DISSERTATION

On

"Application of RVS procedure for condition assessment of structures"

Submitted by-

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M.Tech. (Structural Engineering)

2K14/STE/21

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CERTIFICATE

This is to certify that the report entitled "CONDITION ASSESSMENT OF BUILDINGS USING RAPID VISUAL SCREENING PROCEDURE" is being submitted by me, which is a bonafide record of my own work under the guidance and supervision of my project guide Dr. Alok Verma, in the partial fulfilment of requirement for the award of the degree of Master of Technology (M.Tech.) in Structural Engineering, Department of Civil Engineering, Delhi Technological University (D.T.U.), Delhi.

The matter embodied in the project has not been submitted for the award of any other degree.

Prachi Jain

2K14/STE/21

This is to certify that the above statement made by the candidate is true to the best of my knowledge and belief.

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I would like to express my sincere gratitude to my project guide Dr. Alok Verma ,Associate Professor, Delhi Technological University, for giving me the opportunity to work on this topic. It would never have been possible for me to complete this project without his precious guidance and his relentless support and encouragement.

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I am also thankful to all the faculty members and my classmates for the support and motivation during this work.

Last but not least, I specially thank all the people who are active in this field. Reference material (pictures, tables and forms) from various national and international reports and journals are included in this report as per requirement and all these are quoted under the reference section at the last of this report.

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M TECH

STRUCTURAL ENGINEERING

ABSTRACT

With the occurrence of a number of earthquakes in the past and chances of many more in the future, seismic risk assessment by condition assessment of structures has become an important factor in the seismic risk mitigation and management.Structures deteriorate with time and become seismically vulnerable. Seismic vulnerability depends on many factors including the quality of construction and occupancy type. Our country has a huge inventory of old structures which may require different types of retrofitting measures to become seismically safe.Detailed condition assessment of these structures would require a long time. Therefore a very rapid, reliable and economic method is required to roughly judge the condition and seismic safety of such buildings and Rapid Visual Screening (R.V.S.) method for condition assessment of building structures appropriately serves the purpose.

In the present work, various aspects of Rapid Visual Screening are considered. Rapid visual screening practices in US as per FEMA 154 and those in India are studied and an overview of the topic is developed. Later on, efforts are made to devise a new, more accurate and quicker RVS system for Indian conditions. This new modified system of RVS is proposed and explained in sufficient detail. Separate MS excel programs are developed for this new developed system and for RVS system specified by Bureau of Indian Standards (BIS) and using them screening of a certain number of buildings is carried out in the city of Ahmedabad (Gujarat). Then finally the outcomes and results are stated, comparisons are made and utility and suitability of new developed RVS system is explained.

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2.INTRODUCION

1.1 GENERAL

There is an urgent need to assess the seismic vulnerability of buildings in urban areas of India as most recent constructions in the urban areas consist of poorly designed and constructed buildings. The older buildings, even if constructed in compliance with relevant standards at that time, may not comply with the more stringent specifications of the latest standards.. Detailed seismic vulnerability evaluation is a technically complex and expensive procedure and can only be performed on a limited number of buildings. It is therefore very important to use simpler procedures that can help to rapidly evaluate the vulnerability profile of different types of buildings, so that the more complex evaluation procedures can be limited to the most critical buildings.

In the last few years several different methodologies for the assessment and classification of existing buildings have been developed . Many of them, so called Rapid-Visual-Screening (RVS) methodologies, are based on visual inspection of the buildings using predefined forms. Their main advantage is the fast and elementary implementation, which allows the user to evaluate a large amount of buildings in a relatively short period of time.

One of the basic documents, developed and used in the United States of America, is the RVS methodology described in the FEMA 154 (2002) handbook for seismic evaluation of existing buildings. This method has already been used for years and is an important basis for various international techniques.

But the RVS procedure for Indian conditions is still in its oversimplified preliminary stage and needs to be revived. One possibility is to incorporate the score system as in FEMA 154 with some modifications which would probably make this process more accurate and reliable. Moreover, we should also aim at enhancing the speed of the process by using computer technology. The possibilities in this field are endless and we must strive to explore them.

1.2 OBJECTIVE OF PRESENT STUDY

1.To study different aspects of RVS procedure as per FEMA 154 and IS 13935 methodology.

2.To develop a modified RVS procedure by further developing FEMA 154 and IS 13935 methodology.

3.To make condition assessment of an existing building as per all three above mentioned procedures.

4.To compare results of assessment carried out above.

5.To analyse the extent of usefulness of modified version of RVS compared to the FEMA and IS procedures.

6. To develop a user friendly EXCEL program so that quicker results may be obtained in the case of damage assessment.

1.3FURTHER SCOPE OF STUDY

Following may be the further scope of study:

1.This project will serve as a prototype to a more developed, precise and fast RVS methodology for Indian conditions.Modifications may be made in the excel program developed in this project ,to cover various types of structures.

2.Mathematical models may be developed for various types of structures using commercial design programs.The results of such models may be compared with those obtained from R.V.S procedures.

3.New retrofitting schemes may be developedand these may be linked to results of condition assessment of R.V.S procedures.

1.4 LEVELS IN THIS PROJECT

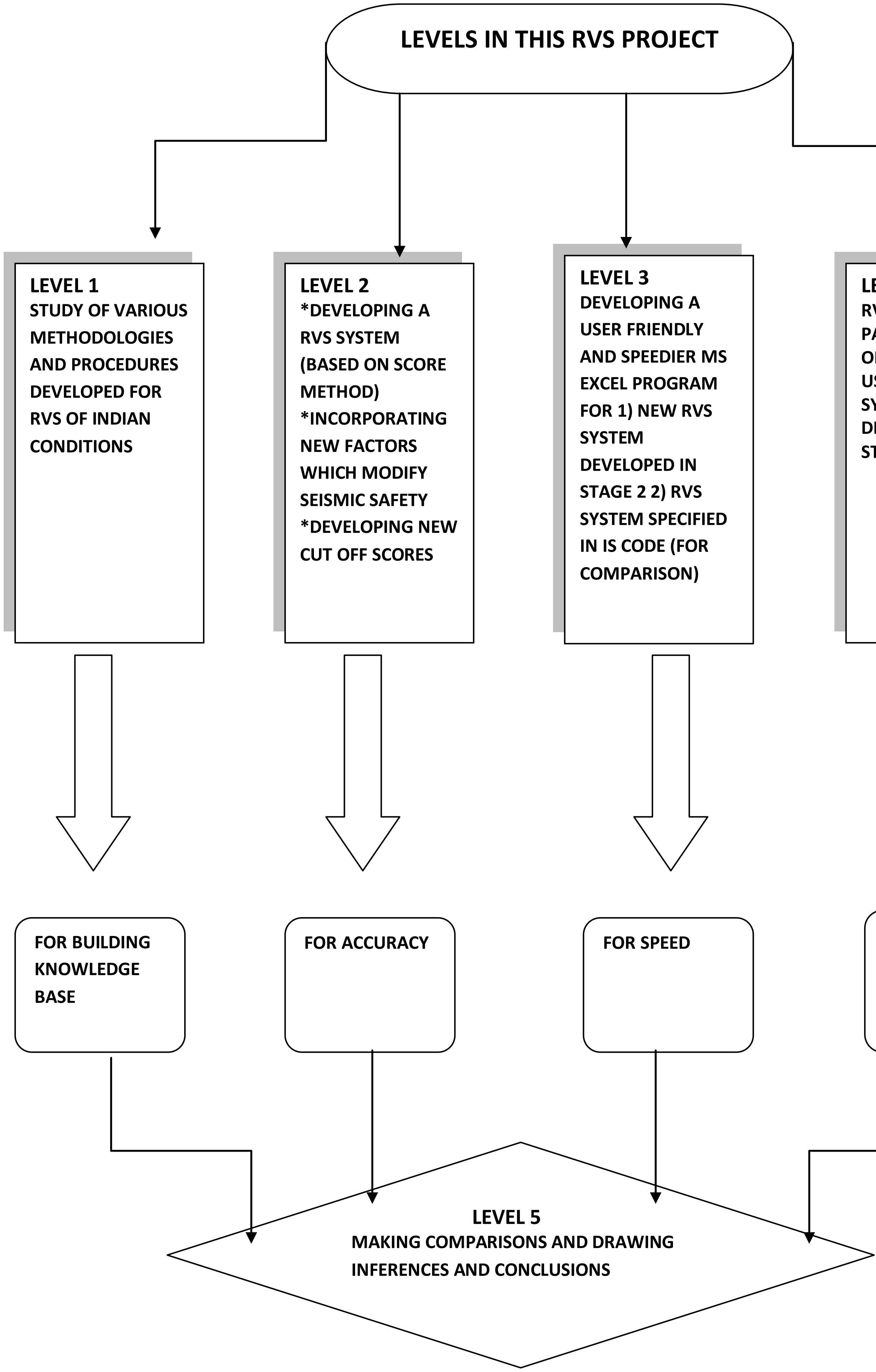


Figure 1: Schematic diagram of levels in this project

2. LITERATURE SURVEY

2.1 RAPID VISUAL SCREENING (RVS) DEFINITION

"Rapid Visual Screening or Sidewalk Survey is a procedure that utilises a damageability grading system that requires the evaluator to (1) identify the primary structural lateral load-resisting system, and (2) identify building attributes that modify the seismic performance expected for this lateral load-resisting system along with non-structural components. The inspection, data collection and decision-making process typically occurs at the building site, and is expected to take couple of hours for a building, depending on its size.

The Rapid Visual Screening method is designed to be implemented without performing any structural calculations.

2.2 NEED FOR RAPID VISUAL SCREENING

The main uses of this procedure in relation to seismic upgrading of existing buildings are:

i. To identify if a particular building requires further evaluation for assessment of its seismic vulnerability.

ii. To assess the seismic damageability (structural vulnerability) of the building and seismic rehabilitation needs.

iii. To identify simplified retrofitting requirements for the building (to collapse prevention level) where further evaluations are not considered necessary or not found feasible.

2.3 LIST OF WORK DONE BY RESEARCHERS IN THE PAST IN THE FIELD OF RAPID VISUAL SCREENING.

1.AHMET YAKUT

A PRELIMINARY SEISMIC ASSESSMENT PROCEDURE FOR REINFORCED CONCRETE BUILDINGS IN TURKEY [1]

SUMMARY

In this paper it has been said that reinforced concrete buildings are predominant type of construction in developing countries like Turkey. It was stated that Scientific and technical know-how alone, cannot solely predict the performance of this construction type, it depends highly on secondary factors such as the soft story, short column, irregularities in plan and elevation, the material quality, workmanship and compliance to the design detailing and sizes. The role of the secondary factors was re-emphasized in the severity of damage observed. Although many procedures have been proposed in the literature to evaluate the performance of existing RC buildings, the influence of the secondary factors has not been included adequately. This study had been undertaken to develop an assessment procedure that takes into account the influence of structural configuration as well as the secondary factors. In this procedure, a basic capacity index is computed considering the assessed orientation, size and material properties of the components comprising the lateral load resisting structural system. This index was then modified by several coefficients that reflect the quality of workmanship, detailing and architectural factors. The procedure had been developed based on the data compiled from damage surveys conducted after the earthquakes that occurred within the last decade in Turkey. The method used attributes of each building to rank their vulnerability within a given inventory. As a result, buildings with high vulnerability were classified as unsafe indicating that they would perform unsatisfactorily under a strong earthquake. The procedure was quite attractive for assessing the vulnerability of a large inventory of buildings because of the ability of arriving at decisions rapidly.

CONCLUSION

The proposed procedure aimed to assess rapidly the likely vulnerability of a group of low-to mid-rise reinforced concrete buildings that have moderate ductility. The procedure differed from other similar procedures in that it includes the effect of certain major parameters such as the presence of irregularities, the influence of regional seismicity, the type of underlying soil and the quality of construction. The procedure relied on the orientation, size and concrete strength of vertical load resisting components. Being a strength based assessment procedure, it was reasonably applicable to the buildings in Turkey which generally had moderate or low level of ductility. The procedure can easily be applied to other regions with a few minor modifications. construction practice in Turkey. The dependence on the as-built properties and on-site surveys made it extremely important to employ a standard data collection when using the procedure decisions or classifications regarding the expected performance, a limit for CPI needs to be assessors. When seeking for a rough assessment in Turkey than the limit might be set at 1.2. Buildings near the cut-off limit may need to be re-evaluated using detailed procedures.set. This limit is best determined for a population of buildings surveyed by the same.

2.M. PAPADRAKAKIS, M. FRAGIADAKIS, V. PLEVRIS (EDS.)

RISK ASSESSMENT OF HISTORIC RESIDENTIAL BRICK-MASONRY BUILDINGS IN VIENNA BY RAPID-VISUAL-SCREENING [2]

SUMMARY

In this paper it was stated that the evaluation of risk levels of existing buildings by Rapid-Visual-Screening (RVS) has become a common tool for seismic hazard assessment. If RVS is applied to buildings of similar type located in a well-defined urban area, it is useful to specify and to adapt existing screening rules and forms to the needs of these buildings. In a research effort presented in this paper the RVS procedure is adapted for the seismic assessment of historic residential brick-masonry buildings located in the City of Vienna, Austria. The evaluation and assessment methodology is based on two parameters, i.e. the damage relevance DR, and the structural parameter SP. Limiting conditions of the damage relevance DR are generated for risk classification to consider human and economic influence of damages on a certain building. The structural parameter SP consists of several indicators to describe the condition of certain structural parts of the building itself. In a large-scale in situ investigation a set of 375 buildings within the 20th district of Vienna has been evaluated by the proposed methodology. The results of this visual investigation are then integrated into a local seismic building hazard map.

CONCLUSION

We can conclude from the paper that the Rapid-Visual-Screening (RVS) technique is a fast and widespread method for Seismic hazard assessment of existing buildings.

The historic residential brick-masonary buildings represent the predominant type of constructions in Vienna,during the last few years a RVS technique was adopted,as so far there was no information about their resistance against seismic actions. The developed methodology to assess historic brick-masonry buildings consists of a visual inspection form and the subsequent evaluation of several parameters to capture the effects of possible damages to the environment and to describe and rate the structural behavior of the building. In this investigation a set of 375 historic brick-masonry buildings were evaluated by the proposed methodology and the results of these tests could be integrated into a local seismic building hazard map.

The outcome of the proposed methodology supplies a good prediction of the damage distribution within the test area. The evaluated hazard maps give useful information for emergency and evacuation planning as well as for identification of critical objects and further investigations.

3.D. D'AYALA1 AND E. SPERANZA1

AN INTEGRATED PROCEDURE FOR THE ASSESSMENT OF SEISMIC VULNERABILITY OF HISTORIC BUILDINGS [3]

SUMMARY

They have presented a procedure aimed at the evaluation of seismic vulnerability of masonry historic buildings subjected to earthquakes. The evaluation is done - based on a failure analysis of the structures through the identification of feasible collapse mechanisms and calculation of their associated failure load factors. Depending on boundary conditions of single walls and quality of materials the mechanisms are ranked in their likelihood to occurr; and the results are further manipulated to produce a measure of vulnerability. A wider range of possible collapse mechanisms and an accurate modelling of the continuity among orthogonal walls has been included in the computer programme which has been developed. Last but not the least a group of buildings in Marche region,Italy were surveyed to prove the capability of the procedure.

