To,

13th Aug 2012

The Dean (R&C)
National Institute of Technology
Hamirpur

Sub: Forwarding of Final Project Report on Development of state-specific guidelines for earthquake safe constructions

Respected Sir,

Please forward the attached final Project Report on Development of state-specific guidelines for earthquake safe constructions to the following address.

The Principal Secretary (Rev)
Govt. of Himachal Pradesh
Shimla

Thanking you

Your Sincerely

Dr Hemant Kumar Vinayak
Assistant Professor
Department of Civil Engineering
National Institute of Technology
Hamirpur -177005

forwarded
13/8/2012

CED-825
Dated: 13-8-2012

Advance Copy

To,

13th Aug 2012

The Principal Secretary (Rev)
Govt. of Himachal Pradesh
Shimla

Sub: Final Project Report on Development of state-specific guidelines for earthquake safe constructions

Respected Sir,

This is in reference to the mentioned. Please find enclosed the Final report of the project on "Development of State-Specific guidelines for Earthquake Safe constructions". In the project 3000 copies of Mason Guide for Improving Earthquake Resistance of Non-Engineering Construction for the Districts of Himachal Pradesh and 3000 copies of Owner Guide for Non-Engineered Construction have been developed. Out of these 2000 copies of Mason Guide and Owner Guide respectively have been delivered to the your DM Cell Department of Revenue Shimla for the distribution during various training for the mason/supervisors/engineers/architects in the state and Himachal Pradesh and the rest 1000 copies have kept by the under signed for distribution in the various relevant trainings being by NIT Hamirpur.

Thanking you

Your Sincerely

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National Institute of Technology
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Advance Copy to:

1. State Project Officer GoI-UNDP DRR Programme Department of Revenue DM Cell, Shimla.

Forwarded
13/8/2012

C.ED-826
Dated: 13-8-2012

DEVELOPMENT OF STATE-SPECIFIC GUIDELINES FOR EARTHQUAKE SAFE CONSTRUCTIONS

FINAL REPORT

Submitted to
Government of Himachal Pradesh,
Department of Revenue(DM Cell)

DEPARTMENT OF CIVIL ENGINEERING
NATIONAL INSTITUTE OF TECHNOLOGY HAMIRPUR
HAMIRPUR – 177 005

AUGUST 2012

NATIONAL INSITUTE OF TECHNOLOGY HAMIRPUR

PROJECT INVESTIGATOR'S DECLARATION

I hereby certify that the work being presented in the project entitled **"Development of State specific guidelines for earthquake safe construction** is work carried out during the period from Jan 2012 to August 2012. This project was sponsored by Disaster Management Cell, Department of Revenue Government of Himachal Pradesh.

Project Investigator

Dr. Hemant Kumar Vinayak
Assistant Professor
Department of Civil Engineering
National Institute of Technology
Hamirpur - 177 005 (H.P.)

ACKNOWLEDGEMENT

The principal investigator is obliged to Disaster Management Cell, Department of Revenue, Himachal Pradesh for giving the opportunity to work for developing some guidelines for earthquake safe construction which would be beneficial for the construction worker in this state.

I am grateful to Sh Deepak Sanan Financial Commissioner (Revenue R&R) GOHP for approving the proposal of demarcation of zone V and zone IV as per the district demarcation of Himachal Pradesh for non-Engineered construction. I am thankful to Sh D.C. Rana State Project Officer UNDP (Himachal Pradesh) for his continuous support during the project be it approval of financial transaction, development of guidelines or conduct of trainings.

I am thankful to the students of batch 2009-13 who have considered it to be one of the best assignments given to them and had carried out the survey of building in the district of Hamirpur and delivered their best. Their names have been mentioned in the report.

I especially thankful to the following students/associates who have been attached with me for the specific work

Priyanka Pandit and Sukriti Dogra students of 2009-14 batch, Department of Architecture NIT Hamirpur for assistance in development of mason guide.

Ankita Sood Ex-Architect, Design Action Group, NIT Hamirpur for assistance in development of owner guide.

Shashwat Srivastava 2008-12 batch student Department of Civil Engineering, NIT Hamirpur for assistance in development of mason guide and reports.

