HANDBOOK ON SEISMIC RETROFIT OF BUILDINGS – A PRIMER

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INTRODUCTION

The Handbook on Seismic Retrofit of Buildings was brought out by the Central Public Works Department under the aegis of Indian Buildings Congress. [1] (Fig. 1)The intention of the Handbook was to present the material in a style that will be understood and appreciated by the people of diverse backgrounds involved in the design and construction of buildings.

The chapters are explained briefly.

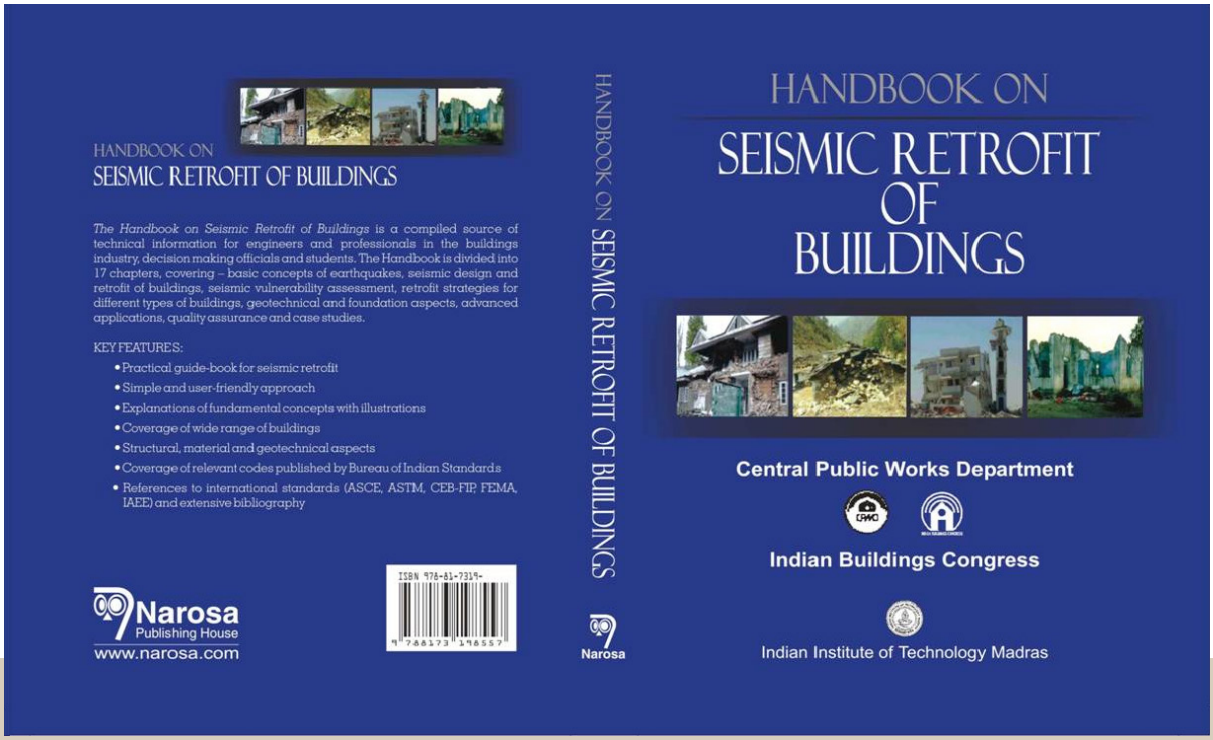

Fig.1: Cover of the Handbook on Seismic Retrofit of Buildings

Making buildings safe against earthquakes

This is a standalone chapter that explains the concepts of seismic design and retrofit in a language suitable for a layperson. The chapter covers the common deficiencies, simple techniques of diagnosis of these deficiencies and suitable retrofit strategies for the major types of buildings in India. A 4-page handout has been included to generate awareness about the do's and don'ts of seismic design of buildings and the questions to be asked before buying a house. (Fig. 2)

Introduction and seismic analysis cum design

The first chapter starts with an explanation of the need of retrofit of buildings in India, with reference to the provisions of IS 1893.* [2]
(*The updated versions of the codes are provided in the reference list.)

The measures emphasised by the National Institute of Disaster Management are highlighted. The chapter explains the attributes of seismic design, goals, objectives

and steps of seismic retrofit. The performance based objectives are mentioned. An option for considering reduced base shear for retrofit of older buildings is provided. There is a glossary of terms associated with seismic retrofit.

