# Innoations in Disaster: Earthquake - Resistant Construction and Practices

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## I.INTRODUCTION

In rural areas of India as well as in the semi-urban pockets a major part of the housing construction is undertaken with the help of local masons without any intervention of the engineers. These masons are usually trained in an informal way and begin their careers as assistants to senior masons. The capacity of such masonsdepends on the skills of senior masons. It has been observed that most of them do not possess the required capacity to build hazard-resistant buildings, which is evident from the devastation in Latur, Uttarkashi, Chamoli, and Bhuj earthquake and Orissa super cyclone.

Therefore, the priority of the masons' training programs conducted under the Disaster Risk Management Programme has been on skill up-gradation of practicingmasons through appropriate hands-on training.

This manual can be used as a ready reference by the trained masons and will alsobe equally helpful for the site supervisors, engineers, and homeowners who want their houses to be built by masons.

Vulnerability to Disasters India has been vulnerable, in varying degrees, to a large number of natural, as well as, human-made disasters on account of its unique geo-climatic and socioeconomic conditions. It is highly vulnerable to floods, droughts, cyclones, earthquakes, landslides, avalanches, and forest fires. Out of 36 states and union territories in the country, 27 of them are disaster-prone. Almost
58.6 percent of the landmass is prone to earthquakes of moderate to very high intensity; over 40 million hectares (12 percent of land) are prone to floods and rivererosion; of the 7,516 km long coastline, close to 5,700 km is prone to cyclones and tsunamis; 68 percent of the cultivable area is vulnerable to drought and hilly areas are at risk from landslides and avalanches.

*Advantages of Resistant Construction*

1) Risk informed approach while constructing for efficient response during adisaster.
2) A basic set of guidelines for construction even for non-engineered buildingsto follow with suitable illustrations.
3) Providing a checklist sheet for onsite safety engineers to ensure theinstructions & regulations are being followed.
4) Proposing a subsidy based plan to encourage builders for adopting disasterresistant construction practices in

hazard prone regions.

5) Safeguarding life & property by taking proper mitigation measures.
6) Faster recovery from hazard.
7) Ensuring longevity of the structure.
8) Minimum amount of damages resulting in economic stability even afterdisaster.
9) Better preparedness in times of calamity.
10) Easier and more economical remodeling & rebuilding after disaster.

*Aim of the Project*

1. Understanding various techniques/technological advancements pertaining to a particular disaster. Each disaster has its own unique problems which require its own unique approach and needs to be dealt with with extreme care. Understanding them briefly can make a huge difference in reducing theimpact of the disaster. (For example use of base isolation devices or seismic dampers to reduce the impact of the earthquake).
2. The use of such advancements/techniques either during construction or post-construction of nonresistant structures to reduce the impact of a disaster. Analysis of a technique and determining if it's feasible economically as well as technically (as skilled or educated labor/mason may not be able to understand/use/acquire the said technique).
3. To come up with the most efficient & economical construction techniques and or technological advancements keeping in mind the available materials, practicability & economic conditions of the region.
4. Ill effects of said natural disasters on the economy as well as the loss of human life & ecosystem to calculate the practicability of a disaster-resistant structure.
5. Brief information regarding the rehabilitation & disaster management & litigation activities by both government & non-government organizations which help us in these testing times
6. A brief study of Indian standards & codes as well as popular foreign publishing regarding disaster-resistant structures & preventive construction.
7. To understand & predict the future possibilities of such structures & preventive technologies in our country & if possible come up with practical & economical preventive measures.

*Objectives*

1) Investigation & Analysis of past data regarding disasters that occurred inIndia to identify and narrow down the hazard-prone regions.
2) Assessment of damage caused by the adversities of disasters to buildings.
3) Evaluating the causes of damage and proposing mitigations.
4) Examining new technologies and practices, being followed over the worldfor disaster-resistant construction.
5) Submitting region-specific guidelines for hazard-resistant construction ofbuildings.
6) Repairing and proposin gretrofitting measures for existing buildingsunequipped of the same.

*Our Approach*

Case Study Review.