Yogendra Bais for developing the webpage of survey carried out by the students of NIT Hamirpur

Finally I am thankful to the Department of Civil Engineering and National Institute of Technology Hamirpur for giving me the approval to work with the HPSDMA GOHP.

Dr Hemant Kumar Vinayak

CONTENTS

1. INTRODUCTION: The state is Himachal Pradesh being highly seismic zone hence such practices should be followed by various those involved people in the construction that generate safe building and are capable of withstanding earthquake However it has been also been sometime felt that codal provision are only limited to the engineers and skill worker are unaware about the codal provision. It has also been observed that in the cases of the construction, the engineers is not always involved hence necessitate the generation of such guidelines and tools which can be distributed through the hands-on training programs to masons, carpenters, bar benders and supervisors. These guidelines and tools should be evolved through some sample surveys and workshop. The guidelines should also be developed for the key players on the constructions i.e. Junior Engineer, Sub-Divisional officer and Executive Engineer. Keeping inview the above aspect the objectives covered in the first phase of this project work are:

- To develop a tool which can be used by bar-benders, masons and supervisors in the field where the instructions from engineers are not available in the state of Himachal Pradesh.
- To develop software for those who are in working in design office in the state of Himachal Pradesh.
- To conduct workshops for bar-benders, masons and supervisors for capacity building in earthquake safe construction and obtain the suggestions to simplify the developed too.

2. MASON GUIDE TOOL

The construction practices that the mason follows are overlooked by the owners and hence lead to deficient construction in respect of earthquake provisions. Hence a tool needs to be developed that would assists the mason during construction keeping in mind their constraint.

2.1 Methodology: The basis of developing the tool for masons, bar-benders and supervisors was that the earthquake hazard map of Himachal Pradesh (BMTPC: Vulnerability Atlas – 2nd Edition; Peer Group, Ministry of Housing and Urban Poverty Alleviation; Map is based on the digitized data of Survey of India, Government of India; Seismic Zones of India Map IS: 1893: 2002; Seismotectonic Atlas of India, Geological Survey of India, Government of India) is not known to them. During construction, the masons do not carry the seismic vulnerability map of India. Hence, are not able to apply the earthquake resistant provisions for non-engineered constructions. Even if the masons, bar-benders and supervisors involved in non-engineered construction are provide with the seismic vulnerability map, these semi-skilled worker will not know about the exact seismic zonation in the state of Himachal Pradesh as the line of demarcation is not related with the locations and hence are not able to follow the exact or clear cut guidelines at the place of work.

However, the mason being clearly aware about the place of work knows exactly the districts in which he is working. Hence, it is necessary that guidelines which can simplify the process of constructing earthquake resistant structures be developed which are in line with implementation of the earthquake resistant provisions.

Further, the codal provisions of non- engineered constructions in which the engineers are hardly involved are not followed correctly. The construction, mostly carried out by the masons, bar-benders, is with the experience either from their forefathers or knowledge from the colleagues. Thus, it is difficult for the state disaster mitigation authorities, such as in the present case of Himachal Pradesh State Disaster Mitigation Authority, to have a state/region where the disaster resistant measures are implemented effectively, leading to a scenario of a region highly vulnerable to a disaster in case of a hazard, such as an earthquake.

It is further necessary that such tools be developed which are easily acceptable to the masons and bar benders. These tools will comply with the guidelines and the code of practice of the Bureau of Indian Standards new Delhi. The language of communication of these tools should also be in line with the language of communication of masons, bar benders and supervisors.

