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Sustainable Design Ideas for Earthquake Prone Region

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Abstract—*It is said that Vishnu with thousand headed snake on which our planet rests, shakes its head, the earth quakes. An earthquake can cause devastation, uproot habitat on a scale far greater than any other individual natural disaster. And every year an average 30,000 people are killed by earthquake. This disaster has made everyone worried and discuss about reduction and mitigation measures. History tells us that earthquakes have shaped man's perspective over the century. 25 A.D, Taxshila near Rawalpindi was leveled to surface by an earthquake, resulting in preceding buildings had deeper substructures.*

Having now acknowledged that major parts of Indian subcontinent are seismically active. Hence the region which has experienced major earthquakes are vulnerable to re-occurrence in future. What is more confusing is the fact that the many buildings in these cities are not sustainable. And earthquake of higher magnitude can be anticipated but cannot be prevented. 100 percent earthquake resistant buildings are highly impractical. But it is possible to minimize the scale of damage by designing sustainable buildings. Design for earthquakes are meant to be such that during a minor shaking, zero to very little non structural damage may be allowed. It is crucially important to take hazards in seismic areas at a an early stage of concept. What measures could be adopted?

First step is to leap forward improving earthquake safety measures and visualize actual three dimensional behaviour of the structures. Training and research are very important mechanism to provide a stronger foundation for the future development. Knowledge is available in the country but to be harnessed and exploited. Hence the buildings in potentially seismic areas should be properly designed and executed. This paper will highlight simple sustainable approach towards designs and steps to reduce devastation by properly designing and by suitable modification to strengthen traditional methods.

Keywords: *Ground movement, Earthquake resistant, Liquefaction, Retrofitting, Horizontal bands, Seismic areas.*

1. Introduction

Earthquake the seismic disaster which Indian subcontinent and State of Assam has been experiencing over the centuries. This disaster is beyond our capability to predict and prevent. It is said that earthquake don't kill people but by buildings collapse created by peoples do! As the country has faced many earthquakes of different magnitudes in the past are more vulnerable to recurrence in future. Thus the structures in potentially seismic areas must be properly designed and constructed. Historic evidences revealed that great earthquake have shaped our outlook over millennium.

Traditional building design handed over the generations have accounted for quake resistant forms of building construction. The 1950 earthquake in Assam with a magnitude of 8.7 on the Richter scale resulted in a comparably lesser death toll of 1,500 due to the use of indigenous light weight materials in Assam type of houses available locally The architectural activities of Assam state can be dated back to 13th century during Ahom dynasty where structures were mostly timber and stones. From the references we can find only few structures for the royals which existed after 16th century and only lower the floors existed till date. And wooden upper floors were destroyed due to earthquake. Some Stone bridges of Ahom dynasty which could resist earthquake for many years are still intact carrying loads hundred vehicles daily..

The damage done by earthquakes cannot be overlooked. There is constant threat to life and property in zone V. By taking action today, we can reduce vulnerability with appropriate technology and materials suitable for North Eastern region. The solution is that the architect need not worry his creative design, but understanding the Richter scale. The architect/designer, however must remember that the structure he is designing is in a seismic zone. Which will be extremely helpful for the owner and he has to start interaction with structural engineer at the conceptual stage of the project.

How to sustain earthquake effects on buildings? First and foremost, awareness of people is needed to assess the safety of their building. They must be aware that it is possible to design sustainable habitat. We believe that these risk do not arise from destiny, but from non-engineered structures.

Inclusion of disaster management at engineering curriculum is a necessity. This paper will focus simple sustainable design ideas for earthquake prone region and steps to reduce damage during earthquake. It is a must that buildings in potentially seismic zone should be designed and detailed. - "a house which is a basic necessity not a luxury of every human being, should after all provide all aspect of security". Hundred percent earthquake proof houses are cost prohibitive.

