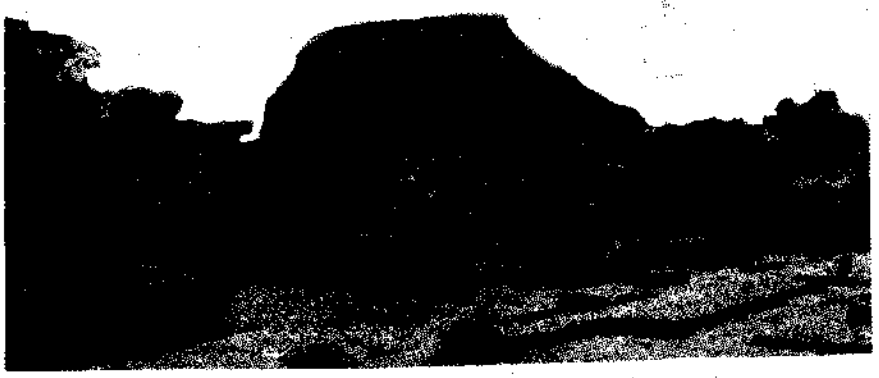


Photo 21(b) Nalanda archaeological remain (undamaged)

Photo 22(a) Shiva temple (wide spread cracks in dome and arches)

Photo 22(c) Shiva temple (outer walls cracked)

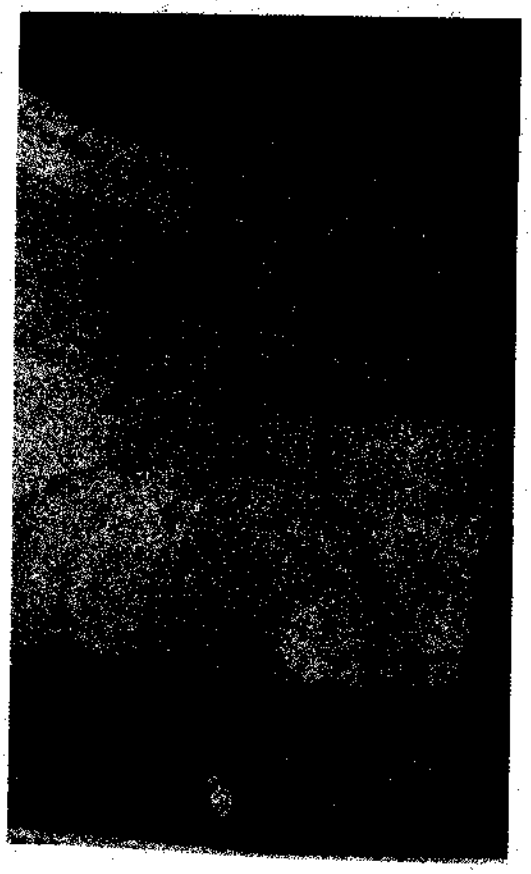


Photo 22(b) Shiva temple (cracks in dome)

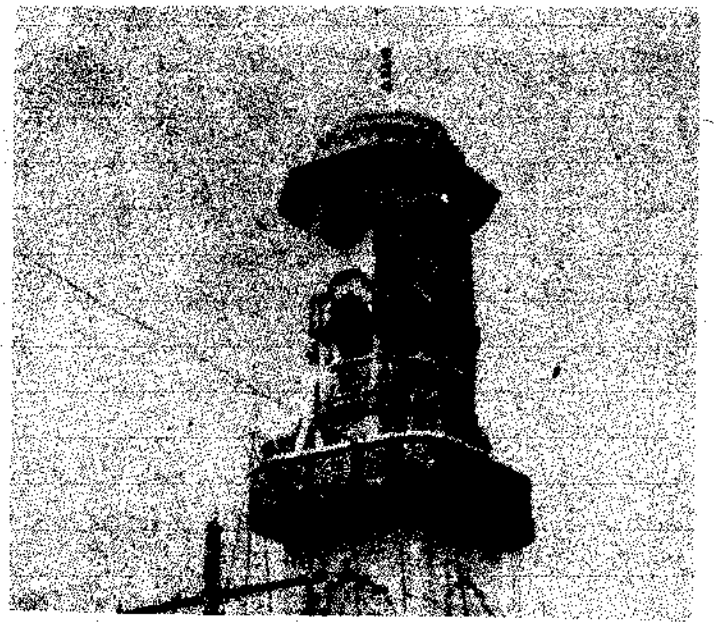


Photo 23(a) Jama masjjid, Darbhanga
(top portion sheared, shifted to left)

Photo 23(b) Jama masjjid, Darbhanga (failure at column top)

Photo 23(c) Jama masjjid, Darbhanga
(cracking at top of column/arch junction

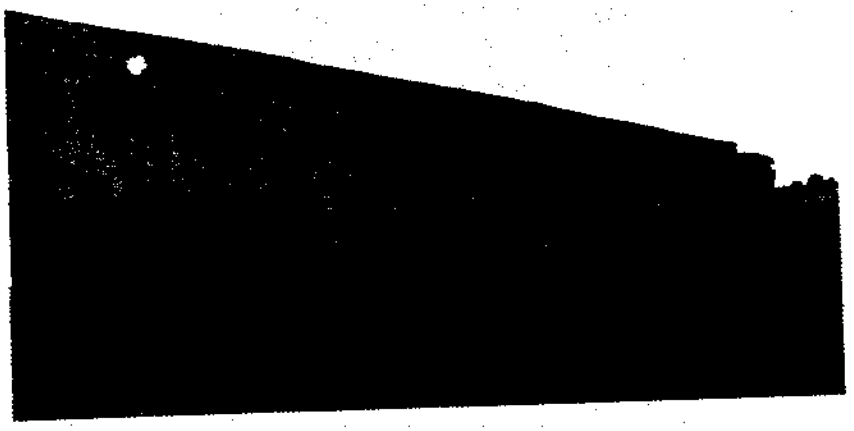


Photo 24(a) Medical college old hostel, Darbhanga
(badly damaged, wide spread cracks)

