GNITED MINDS
Journals

Journal of Advances and Scholarly Researches in Allied Education

Vol. XI, Issue No. XXI, April-2016, ISSN 2230-7540

AN INTERNATIONALLY INDEXED PEER REVIEWED & REFEREED JOURNAL

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Journal of Advances and Scholarly Researches in Allied Education
Vol. XI, Issue No. XXI, April-2016, ISSN 2230-7540

Comparative Study on Different Methods for Seismic Safety Evaluation of Existing Multi-Storied Reinforced Concrete Buildings

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Abstract* – *A research work is to propose a method for seismic safety evaluation of existing multi-storied reinforced concrete buildings It is expected that buildings designed based on the code provisions should be able to with stand minor earthquakes without detriment, resistor-structural damage and resist major earthquakes without moderate earthquakes with some Collapse, but with some structural as well as non-structural damage. Seismic provisions in the building codes have advance over the years to achieve this goal. Many parts of our country in there subjected to major earthquakes of magnitude greater than or equal to 8 (on Richter's past scale). Moderate earthquakes have also caused severe damage in many places. The need for evaluation arises mainly due to two causes: first, most of the existing RC buildings, particularly the old ones, have not been designed to resist earthquake forces due to lack of awareness Secondly, due to the revision of the existing seismic codes, Even buildings designed by previous codes for seismic forces can become unsafe because of the increase in the seismic forces proposed. In India, because of the revision of IS: 1893-1984 in 2002, we are facing this situation. Our town in Hyderabad is now under seismic zone II, while it used to be in zone I. Hence, it is necessary to evaluate the seismic safety of all buildings in general and multi-strayed building sin particular as they are liable to suffer more damage. Unsafe buildings can be strengthened to that resist the future earthquakes safely.to develop a Simplified Seismic Evaluation Method for the assessment of the existing RC buildings for seismic vulnerability. Compare A Results obtained from the proposed method with the results obtained from FEMA -154, FEMAP-155 and New Zealand.

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INTRODUCTION

The surface of the earth may have been sufficiently stable, but sensitive instruments have undoubtedly established that the surface of the earth is in a state of perpetual disturbance due to vibrations of one type or another. Despite severe earthquakes, the destruction caused by the loss of life and property is often alarming. The elastic theory suggests that the source of an earthquake is the sudden displacement of the ground on both sides of the fault resulting from A crustal rock rupture. However, the earthquake itself is a vibration wave system that arises from this disturbance.

MODELING OF THE EXISTING RC STRUCTURES

The building is eight (8) storeyed RCC frame building with brick infill walls of 115 mm thickness & without shear walls. The storey height is 3m. There are five (5) bays in X-direction & four (4) bays in Y- direction. The building is used for residential purpose only. The concrete mix is of grade M20 & grade of steel is Fe 415. The size of column is 230x380 mm & size of beam is 230 x415mm. The c/c distance between columns is 3m. The building is located in Zone II (As per IS: 1893-2002). The building is standing over medium soil. The non-ductile detailing has been carried out for this building. The response reduction factor (R) = 3 (As per IS: 1893-2002) &Importance factor (I) = 1 (As per IS: 1893-2002).