CONCLUSION

A conclusion was drawn that , the seismic behaviour of external walls, propensity and type of damage of historic centres can be characterised by studying the masonry fabric, typological layout and the identification of alterations, non seismic improvement, and seismic strengthening. This study, carried out over the building stock of four medium size historic centres of the Marche Region in Italy, has proven that where the fabric and craftsmanship have not been altered, original buildings show a medium level of vulnerability, which would results in moderate risk and damage. The insertion of ring beams and ties slightly reduce the vulnerability in ordinary (by slenderness) buildings. However they prove very efficient for building of greater slenderness, which would otherwise be intrinsically more vulnerable .The seismic capacity can be impaired by a vertical addition or other alteration such as the dislocation of opening . The results show that most of these buildings have proven to be highly vulnerable. The crucial role played by internal load bearing walls which are properly connected to the outer shell has been highlighted in preventing out of plane mechanisms.

4.P. KAPETANA & S. DRITSOS

SEISMIC ASSESSMENT OF BUILDINGS BY RAPID VISUAL SCREENING PROCEDURES. [4]

SUMMARY

Recently, several pre-earthquake screening methods have been developed in order to rapidly evaluate the vulnerability profile of the existing building stock, which has been constructed before or after the adoption and enforcement of seismic codes. The objective of these methods is to identify, inventory and rank all high-risk buildings in a specified region so that a strategy of priority based interventions to buildings can be formed. Major parameters that have affects on the seismic risk are the seismicity of the location, vulnerability and importance of the building structure. The most known rapid visual screening methods have been developed in countries of high seismic risk such as the USA, Greece, New Zealand, India and Canada and they are briefly described in this paper. Furthermore, these methods are applied to a sample of 456 reinforced concrete buildings, located in Athens, whose structural characteristics and levels of damage by the 1999 Athens earthquake are known. In particular, 93 buildings collapsed, 201 sustained severe damage, 69 moderate and 93 buildings sustained light damage. By the methods' implementation, eight different scores have been determined for each building, according to the scoring systems of the applied methods. The results of those applications are used to evaluate the methods' reliability in identifying potentially seismically hazardous reinforced concrete buildings. The obtained results indicate that the implementation of the Greek method results in the most reasonable connection between damage severity and structural scores for all levels of damage, while the Greek method is represented to be the most efficient in terms of both predicting the damage level and leading to the reliable formation of a high-priority set of buildings.

CONCLUSION

Assessing the results from the implementation of rapid visual screening methods, the following conclusions are reached: (a) A reasonable correlation between structural scores and collapse probability appears to exist only when scoring systems of OASP-0, FEMA-02, Indian and FEMA-G methods are used, (b) The averages of structural scores per building damage category have a reasonable connection with damage severity only when OASP-0, OASP-R, FEMA-02 and the Indian method are implemented. In addition, OASP-0 method appears to have the best scoring difference between averages of collapsed buildings and buildings with little damage, (c) OASP-0, OASP-R, Indian and FEMA-02 methods are characterized by the highest efficiency measures of collapse prediction when 10%, 20% and 50% high priority subsets are examined, with the OASP-0 measure being the highest of all. However, for 50% priority subsets,values of measures are almost the same, apart from that of New Zealand. The reached conclusions above come from a limited number of data, related to the seismic response of existing buildings in earthquake. Thus, in order to propose the most reasonable rapid evaluation procedure, the assessment of additional data is required.

5. SUDHIR K. JAIN, M.EERI, KEYA MITRA, MANISH KUMAR, M.EERI, AND MEHUL SHAH

A PROPOSED RAPID VISUAL SCREENING PROCEDURE FOR SEISMIC EVALUATION OF RC-FRAME BUILDINGS IN INDIA [5]

SUMMARY

This paper states that Poor performance of reinforced concrete (RC) frame buildings in India during past earthquakes has been a matter of serious concern. Hence, it becomes important to identify and strengthen the deficient buildings. When dealing with a large building stock, one needs evaluation methods for quick assessment of the seismic safety of existing buildings so that corrective retrofitting measures may be undertaken on the deficient buildings. This paper presents a review of some of the available methods for rapid visual screening (RVS) of RC-frame buildings and proposes a RVS method for RC-frame buildings in India based on systematic studies on damage data of the 2001 Bhuj earthquake.

CONCLUSION

It can be concluded that the identification of seismically vulnerable buildings and neighborhoods is a necessary first step in developing effective disaster mitigation programs for the community. Even though such assessment tools exist in other seismic countries such as U.S.A and Turkey, these are not applicable to Indian building typologies. Hence a need has long been felt to develop a methodology for rapid visual assessment of a large building stock that can be applied to Indian buildings. Since Ahmedabad was the only Indian city to have been significantly impacted during a recent earthquake (Bhuj 2001) from where data collection was possible, a sample survey of buildings was carried out in Ahmedabad on a representative sample of 270 RC-frame buildings. These buildings had been assigned different grades of damage in the immediate aftermath of the earthquake in 2001. The findings were used to understand the significance of the different vulnerability parameters by looking at the distribution of buildings with each of these vulnerability parameters across the different grades of damage. The vulnerability parameters considered were general, broad based, and easily observable from a sidewalk survey.A set of six vulnerability parameters are used in the proposed method: presence of basements, number of stories, apparent quality of maintenance, re-entrant corners, open stories, and short columns. In addition, performance scores are assigned for building usage (residential versus nonresidential), seismic zone, and soil type. A statistical analysis has been performed to develop Expected Performance Score (*EPS*) for buildings based on the rapid visual surveys undertaken in Ahmedabad. It accounts for the fact that the surveyed samples did not represent all the damage groups adequately, by doing multiple imputation analysis employing parametric regression method. Correctness of fit between the *EPS* obtained by the proposed method, as compared to their *OPS*, was determined to check the level of correctness of the method. It was found that for the Combined Sample, the method has predicted the damage category correctly in 46% of the buildings and within one level of incorrectness for the 88% buildings. The histogram of average absolute percentage error obtained using 1,000 bootstrap samples drawn from the Combined Sample indicates that the errors range from 17% to 25%, with a mean error of about 20%. The proposed method is based on limited data from damages in one Indian city on one building typology. This needs to be updated as well as tested as more data becomes available. Also, similar method needs to be developed for other prominent building typologies, e.g., the unreinforced masonry constructions.

6. KRAISORN LUCKSIRIA; THOMAS H. MILLERB, RAKESH GUPTAC, SHILING PEID, JOHN W. VAN DE LINDTE

A PROCEDURE FOR RAPID VISUAL SCREENING FOR SEISMIC SAFETY OF WOOD-FRAME DWELLINGS WITH PLAN IRREGULARITY [6]

SUMMARY

This paper highlights the development of a rapid visual screening (RVS) tool to quickly identify, inventory, and rank residential buildings that are potentially seismically hazardous, focusing on single-family, wood-frame dwellings with plan irregularity. The SAPWood software was used to perform a series of nonlinear time-history analyses for 480 representative models, covering different combinations of plan shapes, numbers of floors, base-rectangular areas, shape aspect ratio, area percentage cutoffs, window and door openings, and garage doors. The evolutionary parameter hysteresis model was used to represent the load-displacement relationship of structural panel-sheathed shear walls and a ten parameter CUREE hysteresis model for gypsum wallboard sheathed walls. Ten pairs of ground motion time histories were used and scaled to four levels of spectral acceleration at 0.167g, 0.5g, 1.0g, and 1.5g. An average seismic performance grade for each model was generated based on the predicted maximum shear wall drifts. Five seismic performance grades: 4, 3, 2, 1, and 0, are associated with the 1% immediate occupancy drift limit, 2% life safety limit, 3% collapse prevention limit, 10% drift, and exceeding 10% drift, respectively. The obtained average seismic performance grades were used to develop a new RVS tool that is applicable for checking the seismic performance of either existing or newly designed single-family, wood-frame dwellings. It examines the adequacy of the structure's exterior shear walls to resist lateral forces resulting from ground motions, including torsional forces induced from plan irregularity.

CONCLUSION

The following conclusions were drawn in this paper:

1. The new rapid visual screening (RVS) tool, developed in this study, examines the adequacy of single-family, wood-frame dwellings in Oregon to resist lateral forces resulting from ground motions and torsion induced from plan irregularity. The evaluation

procedure takes into consideration the shape of the floor plan, number of stories, base-rectangular area, percent cutoff, and openings from doors/windows and garage doors.

2. Application of the proposed RVS tool does not cover other sources of seismic vulnerabilities such as the effects of forces at reentrant corners, vertical irregularity, liquefaction, slope failure, unreinforced masonry chimneys, and foundation connections. Other issues such as different nail spacing for wall lines with large openings should also be further investigated.

3. The tool can be used together with FEMA 154 to identify whether a building with a particular plan shape and plan irregularity, focusing on torsional effects, can be potentially hazardous. Since performance grades from the new RVS method relate the predicted maximum shear wall drifts to immediate occupancy, life safety, and collapse prevention limits, the screener can use a final score of 2.0, which relates to collapse prevention performance, as a cutoff grade. It is also possible to incorporate this tool into Tier 1 (screening phase) of ASCE/SEI 31 to check the adequacy of the exterior shear walls in an existing building.

4. Using non-linear time-history analysis with pancake model, the effect of torsion due to mass eccentricities is included. Duration of ground motion shaking and number of cycles are taken into account through the numerical integration of the equation of motion. Since the development was based on a worst-case-scenario concept, and the representative models were based only on structural details observable from a side-walk survey (no contributions from any interior walls were included), the predicted results are considered to be reasonable and conservative for evaluations to meet the target performance objectives.

5. When ignoring the contributions from interior walls, increasing the base-rectangular area degrades the overall seismic performance. Buildings with two stories, a larger percentage of openings, and having a garage door were found to be more vulnerable to seismic events, as expected. In general, plan shape and plan irregularity were found to be important features especially in houses located in high 1 and high 2 seismicity regions, as they could potentially lead to severe damage. For low and moderate seismicity, the performance ranges from satisfying the collapse prevention limit to the immediate occupancy limit.

7.G.ACHS VCE HOLDING GMBH,AUSTRIAC.ADAM UNIVERSITY OF INNSBURCK , DEPARTMENT OF CIVIL ENGINEERING SCIENCES, AUSTRIA

A RAPID -VISUAL- SCREENING METHODOLOGY FOR THE SEISMIC VULNERABILITY ASSESSMENT OF HISTORIC BRICK – MASONARY BUILDINGS IN VIENNA [7]

SUMMARY

This paper addresses seismic vulnerability assessment of historic brick-masonry buildings located in the city of Vienna based on Rapid-Visual-Screening (RVS). The RVS methodology has been adopted for this specific type of buildings considering their consistent typology and consequently, enhancing the validity and quality of the seismic assessment. In this connection two parameters of the inspected object are evaluated, i.e. the damage relevance and an overall structural parameter. Based on the derived score of these parameters the building is classified into one of four vulnerability classes. In a large-scale in-situ investigation a set of 375 buildings within the 20th district of Vienna has been seismically assessed. The resulting vulnerability map gives useful information for emergency and evacuation planning as well as for identification of critical objects vulnerable to seismic loading.

CONCLUSION

It can be concluded that the Rapid-Visual-Screening (RVS) methodology is a fast and widespread method for seismic assessment of existing buildings. Recently, a RVS technique for historic brick-masonry buildings in Vienna was adopted, due to the fact that those buildings represent the predominant type of constructions in the city centre of Vienna, and so far there was no information about their vulnerability under seismic actions. The developed methodology consists of a visual inspection form and the subsequent evaluation of several parameters to capture the effects of possible damages on the environment and to describe and classify the structural behaviour of the building under earthquake loading. Subsequently, the buildings are classified into four vulnerability classes to prioritize the building stock by using the evaluated parameters. In a large-scale investigation a set of 375 historic brick-masonry buildings was evaluated by the proposed RVS methodology. The results of these tests were integrated into a local seismic building vulnerability map.

2.4 RVS TIMELINE

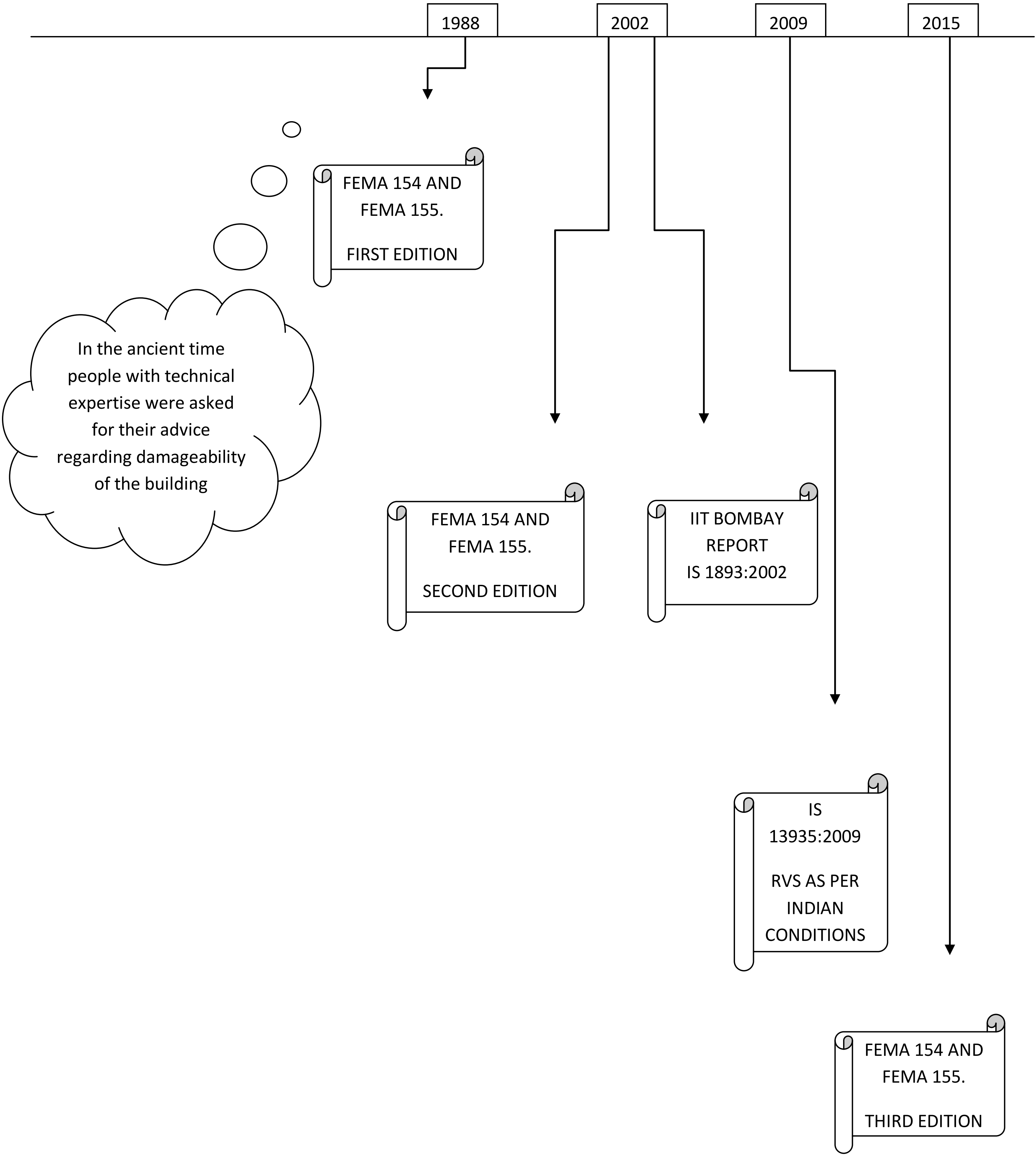


FIGURE 2: figure depicting RVS timeline

2.5 HISTORY OF RVS

RVS has been the preliminary step in assessing the damageability of the buildings since time immemorial.In the ancient civilizations the people with expertise in construction were asked for the advice for renovation and repair of the building.