Photo 24(b) Medical college old hostel, Darbhanga
(failure of arches, partial collapse)

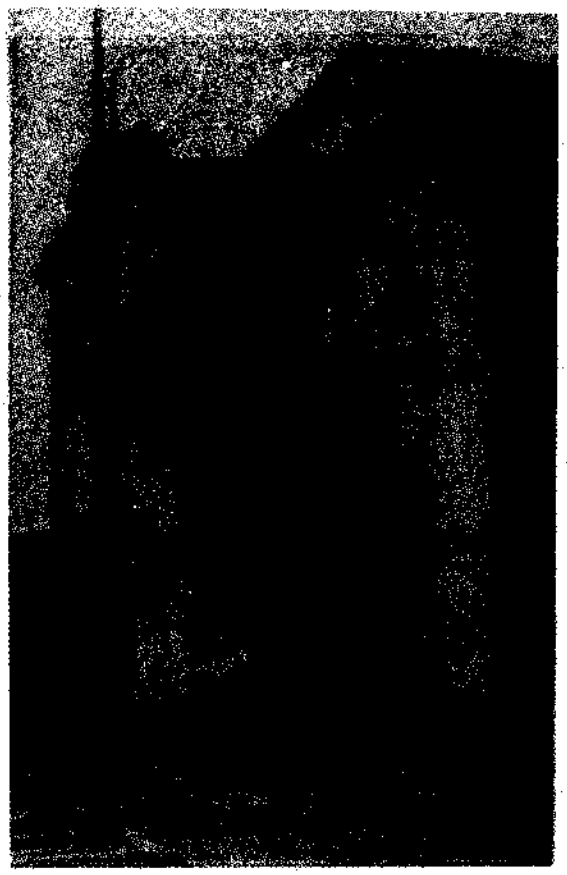


Photo 24(c) Medical college hostel, Darbhanga
(arch failure, failure of stair case)

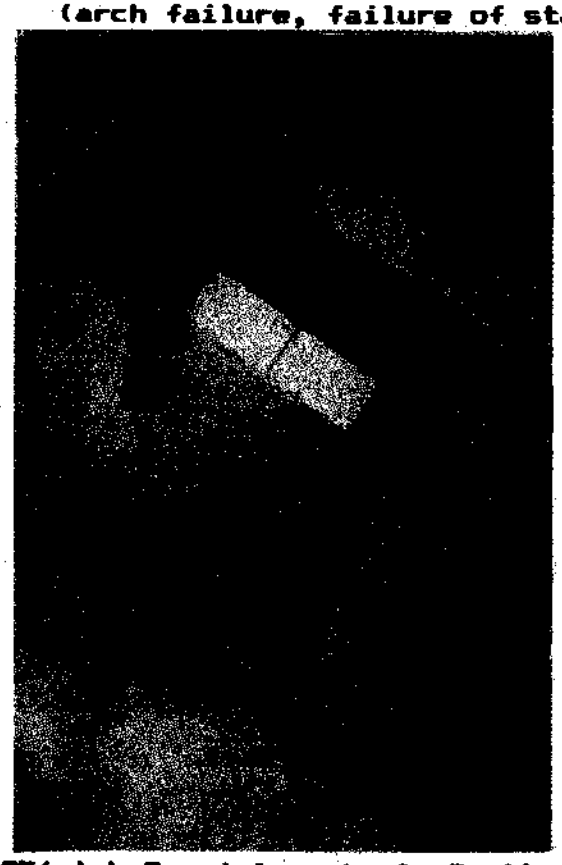


Photo 25(a) L.R. girls school, Darbhanga
(cracking of walls and roof)

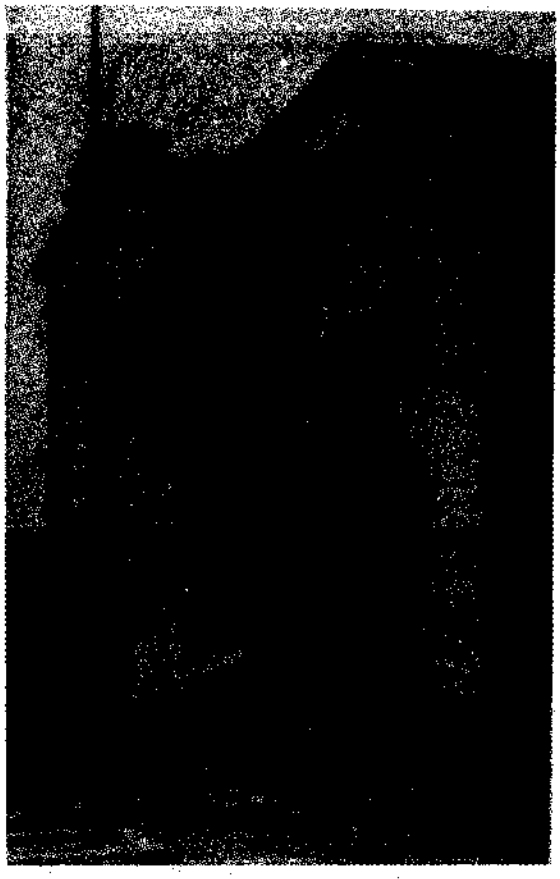


Photo 24(c) Medical college hostel, Darbhanga
(arch failure, failure of stair case)