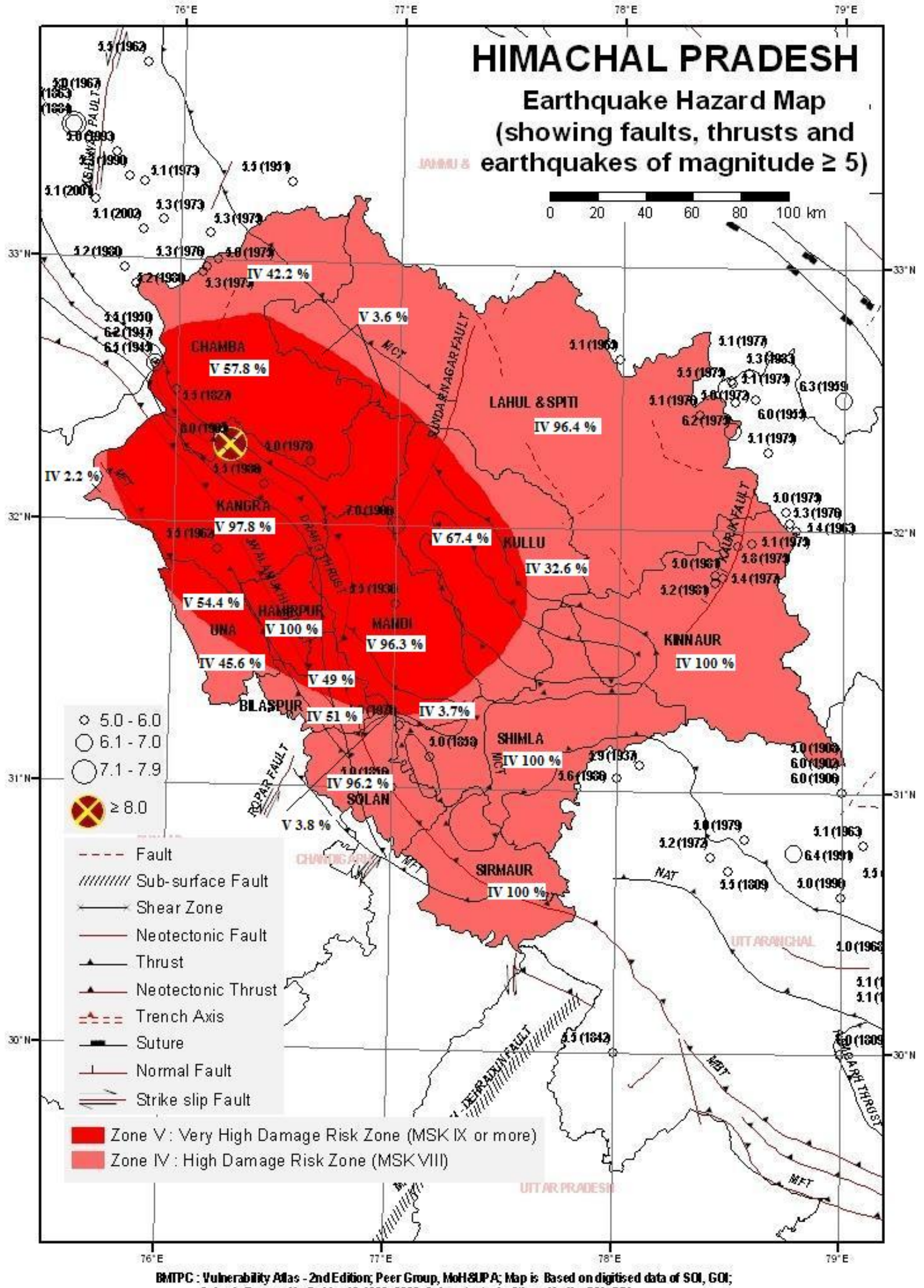
Considering the above lacunas, the tool with the following parameters has been developed (Fig. 1, Fig.2). The whole state of Himachal Pradesh is either in Zone IV or Zone V. Presently following are the areas of districts of Himachal Pradesh lying in Zone IV or Zone V (Fig. 2).

	District	Percentage area in Zone V	Zone IV
a)	Hamirpur	100% in Zone V	
b)	Kangra	97.8% in Zone V	2.2% in Zone IV
c)	Mandi	96.3% in Zone V	3.7% in Zone IV
d)	Kullu	67.4% in Zone V	32.6% in Zone IV
e)	Chamba	57.8% in Zone V	42.2% in Zone IV
f)	Una	54.4% Zone V	45.6% in Zone IV
g)	Bilaspur	49.0% in Zone V	51.0% in Zone IV
h)	Lahul & Spiti	96.4% in Zone IV	3.6% in Zone V
i)	Solan	96.2% in Zone IV	3.8% in Zone V
j)	Kinnaur	100% in Zone IV	
k)	Shimla	100% in Zone IV	
l)	Sirmaur	100% in Zone IV	