With the time, efforts have been made to standardize the RVS procedure.Breakthrough in this field occurred with the publication of FEM A 154 Report in 1988.The report was named FEMA 154,Rapid visual screening of Buildings for Potential Seismic Hazards:A Handbook.

The purpose of FEMA 154, which was developed by ATC , was to provide a methodology to evaluate the seismic safety of a large inventory of buildings quickly and inexpensively, with minimum access to the buildings, and determine those buildings that require a more detailed examination.

In 2002, FEMA 154 was updated to create a Second Edition, based on (1) experience from the widespread use of FEMA 154 by federal, state, and municipal agencies and others; (2) new knowledge about the performance of buildings during damaging earthquakes; (3) new knowledge about seismic hazards; and (4) other then-new seismic evaluation and performance prediction tools, such as the FEMA 310 report, Handbook for the Seismic Evaluation of Buildings - A Prestandard (FEMA, 1998). Both the original FEMA 154 Handbook and the Second Edition were accompanied by a Supporting Documentation report (FEMA 155), which described the technical basis for the scoring system and other guidance provided in FEMA 154.
In 2011, the Applied Technology Council (ATC), with funding from the Federal Emergency Management Agency (FEMA) under Task Order Contract HSFEHQ-08-D-0726, commenced a series of projects (ATC-71-4, ATC-71-5, and ATC-71-6) to update the FEMA 154 Report, Rapid Visual Screening of Buildings for Potential Seismic Hazards: A Handbook (FEMA, 2002a).

Since the publication of the second edition of FEMA 154, there have been several initiatives that have advanced the state-of-the-art in rapid visual screening of buildings for seismic risk. One of these was the development of the FEMA P-154 Rapid Observation of Vulnerability and Estimation of Risk (ROVER) software for use on smart phones (FEMA, 2014), which enables users to document and transmit data gathered in the field. The rapid visual screening application of FEMA P-154 ROVER is based on the second edition of FEMA 154 and incorporates several improvements made possible by the electronic calculation capability of the device (e.g., site-specific determinations of the seismic shaking hazard).

The objective of the Third Edition remains the same as its predecessors: to identify, inventory, and screen buildings that are potentially hazardous. Although some sections of the text remained unchanged from the Second Edition, the Third Edition incorporates several major enhancements, including:

- Update of the Data Collection Form, and the addition of an optional more detailed page to the form,
- Update of the Basic Scores and Score Modifiers,
- Update of the ground motion definitions,
- Preparation of additional reference guides,
- Inclusion of additional building types that are prevalent,
- Inclusion of additional considerations, such as nonstructural hazards, existing retrofits, building additions, and adjacency,
- Addition of an optional electronic scoring methodology, and
- Additional information on how to run an effective screening program.

2.6 RVS PROCEDURE AS PER FEMA

2.6.1 Introduction, overview and scope

The RVS procedure presented in FEMA 154 *Handbook* has been formulated to identify, inventory, and rank buildings that are potentially seismically hazardous.The RVS procedure can be implemented relatively quickly and inexpensively to develop a list of potentially hazardous buildings without the high cost of a detailed seismic analysis of individual buildings. If a building receives a high score (i.e., above a specified cut-off score, as discussed later in this *Handbook*), the building is considered to have adequate seismic resistance. If a building receives a low score on the basis of this RVS procedure, it should be evaluated by a professional engineer having experience or training in seismic design. On the basis of this detailed inspection, engineering analyses, and other detailed procedures, a final determination of the seismic adequacy and need for rehabilitation can be made.

The RVS procedure in the *Handbook* is designed to be implemented without performing structural analysis calculations. The RVS procedure utilizes a scoring system that requires the user to (1) identify the primary structural lateral-load-resisting system; and (2) identify building attributes that modify the seismic performance expected of this lateral-load-resisting system.

2.6.2 Planning and Managing Rapid Visual Screening

The general sequence of implementing the RVS procedure is as follows:

• Budget development and cost estimation, acknowledging the expected extent of the screening and further use of the collected data;

•Planning before going to the field, including selection of the area to be surveyed, identification of building types to be screened, selection and development of a record-keeping system, and compilation and development of maps that document local seismic hazard information;

• Selection of the Data Collection Form;

• Selection and training of screening personnel;

• Gathering and review of pre-field data; including review of existing building files and databases to document information identifying buildings to be screened (e.g., address, lot number, number of stories, design date) and identifying soil types for the survey area;

• Review of existing building plans, if available;

• Field screening of individual building , which consists of:

1. Verifying and updating building identification information,
2. Walking around the building and sketching a plan and elevation view on the Data Collection Form,
3. Determining occupancy (that is, the building use and number of occupants),
4. Determining soil type, if not identified during the pre-planning process,
5. Identifying potential nonstructural falling hazards,

6. Identifying the seismic-lateral-loadresisting system (entering the building, if possible, to facilitate this process) and circling the Basic Structural Hazard Score on the Data Collection Form
7. Identifying and circling the appropriate seismic performance attribute Score Modifiers (e.g., number of stories, design date, and soil type) on the Data Collection Form,
8. Determining the Final Score, *S* (by adjusting the Basic Structural Hazard Score with the Score Modifiers identified , and deciding if a detailed evaluation is required, and
9. Photographing the building; and

• Checking the quality and filing the screening data in the record-keeping system, or database.

2.6.3 Important FEMA parameters

1. NUMBER OF STORIES: The height of a structure is sometimes related to the amount of damage it may sustain. On soft soils, a tall building may experience considerably stronger and longer duration shaking than a shorter building of the same type. The number of stories is a good indicator of the height of a building (approximately 9-to-10 feet per story for residential, 12 feet per story for commercial or office).

2. YEAR BUILT:This information is one of the key elements of the RVS procedure. Building age is tied directly to design and construction practices. Therefore, age can be a factor in determining building type and thus can affect the final scores.

3. TOTAL AREA: The total floor area, in some cases available from building department or assessor files , will most likely be estimated by multiplying the estimated area of one story by the total number of stories in the building.

4. DETERMINING SOIL TYPE:Soil type should be identified and documented on the Data Collection Form during the pre-field soils data acquisition and review phase. If soil type has not been determined as part of that process, it needs to be identified by the screener during building site visit. If there is no basis for classifying the soil type, a soil type E should be assumed.

5. OCCUPANCY: The occupancy of a building refers to its use, whereas the occupancy load is the number of people in the building . Although usually not bearing directly on the structural hazard or probability of sustaining major damage, the occupancy of a building is of interest and use when determining priorities for mitigation.

There are nine ocuupancy classes as follows:

i) Assembly
ii) Commercial
iii) Emergency services
iv) Government
v) Historic
vi) Industrial
vii) Office
viii) Residential
ix) School

6. IDENTIFYING POTENTIAL NON STRUCTURAL FALLING HAZARDS:

. Unreinforced Chimneys. Unreinforced masonry chimneys are common in older masonry and wood- frame dwellings. They are often inadequately tied to the house and fall when strongly shaken.

• Parapets. Unbraced parapets are difficult to identify from the street as it is sometimes difficult to tell if a facade projects above the roofline. Parapets often exist on three sides of the building, and their height may be visible from the back of the structure.

• Heavy Cladding. Large heavy cladding elements, usually precast concrete or cut stone, may fall off the building during an earthquake if improperly anchored. The loss of panels may also create major changes to the building stiffness (the elements are considered nonstructural but often contribute substantial stiffness to a building), thus setting up plan irregularities or torsion when only some fall.

7. IDENTIFYING THE LATERAL-LOAD-RESISTING SYSTEM AND DOCUMENTING THE RELATED BASIC STRUCTURAL SCORE:This has been discussed in detail in a section later in this project.

8. IRREGULAR BUILDINGS:

Irregularities in buildings are defined under the following subheads:

i. Plan Irregularities: These are defined in Table 4 of the Code as follows:

a) Torsion Irregularity

b) Re-entrant Corners

c) Diaphragm Discontinuity

d) Out of Plane Offsets

e) Non – Parallel Systems

The Geometric Irregularities in building plans.These irregularities enhance the overall damage (increased grade of damage e.g. at re-entrant corners). Such a building may be recommended for detailed evaluation.

ii. Vertical Irregularities: The following vertical irregularities may be seen in masonry buildings

a) Mass Irregularity

b) Vertical Geometric Irregularity

c) In-Plane Discontinuity in vertical Elements Resisting Lateral Forces.

If any of these irregularities are noticed, the building should be recommended for detailed evaluation.

2.6.4 Basic structure types and their behaviour

Following are the fifteen building types used in the RVS procedure as per 2^{nd} edition FEMA 154(2002). Alpha-numeric reference codes used on the Data Collection Form are shown in parentheses.

1. Light wood-frame residential and commercial buildings smaller than or equal to 5,000 square feet (W1)
2. Light wood-frame buildings larger than 5,000 square feet (W2)
3. Steel moment-resisting frame buildings (S1)
4. Braced steel frame buildings (S2)
5. Light metal buildings (S3)
6. Steel frame buildings with cast-in-place concrete shear walls (S4)
7. Steel frame buildings with unreinforced masonry infill walls (S5)
8. Concrete moment-resisting frame buildings (C1)
9. Concrete shear-wall buildings (C2)
10. Concrete frame buildings with unreinforced masonry infill walls (C3)
11. Tilt-up buildings (PC1)
12. Precast concrete frame buildings (PC2)

13. Reinforced masonry buildings with flexible floor and roof diaphragms (RM1)
14. Reinforced masonry buildings with rigid floor and roof diaphragms (RM2)
15. Unreinforced masonry bearing-wall buildings (URM)

CLASSIFICATION OF STRUCTURES FOR RVS [8]

Building Identifier	*Photograph*	*Basic Structural Hazard Score*	*Characteristics and Performance*
W1 Light wood frame residential and commercial buildings equal to or smaller than 5,000 square feet		H = 2.8 M = 5.2 L = 7.4	• Wood stud walls are typically constructed of 2-inch by 4-inch vertical wood members set about 16 inches apart (2-inch by 6-inch for multiple stories). • Most common exterior finish materials are wood siding, metal siding, or stucco. • Buildings of this type performed very well in past earthquakes due to inherent qualities of the structural system and because they are lightweight and low rise. • Earthquake-induced cracks in the plaster and stucco (if any) may appear, but are classified as non-structural damage. • The most common type of structural damage in older buildings results from a lack of connection between the superstructure and the foundation, and inadequate chimney support.
W2 Light wood frame buildings greater than 5,000 square feet		H = 3.8 M =4.8 L = 6.0	• These are large apartment buildings, commercial buildings or industrial structures usually of one to three stories, and, rarely, as tall as six stories.

Building Identifier	*Photograph*	*Basic Structural Hazard Score*	*Characteristics and Performance*
S1 Steel moment-resisting frame		H = 2.8 M = 3.6 L = 4.6	• Typical steel moment-resisting frame structures usually have similar bay widths in both the transverse and longitudinal directions, around 20-30 ft. • The floor diaphragms are usually concrete, sometimes over steel decking. This structural type is used for commercial, institutional and public buildings. • The 1994 Northridge and 1995 Kobe earthquakes showed that the welds in steel moment- frame buildings were vulnerable to severe damage. The damage took the form of broken connections between the beams and columns.
S2 Braced steel frame	  Zoom-in of upper photo	H = 3.0 M = 3.6 L = 4.8	• These buildings are braced with diagonal members, which usually cannot be detected from the building exterior. • Braced frames are sometimes used for long and narrow buildings because of their stiffness. • From the building exterior, it is difficult to tell the difference between steel moment frames, steel braced frames, and steel frames with interior concrete shear walls. • In recent earthquakes, braced frames were found to have damage to brace connections, especially at the lower levels.

Building Identifier	*Photograph*	*Basic Structural Hazard Score*	*Characteristics and Performance*
S3 Light metal building		H = 3.2 M = 3.8 L = 4.6	• The structural system usually consists of moment frames in the transverse direction and braced frames in the longitudinal direction, with corrugated sheet-metal siding. In some regions, light metal buildings may have partial-height masonry walls. • The interiors of most of these buildings do not have interior finishes and their structural skeleton can be seen easily. • Insufficient capacity of tension braces can lead to their elongation and consequent building damage during earthquakes. • Inadequate connection to a slab foundation can allow the building columns to slide on the slab. • Loss of the cladding can occur.
S4 Steel frames with cast-in-place concrete shear walls		H = 2.8 M = 3.6 L = 4.8	• Lateral loads are resisted by shear walls, which usually surround elevator cores and stairwells, and are covered by finish materials. • An interior investigation will permit a wall thickness check. More than six inches in thickness usually indicates a concrete wall. • Shear cracking and distress can occur around openings in concrete shear walls during earthquakes. • Wall construction joints can be weak planes, resulting in wall shear failure below expected capacity.

Building Identifier	Photograph	Basic Structural Hazard Score	Characteristics and Performance
S5 Steel frames with unreinforced masonry infill walls		H = 2.0 M = 3.6 L = 5.0	• Steel columns are relatively thin and may be hidden in walls. • Usually masonry is exposed on exterior with narrow piers (less than 4 ft wide) between windows. • Portions of solid walls will align vertically. • Infill walls are usually two to three wythes thick. • Veneer masonry around columns or beams is usually poorly anchored and detaches easily.
C1 Concrete moment-resisting frames		H = 2.5 M = 3.0 L = 4.4	• All exposed concrete frames are reinforced concrete (not steel frames encased in concrete). • A fundamental factor governing the performance of concrete moment-resisting frames is the level of ductile detailing. • Large spacing of ties in columns can lead to a lack of concrete confinement and shear failure. • Lack of continuous beam reinforcement can result in hinge formation during load reversal. • The relatively low stiffness of the frame can lead to substantial nonstructural damage. • Column damage due to pounding with adjacent buildings can occur.

Building Identifier	Photograph	Basic Structural Hazard Score	Characteristics and Performance
C2 Concrete shear wall buildings		H = 2.8 M = 3.6 L = 4.8	• Concrete shear-wall buildings are usually cast in place, and show typical signs of cast-in-place concrete. • Shear-wall thickness ranges from 6 to 10 inches. • These buildings generally perform better than concrete frame buildings. • They are heavier than steel-frame buildings but more rigid due to the shear walls. • Damage commonly observed in taller buildings is caused by vertical discontinuities, pounding, and irregular configuration.
C3 Concrete frames with unreinforced masonry infill walls		H =1.6 M = 3.2 L = 4.4	• Concrete columns and beams may be full wall thickness and may be exposed for viewing on the sides and rear of the building. • Usually masonry is exposed on the exterior with narrow piers (less than 4 ft wide) between windows. • Portions of solid walls will align vertically. • This type of construction was generally built before 1940 in high-seismicity regions but continues to be built in other regions. • Infill walls tend to buckle and fall out-of-plane when subjected to strong lateral out-of-plane forces. • Veneer masonry around columns or beams is usually poorly anchored and detaches easily.

