LESSONS LEARNT ON ENGINEERING PREPAREDNESS FROM THE 1988 BIHAR EARTHQUAKE

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SYNOPSIS

The rather moderate sized (magnitude 6.6) Bihar earthquake of August 1988 has clearly demonstrated that we are far from "prepared" from engineering view point for a big earthquake. During the author's extensive travel within the affected areas of this earthquake, it became clear that the engineering community must immediately initiate a serious and coordinated effort to gear itself for a big earthquake that may hit many parts of the country. This paper discusses some such efforts. These include rationalization and implementation of IS codes on aseismic design, review of actual construction practices in the country, seismic safety evaluation of critical facilities such as dams, refineries, etc., training and preparation of field engineers for handling post - earthquake situation, and learning from earthquakes to prepare ourselves better for future events.

INTRODUCTION

The Bihar earthquake of August 21, 1988, even though tragic due to loss of life and property it has caused, has also provided us an opportunity to prepare ourselves better for big earthquakes that may hit many parts of the country. Through this earthquake the nature has conducted a real - life full - scale test on construction practices in our country as well as on our post earthquake handling capabilities. During the author's extensive travel in north Bihar, Sikkim and Darjeeling many instances were noted where the engineering community could have performed much better had it been "prepared" for such events. In the following these and other areas are discussed on which we must initiate a coordinated effort to "prepare" ourselves.

IMPLEMENTATION ASPECTS OF I.S. CODES

The implementation of codes on earthquake resistant design remains very poor in the country. Many instances were noticed where not only the private organizations but also government departments do not follow IS code specifications. For instance many state departments in Bihar prescribe cement/ sand mortar in the ratio of 1:8 even for masonry load bearing construction in towns which lie in seismic zones IV and V. IS code specifications require a minimum of 1:6 for such situations. Even in Delhi which lies in zone IV, IS code requirement of lintel band in load bearing brick masonry buildings is hardly followed. Obviously the codes cannot be enforced without understanding and removing the difficulties faced by private and government organizations in their implementation. Thus, there is a clear need to understand, rationalize and implement codal provisions on aseismic design. For this it is suggested that an expert committee, including active representation from government engineering departments, consulting engineers, builders and contractors, legal experts, Bureau of Indian Standards and researchers in earthquake resistant design must look into the following aspects:

Legal Aspects

Legal aspects regarding compliance or non - compliance of I.S. codes by government, public sector, municipalties, private builders, real estate developers as well as individual citizens must be understood, documented and widely dissiminated.

Cost Aspects

Cost implications of code provisions on aseismic design for various types of building need to be studied. This is essential for implementation as well as rationalization of IS codes. It will also help in evolving better engineering solutions for earthquake protection to buildings. In fact it may turn out that the increase in cost of construction, to make buildings earthquake resistant, as compared to the overall cost of building, is insignificant provided proper choice of structural system has been made. Such a conclusion on the basis of a detailed and scientific study will definitely encourage aseismic construction. The committee could work in lines with the committee set up by the Structural Engineers Association of Southern California (SEAOC) (Degenkolb, et al, 1970). Table I summarizes the estimated increase in cost to provide earthquake resistance in the U.S.A. according to this committee. Jain and Patnaik (1989) have studied the cost implications of aseismic design as per existing IS provisions on three real life R.C. frame buildings. More such detailed studies on buildings with more number of storeys, varying configuration and design features, those with shear walls as well as for masonry and non - engineered buildings need to be undertaken.

TABLE I: ESTIMATED INCREASED COST TO PROVIDE EARTHQUAKE RESISTANCE IN STRUCTURES IN THE U.S.A. [Adapted from Degenkolb et al, 1970]

Area (Zone) / Type of building	Areas which now enforce design for hurricane, cyclone, tornado or abnormally high winds	Other U.S. areas to meet Zone 3 requirements	Other U.S. areas located in Zones 0, 1 & 2 to provide minimum requirements
1 & 2 storey wood frame	0.5%	2%	1%
1, 2, 3 storey brick or conc. block	4%	8%	4%
4 storey & up brick or conc. block	5%	10%	5%
Concrete frame	2%	5%	2%
Steel frame	0.5%	3%	1%

NOTE:

1. Tabulated costs include extra design and inspection costs required in earthquake prone areas since more analysis, drafting and field inspections are customarily required in these areas.