The above information shows that the line of demarcation of Zone IV and Zone V in the state of Himachal Pradesh are not in line with the district demarcation of Himachal Pradesh. However, if such

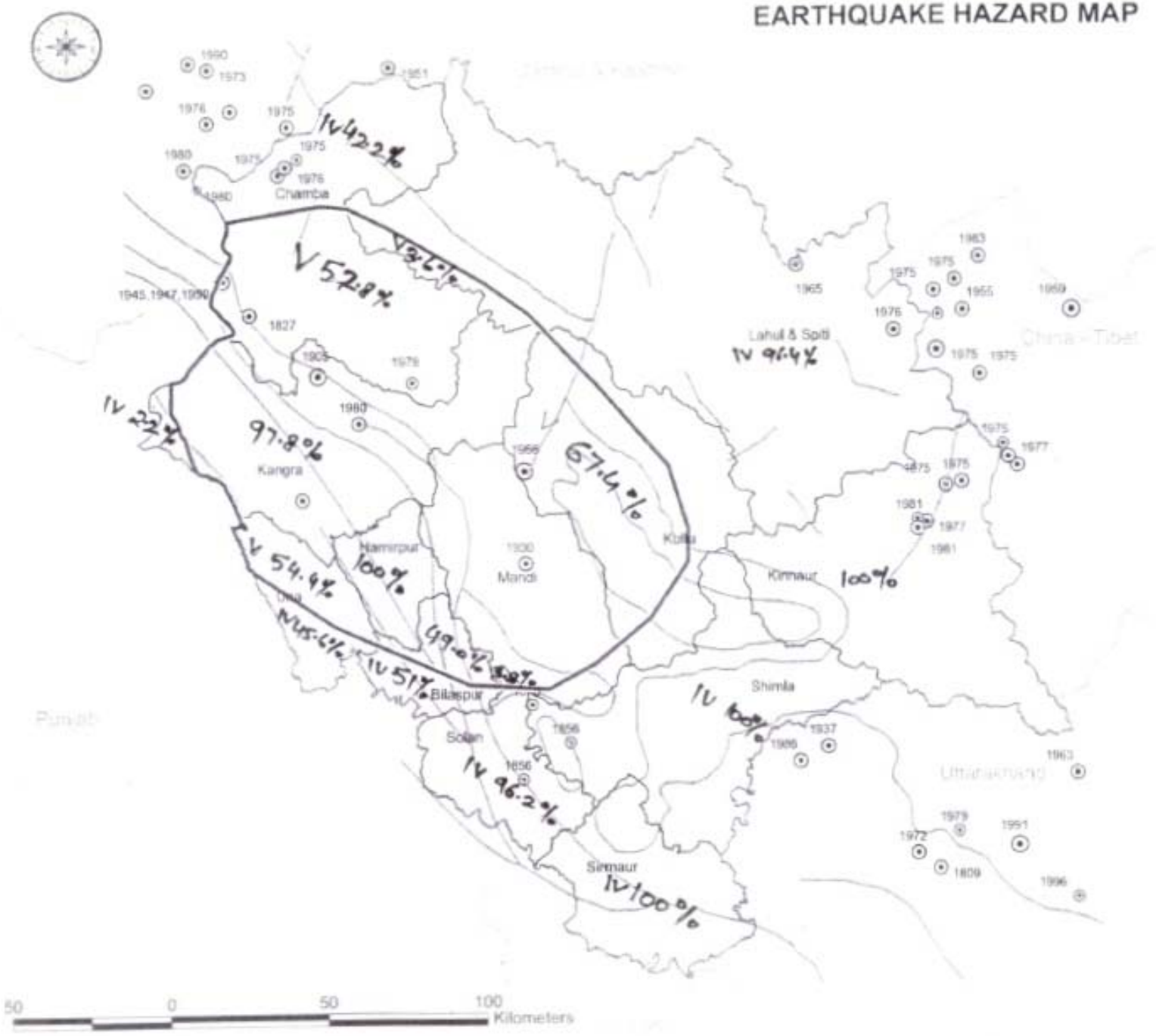
a criteria is considered that the line of demarcation of Zone IV and Zone V is in line with the demarcation of the districts, the following scenario of Table1 can be obtained in which the Districts with Zone V is marked as hp5 and the districts with zone IV is marked as hp4. Thus the two zone in Himachal Pradesh can be based on line demarcation of districts.

