A Prognostics Earthquake Damage Scenario of Traditional and Conventional Housing in the Guwahati Urban Centre

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Abstract— An attempt has been made to present a prognostic earthquake damage scenario of Traditional and Conventional housing in the Guwahati urban centre. The Guwahati urban centre represents the Guwahati city development area as per the Comprehensive Master Plan 2025, which includes the Guwahati Municipal Corporation (GMC) area, the additional area towards western Guwahati, part of the eastern expansion and the newly formed wards in the North Guwahati area. The revenue villages around Guwahati are mostly dominated by Traditional houses for which Ikra bamboo-reinforced biomass are traditionally used as cladding material while thatch or corrugated iron sheets are used as roofing materials. The downtown area of the city has witnessed a sustained unscientific transition from Traditional housing practices to more vulnerable unconfined and confined masonry housing. The distribution of such houses over the ward level units of the city has been studied and the study has evaluated the damageability of these building based on their typology for earthquake intensity IX and the percentage of the building suffering various grades of damage are presented ward-wise as a prognostic damage scenario.

Index Terms— Earthquake, Intensity, Vulnerability, Damage Grade, Damageability, Building Typology

1 Introduction

An attempt has been in this study made to present a prognostic damage scenario of the Guwahati urban centre. The prognostic damage scenario of a given urban area starts with the understanding of the prevailing building types and the distribution of the building types within the study area. The Traditional Assam Type housing, which is well known for their seismic resistance are being replaced by more vulnerable confined or unconfined masonry house over the years. In this paper, the prognostic damage scenario of the vulnerable housing replacing the Traditional Assam Type houses is presented. The study area or the Guwahati urban centre, adopted here is the current Guwahati city development area as per the Comprehensive Master Plan 2025 (CMP–2025) published by GMDA (2009,2013).

2 Spatial Growth Pattern of Guwahati Urban Centre

The Guwahati urban centre originally represents the Guwahati Municipal Corporation (GMC) area, which is now expanded to Guwahati Metropolitan Area (GMA). The urban centre of Guwahati has seen the maximum expansion in the year 1990, with apparent growth in all direction. The expansion was more pronounced towards the southern side of the city. The total built-up land summed up to 132.19 km^2 in the year 1990. During the decade of 1990-2000, the city has witnessed a sprawl along the major corridors.

2.1 Extent of Study Area

The study area represents the Guwahati city development area as per the Comprehensive Master Plan 2025, which includes the Guwahati Municipal Corporation (GMC) area and the additional area towards western Guwahati, part of the eastern expansion and the newly formed wards in the North Guwahati area. The Guwahati Municipal Corporation (GMC) area is subdivided into 60 municipal wards as delineated by the Guwahati Municipal Corporation.

None of these wards shows any typical formation of building clusters and therefore a large number of data required to be collected through field survey. The footprints of individual buildings have been studied from satellite imagery such as Google™Earth. The survey of representative samples from these areas was conducted and the building data are generated based on sample survey over all the wards.

2.2 General observations - Built Environment

The revenue villages around Guwahati are mostly dominated by Traditional houses for which Ikra and bamboo-reinforced biomass was traditionally used as cladding material while thatch or corrugated iron sheets were used as roofing materials. The majority of houses in these villages around the city of Guwahati are of the Traditional Assam Type housing typology where the roofing system consists of timber / bamboo trusses supporting thatch or CGI sheets, and the wall system is made of Ikra and bamboo-reinforced biomass cladding. However, a

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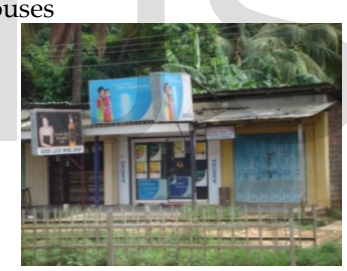
gradual shift towards confined/ unconfined masonry houses is observed in and around the city.