2. Objectives

i. To design and construct buildings that they are sustainable for earthquake prone areas.

ii. To review the basic concepts involved in achieving appropriate sustainable buildings in North eastern region of India.

iii. To identify potential earthquake hazards in structures.

3. Methodology

A methodical study is done on secondary data and first hand experiences. The secondary data is reviewed from published articles on journals, internet and newspapers. A significant numbers of documents were collected and shortlisted for detail reviewing and study purposes.

4. Illustration of the study area

Special attention is given to state of Assam and targeting other parts of North Eastern region of India . Assam falls in the Zone V of seismic map. Mild ground shaking are familiar in this region, high intensity are very rare. In 1950 Assam has experienced earthquake magnitude of 8.7 on the Richter scale with many for socks and after socks.

Topography: ▪ Latitude- Extending from 24dg. 8'North to 28 dg.2'. North, ▪ Longitude – Extending from 89 dg 42 East' to 96 dg. East

5. General principle for earthquake resistant buildings

A absolute earthquake resistant building will be cost prohibitive.

The earthquake resistant design principle may be described as follows:

a) The building should be able to withstand minor but frequent shaking that takes place in the region. The main superstructure that is subjected to vertical and horizontal forces cannot be damaged, but parts that are not subjected to load may sustain little repairable damage. (Fig.1a)

b) The building should be able to withstand moderate earthquake called design basic earthquakes (DBE) with occasional shaking during the life span of the building, the main superstructure may resist without significant structural repairable damage, while other parts building may be destroyed. (Fig.1b)

c) The building will be able to withstand a sudden and maximum considered earthquake (MCE), main superstructure may resist extreme or even irreparable damage, but the properly designed structure would not be able to collapse. (Fig.1c)

(a) Minor shaking **(b) Moderate shaking** **(c) Maximum shaking**

Fig. 1: Behaviour of buildings under different intensities of shaking

The primary goal for sustainable design is to prevent collapse and loss of life. Buildings for essential services must be functional with minimum probability of collapse in post earthquake. And public building must sustain repairable damage and should withstand higher magnitude of earthquake. Assam has many hydro power plants, can be catastrophic causing flood in the plains, which will arise a secondary disaster during major earthquake.

6. General principles can be practical for North Eastern Region

Improvement detail and construction practices

- The building should be as lighter with its safety requirement. Roof and upper stories should be as light as with structural feasibility and functional necessities
- The whole structure must be properly attached to behave as one unit. When future extensions are required utmost care is needed to ensure its continuity between old and new parts. Additions and alternations to the building should be done with provisions of "separation''(Fig.2). of the "crumple" section between the new and the old structure,
- Overhang beyond the building is not advisable. If projections are provided these should be properly fixed .
- Building plans as far as possible should be symmetric. Non-symmetrical building plans lead to heavy torsion.
- Stone masonry walls with more than 350 mm should be avoided.
- Buildings should have foundation for uniform soil and sufficient soil bearing capacity, Liquefaction might occur in unstable soils during ground shaking and object might float. If unavoidable, suitable soil stabilization is a must.
- C.G.I sheets, Poly vinyl sheets and asbestos sheets are preferable to tile roof.
- It is necessary to provide good fixing for the roof with the walls and foundations. Diagonal braces in the plan should be provided if truss roofs for lateral forces.
- Vertical walls in brick masonry should be properly built with breaking of vertical joints between courses. Special care should be taken to ensure stability at corners. Provision of normal reinforcement at corners of walls improves overall performance.
- Openings in walls reduce their lateral load resistance. The total length of opening should be less than 40% for single-storied and 35 % for double storied buildings. Horizontal band at lintel level considerably improves the total performance of the building block.
- Walls towards rain direction lose their strength due to penetration of moisture and care should be taken to avoid seepage of water. Weather shield plastering and paint is required..
- Roof trusses or rafters should be avoided over an opening, particularly in case of mud walls.
- Provide minimum two to three , continuous horizontal bands of wooden collar beams adequately fixed at the corners. One such band should be near the plinth and other just below the roof which provide the overall integrity of the building.
- Slabs should be rigidly connected or cast with the support beams.