In case the percentage of area is less than 5% in Zone V, then that district is considered in Zone IV, else districts are considered in Zone V.



BMTPC : Vulnerability Atlas - 2nd Edition; Peer Group, MoH&UPA; Map is Based on digitised data of SOI, GOI;
Seismic Zones of India Map IS:1893: 2002; Seismotectonic Atlas of India, GSI, GOI

EARTHQUAKE HAZARD MAP



LEGEND

- District Boundary
  [Source: Census of India, 2001]
- ABC District Name
  [Source: Census of India, 2001]

Earthquake Hazard Zonation

[Source: Vulnerability Atlas of India, BMTPC]

- Zone – IV
- Zone – V
- Thrust and Fault Lines
- Buffer Zone to Thrust and Fault Lines

Epicenter (Richter Scale)

- 0 – 2
- 2.1 – 5
- 5.1 – 6
- 6.1 – 8

EARTHQUAKE SAFETY INITIATIVE
Himachal Pradesh

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TECHNICAL SUPPORT

Fig. 2

Table 1: Districts demarcation as hp5 and hp4

	District	Considered Zone	Our Designation	Remarks
a)	Hamirpur	Zone V	hp5	100% is in Zone V
b)	Kangra	Zone V	hp5	97.8% is in Zone V and considering 2.2% of Zone IV in Zone V
c)	Mandi	Zone V	hp5	96.3% is in Zone V and considering 3.7% of Zone IV in Zone V
d)	Kullu	Zone V	hp5	67.4% is in Zone V and considering 32.6% of Zone IV in Zone V
e)	Chamba	Zone V	hp5	57.8% is in Zone V and considering 42.2% of Zone IV in Zone V
f)	Una	Zone V	hp5	54.4% is in Zone V and considering 45.6% of Zone IV in Zone V
g)	Bilaspur	Zone V	hp5	49.0% is in Zone V and considering 51.0% of Zone IV in Zone V
h)	Lahul & Spiti	Zone IV	hp4	96.4% is in Zone IV and considering 3.6% of Zone V in Zone IV
i)	Solan	Zone IV	hp4	96.2% is in Zone IV and considering 3.8% of Zone V in Zone IV
j)	Kinnaur	Zone IV	hp4	100% is in Zone IV
k)	Shimla	Zone IV	hp4	100% is in Zone IV
l)	Sirmaur	Zone IV	hp4	100% is in Zone IV

The basis developed in Table 1 is first fundamental beginning for the tool that is developed. Further the tool incorporate the following provision/clause of the BIS Code as given in Table 2 to Table 6.

Table 2: Vertical Steel Reinforcement in Masonry Walls with Rectangular Masonry Units (Table 7 IS 4326:1993)

No. of storeys	Storey	Diameter of HSD Single Bar in mm at Each Critical Section	
		Building Category D Zone IV	Building Category E Zone V
One	------	10	12
Two	Top	10	12
	Bottom	12	16
Three	Top	10	12
	Middle	12	16
	Bottom	12	16
Four	Top	10	Four Storeyed building not permitted
	Third	12	
	Second	16	
	Bottom	20	

Table 3: Recommended Long. Steel in Reinforced Concrete Bands (Table 6 IS 4326:1993)

Span	Diameter of HSD Single Bar in mm at Each Critical Section			
	Building Category D (Zone IV)		Building Category E (Zone V)	
	No of Bars	Dia	No of Bars	Dia
5 or Less	2	8	2	10
6	2	10	2	12
7	2	12	4	10
8	4	10	4	12

Table 4: Size and Positions of Opening in Bearing Walls (Table 4 IS 4326:1993)

Position of Opening	Details of Opening for building category
For total length of openings, the ratio window and door to the wall length	D (Zone IV) and E (Zone V)
One storeyed Building	0.5
Two storeyed Building	0.42
3 or 4 storeyed Building	0.3

Table 5: Maximum slenderness ratio for load bearing wall (Table 7 IS 1905:1987)

No. of Storey	Maximum Slenderness ratio
Any storey	Using OPC or PPC in Mortar – 27

Table 6 Stone Masonry wall Thickness (Cl. 8.3.3 IS 13828:1993)

Cl. 8.3.3 Wall thickness t should not be larger than 450 mm. Preferably it should be about 350mm.