Figures 1.1 to 1.4 illustrate some randomly chosen buildings that are located in various wards of the Guwahati Municipal Area. Most of the residential buildings in Guwahati are constructed following socio-economic condition.


Figures 1.1 Traditional Housing - Assam Type Houses


Figures 1.2 Conventional Housing - Confined Masonry Houses

Figures 1.3 Conventional Housing - Unconfined Masonry Houses


Figures 1.4 Conventional Housing - Multilevel RC framed houses with light roofing

Figures 1.1 and 1.2 represent examples of residential buildings in Guwahati city which are primarily ductile or non-ductile RC frame structures with lightweight roofing systems. The roofs are generally pitched due to high rainfall in the rainy season. Since the year 1995-96 there has been a phenomenal increase in construction of multistoried (mostly G+5 to G+8) apartment and commercial buildings. The promotion for housing finance under the national housing policy fuelled the growth of apartment housing in Guwahati since the year 1990.

2.3 Building Typology Classification Procedure

The building classification scheme that is described herein resulted from various building inventory surveys conducted by Assam Engineering College (AEC) as provided in Pathak (2008) and AEC and NORSAR (2013, 2015). It reflects the building typologies and materials identified in the Guwahati urban area as well as in several revenue villages around Guwahati city. The classification is provided based on:

- Available wall materials
- Available roof and floor system types
- Available building typologies, i.e. regarding lateral load-resisting system and material

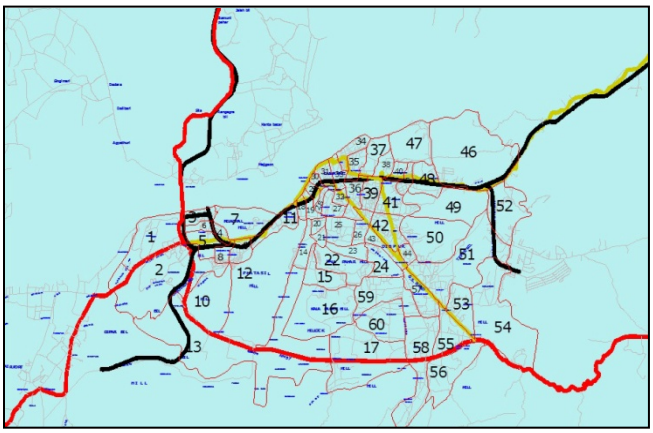
Guwahati's building stock is dominated by three groups of building typologies:

- Traditional Assam-type houses,
- confined/ unconfined clay brick masonry houses,
- ductile and non-ductile RC frame structures.

In the semi-urban and rural areas around the city, the 'Traditional Assam-type houses' are still observed as a major building stock, though being gradually replaced by confined masonry houses with a wide range of variations. However, the Traditional houses can still be found in large numbers in urban areas. In this work, damage scenario is studied for Traditional Assam Type houses, Unconfined Masonry houses and Confined Masonry houses. These types are classified as **W5, UFB4** and **RM3** respectively as per PAGER classifications as given in AEC and NORSAR (2013, 2015).

2.4 Inventory of Building Data

The process involved the compilation of existing building inventory data from the Microzonation report of the Guwahati City(AMTRON 2008; Pathak 2008). The compilation was followed by the conduct of random visual walk-down surveys in all wards and surrounding suburban areas (**Figure 1.7**) - collecting various parameters on the building's structural typology and occupancy.



Figures 1.7 GMA area showing old ward-wise division (old 60 Wards are merged to 31 Wards at present)

Structural typologies were assigned using a customized classi-

fication scheme for Guwahati. The study identified building typology distribution based on the results of the field survey for each ward.

2.7 Clustering of Study Area

Guwahati city is subdivided into subunits called wards as shown in **Figure 1.7**. Guwahati's ward map was revised in June 2013 when the Guwahati Municipal Corporation (GMC) decided to merge the previous 60 wards to 31 new wards. However, the present study is carried out over 60 wards continued based on the previous ward division.