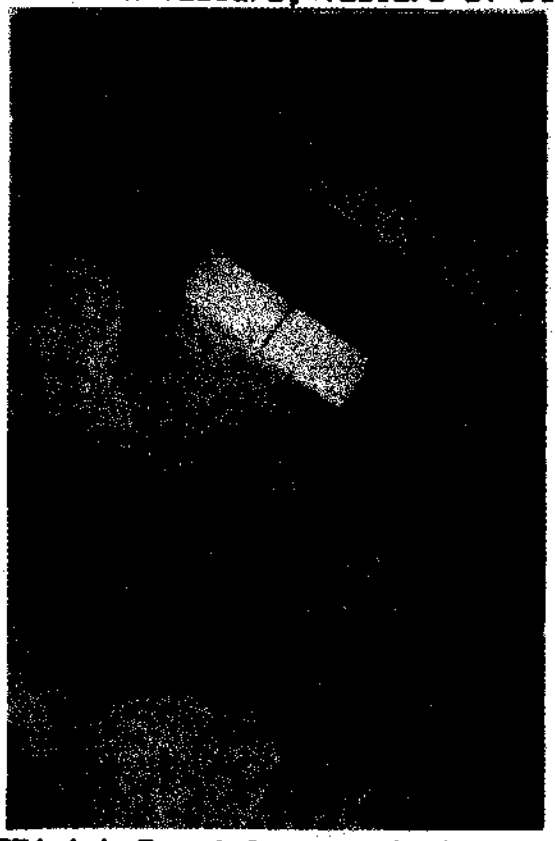


Photo 25(a) L.R. girls school, Darbhanga
(cracking of walls and roof)

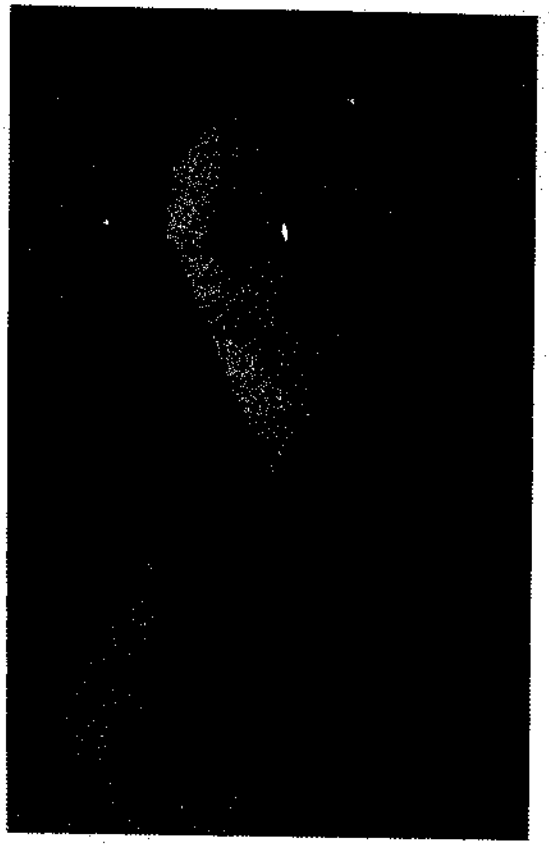


Photo 25(b) L.R. girls school, Darbhanga (falling of plaster, wall cracking, separation)

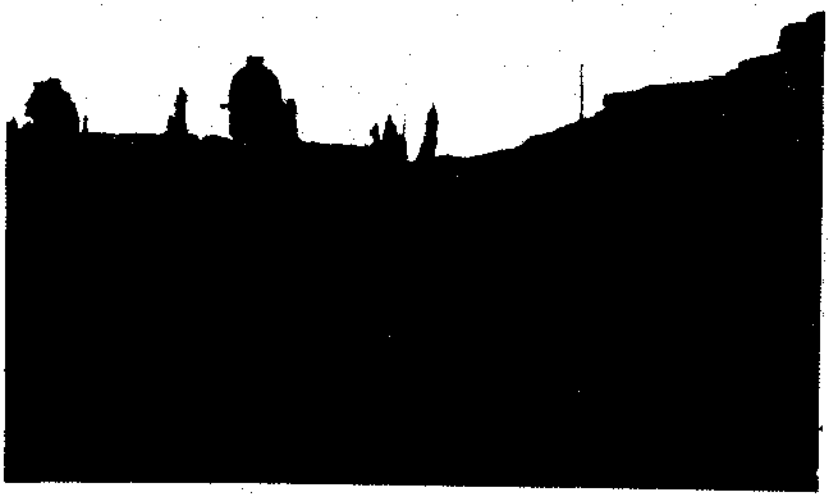


Photo 26(a) Madarsa building, Darbhanga (collapse of brick arches)