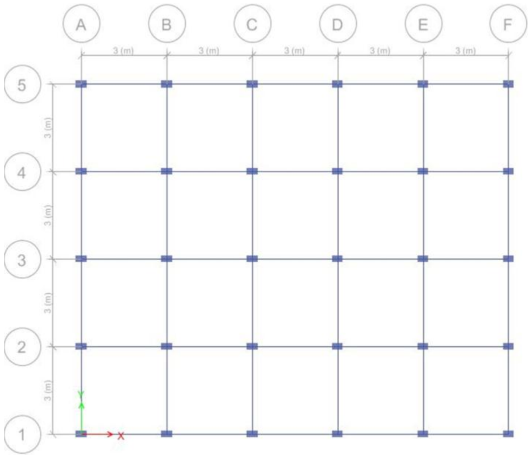

Fig – PLAN OF BUILDING

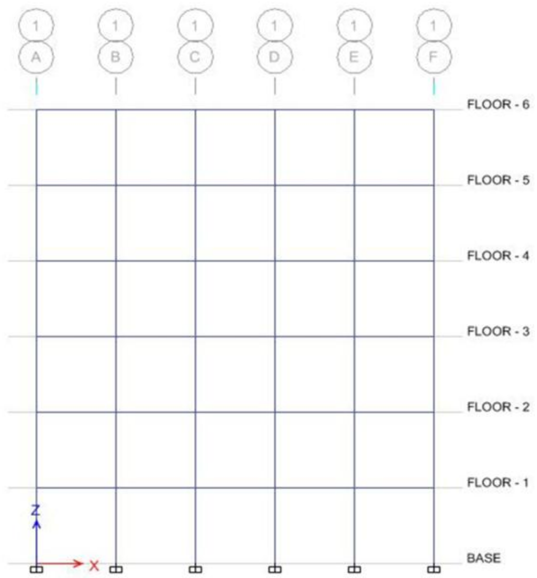

Fig – ELEVATION OF BUILDING

DATA OF BUILDING CONSIDERED FOR STUDY:-

S. No.	DISCRIPTION	INFORMATION
1	**Building Considered** :-	
	❖ Building plan ❖ Type of building ❖ Area of building ❖ No. of storeys	❖ Symmetrical plan RCC frame building 180 m2 eight
2	**Cross- Section Details** :-	
	❖ Column ❖ Beam ❖ Slab Thickness	❖ 300 x 230 mm ❖ 230 x 300 mm ❖ 115 mm
3	**Loads** :-	
	❖ Dead Loads - I.S : 875 (Part – I) • Dead load of structure • Wall load - Exterior floor beams Interior floor beams Parapat ❖ Live Load - I.S : 875 (Part – I) • Live load ❖ Earthquake Load - I.S : 1893 -2002 ❖ Useable Life Factors - I.S : 15988-2013 ❖ Knowledge Factors - I.S : 15988-2013	6.0 kN / m 6 .0 kN / m 3 .0 kN / m 2.0 kN / m² 1.0 1.0 to 0.5
4	**Seismic Parameters** :-	
	❖ Zone Factor (Z) ❖ Importance Factor (I) ❖ Response Reduction Factor (R) Non- Ductile Frame Ductile Frame ❖ Type of soil	0.1 1 3 5 Hard Soil Medium Soil Soft Soil

G + 3 ORDINARY MOMENT RESISTING FRAME BUILDINGS RESTING ON TYPE–I SOIL (HARD SOIL)

Design Life of Building	100 Yrs
Remaining Life of Building	100 Yrs
Useable Life Factor (U)	1.0

PROCURINGOFMETHODS CONSIDERED

New Zealand

The NZSEE recommends a two - stage evaluation procedure. A general outline of the recommended process and discussed in Section 2 (which still needs to be updated) The initial seismic evaluation (ISA) is intended to be a coarse evaluation involving as few resources as possible and is the first recommended step in the overall evaluation process. For those buildings identified in the ISA as likely to be an Earthquake Prone Building (EPB) under the provisions of the New Zealand Building Act 2004, a detailed seismic assessment (DSA) is expected to follow the ISA. or where important decisions relating to the seismic status of the building are intended. Such decisions could include pre - purchase due diligence, arrangement of insurance, confirmation of the prone status of the earthquake and prior to the design of seismic upgrades.

The process adopted for the ISA will depend to a large extent on the specific goals of the evaluation and the number of buildings involved. The ISA process for a building portfolio or for the identification by a Territorial Authority (TA) of earthquake - prone buildings may have a different focus from that for a single building. The main elements in the ISA process can be found in Figure 3.1. The primary objective of assigning earthquake prone status is to screen buildings where the outcome is reasonably certain without necessarily requiring a formal assessment. When multiple buildings are involved, priority may be necessary, as it may be impractical to simultaneously and immediately evaluate all buildings. Consequently, resources must be concentrated on buildings that have the potential for the greatest gains.

FEDERAL EMERGENCY MANAGEMENT AGENCY (FEMA)

Rapid visual screening of buildings for potential seismic hazards, as described herein, began in 1988 with the publication of the FEMA 154 Report on Rapid Visual Screening of Buildings for Seismic Risks A manual. Written for a wide audience ranging from engineers and building officials to adequately trained non - professionals, the manual provided a sidewalk survey approach that allowed users to classify surveyed buildings into two categories. Those acceptable for life safety risk or those that may be seismically hazardous and should be assessed in more detail by a seismic design expert. In the decade after the first FEMA 154 Handbook was published, Private sector organizations and government agencies used the Rapid Visual Screening (RVS) procedure to evaluate more than 70,000 buildings across the country (ATC 2002). This widespread application provided important information on the purpose of the document the ease of use of the document and views on the accuracy of the scoring system on which the procedure was based. Data and information were collected in the first decade following publication Experience with the application of the original manual, new data on earthquake performance and new ground - breaking information) has been used to update and improve the rapid visual screening procedure provided in this second edition of the FEMA 154 report. Rapid visual screening of potentially seismic hazards in buildings: a manual. Figure 1 - 1 Seismic regions of the United States are high, moderate and low. For each of these regions, a different RVS data collection form has been developed. Enlarged maps can be found in Appendix A.