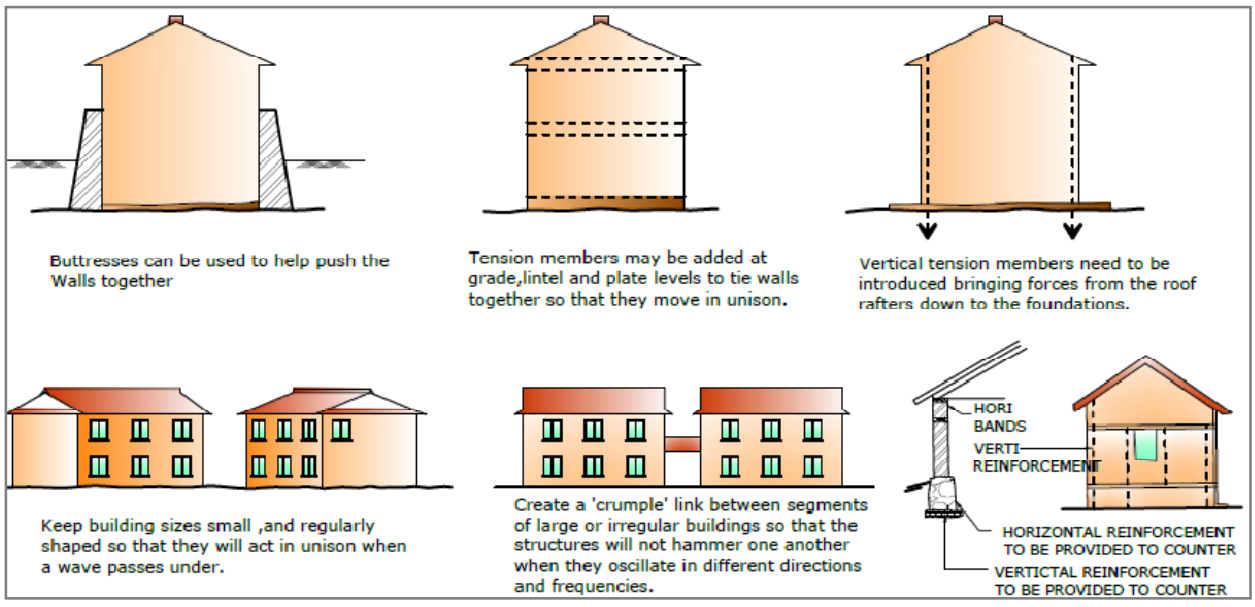


Fig. 2: Modification and improvement of hazardous structures in earthquake prone areas