2. The increased cost in percentage is to be applied to the complete engineering and architectural building, including structure, foundation, walls, architectural treatment, mechanical and electrical facilities, etc. It does not apply to site work such as streets, side walks, paving, drainage, etc.

Propagation Aspects

The committee must evaluate if the letter and spirit of code provisions on aseismic design and detailing can be understood by engineers who have not been specifically trained in this art. If not, the committee must suggest

(i) Improvements in I.S. codes to make them more clear and specific.

(ii) A detailed blue print on imparting such knowledge to engineers, overseers as well as local artisans.

(iii) detailed outlines of monographs, handbooks and commentaries that must be prepared to make earthquake resistant design within a common engineer's / supervisor's comprehension.

REVIEW OF ACTUAL CONSTRUCTION PRACTICES IN THE COUNTRY:

There is a very wide variation in actual construction practices in different parts of the country. In some seismic areas there is not much concern for seismic safety of structures and facilities while in other parts even the private builders are quite aware of the earthquake hazard even if not properly trained in aseismic construction. For instance, in Bihar during the recent earthquake long stretches of flood control embankments developed longitudinal cracks while at a few places the embankments subsided by a very significant amount (e.g., Jain, et al, 1988). In the author's opinion, total lack of compaction in construction of these embankements was largely responsible for this. Fig. (1) shows the repair of a subsided embankement with obviously no compaction even after the earthquake. On the other hand the author found much better awareness in Siliguri for earthquake resistant design among government as well as private builders. This went to the extent that even in the multistorey R.C. frame buildings "lintel band" is commonly provided; except that it does not act as a band because it is not connected to the columns and hence is not continuous around the building. Fig. (2) shows one such building. Obviously in the latter case a very encouraging climate exists for earthquake resistant construction but the builders lack proper training and hence misunderstand the code provision of lintel band in masonry load bearing construction to also apply to partition masonry in frame buildings.

Thus before the implementation of I.S. codes can be ensured a document needs to be prepared on actual practices being followed particularly in the seismically active parts of the country. This will give a clear picture of reasons on

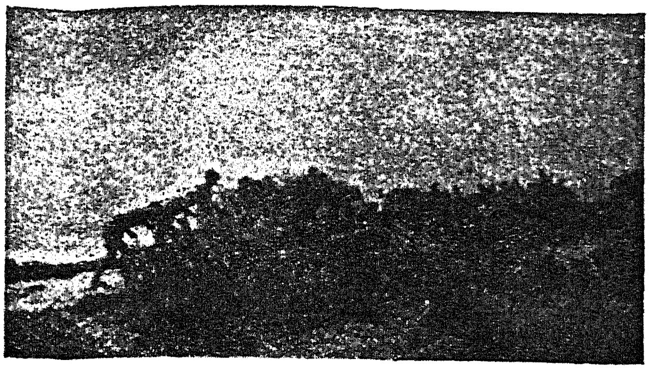

FIG. (1) RESTORATION OF A SUBSIDED EMBANKMENT WITHOUT ANY COMPACTION

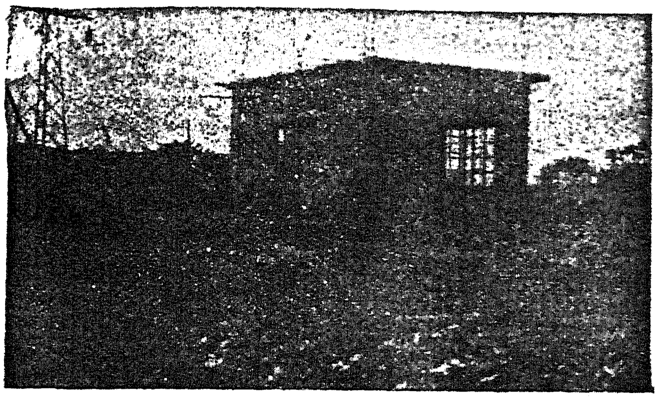

FIG. (2) A R.C. FRAME BUILDING IN SILIGURI WITH "LINTEL BAND"

why and where aseismic design practices are not being followed so that effort can be directed towards specific training and persuason in such areas.