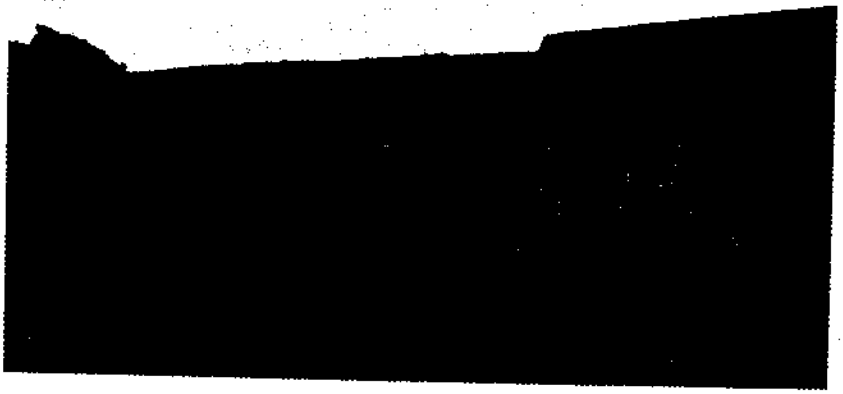


Photo 26(b) Madarsa building, Darbhanga (failure of arches)

Photo 26(c) Madarsa building, Darbhanga (failure of roof)

Photo 26(d) Madarsa building, Darbhanga (failure of arches, roof)

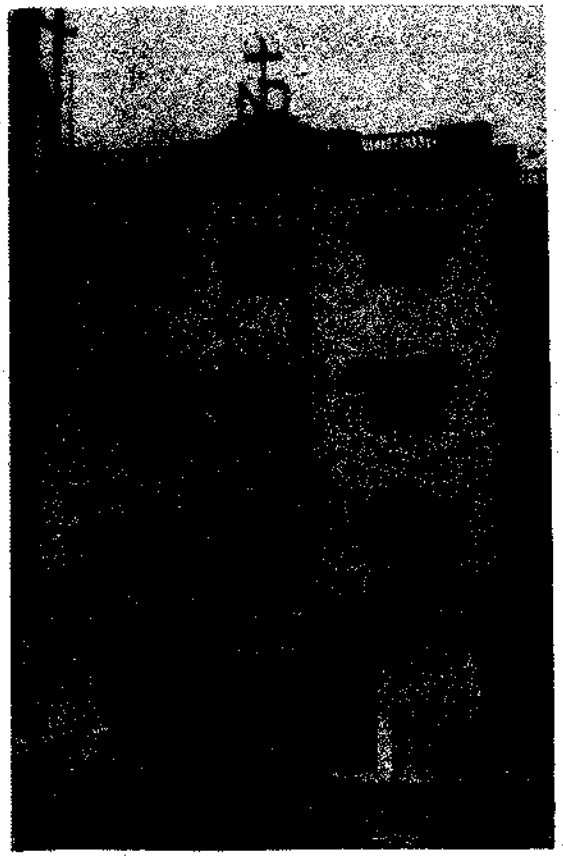


Photo 27(a) Notre dame school, Jamalpur
(cracking of walls blackboard)

Photo 27(b) Notre dame school, Jamalpur
(cracking of lintel beam)

Photo 28(a) Surgical ward, Darbhanga (cracks in r.c. columns)

Photo 27(b) Notre dame school, Jamalpur
(cracking of lintel beam)

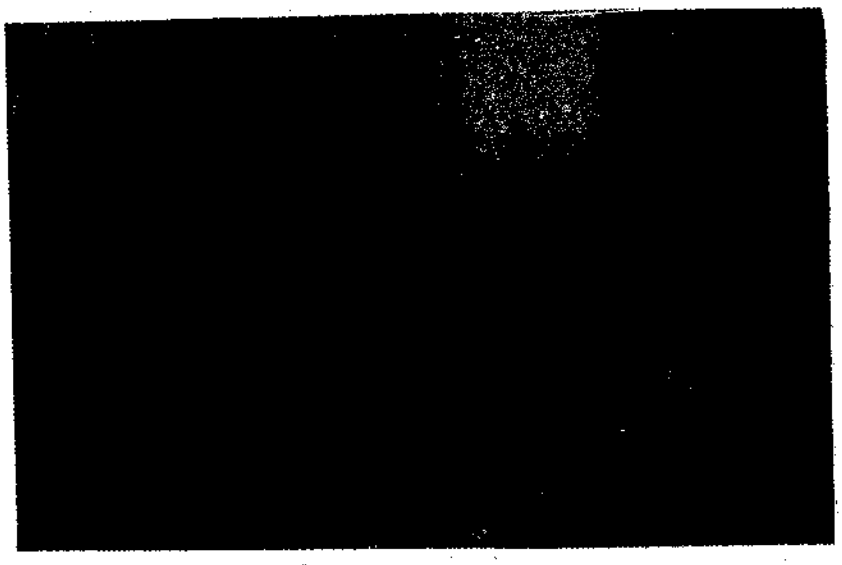


Photo 28(a) Surgical ward, Darbhanga (cracks in r.c. columns)

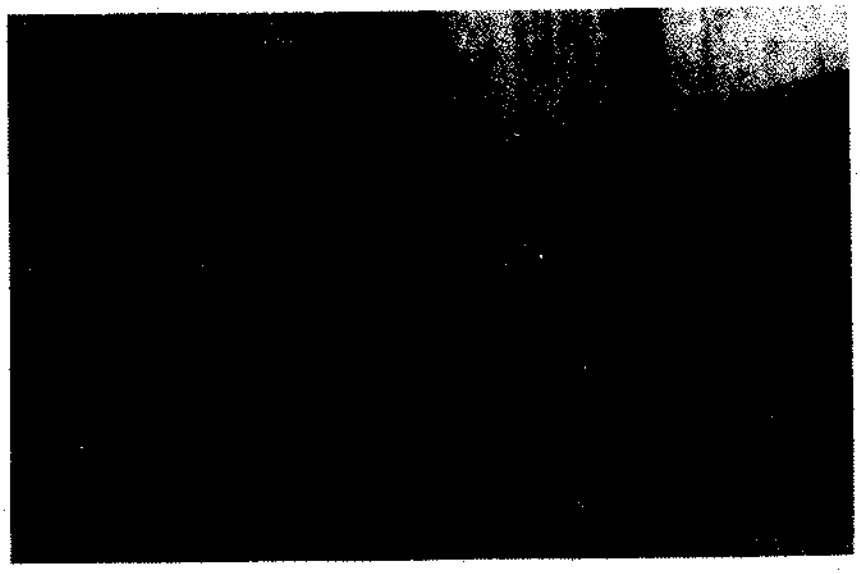


Photo 28(b) Surgical ward, Darbhanga (cracking of wall)