7. Architectural features that affects during earthquake

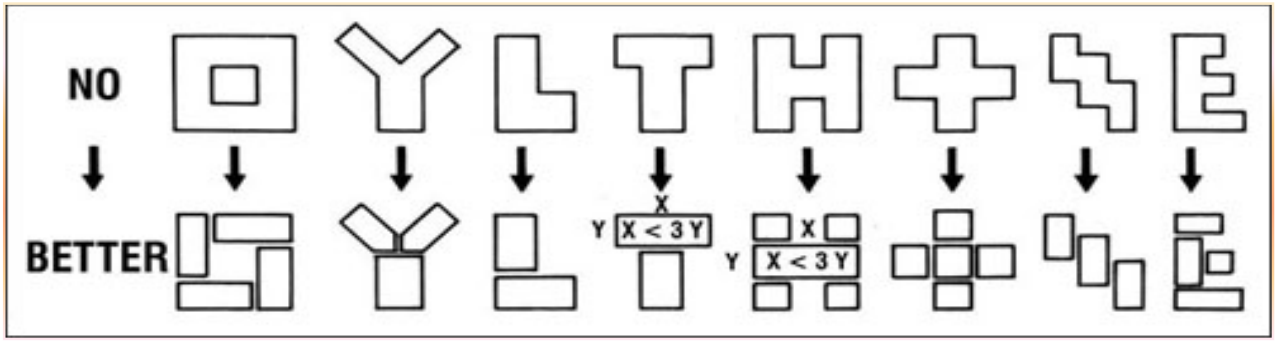
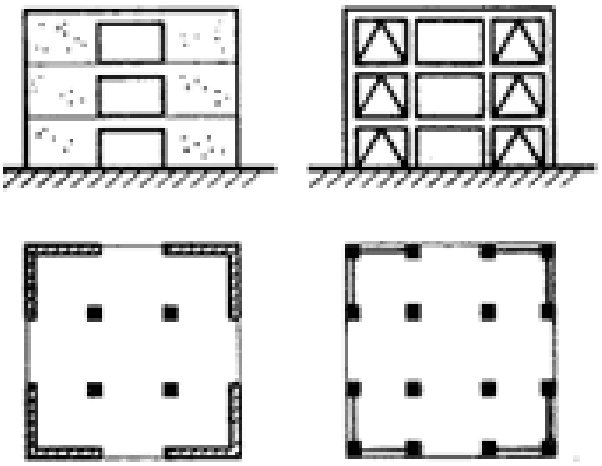


Fig. 3: Simple building plans and separated units.

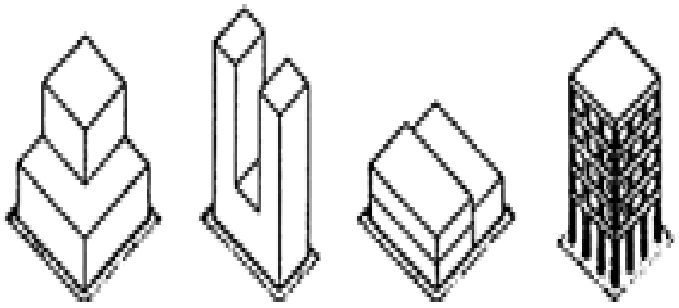
- Architectural features that are detrimental to earthquake should be minimized. Heavy water tanks and swimming pools should be at the centre of the roof or at ground level to counter balance the earthquake forces. Symmetrical plan and regular configuration (Fig. 4) do well and produces uniform deformation in vertical element. Shape like H ,L, T, E and Y with re-entrant corners should be broken into simple units (Fig.3). Asymmetrical causes eccentricity which leads to torsion and stress concentration.



Shear wall **Bracing in corners**

Fig. 4: Regular configuration

Building with setback, very tall structure and split level should be avoided as they inefficient to seismic forces (Fig. 5).



Setbacks **Tall towers** **Split levels** **Soft storey**

Fig. 5: Building with setback, split level and tall towers

The height**:** depth ratio of the structure should be limited to three to four. Symmetrical shapes can be overtaken by asymmetrical shapes with more insight into earthquake related studies.

- Horizontal band of reinforced concrete are the most important resistant feature in masonry building to impact horizontal bending strength (Fig.6) & (Fig.7). One such band should be constructed in the plinth level other just below the roof for overall integrity of the building (Fig.9).

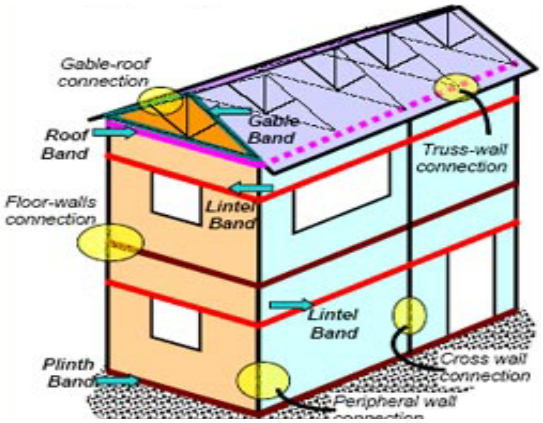


Fig. 6: Horizontal bands at different level

Fig. 7: Suggestion of Horizontal bands at different level as protective measures.