Seismic Safety Evaluation Method (SSEM)

The proposed method of evaluation of seismic safety (SSEM) is carried out in two stages, the primary and secondary stages.

Primary Stage :-

The primary stage is the collection of relevant data on the building under consideration, such as the building's address, the seismic zone in which the building is located, the construction year, the total area of the building, the type of building, the use of the building, the year of construction, presence of soft storage plan and vertical irregularities, apparent building quality, architectural and structural drawing availability, geo-tech report and any appropriate data.

Secondary Stage:-

The second step is taken to obtain the final capacity of the building. The building's final capacity score (FCS) is obtained by taking the sum of the modified initial capacity score (AICS) and the modified seismic susceptibility score (ASSS) .Depending on the final capability score (FCS), the building safety is assessed If the final capacity score (FCS) is less than " 2, " the building is considered unsafe and a detailed assessment of the building is advised. If the final capacity score (FCS) exceeds " 2, " the building shall be considered safe. The secondary stage is performed in the following steps:

Step–1:- The building's initial capacity score (ICS) is selected according to the building being evaluated.

Step–2: Modified Initial Capacity Score (AICS) is achieved by multiplying the basic score with the M1, M2 & M3 AICS= (ICS) (M1) (M2) (M3) Modifiers

Step–3:- Seismic susceptibility score (SSS) values are selected based on the number of building floors to be evaluated.

Step – 4:- The values of the Seismic Susceptibility Score (SSS) are multiplied by the Seismic Susceptibility Score Moderator (SSSM) for all items. The final Seismic Susceptibility Score (ASSS) is obtained for the whole building by adding all values.

ASSS = Σ {(SSS). (SSSM)}

Step – 5:- The final building capacity score (FCS) is achieved by adding ASSS to AICS:

FCS = AICS + ASSS

RESULTS

BUILDING = G + 7 ZONE - II with plan & vertical irregularity R = 3 U=1

	APPARENT QUALI	K	FEMA	SSEM	NEW ZEALAND
HARD	GOOD	K= 1.0	SAFE	UNSAFE	UNSAFE
		K= 0.9	SAFE	UNSAFE	
	MODERATE	K= 0.8	SAFE	UNSAFE	
		K= 0.7	SAFE	UNSAFE	
	POOR	K= 0.6	SAFE	UNSAFE	
		K= 0.5	SAFE	UNSAFE	
	APPARENT QUALI	K	FEMA	SSEM	
MEDIUM	GOOD	K= 1.0	SAFE	UNSAFE	
		K= 0.9	SAFE	UNSAFE	
	MODERATE	K= 0.8	SAFE	UNSAFE	
		K= 0.7	SAFE	UNSAFE	
	POOR	K= 0.6	SAFE	UNSAFE	
		K= 0.5	SAFE	UNSAFE	
	APPARENT QUALI	K	FEMA	SSEM	
SOFT	GOOD	K= 1.0	SAFE	UNSAFE	
		K= 0.9	SAFE	UNSAFE	
	MODERATE	K= 0.8	SAFE	UNSAFE	
		K= 0.7	SAFE	UNSAFE	
	POOR	K= 0.6	SAFE	UNSAFE	
		K= 0.5	SAFE	UNSAFE	

BUILDING = G + 7 ZONE - III with plan & vertical irregularity R = 3 U=1					
	APPARENT QUALI	K	FEMA	SSEM	NEW ZEALAND
HARD	GOOD	K= 1.0	SAFE	UNSAFE	UNSAFE
		K= 0.9	SAFE	UNSAFE	
	MODERATE	K= 0.8	SAFE	UNSAFE	
		K= 0.7	SAFE	UNSAFE	
	POOR	K= 0.6	SAFE	UNSAFE	
		K= 0.5	SAFE	UNSAFE	
	APPARENT QUALI	K	FEMA	SSEM	
MEDIUM	GOOD	K= 1.0	SAFE	UNSAFE	
		K= 0.9	SAFE	UNSAFE	
	MODERATE	K= 0.8	SAFE	UNSAFE	
		K= 0.7	SAFE	UNSAFE	
	POOR	K= 0.6	SAFE	UNSAFE	
		K= 0.5	SAFE	UNSAFE	
	APPARENT QUALI	K	FEMA	SSEM	
SOFT	GOOD	K= 1.0	SAFE	UNSAFE	
		K= 0.9	SAFE	UNSAFE	
	MODERATE	K= 0.8	SAFE	UNSAFE	
		K= 0.7	SAFE	UNSAFE	
	POOR	K= 0.6	SAFE	UNSAFE	
		K= 0.5	SAFE	UNSAFE	