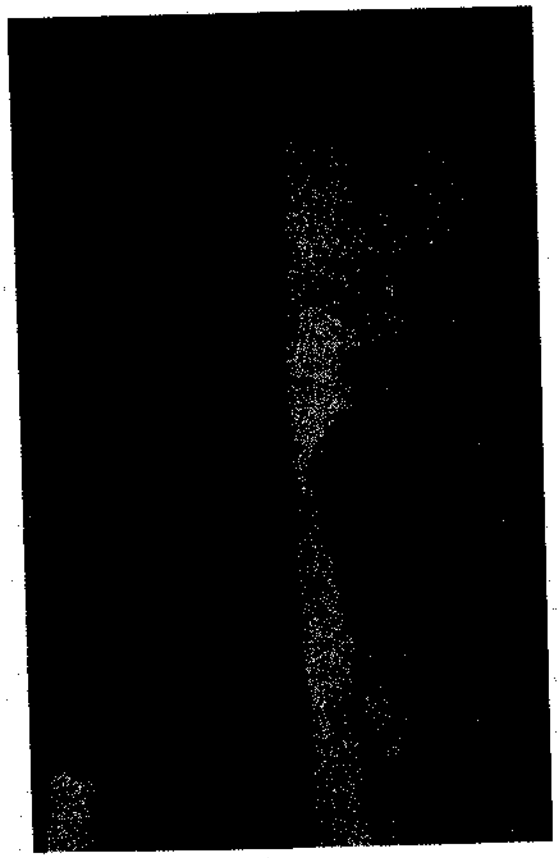


Photo 28(c) Surgical ward, Darbhanga (cracks in r.c. columns)

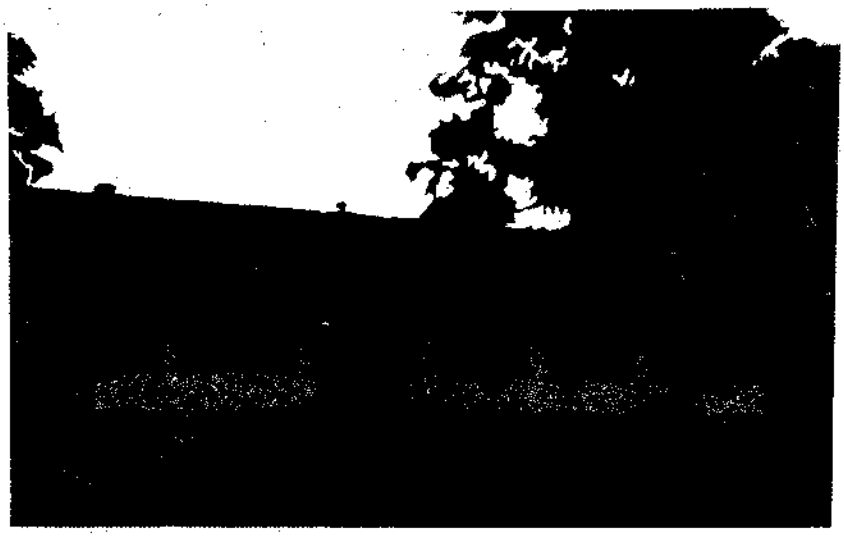


Photo 29(a) Museum, Laheriasarai (cracking of arches)

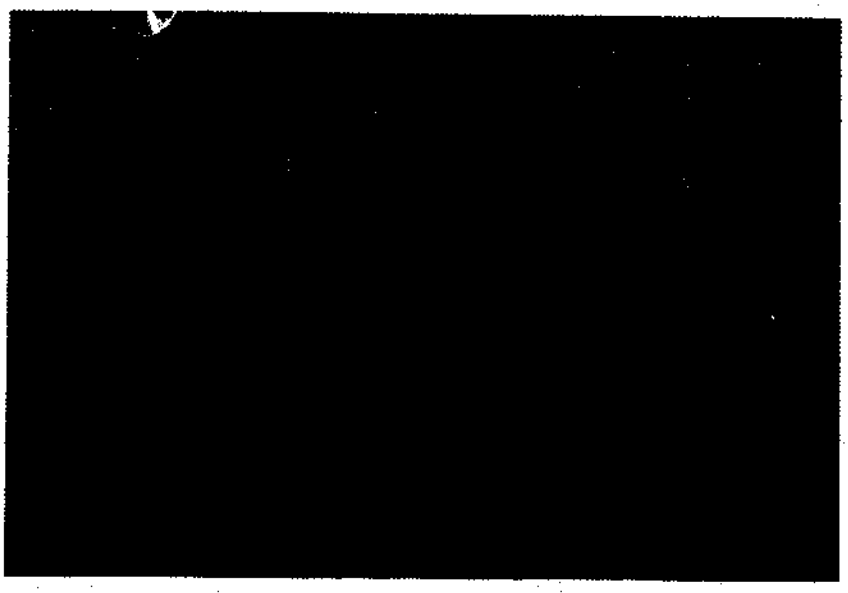


Photo 29(b) Museum, Laheriasarai (overturning of statue)