- Cantilever or overhanging parts damage more in earthquake (Fig.8). But where it is necessary should be properly designed by considering earthquake load and should be fully attached to the main frame .

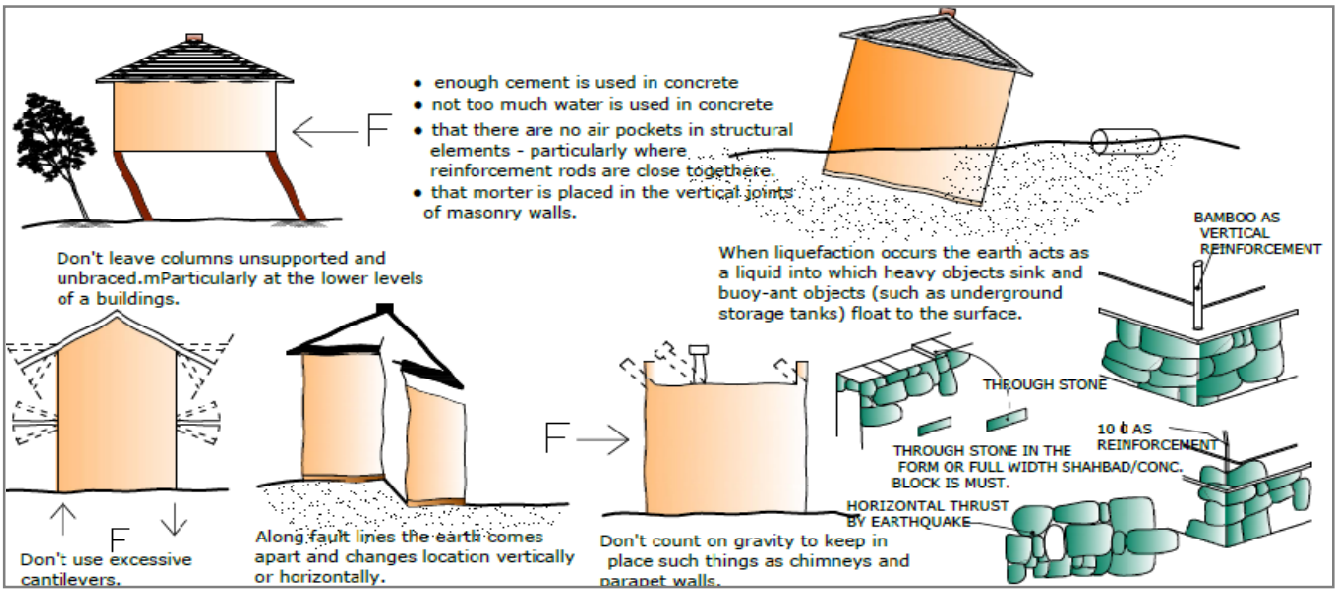


Fig. 8: Diagram indicating faulty constructions and few simple detailing of rubble walls.