2.7 Prognostic Damage Scenario

To develop prognostic damage scenario that is related to the direct structural damage of the building stock - the expected structural damage level are to be estimated for the various building typologies. The damage states considered are namely - slight, moderate, extensive and complete.

2.7.1 Definition of Damage States

Arya and Agarwal (2007) developed a procedure for probable damage assessment of various building typologies on behalf of National Disaster Management Authority (NDMA), India, under Govt. of India -UNDP initiative. Under the procedure developed, damageability grading system is proposed by identifying the (1) the primary structural lateral load-resisting system, and (2) building attributes that modify the seismic performance expected for this lateral load-resisting system along with non-structural components.

The screening is based on Code based Seismic Intensity, Building Type and Damageability Grade as observed in past earthquake and covered in MSK / European macro-intensity scale.

As per IS 1893:2002 (Part 1), India has been divided into four seismic hazard zones.

- Zone II, Zone III, Zone IV and Zone V
- Zone V Very high seismic hazard (maximum damage during earthquake may be of MSK Intensity IX or greater)

The study area falls in Zone V. The different building types experience different levels of damage depending on their inherent characteristics for a given earthquake intensity. The basic vulnerability class of a building type depends on the average expected seismic performance for that building type. All buildings have been divided into type A to type F based on the European Macro-seismic Scale (EMS-98) recommendations(Arya and Agarwal, 2007). The buildings in type A have the highest seismic vulnerability while the buildings in type F have the lowest seismic vulnerability as shown in **Table 1.1**.

The building vulnerability is stated to be highest with the use of local materials without engineering inputs and lowest with the use of engineered materials and skills. However, the Traditional building typology, the Assam Type housing (**W5**) is found to be of lowest vulnerability and much lower than even engineered buildings.

Table 1.1 Masonry Building Types classified by Arya and Agarwal (2007)

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.

Therefore, it is required to recast of the typology based vulnerability classification for Assam in general and Guwahati in particular.

2.8 Relationship Among Building Types, Earthquake Intensity and Damageability

Arya and Agarwal (2007) provides guidance regarding expected performance of the building in the event of design-level earthquake intensity postulated in a given seismic zone. The Indicative quantities ***Few***, ***Many*** and ***Most*** as defined in European Intensity Scales are as follows:

Few: Less than (15+-5) %; *Many*: Between (15+-5) to (55+-5) %; *Most*: Between (55+-5) to100%

As per MSK Intensity scale, the average values of these terms may be taken as follows:

Few: 5-15% ; *Many*: 50% ; *Most*: 75%

Table 1.2 Grades of Damageability of Masonry Buildings

NDMA (Arya and Agarwal, 2007)	Present Work
G1: Negligible to slight damage (no structural damage, slight non-structural damage)	Slight
G2: Moderate damage (Slight structural damage, moderate non-structural damage)	Slight
G3: Substantial to heavy damage (moderate structural damage, heavy nonstructural damage)	Moderate
G4: Very heavy damage (heavy structural damage, very heavy non-structural damage)	Extensive
G5: Destruction (very heavy structural damage)	Complete

The present study has defined the damage states in three levels - namely Slight, Moderate, Extensive and Complete. The damage levels considered in this work may be correlated as given in **Table 1.2**

In this study, prognostic damage scenario for Traditional Assam Type (**W5**), Unconfined Masonry (**UFB4**) and Confined Masonry (**RM3**) are presented to understand, how the unscientific transition from safer Traditional practices to vulnerable masonry houses has changed the damage scenario in and around the Guwahati urban centre. **Table 1.3** shows the correlated building classification as given by Arya and Agarwal (2007) - NDMA and present work.