2.2 Salient features of Mason Guide tool

However to develop the tools modification were necessary to make it effective for implementation. Thus, the salient feature that have been considered while developing the tool are as follows

1. Dimensions in tool are in Feet rather in meters since the mason work with dimension of feets and inches however the codal provision are given in the m. The following equivalent dimensions have been considered in considering the wall length for the recommended longitudinal in Reinforced Concrete band (Table 6 IS 4326:1993)

5 m	as 16 ft,	which is conservative dimension
6 m	as 20 ft	which is non conservative dimension by 1.6 %
7 m	as 23 ft	which is non conservative dimension by 0.15 %
8 m	as 26 ft	which is conservative dimension

2. The total opening to the wall length is considered as fraction and not in decimal as per the codal provision (Table 4 IS 4326 Size and Position of Opening in Bearing Walls) as the mason are more familiar in working with the fractions rather than decimals.

One storey	0.5	as 1/2	which is same as the codal provision
Two storey	0.42	as 1/2.5	which is conservative as the codal provision
Three storey	0.33	as 1/3	which is same as the codal provision

3. The thickness of brick masonry has been given in terms of bricks rather than dimension considering the ease of working of masons.

4. The thickness of stone masonry has been given in terms of inches rather than in metri system.

5. The minimum horizontal distance of the opening for the brick masonry and stone is 600 mm which is same as the codal provision of Table 2 IS 13828;1993 for stone masonry in weak mortar and conservative with respect to Table 4 IS 4326 1993 considering brick masonry construction.

6. This has been observed that in himachal Pradesh most of the construction is with cement sand mix only and not with the cement lime sand mix. Hence tool includes the provision of only Cement Sand mix as 1:4.

The implication of using Mason Guide for improving Earthquake Resistance of Non-Engineering Construction for the Districts of Himachal Pradesh would be as follows

1. The portion of the district of zone IV which are to be included in Zone V would have structure which would be more ductile and hence increase the life safety performance limit of building and reduce risk in case of any hazard. Since the thicknesses of the wall are independent of the building category and the total openings to the wall length are same for the category D and Category E buildings, hence such change would not have much effect on the overall cost of the building with the cost implication dependent only on increase in steel and reduced opening size.

2. The portion of the district of zone V which are to be included in Zone IV although would result in structure which would be less ductile for that specific region but atleast such consideration would ensure provision earthquake safe construction as per the codal provision which at present is unknown due to the non-availability of such tools for the semi skill / skilled worker. Also such provision would have implication in less than 5 % of the portions of districts Lahul spiti which has 94.5% of Unburnt Brick Wall and stone wall houses and Solan has 48.4 % of Unburnt Brick Wall and stone wall houses and 47.9% of Burnt Brick wall house. In all these three types of Construction the Engineers are rarely involved to implement the codal provision. Since, the wall thickness are independent of the building category and the total openings to the wall length are same for the category D and Category E buildings, hence such change would not have much effect on the stiffness of the building.

Thus necessary discussion and approvals are required to implement the developed Mason Guide tool as a step for proper implementation of codal provision of Non-Engineering Construction in the state of Himachal Pradesh.

3. Engineers Tool- The codal provisions given in the Bureau India Standard Codes although can be implemented by the Engineers but may not have the developed standard format which includes the clauses for Earthquake Safe construction for Non Engineered Buildings. Hence the spreadsheets as a ready reckoner for zone IV and Zone V have been developed incorporating various codal provision for the non-engineered constructions (Fig. 3 and Fig. 4). These spreadsheet can be utilized by various government agency/private practiioners involved in non-engineered construction. The mode of use is given in spreadsheet itself. This tool can be uploaded on the HPSDMA website for the successful distribution to various practicing Engineers.