SEISMIC SAFETY EVALUATION OF DAMS AND OTHER CRITICAL FACILITIES

Numerous dams have been built in the country at different points of time as per the state of engineering knowledge available at that time. Failure of a dam during an earthquake can be very disasterous for the downstream population. In recent years the art of seismic analysis of dams has made very significant progress. Hence there is a need to undertake a programme for seismic safety evaluation of existing dams with the latest state of the art. It must be mentioned here that in such an excercise the safety criteria plays a very significant role and a very serious thought must be given to evolve this before undertaking such an excercise.

Similarly, many critical facilities, such as refineries and other chemical factories, exist in seismically active zones of the country. The Bhopal disaster has clearly shown the danger they pose to population around them in case of leakage and dissipation of hazardeous gases. This could indeed take place in case of a moderate to big earthquake. In fact, the recent Bihar earthquake did cause some relatively minor damage to a few facilities in the Indian Oil Corporation refinery in Barauni (Hulyalkar, 1988). Hence, all such facilities must be evaluated from earthquake point of view and necessary strengthening measures should be taken.

HANDBOOK ON POST EARTHQUAKE HANDLING OF BUILDINGS

After the last Bihar earthquake the local engineers found themselves quite handicapped for handling an altogether different type of technical task created by the earthquake. An earthquake damaged building poses questions such as

(i) Is the building safe for occupants particularly in view of the likely aftershocks?

(ii) If the building is unsafe, can some temporary strengthening measures be taken to avoid immediate evacuation in large numbers ? The problem becomes particularly difficult in view of the large number of government officials living in government owned houses. One would not like to have a substantial number of government officials leave the town as they are also required for post earthquake relief work. After the recent earthquake, Railway engineers faced difficulty because the railway employees were reluctant to vacate the premises even after those buildings were declared unsafe by the concerned engineers.

(iii) In the long run is the structure repairable or should it be replaced by a new structure?

(iv) If the building is indeed repairable, how and what type of restoration to carry out so as to make it comparable to a newly constructed building with latest seismic code provisions ?

All these are quite specialized issues and an average engineer does not handle such a situation often. Hence, a handbook needs to be developed on handling such buildings with explicit details and case histories.

CONTINGENCY PLANS

Besides the different kind of technical problems, an earthquake also poses a variety of administrative difficulties and dilemma for engineers. For instance what is the role of local government engineers, particularly if the concerned town has only relatively junior engineers, regarding a religeous building which is at the verge of collapse ? In Darbhanga one Mehrab of the local Jama Masjjid was severly damaged and its top was in the danger of falling off over the surrounding locality. The local residents were obviously concerned and wanted an immediate restoration by the overnment. The repair was ultimately undertaken by the Army engineers. Another issue that is faced by the government engineers is damage evaluation of private houses from the view point of providing financial relief to the residents for restoration. The residents naturally expect an immediate action so that they could undertake necessary repairs etc. at the earliest. However, the engineers in the area not only get very much involved in taking care of government buildings but in many instances the administrative responsibilities and other implications regarding private buildings remain vague for them. This results in delays and hence in great agony to the already suffering population.

Thus, detailed contingency plans of action, with clear outline of responsibilities and authorities, need to be prepared and widely dissiminated for important engineering departments such as P.W.D., Water Supply and Sewerage, Electricity, P & T, Railways, etc. to handle post earthquake situation without any loss of time in consultations, approvals, etc. Railways, for instance, have their well tested plan of action for the event of a railway accident wherein each one of its concerned employees knows what he is supposed to do. This kind of experience, even if for different contingencies, will be useful in preparing contingency plans for earthquake situation. A plan of action for the overall district machinery, including engineering departments, has recently been prepared at IIT Kanpur (Siddiqui, 1988). However this needs to be widely circulated for initiating a discussion on it.