(Continued)

Building Identifier	Photograph	Basic Structural Hazard Score	Characteristics and Performance
PC1 Tilt-up buildings	  Partial roof collapse due to failed diaphragm-to-wall connection	H = 2.6 M = 3.2 L = 4.4	• Tilt-ups are typically one or two stories high and are basically rectangular in plan. • Exterior walls were traditionally formed and cast on the ground adjacent to their final position, and then "tilted-up" and attached to the floor slab. • The roof can be a plywood diaphragm carried on wood purlins and glulam beams or a light steel deck and joist system, supported in the interior of the building on steel pipe columns. • Weak diaphragm-to-wall anchorage results in the wall panels falling and the collapse of the supported diaphragm (or roof).

Building Identifier	Photograph	Basic Structural Hazard Score	Characteristics and Performance
RM1 Reinforced masonry buildings with flexible diaphragms	  Truss-joists support plywood and lightweight concrete slab  Detail showing reinforced masonry	H = 2.8 M = 3.6 L = 4.8	• Walls are either brick or concrete block. • Wall thickness is usually 8 inches to 12 inches. • Interior inspection is required to determine if diaphragms are flexible or rigid. • The most common floor and roof systems are wood, light steel, or precast concrete. • These buildings can perform well in moderate earthquakes if they are adequately reinforced and grouted, with sufficient diaphragm anchorage. • Poor construction practice can result in ungrouted and unreinforced walls, which will fail easily.

Building Identifier	*Photograph*	*Basic Structural Hazard Score*	*Characteristics and Performance*
RM2 Reinforced masonry buildings with rigid dia-phrams		H = 2.8 M = 3.4 L = 4.6	• Walls are either brick or concrete block. • Wall thickness is usually 8 inches to 12 inches. • Interior inspection is required to determine if diaphragms are flexible or rigid. • The most common floor and roof systems are wood, light steel, or precast concrete. • These buildings can perform well in moderate earthquakes if they are adequately reinforced and grouted, with sufficient diaphragm anchorage. • Poor construction practice can result in ungrouted and unreinforced walls, which will fail easily.
URM Unreinforced masonry buildings		H = 1.8 M = 3.4 L = 4.6	• These buildings often used weak lime mortar to bond the masonry units together. • Arches are often an architectural characteristic of older brick bearing wall buildings. • Other methods of spanning are also used, including steel and stone lintels. • Unreinforced masonry usually shows header bricks in the wall surface. • The performance of this type of construction is poor due to lack of anchorage of walls to floors and roof, soft mortar, and narrow piers between window openings.

Figure 3:Classification of structures for RVS

2.6.5 DATA COLLECTION FORMS (AS PER FEMA 154(2002)) [8]

Rapid Visual Screening of Buildings for Potential Seismic Hazards

FEMA-154 Data Collection Form

LOW Seismicity

Address: ____________________

____________________ **Zip** __________

Other Identifiers ____________________

No. Stories ____________________ **Year Built** __________

Screener ____________________ **Date** __________

Total Floor Area (sq. ft.) ____________________

Building Name ____________________

Use ____________________

Scale:

PHOTOGRAPH

OCCUPANCY			SOIL						TYPE	FALLING HAZARDS
Assembly	Govt	Office	Number of Persons	A Hard Rock	B Avg. Rock	C Dense Soil	D Stiff Soil	E Soft Soil	F Poor Soil	☐ Unreinforced Chimneys
Commercial	Historic	Residential	0 – 10 11 – 100							☐ Parapets
Emer. Services	Industrial	School	101-1000 1000+							☐ Cladding
										☐ Other: ______

BASIC SCORE, MODIFIERS, AND FINAL SCORE, *S*

BUILDING TYPE	W1	W2	S1 (MRF)	S2 (BR)	S3 (LM)	S4 (RC SW)	S5 (URM INF)	C1 (MRF)	C2 (SW)	C3 (URM INF)	PC1 (TU)	PC2	RM1 (FD)	RM2 (RD)	URM
Basic Score	**7.4**	**6.0**	**4.6**	**4.8**	**4.6**	**4.8**	**5.0**	**4.4**	**4.8**	**4.4**	**4.4**	**4.6**	**4.8**	**4.6**	**4.6**
Mid Rise (4 to 7 stories)	N/A	N/A	+0.2	+0.4	N/A	+0.2	-0.2	+0.4	-0.2	-0.4	N/A	-0.2	-0.4	-0.2	-0.6
High Rise (>7 stories)	N/A	N/A	+1.0	+1.0	N/A	+1.0	+1.2	+1.0	0.0	-0.4	N/A	-0.2	N/A	0.0	N/A
Vertical Irregularity	-4.0	-3.0	-2.0	-2.0	N/A	-2.0	-2.0	-1.5	-2.0	-2.0	N/A	-1.5	-2.0	-1.5	-1.5
Plan Irregularity	-0.8	-0.8	-0.8	-0.8	-0.8	-0.8	-0.8	-0.8	-0.8	-0.8	-0.8	-0.8	-0.8	-0.8	-0.8
Pre-Code	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Post-Benchmark	0.0	+0.2	+0.4	+0.6	N/A	+0.6	N/A	+0.6	+0.4	N/A	+0.2	N/A	+0.2	+0.4	+0.4
Soil Type C	-0.4	-0.4	-0.8	-0.4	-0.4	-0.4	-0.4	-0.6	-0.4	-0.4	-0.4	-0.2	-0.4	-0.2	-0.4
Soil Type D	-1.0	-0.8	-1.4	-1.2	-1.0	-1.4	-0.8	-1.4	-0.8	-0.8	-0.8	-1.0	-0.8	-0.8	-0.8
Soil Type E	-1.8	-2.0	-2.0	-2.0	-2.0	-2.2	-2.0	-2.0	-2.0	-2.0	-1.8	-2.0	-1.4	-1.6	-1.4

FINAL SCORE, *S*

COMMENTS

Detailed Evaluation Required

YES NO

* = Estimated, subjective, or unreliable data
DNK = Do Not Know

BR = Braced frame
FD = Flexible diaphragm
LM = Light metal

MRF = Moment-resisting frame
RC = Reinforced concrete
RD = Rigid diaphragm

SW = Shear wall
TU = Tilt up
URM INF = Unreinforced masonry infill

Rapid Visual Screening of Buildings for Potential Seismic Hazards
FEMA-154 Data Collection Form

MODERATE Seismicity

Scale:

Address: ____
____________________________ Zip ______________
Other Identifiers ____________________________________
No. Stories ____________________________ Year Built ________
Screener ____________________________ Date ______________
Total Floor Area (sq. ft.) ____________________________
Building Name ______________________________________
Use ____

PHOTOGRAPH

OCCUPANCY			SOIL	TYPE						FALLING HAZARDS			
Assembly	Govt	Office	Number of Persons	A	B	C	D	E	F	☐	☐	☐	☐
Commercial	Historic	Residential	0 – 10 / 11 – 100	Hard Rock	Avg. Rock	Dense Soil	Stiff Soil	Soft Soil	Poor Soil	Unreinforced Chimneys	Parapets	Cladding	Other: ______
Emer. Services	Industrial	School	101-1000 / 1000+										

BASIC SCORE, MODIFIERS, AND FINAL SCORE, *S*

BUILDING TYPE	W1	W2	S1 (MRF)	S2 (BR)	S3 (LM)	S4 (RC SW)	S5 (URM INF)	C1 (MRF)	C2 (SW)	C3 (URM INF)	PC1 (TU)	PC2	RM1 (FD)	RM2 (RD)	URM
Basic Score	**5.2**	**4.8**	**3.6**	**3.6**	**3.8**	**3.6**	**3.6**	**3.0**	**3.6**	**3.2**	**3.2**	**3.2**	**3.6**	**3.4**	**3.4**
Mid Rise (4 to 7 stories)	N/A	N/A	+0.4	+0.4	N/A	+0.4	+0.4	+0.2	+0.4	+0.2	N/A	+0.4	+0.4	+0.4	-0.4
High Rise (>7 stories)	N/A	N/A	+1.4	+1.4	N/A	+1.4	+0.8	+0.5	+0.8	+0.4	N/A	+0.6	N/A	+0.6	N/A
Vertical Irregularity	-3.5	-3.0	-2.0	-2.0	N/A	-2.0	-2.0	-2.0	-2.0	-2.0	N/A	-1.5	-2.0	-1.5	-1.5
Plan Irregularity	-0.5	-0.5	-0.5	-0.5	-0.5	-0.5	-0.5	-0.5	-0.5	-0.5	-0.5	-0.5	-0.5	-0.5	-0.5
Pre-Code	0.0	-0.2	-0.4	-0.4	-0.4	-0.4	-0.2	-1.0	-0.4	-1.0	-0.2	-0.4	-0.4	-0.4	-0.4
Post-Benchmark	+1.6	+1.6	+1.4	+1.4	N/A	+1.2	N/A	+1.2	+1.6	N/A	+1.8	N/A	2.0	+1.8	N/A
Soil Type C	-0.2	-0.8	-0.6	-0.8	-0.6	-0.8	-0.8	-0.6	-0.8	-0.6	-0.6	-0.6	-0.8	-0.6	-0.4
Soil Type D	-0.6	-1.2	-1.0	-1.2	-1.0	-1.2	-1.2	-1.0	-1.2	-1.0	-1.0	-1.2	-1.2	-1.2	-0.8
Soil Type E	-1.2	-1.8	-1.6	-1.6	-1.6	-1.6	-1.6	-1.6	-1.6	-1.6	-1.6	-1.6	-1.6	-1.6	-1.6

FINAL SCORE *S*

COMMENTS

Detailed Evaluation Required

YES NO

* = Estimated, subjective, or unreliable data
DNK = Do Not Know

BR = Braced frame
FD = Flexible diaphragm
LM = Light metal

MRF = Moment-resisting frame
RC = Reinforced concrete
RD = Rigid diaphragm

SW = Shear wall
TU = Tilt up
URM INF = Unreinforced masonry infill

Rapid Visual Screening of Buildings for Potential Seismic Hazards

FEMA-154 Data Collection Form

HIGH Seismicity

Scale:

Address: ______________________________

______________________ **Zip** __________

Other Identifiers ______________________

No. Stories ________________ **Year Built** ________

Screener ________________ **Date** ________________

Total Floor Area (sq. ft.) ______________________

Building Name ______________________

Use ______________________

PHOTOGRAPH

OCCUPANCY			SOIL							FALLING HAZARDS			
Assembly	Govt	Office	Number of Persons	A	B	C	D	E	F	☐	☐	☐	☐
Commercial	Historic	Residential	0 – 10 / 11 – 100	Hard Rock	Avg. Rock	Dense Soil	Stiff Soil	Soft Soil	Poor Soil	Unreinforced Chimneys	Parapets	Cladding	Other: ______
Emer. Services	Industrial	School	101-1000 / 1000+										

BASIC SCORE, MODIFIERS, AND FINAL SCORE, *S*

BUILDING TYPE	W1	W2	S1 (MRF)	S2 (BR)	S3 (LM)	S4 (RC SW)	S5 (URM INF)	C1 (MRF)	C2 (SW)	C3 (URM INF)	PC1 (TU)	PC2	RM1 (FD)	RM2 (RD)	URM
Basic Score	**4.4**	**3.8**	**2.8**	**3.0**	**3.2**	**2.8**	**2.0**	**2.5**	**2.8**	**1.6**	**2.6**	**2.4**	**2.8**	**2.8**	**1.8**
Mid Rise (4 to 7 stories)	N/A	N/A	+0.2	+0.4	N/A	+0.4	+0.4	+0.4	+0.4	+0.2	N/A	+0.2	+0.4	+0.4	0.0
High Rise (> 7 stories)	N/A	N/A	+0.6	+0.8	N/A	+0.8	+0.8	+0.6	+0.8	+0.3	N/A	+0.4	N/A	+0.6	N/A
Vertical Irregularity	-2.5	-2.0	-1.0	-1.5	N/A	-1.0	-1.0	-1.5	-1.0	-1.0	N/A	-1.0	-1.0	-1.0	-1.0
Plan irregularity	-0.5	-0.5	-0.5	-0.5	-0.5	-0.5	-0.5	-0.5	-0.5	-0.5	-0.5	-0.5	-0.5	-0.5	-0.5
Pre-Code	0.0	-1.0	-1.0	-0.8	-0.6	-0.8	-0.2	-1.2	-1.0	-0.2	-0.8	-0.8	-1.0	-0.8	-0.2
Post-Benchmark	+2.4	+2.4	+1.4	+1.4	N/A	+1.6	N/A	+1.4	+2.4	N/A	+2.4	N/A	+2.8	+2.6	N/A
Soil Type C	0.0	-0.4	-0.4	-0.4	-0.4	-0.4	-0.4	-0.4	-0.4	-0.4	-0.4	-0.4	-0.4	-0.4	-0.4
Soil Type D	0.0	-0.8	-0.6	-0.6	-0.6	-0.6	-0.4	-0.6	-0.6	-0.4	-0.6	-0.6	-0.6	-0.6	-0.6
Soil Type E	0.0	-0.8	-1.2	-1.2	-1.0	-1.2	-0.8	-1.2	-0.8	-0.8	-0.4	-1.2	-0.4	-0.6	-0.8
FINAL SCORE, *S*															

COMMENTS

Detailed Evaluation Required

YES NO

* = Estimated, subjective, or unreliable data
DNK = Do Not Know

BR = Braced frame
FD = Flexible diaphragm
LM = Light metal

MRF = Moment-resisting frame
RC = Reinforced concrete
RD = Rigid diaphragm

SW = Shear wall
TU = Tilt up
URM INF = Unreinforced masonry infill

2.6.6 FORM DETAILS AND SCORE MODIFIERS (FEMA 154 (2002)) [8]

Rapid Visual Screening of Buildings for Potential Seismic Hazards (FEMA 154)
Quick Reference Guide (for use with Data Collection Form)

1. Model Building Types and Critical Code Adoption and Enforcement Dates

Structural Types		**Year Seismic Codes Initially Adopted and Enforced***	**Benchmark Year when Codes Improved**
W1	Light wood frame, residential or commercial, ≤ 5000 square feet	_______	_______
W2	Wood frame buildings, > 5000 square feet.	_______	_______
S1	Steel moment-resisting frame	_______	_______
S2	Steel braced frame	_______	_______
S3	Light metal frame	_______	_______
S4	Steel frame with cast-in-place concrete shear walls	_______	_______
S5	Steel frame with unreinforced masonry infill	_______	_______
C1	Concrete moment-resisting frame	_______	_______
C2	Concrete shear wall	_______	_______
C3	Concrete frame with unreinforced masonry infill	_______	_______
PC1	Tilt-up construction	_______	_______
PC2	Precast concrete frame	_______	_______
RM1	Reinforced masonry with flexible floor and roof diaphragms	_______	_______
RM2	Reinforced masonry with rigid diaphragms	_______	_______
URM	Unreinforced masonry bearing-wall buildings	_______	_______

*Not applicable in regions of low seismicity

2. Anchorage of Heavy Cladding

Year in which seismic anchorage requirements were adopted: _______

3. Occupancy Loads

Use	Square Feet, Per Person	Use	Square Feet, Per Person
Assembly	varies, 10 minimum	Industrial	200-500
Commercial	50-200	Office	100-200
Emergency Services	100	Residential	100-300
Government	100-200	School	50-100

4. Score Modifier Definitions

Mid-Rise:	4 to 7 stories
High-Rise:	8 or more stories
Vertical Irregularity:	Steps in elevation view; inclined walls; building on hill; soft story (e.g., house over garage); building with short columns; unbraced cripple walls.
Plan Irregularity	Buildings with re-entrant corners (L, T, U, E, + or other irregular building plan); buildings with good lateral resistance in one direction but not in the other direction; eccentric stiffness in plan, (e.g. corner building, or wedge-shaped building, with one or two solid walls and all other walls open).
Pre-Code:	Building designed and constructed prior to the year in which seismic codes were first adopted and enforced in the jurisdiction; use years specified above in Item 1; default is 1941, except for PC1, which is 1973.
Post-Benchmark:	Building designed and constructed after significant improvements in seismic code requirements (e.g., ductile detailing) were adopted and enforced; the benchmark year when codes improved may be different for each building type and jurisdiction; use years specified above in Item 1 (see Table 2-2 of FEMA 154 *Handbook* for additional information).
Soil Type C:	Soft rock or very dense soil; S-wave velocity: 1200 – 2500 ft/s; blow count > 50; or undrained shear strength > 2000 psf.
Soil Type D:	Stiff soil; S-wave velocity: 600 – 1200 ft/s; blow count: 15 – 50; or undrained shear strength: 1000 – 2000 psf.
Soil Type E:	Soft soil; S-wave velocity < 600 ft/s; or more than 100 ft of soil with plasticity index > 20, water content > 40%, and undrained shear strength < 500 psf.