Table 1.3 Correlated Building Classification

	NDMA	PRESENT WORK
Assam Type	**- NA -**	**W5**
Unconfined Masonry	**B, B+, C**	**UFB4**
Confined Masonry	**C+, D**	**RM3**

3.0 Analysis and Results

3.1 Distribution of Building Data Ward-wise

As discussed, the building inventory data comprised building inventory data from the Microzonation report of the Guwahati City(AMTRON 2008; Pathak 2008) and the building data collected through field surveys in all wards and surrounding suburban areas. Based on the results, a building typology distribution is identified for each ward and then extrapolated to the total number of buildings in the respective wards. The building distribution data was focused mainly on the Traditional Assam Type Houses and Conventional houses viz. Confined and Unconfined masonry houses.

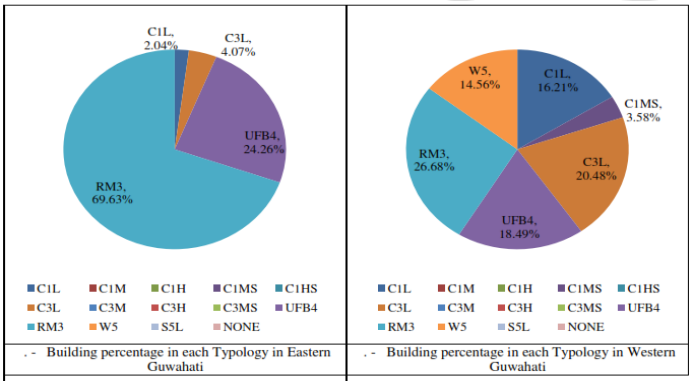


Figure 1.8 Building Typology Distribution in few typical ward level units around Guwahati

It has been observed from the building typology distribution of the city that, areas like Northern part of Guwahati is still dominated by the Traditional Housing – whereas the Western and Eastern extension of City Municipal areas are witnessing replacement of Traditional Housing (W5) with more vulnerable Unconfined Masonry Housing (UFB4)

It may also be seen from the Building Typology Distribution over the wards of the city that, the Traditional Housing is being replaced by Confined and Unconfined Masonry Housing or Non-Ductile / Ductile RC Housing towards the areas central to the study area.

3.2 Distribution of Building Damage Ward-wise

An attempt has been made in the study to present prognostic damage scenario of Traditional (Assam Type Housing) and Conventional (Modified Assam Type Housing in masonry) distributed around Guwahati Urban centre based on MSK Intensity scale IX and assigned damageability grades

The damage distribution of typologies **W5, UFB4** and **RM3** with various grades are presented in Figure 1.9 to Figure 2.2 in few wards of the city.