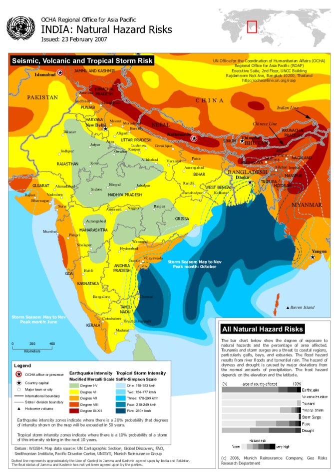
1) In-depth analysis regarding causes, frequency & magnitude of various natural disasters (like earthquakes, cyclones, tsunamis, sandstorms, floods, landslides, etc) prevalent across the country to form the basis of our project work.
2) Isolating regions of study by considering the above-mentioned factors.
3) Research and examination of existing practices of construction.
4) Investigation & Examination Of new methodologies.
5) Filtering the technologies suitable for the region of study.
6) Building practical guidelines in an illustrative and easy-to-understandformat.
7) providing alternatives and options for native as well as professional buildersin the set rule book.
8) Compilation of the work and cross-examination with the existingstandardized codes.

## II. MAJOR DISASTERS IN INDIA AND THEIR DATA

*REGION-WISE DISTRIBUTION OF DISASTERS IN-COUNTRY,INTENSITY, AND FREQUENCY.*

| YEAR | DISASTER | STATE | FATALITIES | ECONOMIC LOSSES IN CR | PEOPLE AFFECTED |
|---|---|---|---|---|---|
| 2001 | EARTHQUAKE | GUJRAT | 20000 | 49358 | 250000 |
| 2005 | FLOOD | MAHARASHTRA | 1150 | 32264 | 15000 |
| 2006 | FLOOD | GUJRAT | 350 | 31820 | 4000000 |
| 2009 | FLOOD | ANDHRA PRADESH | 300 | 41662 | 2000000 |
| 2013 | FLOOD | UTTRANCHAL | 5748 | 20054 | 275000 |
| 2014 | STORM | ANDHRA PRADESH | 68 | 55500 | 1000 |
| 2014 | FLOOD | J&K | 665 | 47730 | 100000 |
| 2015 | FLOOD | TAMIL NADU | 289 | 21238 | 150000 |
| 2015 | STORM | HIMALAYA | 80 | 750 | 20000 |
| 2018 | FLOOD | KERALA | 504 | 26048 | 223139 |
| 2020 | HURRICANE | WEST BENGAL | 103 | 99900 | 500000 |

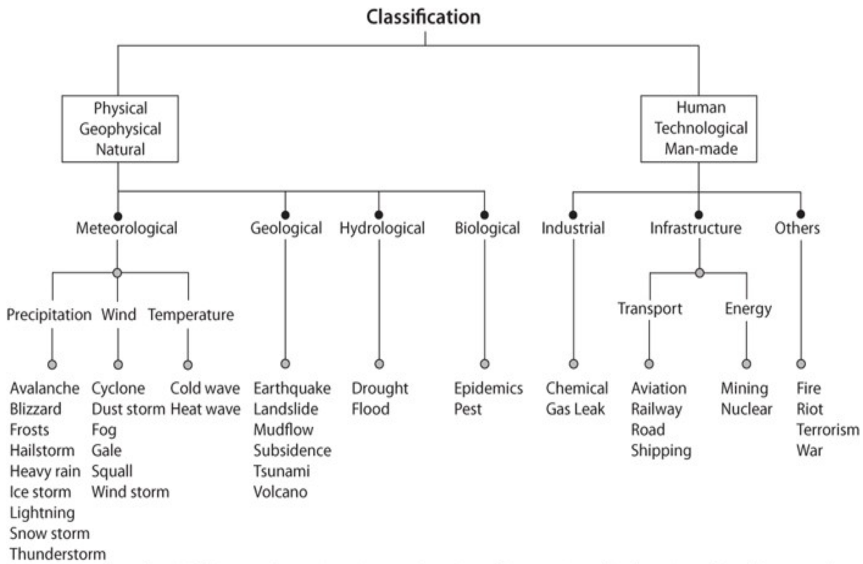
*DISASTERS & THEIR CLASSIFICATION*




*VULNERABILITY PROFILE OF INDIA*

- India is vulnerable in varying degrees to a large number of natural as well asman-made disasters.
- Over 40 million hectares (12 per cent of land) is prone to floods and river erosion.
- 58.6 percent of the landmass is prone to earthquakes of moderate to very high intensity.
- Of the 7,516 km long coastline, close to 5,700 km are prone to cyclones and tsunamis.
- 971 Blocks in 183 Districts covering an area of 74.6 million hectare identified as drought prone areas and hilly areas are at risk from landslides and avalanches.