2.7 DETERMINING THE CUT OFF SCORE:

“The Rapid Visual Screening (RVS) structural Cut off Score (Cut off S) is decided on the basis of relative importance of “Costs of Safety” v/s “Benefits” ”[8]

The costs of safety include:

- The costs of reviewing and investigating in detail hundreds or thousands of buildings in order to identify some fraction of those that would actually sustain major damage in an earthquake; and
- The costs associated with rehabilitating those buildings finally determined to be unacceptably weak.

The most compelling benefit is the saving of lives and prevention of injuries due to reduced damage in those buildings that are rehabilitated. This reduced damage includes not only less material damage, but fewer major disruptions to daily lives and businesses.

Every community or authority is free to choose its cut off score depending upon to which factor it gives more importance, Cost of safety or Benefits.

As per National Bureau of Standards (NBC) of U.S. (1980) and SAC (2000) , value of Cut off Score S of about 3 is appropriate for day to- day loadings, and a value of about 2, or somewhat less, is appropriate for infrequent, but possible, earthquake loadings.

Unless a community itself considers the cost and benefit aspects of seismic safety, an S value of about 2.0 is a reasonable preliminary value to use within the context of RVS to differentiate adequate buildings from those potentially inadequate and thus requiring detailed review. Use of a higher cut-off S value implies greater desired safety but increased community-wide costs for evaluations and rehabilitation; use of a lower value of S equates to increased seismic risk and lower short-term community-wide costs for evaluations and rehabilitation (prior to an earthquake).

Further guidance on cost and other societal implications of seismic rehabilitation of hazardous buildings is available in other publications of the FEMA report series on existing buildings (FEMA-156 and FEMA-157, Typical Costs for Seismic Rehabilitation of Buildings, 2nd Edition, Volumes 1 and 2, and FEMA-255 and FEMA-256, Seismic Rehabilitation of Federal Buildings – A Benefit/Cost Model, Volumes 1 and 2 (VSP, 1994).

2.8 RAPID VISUAL SCREENING (RVS) FOR INDIAN CONDITIONS

2.8.1 Overview:

The FEMA methodology of rapid visual screening is not exactly suitable for Indian conditions in its original form. The reason behind this is that India is diversified country with construction practices ranging from highly urban construction comprising of modular steel and RCC structures to basic mud or earthen structures in villages. Hence only some not all structure types mentioned in FEMA 154 can be associated with Indian structures. Moreover the difference in size and occupancy and construction practices used to build these structures also has their own influence. The seismicity variation in India cannot be also overlooked. Thus we need a somewhat different methodology for RVS as per Indian conditions.

In this regard the contributions of Prof. Ravi Sinha and Prof. Alok Goyal (IIT Bombay) and Dr. Anand S. Arya (Professor Emeritus, Dept. of Eq. Engineering, IIT Roorkee, Chairman, BIS Committee CED 39) are worth mentioning who contributed to development of basic philosophy of RVS for Indian Structures (RCC, steel frame and Masonry) through their research on the basis of norms of new seismic code of India IS 1893:2002. Prof. Sinha and Prof. Goyal used score system of FEMA 154 to and made the use of final structural score S to classify various damageability grades derived from European Macro seismic Scale (EMS-98). Later, based on same European Macro seismic Scale (EMS-98) recommendations, classification of Indian structures and damageability that particular structure could undergo was done by Dr. Arya. Data collection forms were prepared and suitable procedure was proposed. Later on the same methodology was incorporated in IS 13935:2009 "Indian Standard Seismic Evaluation, Repair and Strengthening of Masonry Buildings- Guidelines (First Revision)"

Rapid Visual Screening (RVS) for Indian conditions as specified in IS 13935:2009 is based on a "Logical system" rather than a "structural score system" as in FEMA 154. In this system 6 building types are mentioned (A to F) in which some types (C and D) are common for both masonry and RCC/steel frame structures. + Sign is used to specify slightly more seismic strength or lower seismic vulnerability. Five Damageability Grades (G1 to G5) are also specified separately for masonry and RCC/Steel frame structures. Based on the type of structure and its location in a particular seismic zone (zone 2 to zone 5), the damage which it can undergo is specified in the form of a table. Moreover some other parameters like falling hazards, special hazards, URM infills and Special observations are specified.

Based on these parameters and the type of structure and seismic zone the observer or screener can identify the damage which the structure can undergo (in terms of damageability grade G) and Remedial measures that could be done for its prevention. All this is recorded in Data Collection Forms (separate form for each seismic zone (4 zones) ; total 8 forms, 4 for masonry structures and 4 for RCC/Steel frame Structures)

2.8.2 SEISMIC ZONES IN INDIA [13]:

As per IS 1893:2002 (Part 1), India has been divided into 4 seismic hazard zones (see Fig.A.1). The details of different seismic zones are given below:

Zone II Low seismic hazard (damage during earthquake may be of MSK Intensity VI or lower)

Zone III Moderate seismic hazard (maximum damage during earthquake may be up to MSK Intensity VII)

Zone IV High seismic hazard (maximum damage during earthquake may be up to MSK Intensity VIII)

Zone V Very high seismic hazard (maximum damage during earthquake may be of MSK Intensity IX or greater)

.

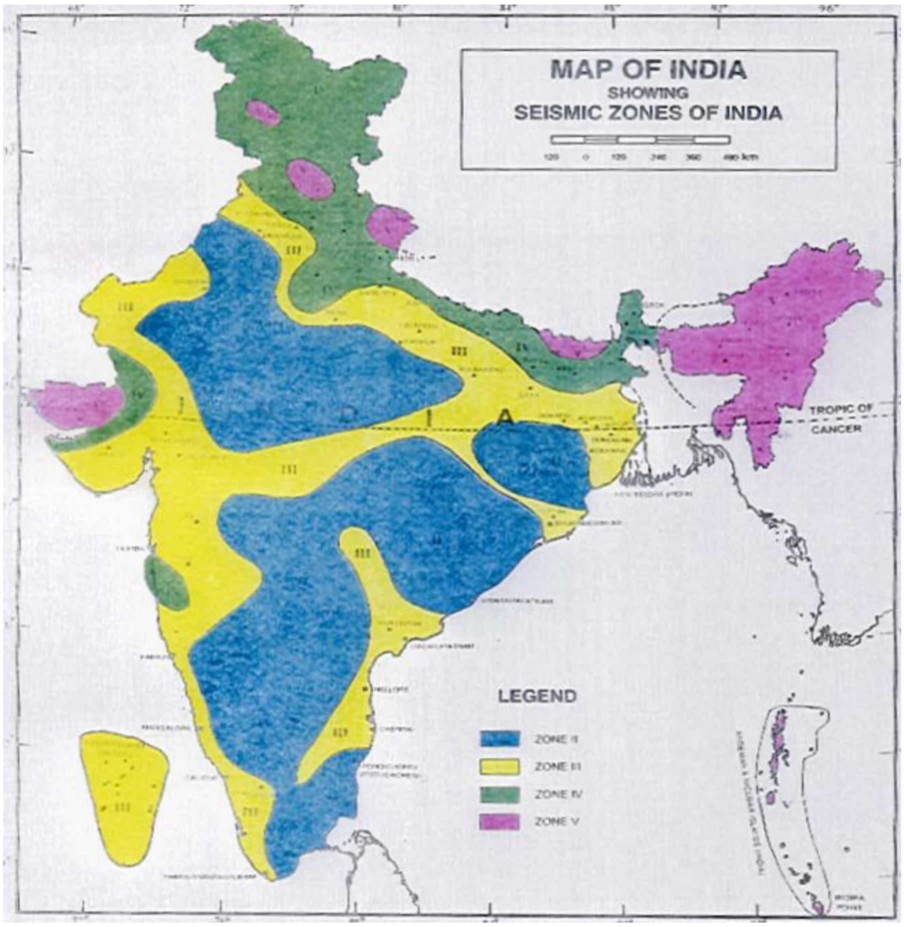


Figure 4 [11]: Seismic zones in India as per IS: 1893-2002

2.8.3 STRUCTURE TYPES FOR RVS AS PER INDIAN CONDITIONS:

Variety of construction types and building materials are used in urban and rural areas of India. These include local materials such as mud, straw and wood, semi-engineered materials such as burnt brick and stone masonry and engineered materials such as concrete and steel.

The seismic vulnerability of the different building types depends on the choice of building materials and construction technology adopted. The building vulnerability is generally highest with the use of local materials without engineering inputs and lowest with the use of engineered materials and skills. The basic vulnerability class of a building type is based on the average expected seismic performance for that building type.

All buildings have been divided into 6 types; type A to type F based on the European Macro seismic Scale (EMS-98) recommendations. The buildings in type A have the highest seismic vulnerability while the buildings in type F have the lowest seismic vulnerability.

A building of a given type, however, may have its vulnerability different from the basic class defined for that type depending on the condition of the building, presence of earthquake resistance features, architectural features, number of storeys etc. It is therefore possible to have a damageability range for each building type considering the different factors affecting its likely performance. Some variations in building type are therefore defined as A, B, B+ etc.

Table 1 [11] : Classification of Masonry Structures for RVS

Building Type	Description
A	a) Rubble (Field stone) in mud mortar or without mortar usually with sloping wooden roof. b) Uncoursed rubble masonry without adequate 'through stones'. c) Masonry with round stones.
B	Semi-dressed, rubble, brought to courses, **with** *through* stones and long *corner* stones; unreinforced brick walls with country type wooden roofs; unreinforced CC block walls constructed in mud mortar or weak lime mortar.
B+	a) Unreinforced brick masonry in mud mortar with vertical wood posts or horizontal wood elements or seismic band (IS: 13828) b) Unreinforced brick masonry in lime mortar.
C	a) Unreinforced masonry walls built from fully dressed (Ashler) stone masonry or CC block or burnt brick using good cement mortar, either having RC floor/roof or sloping roof having eave level horizontal bracing system or seismic band. b) As at B with horizontal seismic bands (IS: 13828)
C+	Like C(a) type but having horizontal seismic bands at lintel level of doors & windows (IS: 4326)
D	Masonry construction as at C(a) but reinforced with bands & vertical reinforcement, etc (IS: 4326), or *confined* masonry using horizontal & vertical reinforcing of walls.

Table 2 [12]: Classification of RCC/Steel Frame Structures for RVS

Frame Type	Description
C	a) RC Beam Post buildings without ERD or WRD, built in non-engineered way. b) SF without bracings having hinge joints;. c) RCF of ordinary design for gravity loads without ERD or WRD. d) SF of ordinary design without ERD or WRD
C+	a) MR-RCF/MR-SF of ordinary design without ERD or WRD. b) Do, with unreinforced masonry infill. c) Flat slab framed structure. d) Prefabricated framed structure.
D	a) MR-RCF with ordinary ERD without special details as per IS: 13920, with ordinary infill walls (such walls may fail earlier similar to C in masonry buildings. b) MR-SF with ordinary ERD without special details as per Plastic Design Hand Book SP:6(6)-1972.
E	a) MR-RCF with high level of ERD as per IS: 1893-2002 & special details as per IS: 13920. b) MR-SF with high level of ERD as per IS: 1893-2002 & special details as per Plastic Design Hand Book, SP:6(6)-1972
E+	a) MR-RCF as at E with well designed infills walls. b) MR-SF as at E with well designed braces
F	a) MR-RCF as at E with well designed & detailed RC shear walls. b) MR-SF as at E with well designed & detailed steel braces & cladding. c) MR-RCF/MR-SF with well designed base isolation.

2.8.4 DAMAGE CLASSIFICATION AS PER INDIAN CONDITIONS:

Table 3 [11]

Classification of damage to masonry buildings	
Grade 1: Negligible to slight damage (no structural damage, slight non-structural damage)	
Structural:	Hair-line cracks in very few walls.
Non-structural:	Fall of small pieces of plaster only. Fall of loose stones from upper parts of buildings in very few cases.
Grade 2: Moderate damage (Slight structural damage, moderate non-structural damage)	
Structural:	Cracks in many walls, thin cracks in RC* slabs and A.C.* sheets.
Non-structural:	Fall of fairly large pieces of plaster, partial collapse of smoke chimneys on roofs. Damage to parapets, chajjas. Roof tiles disturbed in about 10% of the area. Minor damage in under structure of sloping roofs.
Grade 3: Substantial to heavy damage (moderate structural damage, heavy non-structural damage)	
Structural:	Large and extensive cracks in most walls. Wide spread cracking of columns and piers.
Non-structural:	Roof tiles detach. Chimneys fracture at the roof line; failure of individual non-structural elements (partitions, gable walls).
Grade 4: Very heavy damage (heavy structural damage, very heavy non-structural damage)	
Structural:	Serious failure of walls (gaps in walls), inner walls collapse; partial structural failure of roofs and floors.
Grade 5: Destruction (very heavy structural damage)	
	Total or near total collapse of the building.

** RC = Reinforced Concrete; AC = Asbestos Cement*

Table 4 [12]

Classification of damage to buildings of reinforced concrete
Grade 1: Negligible to slight damage (no structural damage, slight non-structural damage) Fine cracks in plaster over frame members or in walls at the base. Fine cracks in partitions & infills.
Grade 2: Moderate damage (Slight structural damage, moderate non-structural damage) Cracks in columns & beams of frames & in structural walls. Cracks in partition & infill walls; fall of brittle cladding & plaster. Falling mortar from the joints of wall panels.
Grade 3: Substantial to heavy damage (moderate structural damage, heavy non-structural damage) Cracks in columns & beam column joints of frames at the base & at joints of coupled walls. Spalling of concrete cover, buckling of reinforced rods. Large cracks in partition & infill walls, failure of individual infill panels.
Grade 4: Very heavy damage (heavy structural damage, very heavy non-structural damage) Large cracks in structural elements with compression failure of concrete & fracture of rebar's; bond failure of beam reinforcing bars; tilting of columns. Collapse of a few columns or of a single upper floor.
Grade 5: Destruction (very heavy structural damage) Collapse of ground floor parts (e.g. Wings) of the building.