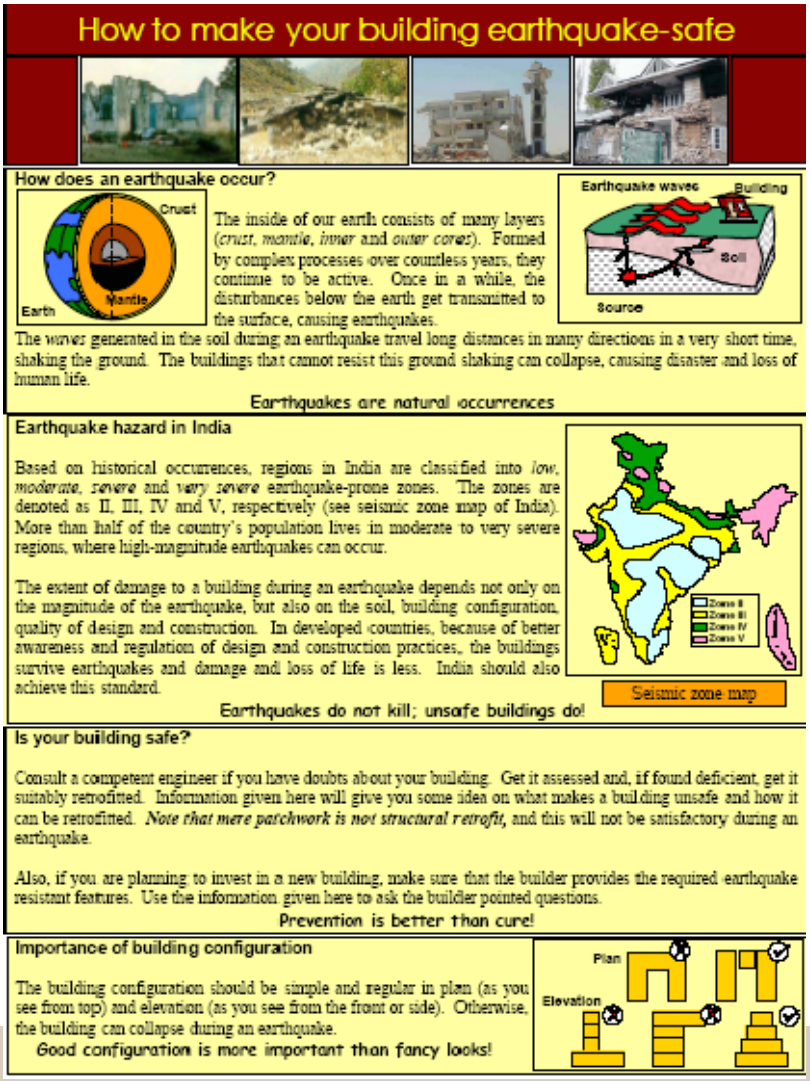

Fig. 2: First page of the 4-page handout

In the second chapter, first the fundamentals of earthquakes, its characterisation, seismic zone map, seismic micro-zonation and response spectrum are briefly explained. Next, the layout and configuration of buildings for seismic design and the different types of lateral load resisting systems are explained.

Rapid visual screening, data collection and preliminary evaluation

In India, the Rapid Visual Screening (RVS) method was introduced for masonry buildings in IS 13935. [3] The RVS data sheet identifies a building into a certain type based on seismic resistant features and provides an estimate of damage for the building based on the seismic zone. The data sheet and the background information are explained in this chapter.

To facilitate seismic evaluation of a building, it is necessary to collect relevant data of the building as much as possible. This step in a retrofit programme is referred to as Data Collection. The data tables were adopted from the Model Town and Country Planning Legislation, Zoning Regulations, Development Control, Building Regulation / Byelaws for Natural Hazards Zones of India. The required information includes building description, the seismic resistant features and miscellaneous data.

For a building identified for seismic evaluation, the preliminary evaluation involves a set of initial calculations to identify areas of potential weaknesses in the building. These calculations are called quick checks. The preliminary evaluation also checks the compliance with the provisions of the seismic design and detailing codes. [4]

Condition assessment of buildings

Condition assessment describes the process of assessing the actual condition of a structure in relation to its use. This chapter describes the techniques to assess the condition of the structure. An initial visual inspection of the structure can reveal useful information about areas that need a closer look. A number of investigative techniques are available to study the condition of the material in a structure. These include non-destructive tests, intrusive tests and load tests. The tests are briefly described and the associated codes are cited.