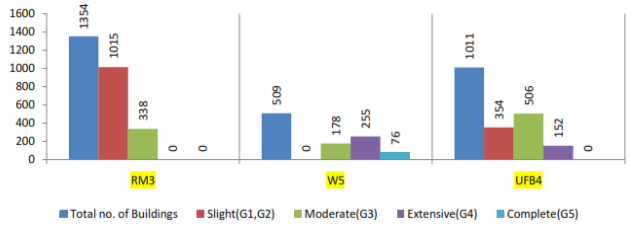


Figure 1.9 Number of Buildings with Typology and Damageability in WARD 1

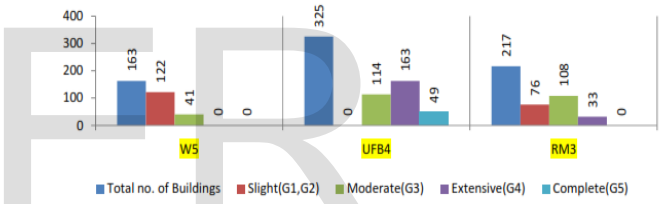


Figure 2.0 Number of Buildings with Typology and Damageability in Ward 14

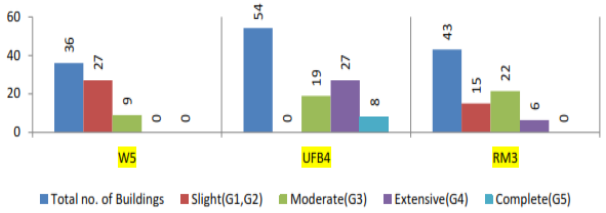


Figure 2.1 Number of Buildings with Typology and Damageability in Ward 21

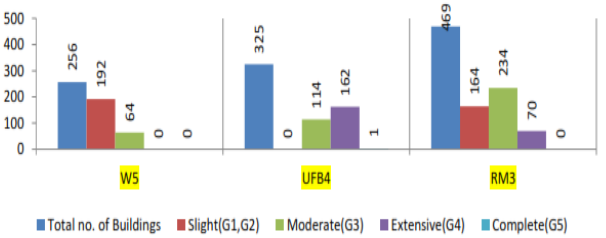


Figure 2.2 Number of Buildings with Typology and Damageability in Ward 62

It has been observed from the analysis that, there are approximately 32000 nos. of conventional Confined masonry houses distributed over the Guwahati urban centre and about 16000 nos. or 50% of these houses will experience moderate damage; whereas, about 11000 nos. of such houses will suffer slight damage and about 5000 nos. of such houses are likely to experience extensive damage.

In case of conventional Unconfined masonry houses, the numbers estimated are approximately 15000 and more than half of them are likely to experience extensive to complete damage, while about 6000 nos. of such houses are likely to experience moderate damage.

The overall nos. of Traditional Assam Type houses are approximately 8500 and 2000 nos. of such Traditional houses are likely to experience moderate damage whereas 6500 nos. of such houses are likely to experience only slight damage.

4.0 Conclusion

The study shows, there is unscientific transition from safer construction practice of Traditional Assam Type houses to more vulnerable construction practice viz. Unconfined or Confined Masonry houses. This transition has happened in and around the Guwahati urban centre due lack of Traditional building materials required to adopt Traditional housing practices. The study shows that, out of the Traditional

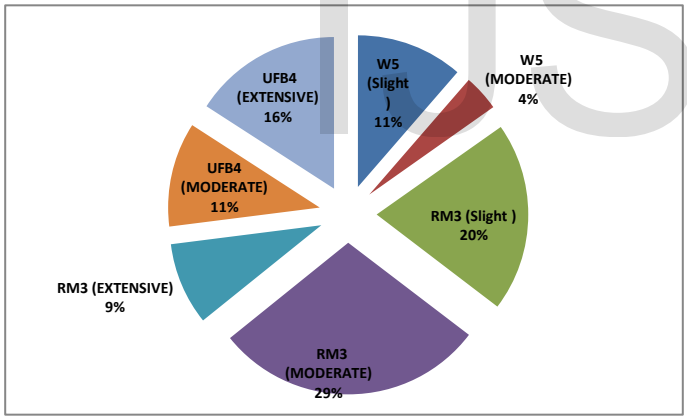


Figure 2.3 Number of Buildings with Typology and their Damageability

and Conventional building stock , 25% of the buildings will experience extensive to complete damage and 16% of these building stock are classified as vulnerable Unconfined masonry houses. About 40% of the building stock are likely to suffer moderate damage and they comprises mainly Unconfined and Confined masonry houses. It clearly shows that, the transition from Traditional to more vulnerable masonry houses has increased the seismic vulnerability of the building stock in the Guwahati urban centre. The study will help to identify these vulnerability to adopt a strategy of retrofitting at ward level units to reduce loss of life and property for probable earthquakes in future.

Acknowledgment

The authors gratefully acknowledges the support received from the work done under the "EQRisk" project at Department of Civil Engineering , Assam Engineering College in collaboration with NORSAR. The guidance and support received from Dr. Domink Lang, Head of Department "Earthquake Hazard and Risk", NORSAR foundation during the work is deeply acknowledged.

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