*The grades of damage in steel and wood buildings will also be based on non-structural and structural damage classification. Non-structural damage to infills would be the same as indicated for masonry building in the above table. Structural damage grade in steel & wooden elements still needs to be defined.

2.8.5 BUILDING TYPE AND DAMAGE CORRELATION AS PER INDIAN CONDITIONS:

Table 5 [11]: Structure type and Damageability correlation for Masonry Buildings

	Type of Building	Zone II MSK VI or less	Zone III MSK VII	Zone IV MSK VIII	Zone V MSK IX or More
MASONRY BUILDINGS	A	*Many* of grade 1 *Few* of grade 2 (rest no damage)	*Most* of grade 3 *Few* of grade 4 (rest of grade2or1)	*Most* of grade 4 *Few* of grade 5 (rest of grade 3,2)	*Many* of grade 5 (rest of grade 4&3)
	B and B+	*Many* of grade 1 *Few* of grade 2 (rest no damage)	*Many* of grade 2 *Few* of grade 3 (rest of grade 1)	*Most* of grade 3 *Few* of grade 4 (rest of grade 2)	*Many* of grade 4 *Few* of grade 5 (rest of grade 3)
	C and C+	*Few* of grade 1 (rest no damage)	*Many* of grade 1 *Few* of grade 2 (rest of grade 1,0)	*Most* of grade 2 *Few* of grade 3 (rest of grade 1)	*Many* of grade 3 *Few* of grade 4 (rest of grade 2)
	D		*Few* of grade 1	*Few* of grade 2	*Many* of grade 2 *Few* of grade 3 (rest of grade 1)

NOTE:

1. **As per MSK scale, few, Many and Most may be taken as: Few: 15%, Many: 50% and Most: 75%.**
2. **Buildings having vertical irregularity may under go severe damage in seismic zones III, IV & V if not specifically designed. Hence they will require special evaluation. Also buildings sited in liquefiable or landslide prone areas will require special evaluation for seismic safety.**
3. **Buildings having plan irregularity may under go a damage of one grade higher in zones III, IV & V. The surveyor may recommend re-evaluation.**

Table 6 [12]: Structure type and Damageability Correlation for RCC/Steel Frame Buildings

RCF/SF/BUILDING	**Type of Building**	**Zone II MSK VI or less**	**Zone III MSK VII**	**Zone IV MSK VIII**	**Zone V MSK IX or More**
	C and C+	*Few* of grade 1 (rest no damage)	*Few* of grade 2 (rest of grade 1,0)	*Many* of grade 2 *Few* of grade 3 (rest of grade 1)	*Many* of grade 3 *Few* of grade 4 (rest of grade 2)
	D	-	*Few* of grade 1	*Few* of grade 2	*Many* of grade 2 *Few* of grade 3 (rest of grade 1)
	E and E+	-	-	-	*Few* of grade 2 (rest of grade 1 or 0)
	F	-	-	-	*Few* of grade 1

NOTE:

1. **As per MSK scale, few, Many and Most may be taken as: Few: 15%, Many: 50% and Most: 75%.**
2. **Buildings having vertical irregularity (see note under table 3) may under go severe damage in seismic zones III, IV & V if not specifically designed. Hence they will require special evaluation. Also buildings sited in liquefiable or landslide prone areas will require special evaluation for seismic safety.**
3. **Buildings having plan irregularity may under go a damage of one grade higher in zones III, IV & V. The sur veyor may recommend re-evakuation.**

2.8.6 DATA COLLECTION FORMS FOR MASONRY STRUCTURES [11]:

1 Rapid Visual Screening of Masonry Buildings for Seismic Hazards

Seismic Zone II Ordinary Building

Photograph

Sketch Plan with Length & Breadth

1.1 Building Name ____________________

1.2 Use ____________________

1.3 Address: ____________________

____________________ Pin ________

1.4 Other Identifiers ____________________

1.5 No. of Stories __________ 1.6 Year Built __________

1.7 Total Covered Area; all floors (sq.m) __________

1.8 Ground Coverage (Sq.m): __________

1.9 Soil Type: __________ 1.10 Foundation Type: __________

1.11 Roof Type: __________ 1.12 Floor Type __________

1.12 Structural Components:

1.12.1 Wall Type: BB* ☐ Earthen ☐ UCR* ☐ CCB* ☐

1.12.2 Thickness of wall: ______ 1.12.3 Slab Thickness: ______

1.12.4 Mortar Type: Mud ☐ Lime ☐ Cement ☐

1.12.5 Vert. R/F bars: Corners ☐ T-junctions ☐ Jambs ☐

1.12.6 Seismic bands: Plinth ☐ Lintel ☐ Eaves ☐ Gable ☐

*BB – Burnt Brick, *UCR – Uncoursed Random Rubble
*CCB: Cement Concrete Block

2.0 OCCUPANCY	3.0 SPECIAL HAZARD	4.0 FALLING HAZARD
2.1 Important buildings: Hospitals, Schools, monumental structures; emergency buildings like telephone exchange, television, radio stations, railway stations, fire stations, large community halls like cinemas, assembly halls and subway stations, power stations, Important Industrial establishments, VIP residences & Residences of Important Emergency person. **Any building having more than 100 Occupants may be treated as Important.* ***2.2 Ordinary buildings***:- Other buildings having occupants <100	3.1 High Water Table (within 3m) & if sandy soil, then liquefiable site indicated. Yes ☐ No ☐ 3.2 Land Slide Prone Site Yes ☐ No ☐ 3.3 Severe Vertical Irregularity Yes ☐ No ☐ 3.4 Severe Plan Irregularity Yes ☐ No ☐ **5.0 SPECIAL OBSERVATION** 5.1 Length of wall between two cross walls are as per IS:4326 or IS:13828. Yes ☐ No ☐ 5.2 Percentage of openings in walls is as per IS:4326 or IS:13828 Yes ☐ No ☐ 5.3 Ratio of height & width of wall is as per IS:4326 or IS:13828 Yes ☐ No ☐	4.1 Chimneys ☐ 4.2 Parapets ☐ 4.3 Cladding ☐ 4.4 Others ☐

RECOMMENDED ACTION:-

- ☐ Ensure adequate maintenance.
- ☐ If any Special Hazard 3.0 found, re-evaluate for possible retrofitting.
- ☐ If any of the falling hazard is present, either remove it or strengthen against falling.
- ☐ Special observation if not compliant may lead to more severe damage and will call for retrofitting.

5.0 Probable Damageability in Few/Many Buildings

Building Type	5.1 Masonry Building			
Damage- ability in	A	B / B+	C / C+	D
Zone II	G2	G2 / G1	G1 / G1	-

Note: +sign indicates higher strength hence somewhat lower damage expected as stated. Also average damage in one building type in the area may be lower by one grade point than the probable damageability indicated.

Surveyor will identify the Building Type; encircle it, also the corresponding damage grade.

Surveyor's sign: ____________________
Name: ____________________

Executive Engineer's Sign: ____________________

Date of Survey: ____________________

2 Rapid Visual Screening of Masonry Buildings for Seismic Hazards

Seismic Zone III Ordinary Building

(Also for Zone II Important Building)

Photograph

Sketch Plan with Length & Breadth

1.1 Building Name ____________

1.2 Use ____________

1.3 Address: ____________

____________ Pin ____________

1.4 Other Identifiers ____________

1.5 No. of Stories ________ 1.6 Year Built ________

1.7 Total Covered Area; all floors (sq.m) ________

1.8 Ground Coverage (Sq.m): ________

1.9 Soil Type: ________ 1.10 Foundation Type: ________

1.11 Roof Type: ________ 1.12 Floor Type ________

1.12 Structural Components:

1.12.1 Wall Type: BB* ☐ Earthen ☐ UCR* ☐ CCB* ☐

1.12.2 Thickness of wall: ______ 1.12.3 Slab Thickness: ______

1.12.4 Mortar Type: Mud ☐ Lime ☐ Cement ☐

1.12.5 Vert. R/F bars: Corners ☐ T-junctions ☐ Jambs ☐

1.12.6 Seismic bands: Plinth ☐ Lintel ☐ Eaves ☐ Gable ☐

*BB – Burnt Brick, *UCR – Uncoursed Random Rubble
*CCB: Cement Concrete Block

2.0 OCCUPANCY	3.0 SPECIAL HAZARD	4.0 FALLING HAZARD
2.1 Important buildings: Hospitals, Schools, monumental structures; emergency buildings like telephone exchange, television, radio stations, railway stations, fire stations, large community halls like cinemas, assembly halls and subway stations, power stations, Important Industrial establishments, VIP residences & Residences of Important Emergency person. **Any building having more than 100 Occupants may be treated as Important.* ***2.2 Ordinary buildings***:- Other buildings having occupants <100	3.1 High Water Table (within 3m) & if sandy soil, then liquefiable site indicated. Yes ☐ No ☐ 3.2 Land Slide Prone Site Yes ☐ No ☐ 3.3 Severe Vertical Irregularity Yes ☐ No ☐ 3.4 Severe Plan Irregularity Yes ☐ No ☐ **5.0 SPECIAL OBSERVATION** 5.1 Length of wall between two cross walls are as per IS:4326 or IS:13828. Yes ☐ No ☐ 5.2 Percentage of openings in walls is as per IS:4326 or IS:13828 Yes ☐ No ☐ 5.4 Ratio of height & width of wall is as per IS:4326 or IS:13828 Yes ☐ No ☐	4.1 Chimneys ☐ 4.2 Parapets ☐ 4.3 Cladding ☐ 4.4 Others ☐

5.0 Probable Damageability in Few/Many Buildings

Building Type	5.1 Masonry Building			
Damage- ability in Zone III	A	B / B+	C / C+	D
	G4	G3 / G2	G2 / G1	G1

Note: +sign indicates higher strength hence somewhat lower damage expected as stated. Also average damage in one building type in the area may be lower by one grade point than the probable damageability indicated.

Surveyor will identify the Building Type; encircle it, also the corresponding damage grade.

RECOMMENDED ACTION:-

☐ Ensure adequate maintenance.

☐ Detailed evaluation of B type for need for retrofitting.

☐ Detailed evaluation of A types for need for reconstruction or possible retrofitting.

☐ If any Special Hazard 3.0 found , re-evaluate for possible prevention/retrofitting.

☐ If any of the falling hazard is present, either remove it or strengthen against falling.

☐ Special observation if not compliant may lead to more severe damage and will call for retrofitting.

Surveyor's Sign : ____________
Name: ____________

Executive Engineer's Sign: ____________

Date of Survey: ____________

3 Rapid Visual Screening of Masonry Buildings for Seismic Hazards

Seismic Zone IV Ordinary Building

(Also for Zone III Important Building)

Photograph

Sketch Plan with Length & Breadth

1.1 Building Name ____________________

1.2 Use ____________________

1.3 Address: ____________________

____________________ Pin ________

1.4 Other Identifiers ____________________

1.5 No. of Stories ________ 1.6 Year Built ________

1.7 Total Covered Area; all floors (sq.m) ________

1.8 Ground Coverage (Sq.m): ________

1.9 Soil Type: ________ 1.10 Foundation Type: ________

1.11 Roof Type: ________ 1.12 Floor Type ________

1.12 Structural Components:

1.12.1 Wall Type: BB* ☐ Earthen ☐ UCR* ☐ CCB* ☐

1.12.2 Thickness of wall: ______ 1.12.3 Slab Thickness: ______

1.12.4 Mortar Type: Mud ☐ Lime ☐ Cement ☐

1.12.5 Vert. R/F bars: Corners ☐ T-junctions ☐ Jambs ☐

1.12.6 Seismic bands: Plinth ☐ Lintel ☐ Eaves ☐ Gable ☐

*BB – Burnt Brick, *UCR – Uncoursed Random Rubble
*CCB: Cement Concrete Block

2.0 OCCUPANCY

2.1 Important buildings: Hospitals, Schools, monumental structures; emergency buildings like telephone exchange, television, radio stations, railway stations, fire stations, large community halls like cinemas, assembly halls and subway stations, power stations, Important Industrial establishments, VIP residences & Residences of Important Emergency person.

**Any building having more than 100 Occupants may be treated as Important.*

2.2 Ordinary buildings:- Other buildings having occupants <100

3.0 SPECIAL HAZARD

3.1 High Water Table (within 3m) & if sandy soil, then liquefiable site indicated. Yes ☐ No ☐

3.2 Land Slide Prone Site Yes ☐ No ☐

3.3 Severe Vertical Irregularity Yes ☐ No ☐

3.4 Severe Plan Irregularity Yes ☐ No ☐

4.0 FALLING HAZARD

4.1 Chimneys ☐

4.2 Parapets ☐

4.3 Cladding ☐

4.4 Others ☐

5.0 SPECIAL OBSERVATION

5.1 Length of wall between two cross walls are as per IS:4326 or IS:13828. Yes ☐ No ☐

5.2 Percentage of openings in walls is as per IS:4326 or IS:13828 Yes ☐ No ☐

5.5 Ratio of height & width of wall is as per IS:4326 or IS:13828 Yes ☐ No ☐

RECOMMENDED ACTION:-

☐ A or B: evaluate in detail for need of reconstructions or possible retrofitting to achieve type C or D

☐ B+, C: evaluate in detail for need for retrofitting

☐ If any Special Hazard 3.0 found, re-evaluate for possible prevention/retrofitting.

☐ If any of the falling hazard is present, either remove it or strengthen against falling.

☐ Special observation if not compliant may lead to more severe damage and will call for retrofitting.

5.0 Probable Damageability in Few/Many Buildings

Building Type	5.1 Masonry Building			
Damage- ability in Zone IV	A	B / B+	C / C+	D
	G5	G4 / G3	G3 / G2	G2

Note: +sign indicates higher strength hence somewhat lower damage expected as stated. Also average damage in one building type in the area may be lower by one grade point than the probable damageability indicated.

Surveyor will identify the Building Type; encircle it, also the corresponding damage grade.

Surveyor's
Sign : ____________
Name: ____________

Executive
Engineer's
Sign: ____________

Date of Survey: ____________

4 Rapid Visual Screening of Masonry Buildings for Seismic Hazards

Seismic Zone V All Buildings

(Also for Zone IV Important Building)

Photograph

Sketch Plan with Length & Breadth

1.1 Building Name______________________________

1.2 Use______________________________

1.3 Address:______________________________

____________________ Pin __________

1.4 Other Identifiers______________________________

1.5 No. of Stories__________ 1.6 Year Built __________

1.7 Total Covered Area; all floors (sq.m) _______________

1.8 Ground Coverage (Sq.m):____________________

1.9 Soil Type: ________ 1.10 Foundation Type: ________

1.11 Roof Type:__________ 1.12 Floor Type__________

1.12 Structural Components:

1.12.1 Wall Type: BB* ☐ Earthen ☐ UCR* ☐ CCB* ☐

1.12.2 Thickness of wall:______ 1.12.3 Slab Thickness:______

1.12.4 Mortar Type: Mud ☐ Lime ☐ Cement ☐

1.12.5 Vert. R/F bars: Corners ☐ T-junctions ☐ Jambs ☐

1.12.6 Seismic bands: Plinth ☐ Lintel ☐ Eaves ☐ Gable ☐

*BB – Burnt Brick, *UCR – Uncoursed Random Rubble
*CCB: Cement Concrete Block

2.0 OCCUPANCY

2.1 Important buildings: Hospitals, Schools, monumental structures; emergency buildings like telephone exchange, television, radio stations, railway stations, fire stations, large community halls like cinemas, assembly halls and subway stations, power stations, Important Industrial establishments, VIP residences & Residences of Important Emergency person.