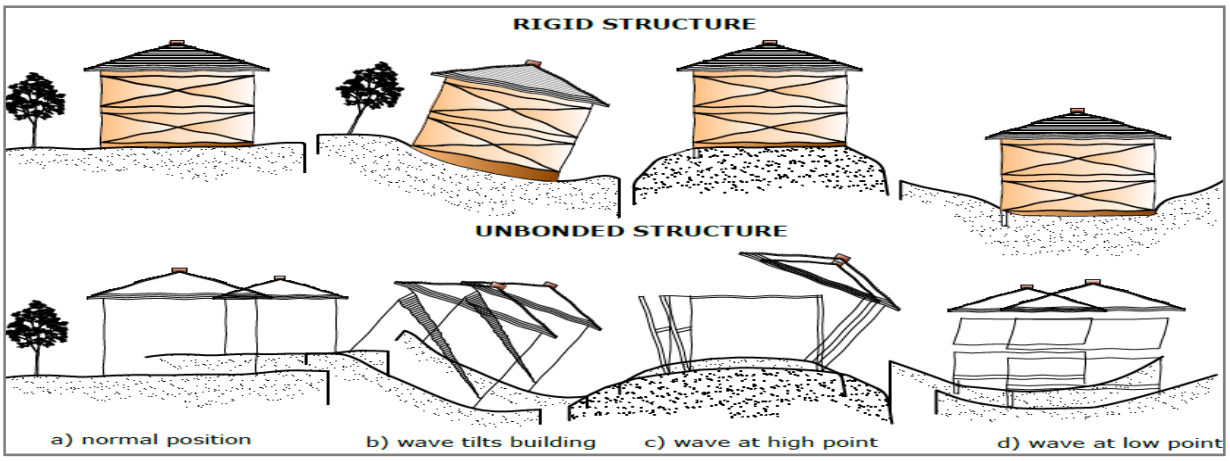


Fig. 9: Performance of connected (rigid) & disconnected (unbonded) houses during earthquake at different intensities.

- The principle of strong-column weak-beam design method should be adopted in seismic areas. Buildings above 15m in height should be framed structures. Very tall building should be checked for wind and earthquake load.
- Avoid soft storey on the ground floor **(** Fig. 10). Columns

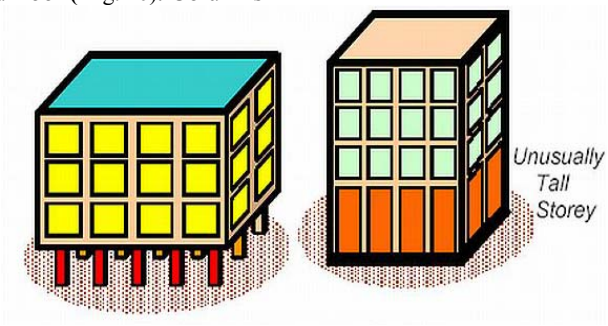
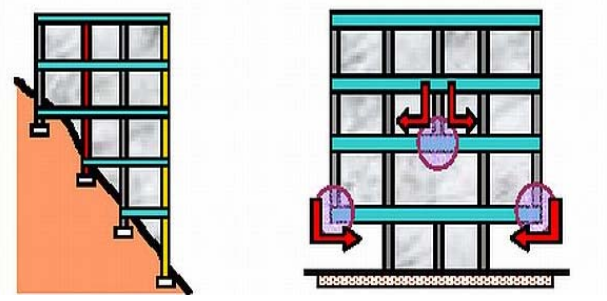


Fig. 10: Building block with flexible soft storey

with bracing or damper and shear walls are required to prevent the structure from shearing apart when the lower part attempts to move under the upper part (Fig.9).

Hilly slopes should be avoided which are liable to slide during an earthquake (Fig. 11). It is advisable to have many



Sloping site **Floating column**

Fig. 11: Building block in slope and block with soft storey

smaller blocks on terraces rather one large block. Building on slopes has unequal height of columns, which causes ill effects twisting and damage in shorter columns. Floating columns are undesirable for earthquake.

- Columns and structural masonry walls behave very unfavorably during earthquakes. Mixed systems of columns and structural masonry walls must therefore be avoided in North Eastern Region.

- Specialized methods like base isolator and seismic dampers can be introduced (Fig. 12). The concept of base isolator can withstand strong earthquake ground movement. Dampers act as hydraulic shock absorbers.