COORDINATION AMONG ENGINEERING DEPARTMENTS

With the rapid developmental works there has been a proliferation of government engineering departments within the states including some public sector construction corporations. This has led to difficulties in post disaster management. For instance many such corporations do not have infrastructure for maintenance and repairs and are unable to provide immediate relief. The local P.W.D., even if it has the necessary infrastructure, finds itself unable to help in the matter for it may amount to interference into somebody else's jurisdiction. One such instance was noticed in Darjeeling with regard to a few residential quarters of an educational institution which required only minor repairs to avoid collapse. Therefore, it is very important to device a plan of action on coordination among the numerous engineering departments by way of sharing resources and expertise in case of an earthquake emergency.

LEARNING FROM EARTHQUAKES

Every disasterous earthquake yields a very valuable experience on performance of man made structures as well as on post earthquake handling. It is a well acknowledged fact that that Earthquake Engineering has progressed more from experience gained from actual earthquakes than from the laboratory tests. Hence, every effort must be made to properly investigate and document the destructive earthquakes. It is therefore suggested that a detailed project be undertaken in lines with the Learning From Earthquakes project of the Earthquake Engineering Research Institute (EERI) in the United States. The objectives of the EERI project were achieved by (EERI 1979):

(i) developing and implementing response procedures and coordination plans,

(ii) developing and distributing to those concerned Planning and Field Guides containing advice on what aspects need more investigation and how to record such information,

(iii) conducting actual investigations, and

(iv) disseminating the lessons learned to members of concerned professions.

The 1977 Planning and Field Guide (Duke and Moran, 1979), prepared under this project, is an excellent documents (about 200 pages). It has, among other things, well prepared forms for collecting information during an earthquake investigation. Appendices (A) and (B) of this paper give two such forms for inspection of buildings after an earthquake.

Thus a similar project in India for our conditions will go a long way in ensuring that we do not miss useful information provided by an earthquake.

CONCLUSION

Many of the above tasks will require cooperation and coordination of several agencies and departments. In this, professional bodies such as the Institution of Engineers (India), Indian Concrete Institute and Indian Society of Earthquake Technology and organizations such as Bureau of Indian Standards, Department of Science and Technology and National Buildings Organization can contribute significantly by financing and coordinating these efforts.

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REFERENCES

Degenkolb, H.J. (Chairman), S.F. Gizienski, J.F. Meehan, D.L. Messinger and C.W. Pinkham. (1970). Report of the Ad Hoc Committee on Cost of Design for Earthquakes. Appendix - B. Proceedings of Structural Engineers Association of California, 171 Second Street, San Francisco, California 94105.

Duke, C.M. and D.F. Moran. (1979). Report to the National Science Foundation on the Learning From Earthquakes Project.

Earthquake Engineering Research Institute Berkeley.

Earthquake Engineering Research Institute. (1977). **Learning From Earthquakes: 1977 Planning and Field Guides.** Berkeley.

Hulyalkar, N.K. (1988). Effect of Earthquake at Barauni Refinery on 21st August, 1988. Presented at the **Workshop on Bihar - Nepal Earthquake of August 21, 1988, held at Indian Institute of Technology, Kanpur** during December 28 - 29, 1988.

Jain, S.K., Agrawal, A.K. and Tripathi, R.P. (1988). Some Geotechnical Aspects of the Bihar - Nepal Earthquake. **Presented at the Workshop on Bihar - Nepal Earthquake of August 21, 1988, held at Indian Institute of Technology, Kanpur during December 28 - 29, 1988.**

Jain, S.K. and Patnaik, A.K. (1989). Design and Cost Implications of I.S. Code Provisions for Aseismic Design of R. C. Frame Buildings. **Bulletin of the Indian Society of Earthquake Technology** (communicated for publication).