**Any building having more than 100 Occupants may be treated as Important.*

2.2 Ordinary buildings:- Other buildings having occupants <100

3.0 SPECIAL HAZARD

3.1 High Water Table (within 3m) & if sandy soil, then liquefiable site indicated. Yes ☐ No ☐

3.2 Land Slide Prone Site Yes ☐ No ☐

3.3 Severe Vertical Irregularity Yes ☐ No ☐

3.4 Severe Plan Irregularity Yes ☐ No ☐

4.0 FALLING HAZARD

4.1 Chimneys ☐

4.2 Parapets ☐

4.3 Cladding ☐

4.4 Others ☐

5.0 SPECIAL OBSERVATION

5.1 Length of wall between two cross walls are as per IS:4326 or IS:13828. Yes ☐ No ☐

5.2 Percentage of openings in walls is as per IS:4326 or IS:13828 Yes ☐ No ☐

5.6 Ratio of height & width of wall is as per IS:4326 or IS:13828 Yes ☐ No ☐

RECOMMENDED ACTION:-

☐ A or B, B+ : evaluate in detail for need of reconstructions or possible retrofitting to achieve type C+ or D

☐ C: evaluate in detail for need for retrofitting to achieve type C+, D.

☐ Wood : evaluate in detail for Retrofitting

☐ If any Special Hazard 3.0 found , re-evaluate for possible prevention/ retrofitting.

☐ If any of the falling hazard is present, either remove it or strengthen against fall.

☐ Special observation if not compliant may lead to more severe damage and will call for retrofitting.

Surveyor's
Sign :_______________
Name:_______________

Executive
Engineer's
Sign:_______________

Date of Survey:____________

5.0 Probable Damageability in Few/Many Buildings

Building Type	5.1 Masonry Building			
	A	B / B+	C / C+	D
Damage- ability in Zone V	G5	G5 / G4	G4 / G3	G3

Note: +sign indicates higher strength hence somewhat lower damage expected as stated. Also average damage in one building type in the area may be lower by one grade point than the probable damageability indicated.

Surveyor will identify the Building Type; encircle it, also the corresponding damage grade.

3.PROPOSED MODIFICATIONS IN RVS PROCEDURE

3.1 FACTORS THAT ARE ALREADY MENTIONED

The **factors that are already mentioned** in RVS procedures given in FEMA 154 and also in IS 13935-2009 that contribute to seismic assessment of a particular building are-

1) Structure Type

2) Height of building

3) Soil type

4) Code Detailing

6) Vertical irregularity

7) Special Hazards Like land slide prone areas, liquefiable soil are also mentioned

3.2 ADDITIONAL MODIFIERS

In the modified system for RVS that is being developed, the structural score system is adopted. Above mentioned factors are taken as such. In addition some new factors are introduced which modify the structural score. Some of these factors were already mentioned in previous reports but not included in calculating scores, while others are completely new.Together they are called "additional score modifiers". They are-

1) Age of Building

2) Condition of building (like Presence of vegetation, cracks, fallen plaster, exposed reinforcement, deflected members etc.)

3) Occupancy (gives the importance of building)

4) Falling Hazards (Claddings, parapets etc.)

5) Bottom Soft storey presence

6) Collateral Damage Vulnerability (like a tall tower in close proximity to the building)

7) Emergency services availability (presence of a fire station and hospital nearby)

8) Ease of Evacuation (construction of wider staircase, no. of exits)

Each of these additional modifiers is rated on a scale of 1 to 10 (except occupancy) to represent their degree of presence or dominance (denoted by D) in a particular structure. As every additional modifier affects the seismic vulnerability to different degree, hence a Sensitivity/weightage factor (denoted by W) is given to each additional modifier.

3.3 DECIDING THE CUT OFF SCORES

With the inclusion of additional modifiers the final cut off score is also modified.The table below gives the final cutoff modifying value.

Table 7: Table showing degree of presence or dominance (D),sensitivity factor (S) and final additional modifier score.

S.No.	Additional Score Modifiers	Degree of Presence or Dominance (D)	Nature of D	Sensitivity/Weightage Factor (W)	Final additional modifier score =[(+/-D) X (W)]
8.	Bottom soft storey presence	5	-	0.1	-0.5
9.	Occupancy	500	-	0.001	-0.5
10.	Condition of building	5	-	0.05	-0.25
11.	Age of Building	5	-	0.05	-0.25
12.	Collateral Damage Vulnerability	5	-	0.025	-0.125
13.	Falling Hazards	5	-	0.025	-0.125
14.	Ease of Evacuation	5	+	0.01	+0.05

15.	Emergency Services Availability	5	+	0.01	+0.05
FINAL CUT OFF MODIFYING VALUE (Summation of final additional modifier scores) = **-1.65**					

Hence we deduct 1.65 to each value of Final Structural Score S range (for various damageability grades) to get new ranges of S for same Damageability grades and also new value of S required to be used as a check if the building requires further evaluation or not. The results obtained are shown below:

Table 8: Final Cut Off scores and score ranges

ORIGINAL CUT OFF SCORES AND SCORE RANGES	**MODIFIED CUT OFF SCORES AND SCORE RANGES**
DAMAGE PROBABILITY BASED ON FINAL STRUCTURAL SCORE S RANGE	
S<0.3 → Grade 5 (High), Grade 4 (Very High)	S<-1.35 → Grade 5 (High), Grade 4 (Very High)
0.3<S<0.7 → Grade 4 (High), Grade 3 (Very High)	-1.35<S<-0.95 → Grade 4 (High), Grade 3 (Very High)
0.7<S<2 → Grade 3 (High), Grade 2 (Very High)	-0.95<S<0.35 → Grade 3 (High), Grade 2 (Very High)
2<S<3 → Grade 2 (High), Grade 1 (Very High)	0.35<S<1.35 → Grade 2 (High), Grade 1 (Very High)
S>3 → Grade 1 (High)	S>1.35 → Grade 1 (High)
NEED OF FURTHER EVALUATION	
YES if S < 2 (2 is the cut off score)	YES if S <0.35 (2-1.65=0.35 is the cut off score)

4.FIELD SURVEY AND RESULTS

4.1 INTRODUCTION

In this project 20 buildings of Ahmedabad were surveyed and were evaluated for the seismic performance by all the three methods.Damageability grade and structural scores are also shown in the table later. Comparison can be made among the three methodologies and suitable conclusions can be drawn.

4.2 BUILDING DETAILS

The building details are as given in the table on the next page.

Table 9:Building details

BUILDING NO	1	2	3
PARAMETERS			
BUILDING NAME	lemon restaurant	4D square mall	Swaminarayan school
ADDRESS	sabarmati	Visat gandhinagar highway	Ranip
No. OF STORIES	4	7	4
YEAR BUILT	N/A	2012	N/A
USE	Commercial	commercial	School
CONSTRUCTION DRAWINGS AVAILABLE	No	No	No
IMPORTANCE OF BUILDING	not imp	not imp	Not imp
BASIC SCORE MODIFIERS			
STRUCTURE TYPE(BASED ON FEMA 154)	C3	C1	C3
LOW RISE (< 4 STORIES)	0	0	0
MEDIUM RISE (4 - 7 STORIES)	1	1	1
HIGH RISE (> 7 STORIES)	0	0	0
VERTICAL IRREGULARITY	1	1	0
PLAN IRREGULARITY	0	1	0
CODE DETAILING PRESENT	1	1	1
SOIL TYPE 1/SOIL TYPE C (HARD SOIL)	0	0	0
SOIL TYPE 2/SOIL TYPE D (MEDIUM SOIL)	0	0	0
SOIL TYPE 3/SOIL TYPE E (SOFT SOIL)	1	1	1
LIQUIFIABLE SOIL	0	0	0
ADDITIONAL SCORE MODIFIER			
BOTTOM SOFT STOREY PRESENCE	-2	-8	-4
OCCUPANCY	-50	-400	-300
CONDITION OF BUILDING	-2	-1	-3
AGE OF BUILDING	-2	-1	-3
COLLATERAL DAMAGE VULNERABILITY	0	-1	-2
FALLING HAZARDS	0	-1	-1
EASE OF EVACUATION	2	6	4
EMERGENCY SERVICES AVAILABILITY	6	6	6

BUILDING NO	4	5	6
PARAMETERS			
BUILDING NAME	market area	Ratna jyot Society	Town planning &valuation department
ADDRESS	nirnay nagar	Nirnay nagar	Chandlodiya
No. OF STORIES	2	7	3
YEAR BUILT	N/A	N/A	N/A
USE	commercial	Residential	Office
CONSTRUCTION DRAWINGS AVAILABLE	No	No	No
IMPORTANCE OF BUILDING	Not imp	Not imp	Not imp
BASIC SCORE MODIFIERS			
STRUCTURE TYPE(BASED ON FEMA 154)	C3	C3	C3
LOW RISE (< 4 STORIES)	1	0	1
MEDIUM RISE (4 - 7 STORIES)	0	1	0
HIGH RISE (> 7 STORIES)	0	0	0
VERTICAL IRREGULARITY	1	1	1
PLAN IRREGULARITY	0	1	1
CODE DETAILING PRESENT	1	1	0
SOIL TYPE 1/SOIL TYPE C (HARD SOIL)	0	0	0
SOIL TYPE 2/SOIL TYPE D (MEDIUM SOIL)	1	0	0
SOIL TYPE 3/SOIL TYPE E (SOFT SOIL)	0	1	1
LIQUIFIABLE SOIL	0	0	0
ADDITIONAL SCORE MODIFIER			
BOTTOM SOFT STOREY PRESENCE	-4	-6	-4
OCCUPANCY	-100	-300	-200
CONDITION OF BUILDING	-2	-3	-2
AGE OF BUILDING	-4	-2	-3
COLLATERAL DAMAGE VULNERABILITY	-1	-1	-1
FALLING HAZARDS	-5	-1	-1
EASE OF EVACUATION	7	5	4
EMERGENCY SERVICES AVAILABILITY	6	6	6

BUILDING NO	7	8	9
PARAMETERS			
BUILDING NAME	Samarpan Society	kishor's house	Samandhar Elegance
ADDRESS	visat gandhinagar highway	visat highway	Sabarmati
No. OF STORIES	2	2	7
YEAR BUILT	N/A	N/A	N/A
USE	Residential	Residential	Commercial and Residential
CONSTRUCTION DRAWINGS AVAILABLE	No	No	No
IMPORTANCE OF BUILDING	Not imp	Not imp	Not imp
BASIC SCORE MODIFIERS			
STRUCTURE TYPE(BASED ON FEMA 154)	C3	C3	C3
LOW RISE (< 4 STORIES)	1	1	0
MEDIUM RISE (4 - 7 STORIES)	0	0	1
HIGH RISE (> 7 STORIES)	0	0	0
VERTICAL IRREGULARITY	1	0	1
PLAN IRREGULARITY	1	0	0
CODE DETAILING PRESENT	1	1	1
SOIL TYPE 1/SOIL TYPE C (HARD SOIL)	0	0	0
SOIL TYPE 2/SOIL TYPE D (MEDIUM SOIL)	1	1	0
SOIL TYPE 3/SOIL TYPE E (SOFT SOIL)	0	0	1
LIQUIFIABLE SOIL	0	0	0
ADDITIONAL SCORE MODIFIER			
BOTTOM SOFT STOREY PRESENCE	-2	-1	-3
OCCUPANCY	-100	-10	-100
CONDITION OF BUILDING	-2	-1	-2
AGE OF BUILDING	-2	-2	-2
COLLATERAL DAMAGE VULNERABILITY	-1	-1	-1
FALLING HAZARDS	-1	-1	-1
EASE OF EVACUATION	6	5	4
EMERGENCY SERVICES AVAILABILITY	5	6	7

BUILDING NO	10	11	12
PARAMETERS			
BUILDING NAME	dilip sir's house	Devnandan Desire society	prasu's hous
ADDRESS	Chandkheda Gam	Motera	Nirnay Naga
No. OF STORIES	2	6	3
YEAR BUILT	2006	N/A	
USE	Residential	Residential	Residential
CONSTRUCTION DRAWINGS AVAILABLE	No	No	No
IMPORTANCE OF BUILDING	Not important	Not imp	Not imp
BASIC SCORE MODIFIERS			
STRUCTURE TYPE(BASED ON FEMA 154)	URM	C1	URM
LOW RISE (< 4 STORIES)	1	0	1
MEDIUM RISE (4 - 7 STORIES)	0	1	0
HIGH RISE (> 7 STORIES)	0	0	0
VERTICAL IRREGULARITY	0	1	1
PLAN IRREGULARITY	0	1	0
CODE DETAILING PRESENT	1	1	1
SOIL TYPE 1/SOIL TYPE C (HARD SOIL)	0	0	0
SOIL TYPE 2/SOIL TYPE D (MEDIUM SOIL)	1	0	1
SOIL TYPE 3/SOIL TYPE E (SOFT SOIL)	0	1	0
LIQUIFIABLE SOIL	0	0	0
ADDITIONAL SCORE MODIFIER			
BOTTOM SOFT STOREY PRESENCE	-1	-4	0
OCCUPANCY	-20	-200	-20
CONDITION OF BUILDING	-2	-2	-1
AGE OF BUILDING	-2	-3	-3
COLLATERAL DAMAGE VULNERABILITY	-1	-1	-1
FALLING HAZARDS	-1	-1	-1
EASE OF EVACUATION	4	4	4
EMERGENCY SERVICES AVAILABILITY	6	6	6

BUILDING NO	13	14	15
PARAMETERS			
BUILDING NAME	Vithla exotica	Mayuri Aunty's house	Balaji Mall
ADDRESS	Motera	Nirnay Nagar	Visat Gandhinagar I
No. OF STORIES	5	2	5
YEAR BUILT	N/A	1990	N/A
USE	Residential + Commercial	Residential	Commercia
CONSTRUCTION DRAWINGS AVAILABLE	No	No	No
IMPORTANCE OF BUILDING	Not imp	Not imp	Not imp
BASIC SCORE MODIFIERS			
STRUCTURE TYPE(BASED ON FEMA 154)	C3	URM	C1
LOW RISE (< 4 STORIES)	0	1	0
MEDIUM RISE (4 - 7 STORIES)	1	0	1
HIGH RISE (> 7 STORIES)	0	0	0
VERTICAL IRREGULARITY	1	0	0
PLAN IRREGULARITY	0	0	0
CODE DETAILING PRESENT	1	1	1
SOIL TYPE 1/SOIL TYPE C (HARD SOIL)	0	0	0
SOIL TYPE 2/SOIL TYPE D (MEDIUM SOIL)	0	1	0
SOIL TYPE 3/SOIL TYPE E (SOFT SOIL)	1	0	1
LIQUIFIABLE SOIL	0	0	0
ADDITIONAL SCORE MODIFIER			
BOTTOM SOFT STOREY PRESENCE	-2	0	0
OCCUPANCY	-100	-20	-100
CONDITION OF BUILDING	-3	-1	-2
AGE OF BUILDING	-2	-3	-2
COLLATERAL DAMAGE VULNERABILITY	-1	-1	-1
FALLING HAZARDS	-1	-1	-1
EASE OF EVACUATION	4	6	4
EMERGENCY SERVICES AVAILABILITY	6	6	6