Repair and retrofit of non-engineered buildings

The non-engineered buildings refer to those, which are not formally designed, but built using traditional vernacular techniques.

Fig. 3a:
Introduction of bands and braces in a school building, Kashmir
(Courtesy: National Centre for People's Action in Disaster Preparedness, Ahmedabad)

The classification of non-engineered buildings as per the Vulnerability Atlas of India [5] is presented. This chapter provides the information on the available codes of practice, the preferred seismic resistant features of non-engineered buildings and the available repair materials and retrofit techniques. Horizontal bands and vertical reinforcement at key locations, proper size and location of the openings as recommended in IS 4326 [6] are emphasized.

Retrofit of masonry buildings

The masonry buildings refer to those with load bearing walls made of fired clay bricks, stone blocks or concrete masonry units without reinforcement. This category comprises a large sector of buildings in the urban areas. This chapter deals with evaluation, field and laboratory tests, and the methods of strengthening masonry buildings. The method of piers for seismic analysis is explained. The retrofit techniques are grouped under local and global techniques. The local retrofit techniques include strengthening of roof, upstairs floors and walls. The global retrofit techniques cover introduction of bands (Figs. 3a & 3b) and strengthening by post-tensioning. The actions for maintenance after undertaking retrofit are highlighted.

Retrofit of historical and heritage structures

Structural assessment and remedial interventions on structural systems of historical buildings require special considerations aimed at retaining the architectural integrity and historical authenticity. A vast majority of historical buildings in India is constituted of stone and brick masonry structures. Hence, the retrofitting techniques in this chapter are based on such structures. The techniques include strengthening of walls, arches, domes and towers.

The chapter also provides an insight into the internationally endorsed principles and recommendations of heritage conservation advocated by the ICOMOS (International Council on Monuments and Sites). The principles of archaeological reconstruction are introduced.

Structural analysis for seismic retrofit

This chapter covers the structural analysis of framed buildings. The analysis is a part of the detailed evaluation of an existing building. The steps involve developing a computational model of the building, applying the external forces, calculating the internal forces in the members of the building, calculating the deformations of the members and building, and finally interpreting the results. The analysis can be linear (elastic) or non-linear (inelastic or geometric non-linear), static or dynamic. The chapter discusses primarily the equivalent

Fig. 3b: Civil Hospital at Kupwada, Kashmir
(Courtesy: Building Materials and Technology Promotion Council, New Delhi)

static analysis. The fundamentals of the response spectrum method, time-history analysis and the pushover analysis are elucidated.

Retrofit of reinforced concrete buildings

In this chapter, first the common deficiencies observed in reinforced concrete (RC) buildings for resisting earthquake forces are listed. Next, suitable strategies to retrofit the deficient buildings are explained and illustrated. The retrofit strategies are compared in terms of their general merits and demerits. The different retrofit strategies are grouped under global or local strategies. Addition of new walls, frames or braces, reduction of any irregularity or mass of the building are grouped under global retrofit strategies. The local retrofit strategies include concrete jacketing of columns (Fig. 4), beams, walls, footings or attaching steel plates to columns [7] or beams.

Fig. 4: Sharavati Hostel, IIT Madras
(Courtesy: Hitech Concrete Solutions, Chennai)

Retrofit of steel buildings

Structural steel is used in different types of single storeyed structures (such as industrial and storage facilities, railway sheds and aircraft hangars) and multi-storeyed buildings. The steel used in these structures may consist of hot rolled sections, cold rolled sections or sections fabricated from steel plates. This chapter discusses the different types of structural systems, the common deficiencies and the suitable retrofit strategies for both the single storeyed structures and multi-storeyed buildings. The uses of non-buckling braces, steel plate shear walls and self-centering post-tensioned connections are briefly explained.

Mitigation of geotechnical seismic hazards and retrofit of foundations

A proper understanding of the geotechnical hazards is necessary for comprehensive retrofit of buildings. This chapter discusses the types of site hazards, site characterisation, modelling of site effects and liquefaction. The ground improvement techniques and strengthening of unstable slopes are broadly presented.

The chapter on Retrofit of Foundations covers modelling of foundations in analysis of buildings, possible types of interventions for retrofitting foundations and methods of execution. The types of intervention include strengthening of rubble masonry foundation, enlarging the area of footing, use of micro-piles, underpinning with piles, strengthening of piles and base plates of steel columns. To execute the retrofit, it is necessary to provide adequate shoring and temporary supports.