- Further, vulnerability to Nuclear, Biological and Chemical (NBC) disasters and terrorism has also increased.




*Source:* Based on the High Power Committee Report (2001) and International Federation of Red Cross and Red Crescent Society (2001).

*CASE STUDY 1*

A Case Study - Low-cost Earthquake resistant house using Cold-Formed Steel [CFS] member.

Introduction: A design of the simple-to-construct small residential building is presented which has the capability to meet the strength and serviceability requirements of major seismic activity.

Cold-Formed member (CFS), a material recommended by AISI-97, is proposed for this house. CFS performs excellently due to its strength. This will be a very economical option for temporary and permanent construction for the years to come.

Structures cannot be completely earthquake-proof, but a good seismic design will minimize structural damage, and most importantly, safeguard the lives of the occupants during a major seismic event. Seismic resistance is best achieved by following modern building codes and standards and in large or complex buildings, using the services of a professional structural engineer.

*Methodology*

<u>1.</u> *Cold-Formed Member [CFS]*

The use of cold-formed steel members in building construction began in 1850 in both the United States & Great Britain. The method of manufacturing is important as it differentiates these products from hot rolled steel sections. Normally, the yield strength of steel sheets used in cold-formed sections is at least 280 N/mm2. Cold-formed steel structural members are shapes commonly manufactured from steel plate, sheet, or strip material. The manufacturing process involves forming thematerial by either press-braking or cold roll-forming to achieve the desired shape. Cold roll-forming is the most widely used method for the production of roof, floor,and wall panels.

*FEATURES OF PROPOSED HOUSE*

The principal material for this house is CFS. It consists of metal panels placed side by side connected with girts using bolts (Figures 5). CFS is selected because it is recommended by AISI as a very good option for making small size houses. Furthermore, all the constituent materials are easily available in the market; the panels are lightweight, which are easy to cast, transport, and assemble. The system has been designed with the do-it-yourself concept in mind. Back-to-back C sections are used for column and rafter and single Z sections are used for girts & purlins.

**Figure 5:** Three dimensional Model of house

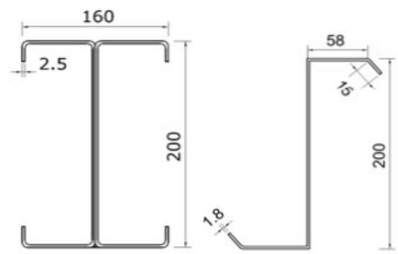



**Figure 8:** Profile of Steel column , Girts and Purlins

*RESISTANCE AGAINST EARTHQUAKE*

Resistance against earthquakes is the primary requirement for any structure. This house is modeled using Staad-Pro, software based on the finite element method, and its response under the seismic activity of zone four is checked. The pseudo-Static analysis is carried out with earthquake forces applied along with both the principal directions. Building connections are considered as hinges at support and fixed at eave and ridge.CFS member is defined as column and rafter in Staad- Pro. Final Stresses in software especially at joints, displacement and sway due to the earthquake are carefully noted for various load combinations. Some of the important Information related to analysis and design is presented below

*GEOMETRY OF BUILDING*

Size of House =7.0mx7.0m , Eave Height of House =3.0m , Roof Slope = 1:10 ,Sidewall Bay Spacing = 2 @ 3.5m, Endwall Bay Spacing = 2 @ 3.5m

*LOADING PARAMETER FOR ANALYSIS OF BUILDING*

a. Dead Load =0.15 kN/m2
b. Live Load =0.57 kN/m2 (Table 3.1)
c. Wind Speed = 44 m/sec. (Nagpur)
d. Wind Pressure =0.84 kN/m2 (Table 5.2(b).) Earthquake Zone = IV
e. Building Condition:
f. Building Design as Enclosed = +/- 0.25 (As per MBMA)
g. Deflection Limit of Building:
h. Sway of Frame = H/100
i. Vertical Deflection of Frame =L/180 Loading Combinations:
j. 1. DL+LL
k. 2. DL+WL
l. 3. DL+EQ

Section Used for Analysis of Column and Rafter:

After the selection of basic parameters of building we need to select the section size for Design of Frame.
*ANALYSIS OUTPUT*

Following results are the maximum out of all combinations.
a. Dead Load Reaction = 2.34kN
b. Live Load Reaction = 7.22kN
c. Maximum Bending Moment =8.31kN-m
d. Maximum Shear Force =9.03kN
e. Sway under Earthquake = 25.0mm < 35.0mm (OK)

Critical Stresses envelopes in the frame are well below the strength of CFS members. Further, the deflection under gravity loads and sway under earthquakes are also working.