Photo 29(c) Museum, Laheriasarai (overturning of specimens)

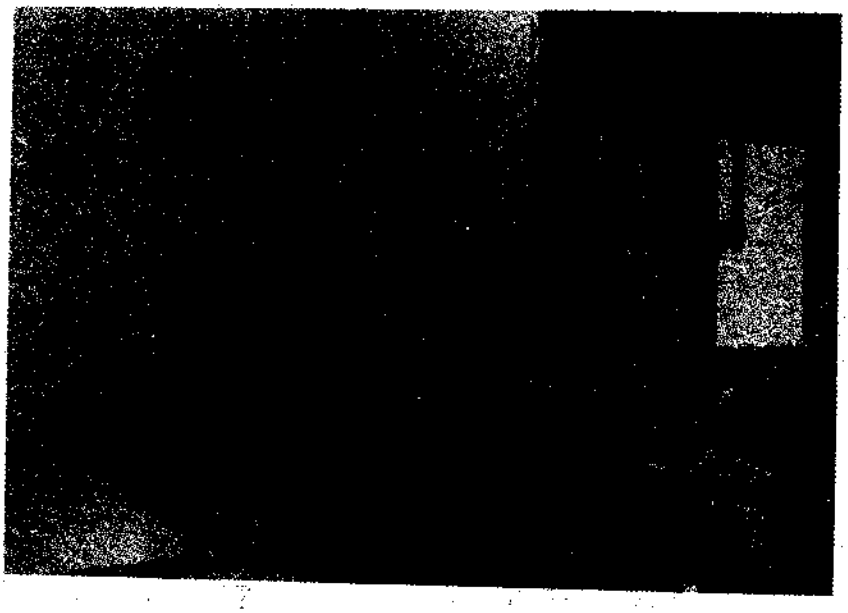


Photo 29(d) Museum, Laheriasarai

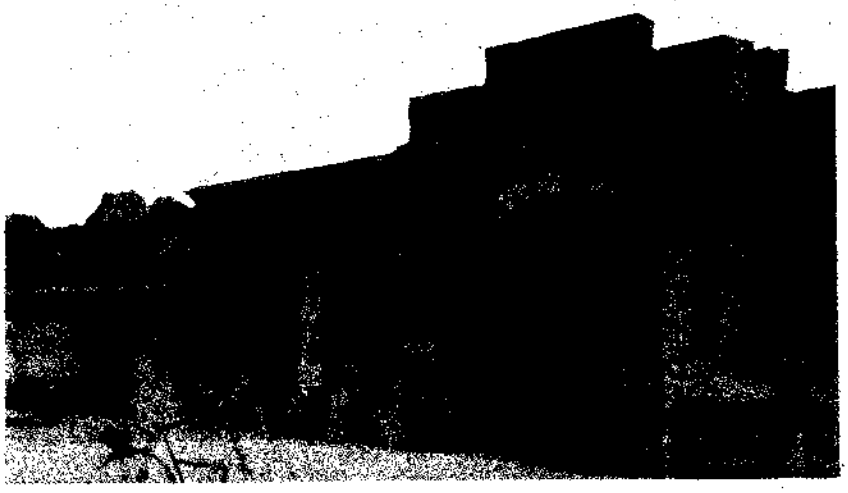


Photo 30(a) Jail building, Darbhanga (jail boundary wall cracked and bulged at some places)

Photo 30(b) Jail building, Darbhanga
(vertical cracks at the bottom of column)

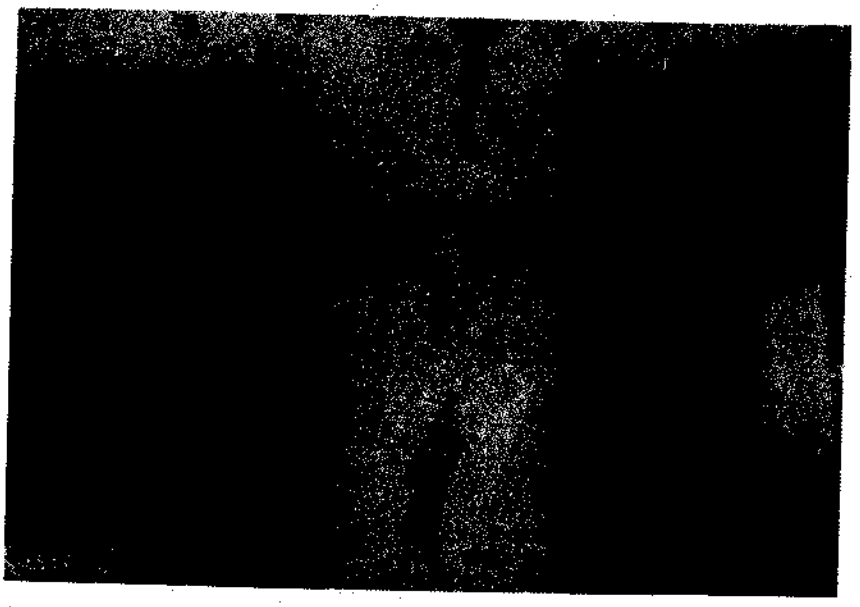


Photo 30(c) Residence of an employee near jail building, Darbhanga (cracking of arches, arch under temporary support)