Siddiqui, I. (1988). Post Event Handling of Earthquake Hit Areas. Presented at the **Workshop on Bihar - Nepal Earthquake of August 21, 1988, held at Indian Institute of Technology, Kanpur during December 28 - 29, 1988.**

APPENDIX I: RECONNAISSANCE INSPECTION FORM - BUIILDINGS (from EERI, 1977)

Investigator: ____ Date: ____

Building or Facility Data

Name: ____ **When Built:** ____

Address (or location): ____

Stories: ____ **Basement(s):** ____

Vertical load system: ____

Lateral load system: ____

Walls: ____

Foundations: ____

Soils: ____

Site: Sloping ____ % Level ____

Strong-motion recording instruments? Yes ____ No ____

Earthquake Damage

General: ____

Estimated total losses: Less than 10% ____ 10-50% ____ Over 50% ____

Is building functional? Yes ____ No ____ Why not? ____

Status of utilities: ____

Does building warrant further investigation? Yes ____ No ____

Why? ____

Estimated Modified Mercalli Intensity ____

Casualties: Deaths ____ Injuries ____ Unknown ____

Miscellaneous Data

Architect: ____ **Engineer:** ____

Are plans available? Yes ____ No ____ Where? ____

Photos: ____ **Roll** ____ **Frame** ____

(Use back for sketches and additional notes)

APPENDIX II: EMERGENCY BUILDING INSPECTION FORM (from EERI. 1977)

DEPT. OF BUILDING AND SAFETY — CITY OR COUNTY OF

A — BUILDING ADDRESS

B — ZIP CODE | C — DISTRICT OFFICE | DATE | TIME

OWNER, TENANT OR MANAGER | PHONE

ADDRESS (OWNER, TENANT OR MANAGER)

CONDITIONS

D — USE OF BUILDING

E — CAUSE OF DISASTER | F — SITE DAMAGE 1 YES ☐ 2 NO ☐

G — BLDG TYPE | H — NO OF STORIES | I — ROOF COVERING

J — NO OF LIVING UNITS | K — NO OF LIVING UNITS DAMAGED | L — EST. YEAR OF CONSTRUCTION

M — EST % OF DAMAGE <10% 10-50% >50% | N — EST VALUATION OF DAMAGE

O — DESCRIBE DAMAGE (CHECK ONE)

NON STRUC. DAMAGE ☐ NONE			
☐ Architectural	☐ Exterior	☐ Interior	☐ Glass
☐ Mechanical	☐ Piping	☐ Equipment	☐ Elevators
☐ Electrical	☐ Equipment	☐ Lights	☐ Controls

STRUCTURAL DAMAGE ☐ NONE	
☐ No Collapse	DAMAGE
☐ Partial Collapse	WHAT PORTION
☐ Total Collapse	

ACTIONS

P	BUILDING SAFE FOR OCCUPANCY	1. YES ☐	2. NO ☐	3. PARTIALLY ☐	
Q	PERMIT REQUIRED	1. YES ☐	2. NO ☐	PLANS REQ'D	
R	JOB ORDER ISSUED	1. YES ☐	2. NO ☐	JOB ORDER NUMBER	
S	BUILDING POSTED AS UNSAFE	1. YES ☐	2. NO ☐	DATE	TIME
T	NEEDS REINSPECTION	1. YES ☐	2. NO ☐	BY	
U	DISCONNECT UTILITIES	1. YES ☐	2. NO ☐	TYPE	
V	BARRICADES REQUIRED	1. YES ☐	2. NO ☐	DATE REQUIRED	
W	CERTIFICATE OF HAZARD ISSUED	1. YES ☐	2. NO ☐	DATE ISSUED	

X — RECOMMENDED ACTION (CHECK ONE)

Vacate (and)			Partially Vacate (and)			Other	
1	2	3	4	5	6	7	8
Repair ☐	Demolish ☐	Only ☐	Repair ☐	Demol ☐	Only ☐	Repair ☐	None ☐

Y — Number of Living Units Vacated | NOTES:

Z — 1. YES ☐ 2. NO ☐

INSPECTED BY | TEAM

CODED BY | TEAM CAPTAIN