*i) FLEXIBILITY OF EXTENSION*

The flexibility of extension and ease of alteration are two of the important features. Although this house is proposed as a 2BHK room, the design has the flexibility to add row houses, etc. Adding more and more frames at a suitable location makes theextension very simple. This small unit can be extended to build a field hospital, combined residence, messing facility, and a warehouse, etc.

*ii) LIGHT ROOFING SYSTEM*

One of the major causes of damage during earthquakes was heavy roofs. During anearthquake the weak vertical supports could not survive and came down with a thick layer of mud, burying everything under it.

Lightweight roofs are better than heavier ones because they:

- Generate lesser force
- Cause less damage if they fall.

The roof system of this proposed house consists of GI corrugated sheets with members of cold-formed rafter & purlin. Every CFS member is strongly coupled with panels by bolted steel fixtures. Bracing connects to the rafter and column member. Wooden trusses, which have been in common use, are deliberately avoided as they are comparatively heavier and cause more damage to life and property in case of collapse.

*a) FOUNDATIONS*

The total service load reaction is 9.56kN which yields a foundation size of 650mm x 650mm for a net allowable bearing capacity of two tons/ft2[200 kPa]. The column is proposed as a 230mm x 230mm RCC block with a 250mm total depth. Total foundation depth is proposed as 450mm. The connection between foundationblocks and columns is developed by an anchor bolt of 16mm diameter with a 230mmx230mm base plate section.

*b) OPENINGS*

Doors can be located at any desired position. It is just a matter of removing the panel and fitting the door jamb and header with a connection bolt and the door opening is ready. Panels with windows and ventilators can also be cast but it is recommended to have ventilators on the roof.

**Table 1:** Estimated cost of proposed house

| Components | Weight of Coldformed steel members. (kg) | Cost of Coldformed steel members. (Rs) |
|---|---|---|
| Primary Members (Column and Rafters) | 764 | 35908 |
| Secondary members (Purlins and Girts ) | 1043 | 49021 |
| Roof and Wall sheeting | 670 | 26130 |
| Connection Plates and Base Plates | 75 | 7500 |
| Secondary (Trims & Flashing) | 599 | 26955 |
| Anchor Bolts | 40 | 2000 |
| Gutter (RM) | 52 | 20000 |
| Downspouts (RM) | 19 | 3800 |
| Cemnet Bags(Nos.) | 13 | 4200 |
| Sand (m3) | 0.88 | 780 |
| Crush(m3) | 1.77 | 1880 |
| Steel | 77.5 | 3300 |
| Total weight of the building (Kg) | | 181474 |

*4) Tentative Cost*

It can be confidently said that cost will not cross rupees 181474/-, which means it is rupees 345/- per square foot. The cost can also be quoted as rupees 7910/- per foot length with a width of [7.0m]. As stated previously, this structure can be easilyextended so the approximate cost for any size can be easily calculated.

## CONCLUSION

1. The main objective of this research work is that its behavior under a majorseismic activity is satisfactory.
2. It can bear the shock with little or no damage. Catastrophic failure will beavoided in any case thus minimizing the loss of life and property.
3. This structure is not only suitable for temporary use but for permanentconstruction as well.
4. Multiple or repetitive uses makes the structures viable with unmatchedsaving from the conventional or classical structure.
5. For such prefabricated CFS members, even erection shall be donemanually without using cranes and other machinery.
6. Time required to construct such buildings shall be a distinct advantage incase of calamities, shelters specially and other structures also.
7. The most important advantage of the designed structure is that it shall be100% salvaged or reused because of its ease of dismantling.
8. It is concluded that in the emergency scenario of economic development,cold-formed steel products have a good future and promise.