Fig. 5: Strengthening of unstable slopes using gabions at Mangalore Refinery

Retrofit using fibre reinforced polymer composites

The constituent materials of fibre reinforced polymer (FRP) composites, the forms of FRP composites and the technique of bonding the laminates on concrete are described in this chapter. For strengthening masonry walls, the possible configurations of FRP laminates are illustrated. The use of FRP in retrofitting

RC beams is explained under strengthening for flexure and shear. The enhancement of shear strength of RC columns and strengthening of exposed beam-column joints are covered. The procedures for analysis of retrofitted members are explained.

Fig. 6: FRP wrapping with near surface mounted plates at Apollo Proton Therapy and Cancer Hospital, Chennai (Courtesy: Sanrachana Structural Strengthening Pvt. Ltd., Larsen & Toubro Construction)

Base isolation and energy dissipation

Conventional seismic design of buildings permits the reduction of design forces for the members below the values corresponding to elastic response. The intended inelastic deformations will cause significant damage of the non-structural elements such as infill walls, partitions and suspended ceilings. Because of these shortcomings, there has been research and development of devices that can reduce the seismic responses of buildings and bridges. The structural control devices can be grouped into four broad areas.

- Base isolation devices
- Passive energy dissipation devices
- Tuned devices
- Active and semi-active control devices

In this chapter, overviews of the first three types of devices are presented.

Fig. 7: Base isolation units placed in the right wing of a prototype building (Courtesy: Sajal K. Deb, Indian Institute of Technology Guwahati)

Quality assurance and control

The requirements of quality in building repair and rehabilitation projects are often not given the same attention as for new projects. This chapter discusses the steps to be taken to ensure that retrofit of structures are conducted in a manner that confirms to contractual and regulatory requirements. Organising for quality, work and material specifications and documentation are briefly described. A typical flow chart for quality control of retrofitting of columns is provided. In addition, temporary construction and safety issues are highlighted.

Retrofit case studies

Two case studies are provided: a heritage masonry building and a multi-storeyed RC building. The calculations for seismic retrofit are explained as per the steps explained in

Fig. 8: Finite element analysis of a retrofitted building

the Handbook. These include rapid visual screening, data collection, preliminary evaluation and detailed evaluation.

CONCLUDING REMARKS

The retrofitting of buildings and other structures for seismic forces has special challenges as compared to the design and construction of new buildings. The huge building stock poses challenge to the practicing professionals. They need easy-to-understand principles, tools to analyse a building, retrofit strategies that are practical and maintain the functional requirement of a building, and methods to estimate the cost of retrofit. The Handbook is an attempt to provide an adequately compiled source of technical information on retrofitting of buildings, for different groups of practicing professionals. The style of presentation and illustrations are intended to be user friendly. Duplication of codes has been avoided. The references list the readily available sources of supporting information.

REFERENCES

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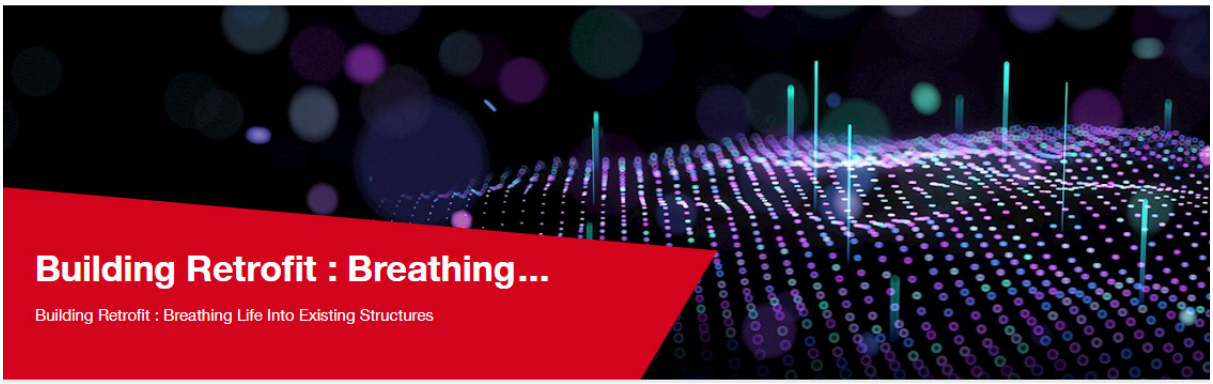

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