BUILDING = G + 7 ZONE - IV with plan & vertical irregularity R = 3 U=1					
	APPARENT QUALI	K	FEMA	SSEM	NEW ZEALAND
HARD	GOOD	K= 1.0	SAFE	UNSAFE	UNSAFE
		K= 0.9	SAFE	UNSAFE	
	MODERATE	K= 0.8	SAFE	UNSAFE	
		K= 0.7	SAFE	UNSAFE	
	POOR	K= 0.6	SAFE	UNSAFE	
		K= 0.5	SAFE	UNSAFE	
	APPARENT QUALI	K	FEMA	SSEM	
MEDIUM	GOOD	K= 1.0	SAFE	UNSAFE	
		K= 0.9	SAFE	UNSAFE	
	MODERATE	K= 0.8	SAFE	UNSAFE	
		K= 0.7	SAFE	UNSAFE	
	POOR	K= 0.6	SAFE	UNSAFE	
		K= 0.5	SAFE	UNSAFE	
	APPARENT QUALI	K	FEMA	SSEM	
SOFT	GOOD	K= 1.0	SAFE	UNSAFE	
		K= 0.9	SAFE	UNSAFE	
	MODERATE	K= 0.8	SAFE	UNSAFE	
		K= 0.7	SAFE	UNSAFE	
	POOR	K= 0.6	SAFE	UNSAFE	
		K= 0.5	SAFE	UNSAFE	

BUILDING = G + 7 ZONE - V with plan & vertical irregularity R = 3 U=1					
	APPARENT QUALI	K	FEMA	SSEM	NEW ZEALAND
HARD	GOOD	K= 1.0	SAFE	UNSAFE	UNSAFE
		K= 0.9	SAFE	UNSAFE	
	MODERATE	K= 0.8	SAFE	UNSAFE	
		K= 0.7	SAFE	UNSAFE	
	POOR	K= 0.6	SAFE	UNSAFE	
		K= 0.5	SAFE	UNSAFE	
	APPARENT QUALI	K	FEMA	SSEM	
MEDIUM	GOOD	K= 1.0	SAFE	UNSAFE	
		K= 0.9	SAFE	UNSAFE	
	MODERATE	K= 0.8	SAFE	UNSAFE	
		K= 0.7	SAFE	UNSAFE	
	POOR	K= 0.6	SAFE	UNSAFE	
		K= 0.5	SAFE	UNSAFE	
	APPARENT QUALI	K	FEMA	SSEM	
SOFT	GOOD	K= 1.0	SAFE	UNSAFE	
		K= 0.9	SAFE	UNSAFE	
	MODERATE	K= 0.8	SAFE	UNSAFE	
		K= 0.7	SAFE	UNSAFE	
	POOR	K= 0.6	SAFE	UNSAFE	
		K= 0.5	SAFE	UNSAFE	

CONCLUSIONS:

There was a difference of values in Zone factor of Zone I and Zone II, that was checked. It was found that in most of the most of the buildings which were designed for seism forces, were safe as per the earlier code. However after up gradation from Zone I to Zone II most of these buildings were found to be unsafe and required retrofitting in some of the members. Hence a detailed study was carried out on a number of existing buildings.

Comparing the results obtained from proposed methods:

(a) The FEDERAL EMERGENCY MANAGEMENT AGENCY (FEMA-154 & FEMA-P-154) results were not in agreement with IS 15988, as the building was found to be safe for all conditions mentioned in IS 15988 results.

(b) Initial Evaluation Procedure (IEP) of NEW ZEALAND.

(i) In Zone II & Zone III the buildings were found to be unsafe.

(ii) In Zone III & Zone IV the buildings were found to be unsafe.

The proposed method of evaluation of seismic safety (SSEM)

In Zone II & Zone III the buildings were found to be unsafe.

(ii) In Zone III & Zone IV the buildings were found to be unsafe.

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