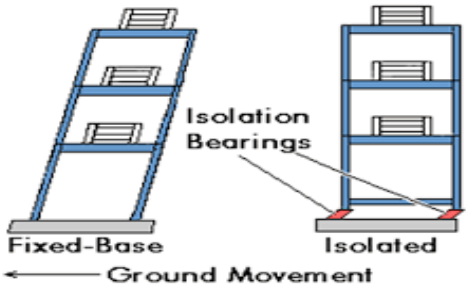


Fig. 12: Building with Base isolator

- Site inspection and quality control out most important. Regular testing of materials at laboratory, updating training of skilled labourers and on site evaluation are elements of quality control for sustainable buildings.

8. Rehabilitation of venerable buildings in earthquake prone areas

Repair and rehabilitation of existing buildings for seismic evaluation is far beyond construction engineering. This requires a lot assessment of the structures. Seismic retrofitting techniques to that extend in Assam may be very costly and can reduce but not totally eradicate damage. The conventional methods to rehabilitate old structure are– brace frame, jacketing columns, beams, shear wall, buttress and foundation.

8.1 Checklist invisible defects in a building to reduce vulnerability during earthquake.

Appoint trained professional to evaluate feasibility and invisible defects in building before acquiring a house.

- Structures more than 20- 25 years old, it is wise to take advice of professional related to structure.
- Never opt for a property with a tilt. It may be due to settlement or sinking in loose soil.
- Extra space is complementary but additional construction like balcony, extra pent house on terrace and removal support members may cause hazards.
- It is preferable to purchase a property that does not require any refurbishment. If there are water marks on the floor, seepage or around the edges of tiles, it could be a crack. Walls should not bend more than 9 mm.
- Be aware of freshly painted old buildings or modification. This may be to hide the earlier defects. It is advisable to take professional help to prevent any disaster.

9. Conclusions and Recommendations

Earthquake a natural disaster which is unavoidable and best we can do is to take steps to reduce to damage and avoid the loss of human life. Creations, which arise from innocence, do rage people not that earthquake. Minimizing earthquake risk is a top agenda not only for architects and civil engineers but for policy makers also. Earthquake and risk reduction are an integral part of sustainable development. To create an aesthetic and functionally efficient structure drives architects to conceive wonderful and imaginative structures. Hence, at the preliminary stage itself, architects and structural engineers must work in synergy to ensure that the undesirable designs are eliminated and visualize a seismically correct conceptual design to achieve building without incurring any significant additional costs.

Study shows that highlighted principles are generally applicable to new building design. Rehabilitation highly recommended for aged structures showing signs of survival. Retrofitting and future expansions embroils contribution of high end technical expertise in the field.

Exploitation of resources is required and it should trickle down to people, otherwise our development of modern techniques and ideas will remain confined to books and publications.. The reviewed general guidelines and details highlighted in this paper can be utilized as earthquake protection measures in buildings. Educational curriculum should include specialized research centre in the Zone V for dissemination of technology.

Our future emphasis is to update the quality of construction and use building codes. Apply the knowledge of base isolator, seismic dampers in new buildings. The answer lies with Government as the facilitator of building process, public awareness and skill training.

Today, new structures in earthquake prone areas are required to be designed to sustain earthquake without collapse with smart use of latest technologies based on local available data. The quality of life in Assam can be improved to some extent by earthquake safe constructions which will reduce damage and increase awareness among the citizens

10. References

[1] Architecture of Assam - Dr. P.C. Sharma
[2] Realty Plus. Vol.2. Nov. 2005
[3] https://www.struckts.com- Design Basic
[4] Earthquake Tips – C.V.R. Murty, IIT Kanpur
[5] Architectural + Design – May- June, 2001
[6] Indian Architect & Builder Nov. 1996
[7] National Programme on Earthquake Engineering Education (www.nice.org/npeee)
[8] https://theconstructor.org/structural-engg/architectural- features-seismic-resistance/2719/
[9] https://www.sekisuichemical.com/about/division/housing/eart hquake/index.html
[10] Architecture, Time Space & People (vol.11. Aug 2011)