BUILDING NO	16	17	18
PARAMETERS			
BUILDING NAME	D Mart	Swimming Pool building	Mansi Hospital
ADDRESS	Visat Gandhinagar Highway	Ranip	Akhbarnagar
No. OF STORIES	3	2	5
YEAR BUILT	N/A	N/A	N/A
USE	Commercial	Commercial	Commercial
CONSTRUCTION DRAWINGS AVAILABLE	No	No	No
IMPORTANCE OF BUILDING	Not imp	Not imp	Imp
BASIC SCORE MODIFIERS			
STRUCTURE TYPE(BASED ON FEMA 154)	C3	C3	C1
LOW RISE (< 4 STORIES)	1	1	0
MEDIUM RISE (4 - 7 STORIES)	0	0	1
HIGH RISE (> 7 STORIES)	0	0	0
VERTICAL IRREGULARITY	0	1	1
PLAN IRREGULARITY	1	0	0
CODE DETAILING PRESENT	1	1	1
SOIL TYPE 1/SOIL TYPE C (HARD SOIL)	0	0	0
SOIL TYPE 2/SOIL TYPE D (MEDIUM SOIL)	1	1	0
SOIL TYPE 3/SOIL TYPE E (SOFT SOIL)	0	0	1
LIQUIFIABLE SOIL	0	0	0
ADDITIONAL SCORE MODIFIER			
BOTTOM SOFT STOREY PRESENCE	0	-1	0
OCCUPANCY	-50	-100	-100
CONDITION OF BUILDING	-2	-3	-2
AGE OF BUILDING	-2	-3	-2
COLLATERAL DAMAGE VULNERABILITY	-1	-1	-7
FALLING HAZARDS	-1	-1	-6
EASE OF EVACUATION	4	5	4
EMERGENCY SERVICES AVAILABILITY	6	6	6

BUILDING NO	19	20
PARAMETERS		
BUILDING NAME	Rupal Bhabhi's house	Supan-14
ADDRESS	shak bazar	Sabarmati
No. OF STORIES	2	5
YEAR BUILT	N/A	N/A
USE	Residential	Residential
CONSTRUCTION DRAWINGS AVAILABLE	No	No
IMPORTANCE OF BUILDING	Not imp	Not imp
BASIC SCORE MODIFIERS		
STRUCTURE TYPE(BASED ON FEMA 154)	URM	C3
LOW RISE (< 4 STORIES)	1	0
MEDIUM RISE (4 - 7 STORIES)	0	1
HIGH RISE (> 7 STORIES)	0	0
VERTICAL IRREGULARITY	0	1
PLAN IRREGULARITY	0	0
CODE DETAILING PRESENT	0	1
SOIL TYPE 1/SOIL TYPE C (HARD SOIL)	0	0
SOIL TYPE 2/SOIL TYPE D (MEDIUM SOIL)	1	0
SOIL TYPE 3/SOIL TYPE E (SOFT SOIL)	0	1
LIQUIFIABLE SOIL	0	0
ADDITIONAL SCORE MODIFIER		
BOTTOM SOFT STOREY PRESENCE	0	-2
OCCUPANCY	-20	-100
CONDITION OF BUILDING	-6	-3
AGE OF BUILDING	-4	-3
COLLATERAL DAMAGE VULNERABILITY	-1	-1
FALLING HAZARDS	-3	-1
EASE OF EVACUATION	4	4
EMERGENCY SERVICES AVAILABILITY	6	6

4.3 DAMAGEABILITY GRADES AND STRUCTURAL SCORE

Table 10: Damagibility grade and structural scores

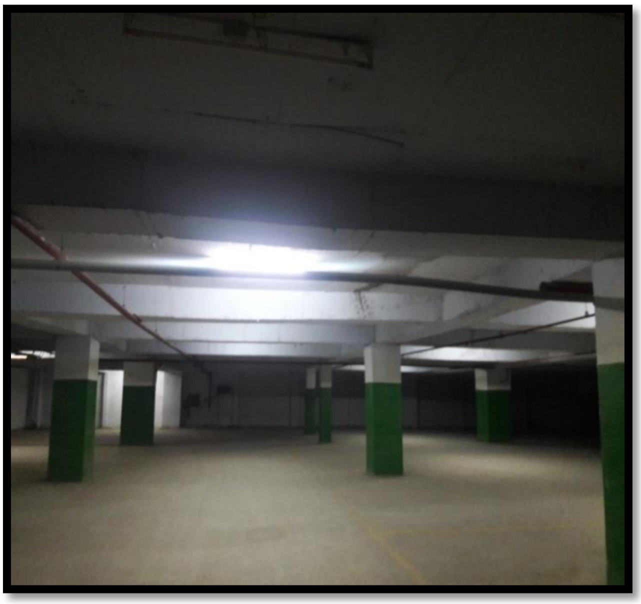
Building no.			**Damagibility Grade**				**STRUCTURAL SCORES**			**NEED FOR FURTHER EVALUATION**		
		RVS as per FEMA 154	RVS as per IS	New developed RVS		RVS as per FEMA 154	RVS as per IS	New developed RVS		RVS as per FEMA 154	RVS as per IS	New developed RVS
1		G2, G3	G2	G1,G2		1.6	-	1.23		Yes	Yes	Yes
2		G1, G2	No Damage	G2,G3		1.3	-	0.07		Yes	yes	Yes
3		G1	G2	G1		3.6	-	2.6		No	yes	No
4		G1, G2	G1,G2	G2,G3		1.8	-	0.98		Yes	yes	No
5		G2, G3	G1,G2	G2,G3		1.1	-	0.01		Yes	yes	Yes
6		G2, G3	G2	G2,G3		0.9	-	0.1		Yes	yes	Yes
7		G2, G3	G2	G1,G2		1.3	-	0.86		Yes	yes	No
8		G1	G2	G1		3.8	-	3.6		No	Yes	No
9		G2, G3	G2	G1,G2		1.6	-	1.06		Yes	Yes	No

10		G1, G2	G2	G1		2.6	-	2.3		No	No	No
11		G2, G3	No Damage	G2,G3		0.9	-	0.1		Yes	Yes	Yes
12		G2, G3	G2	G1,G2		1.1	-	0.93		Yes	No	No
13		G2, G3	G1	G1,G2		1.6	-	1.1		Yes	Yes	No
14		G1, G2	G2	G1		2.6	-	2.45		No	No	No
15		G1	No Damage	G1		3.4	-	3.15		No	No	No
16		G1	G2	G1		3.3	-	3.1		No	Yes	No
17		G2, G3	G2	G1		1.8	-	1.36		Yes	Yes	No
18		G2, G3	No Damage	G1,G2		1.4	-	0.87		Yes	No	No
19		G1, G2	G2	G1		2.6	-	2.08		No	No	No
20		G2, G3	G2	G1,G2		1.6	-	1.05		Yes	No	No

4.4 PHOTOGRAPHS

Building no.1

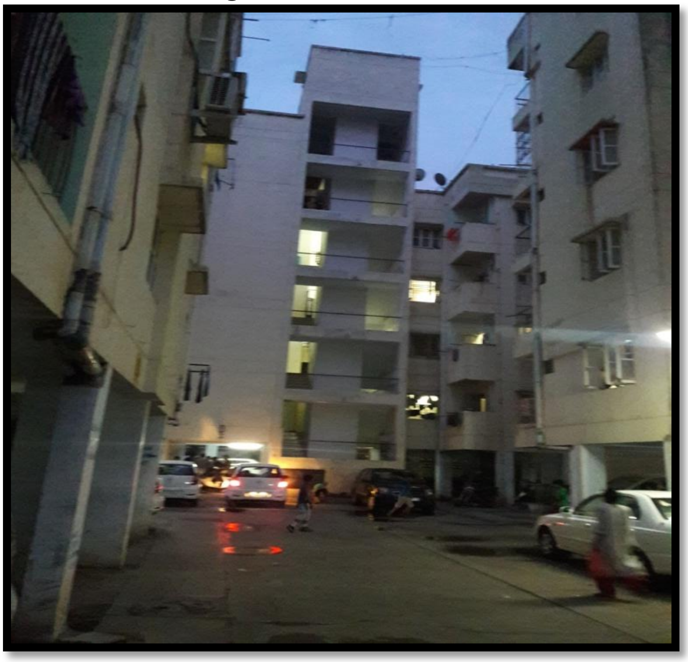
Building no 2



Building no 3

Building No 4

Building no 5



BUILDING No. 6

Building No 7

Building No.8

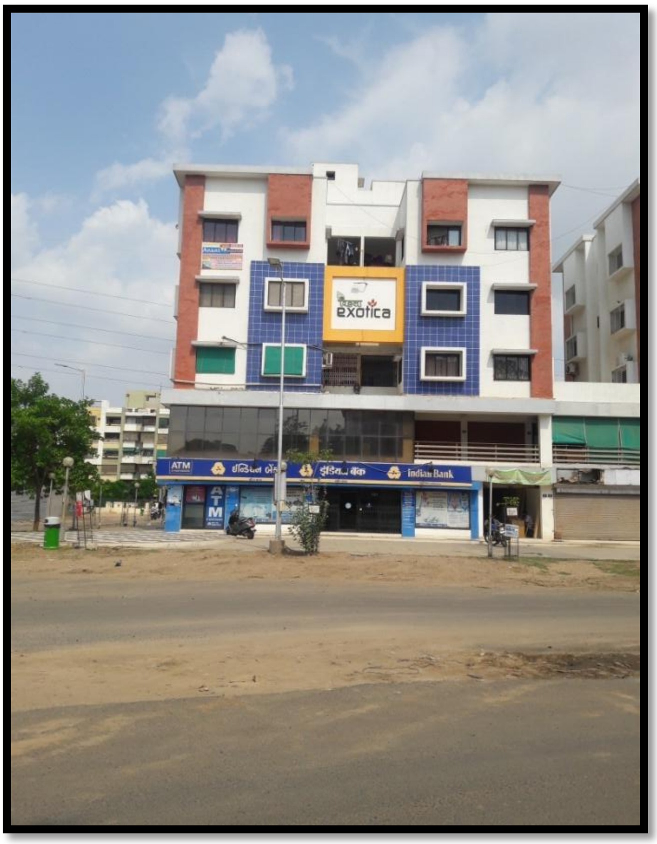
Building No.9

Building No 10

Building No 11

Building No 12

Building No 13



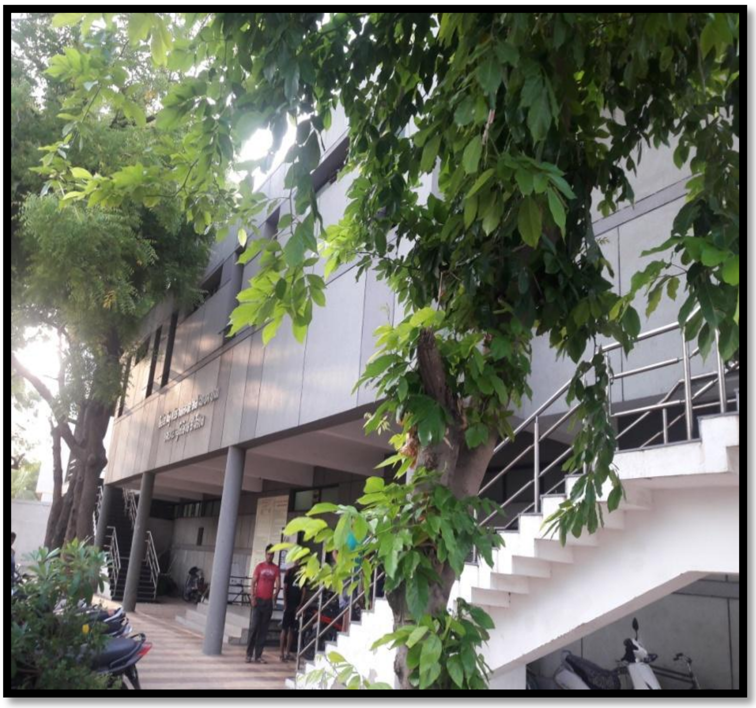
Building No 14

Building No 15

Building No. 16

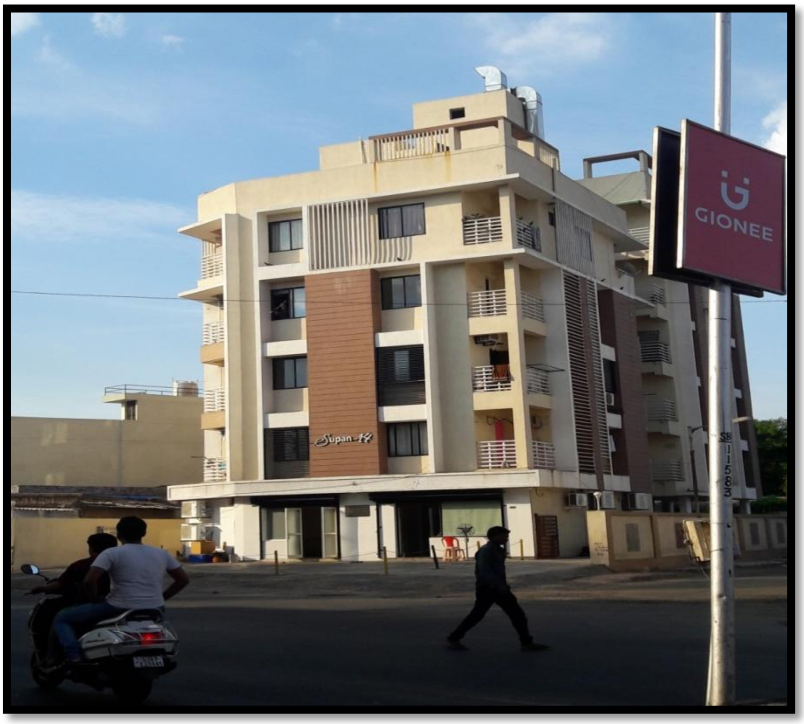
Building No 17

Building No 18



Building No. 19

Building No.20



5.CONCLUSIONS

Following are the conclusions of the study:

1. The New RVS methodology is more aligned with traditional FEMA 154 methodology, in terms of the Damagibility grade as compared to Indian standard method.
2. The New developed RVS methodology gives lower structural score as compared to traditional FEMA 154 methodology.This may provide conservative results and margin of safety in any proposed retrofitting scheme as per proposed new methodology would be greater.
3. The buildings which have the same structural score according to FEMA 154 (e.g. Building no.20,13,9,1) were found to have different structural scores as per the proposed RVS procedure.It may indicate the scope of new classification, as per proposed RVS methodology.
4. Out of 20 buildings of Ahmedabad that were surveyed, 20% buildings were found to expect no damage.Thus buildings may be classified as per RVS procedure in the categories of safe and unsafe buildings.
5. According to new RVS methodology, Building No. 8 is found to be the strongest and Building No. 2 is found to be the weakest with respect to seismic vulnerability . Different design/construction aspects of such buildings may be compared and significance of such aspects may be considered in condition assessment.

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