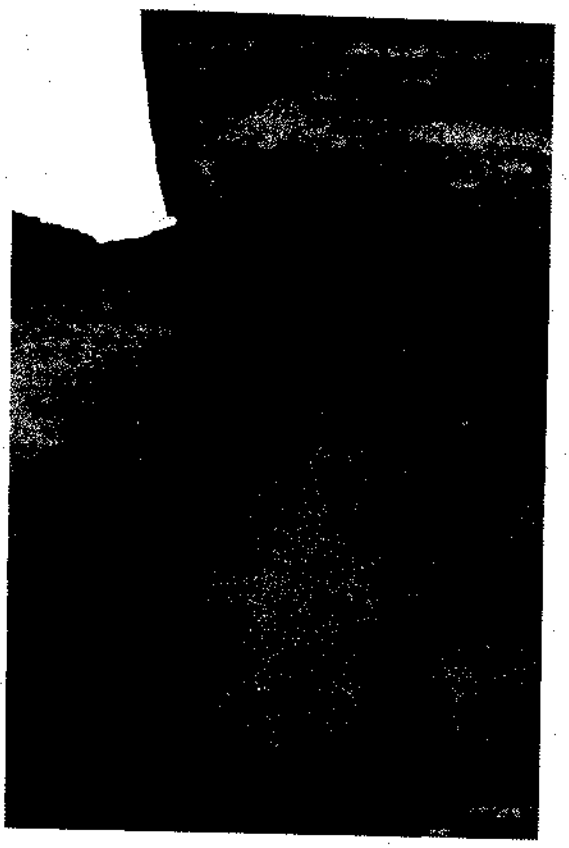


Photo 30(d) Jail building, Darbhanga (cracks near roof)

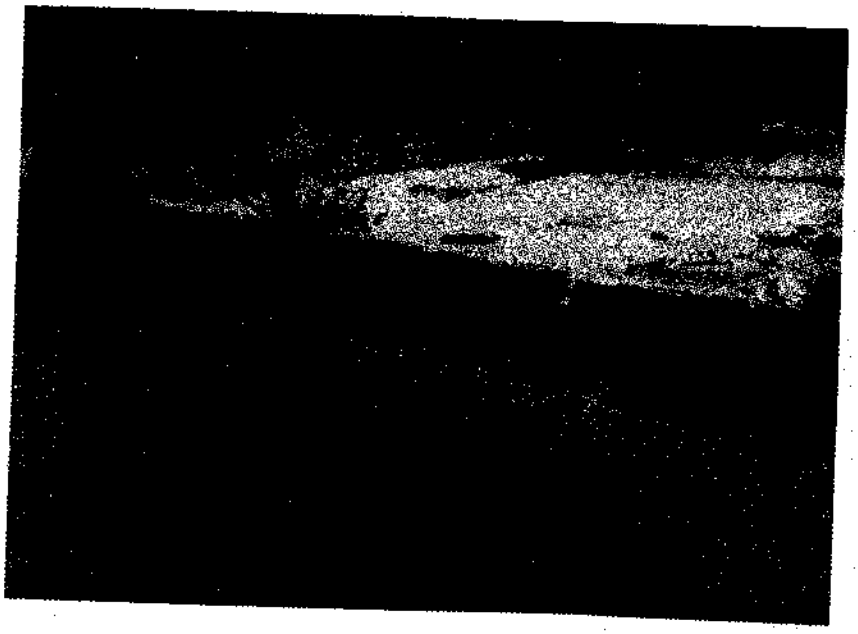


Photo 30(e) Jail building, Darbhanga (circular patch of sand left over after liquefaction)

Photo 30(f) Jail building, Darbhanga (sand patch left over after liquefaction)

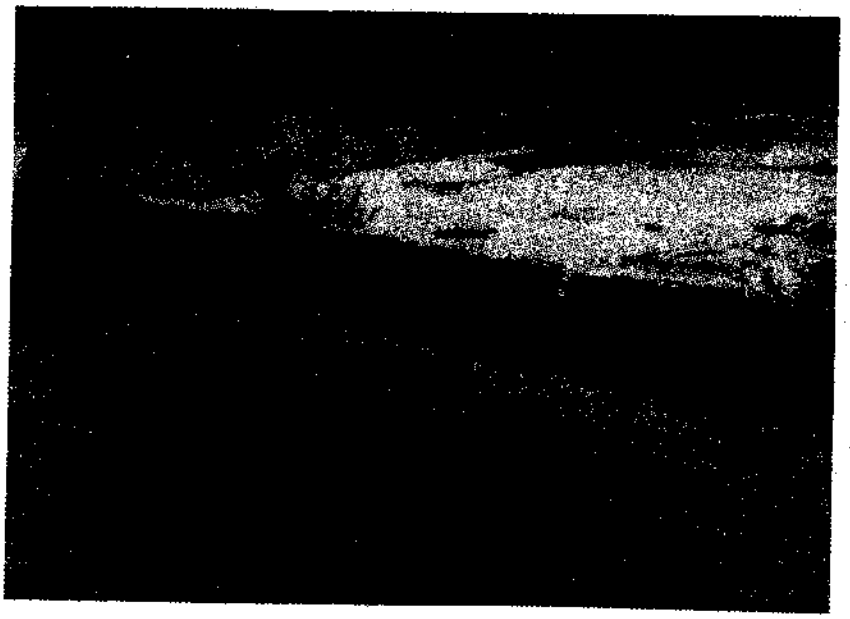


Photo 30(e) Jail building, Darbhanga (circular patch of sand left over after liquefaction)

Photo 30(f) Jail building, Darbhanga (sand patch left over after liquefaction)

Photo 30(g) Jail building, Darbhanga (liquefaction zone)

Photo 30(h) Jail building, Darbhanga
(cracking and bulging of boundary wall)

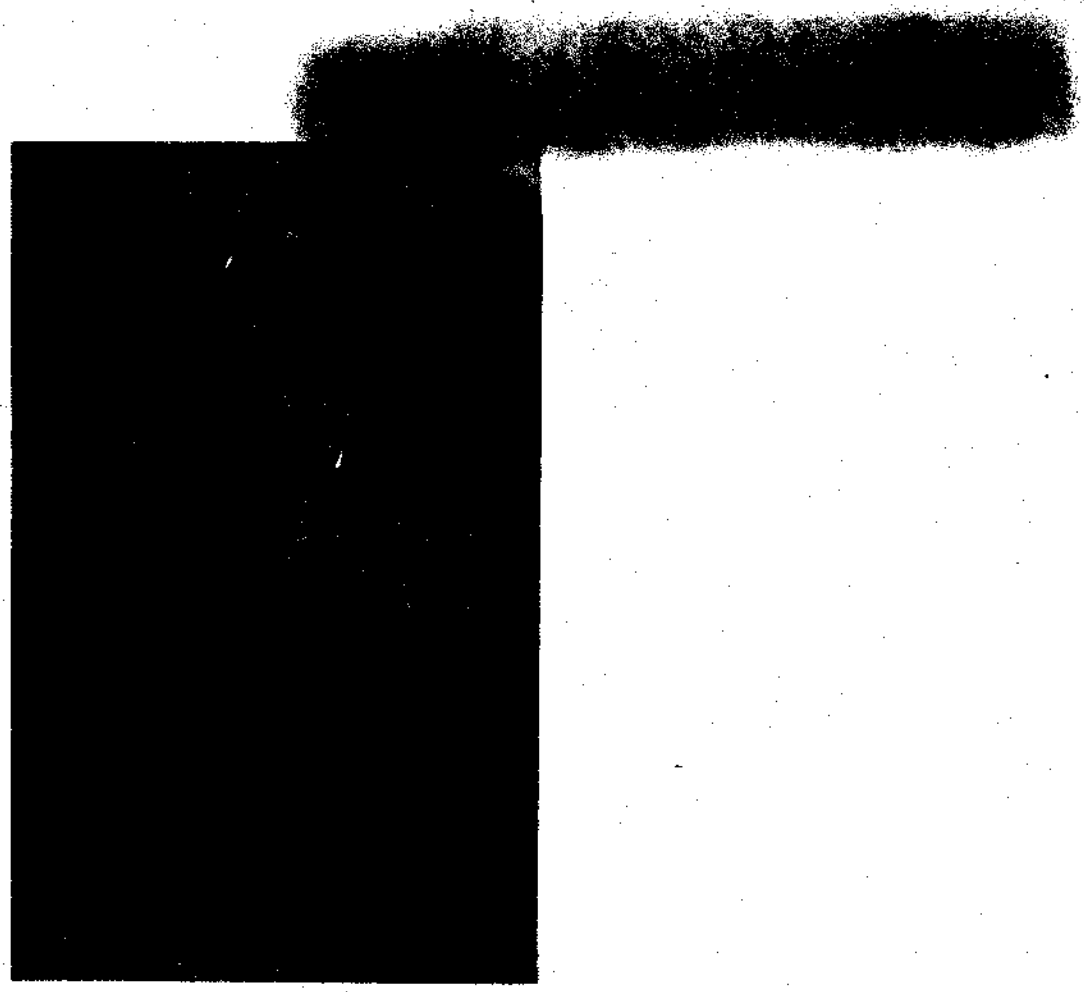


Photo 30(i) Cracking and bulging of boundary wall of Darbhanga jail

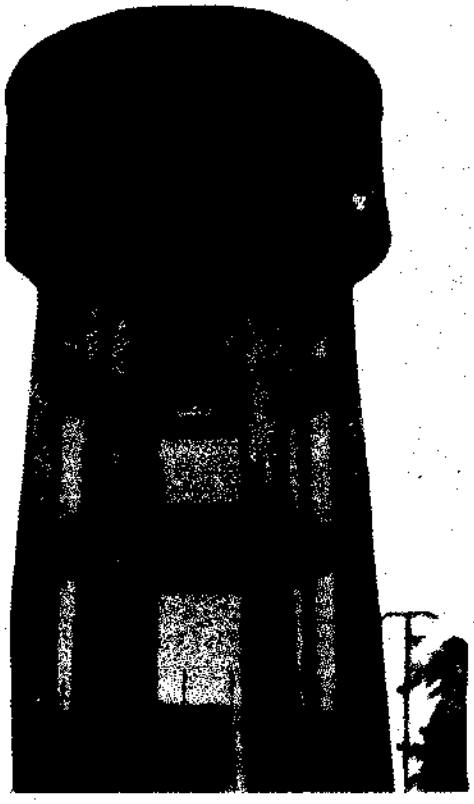


Photo 31(a) Water tower, Munghyer (cracking in the braces)

DAMAGE SURVEY REPORT
ON
BIHAR-NEPAL EARTHQUAKE OF AUGUST 21, 1988

Seismicity, Damage and Recommendations
for
Strengthening and Reconstruction

S. K. Thakkar
Dilip K. Paul
Shyamal Mukerjee
S. Bandyopadhyay
Ashwini Kumar
B.V.K. Lavania

R3148

DEPARTMENT OF EARTHQUAKE ENGINEERING
UNIVERSITY OF ROORKEE
ROORKEE-247667, INDIA