4. Workshop on Capacity Building of Mason/Bar Bender/Supervisor for Earthquake Safe Construction

The mason guide tool developed has possible with the suggestion of various mason bar bender that have been working in the field for the past two decades. To have the interaction with such skill/semi-skilled workers and to make them aware about various earthquake safe construction codal provisions, a platform was required. Thus two workshops on Capacity Building of Mason/Bar Bender/Supervisor for Earthquake safe Construction have organized on 25th Feb 2012 and 2nd Mar 2012 in association with ACC limited. The schedule followed for both workshop is given in Table 7. During this workshop the lecture was given on

- Codal provision of earthquake safe construction,
- Incorrect construction practices being followed by various worker,
- Importance of the water cement ratio,
- Use of super plasticizer in concrete

The participants were mason / bar bender/ supervisor from within District Hamirpur. The List of participants of this workshop is provided as Annexure A and Annexure B of this report. The photographs taken during the workshop of Inauguration, various lectures delivered, practical demonstrations in the Concrete Laboratory of civil Engineering Department of NIT Hamipur, Valedictory ceremony involving prize distribution is in soft copy form in the enclosed CD.

Table 7: Schedule of Workshop on Capacity building of Mason/ Bar bender/ Supervisor for Earthquake Safe Construction on 25th Feb 2012 and 2nd Mar 2012

9.00-9.30 am	9.30 –10.00 am	10.00 – 11.00 am	11.00 – 11.30 am	11.30 – 1.30 pm	1.30 – 2.30 pm	2.30-3.30 pm	3.30 - 3.45 pm	3.45 – 5.00 pm	5.00 pm – 5.30 pm
Registration	Inauguration	Earthquake Engineering Construction practices and detailing H K Vinayak	Tea	Building material composition and detailing ACC Ltd Brijesh Chousksi	Lunch	Practical demonstration of mixing and testing ACC Brijesh H.K.Vinayak	Tea	Feedback on earthquake resistant present construction practices detailing H K Vinayak	Valedictory

The phase 1 of the project was submitted in March 2012 as interim report.

Project Phase 2:

The following remaining objective of the project was covered in the 2nd phase of the project.

- Survey to be carried out for the present practices, materials being used, construction type and style being practiced in District Hamirpur.
- Developing Don'ts for the various key players in the construction process such as Supervisor, Junior Engineer, Sub Divisional Officer and Executive Engineers with the studies of deficiencies and irregularity in practice.
- Evaluation of the existing norms vis-à-vis the practices being followed and assess the necessity to evolve state specific guidelines.

5. Survey carried out for the present practices, materials being used, construction type and style being practiced in District Hamirpur.

The survey of the following building types were carried out in the district of Hamirpur

a. Framed under construction building
b. Load bearing under construction building
c. Composite under construction building
d. Framed constructed building
e. Load bearing constructed building
f. Composite constructed building

The following are the questionnaire given to the students

Present Practices Being Followed In Construction. (Survey Based)

- Dos and Donts according to masons, bar-benders, supervisors. (Survey based)
- Do's and Don'ts according to students based on survey.
- What do the students think regarding the prevalent practices? What should be changed in them?

How to do survey

✓ Visit various building in various village/town of District Hamipur

✓ Visit One RCC, Masonry building, Composite (Both under construction and Constructed) make sure any two of these are on sloping site.

✓ Use videos and/or photos to supplement the above said points

List of figures*:

Fig 1: Your photograph with a Govt. building in the area

Fig 2: Photograph of entire area

Fig 3: Photograph of building cross-section showing the site profile

Fig 4: Photographs of building

Fig 5 to Fig 31: As indicated

* For more than one photograph name it Fig n(A), Fig n(B), ….

Figure size – 3” x 2.5” approx. Compress the figure in Microsoft office picture manager

Do not distort the figure

The following is List of places surveyed by the student of NIT Hamirpur on 24th and 25th Mar 2011

S.No.	Place in Dist.	Name	Roll No.	Name	Roll No
1.	Hamirpur Town, -	Nikhil Kumar	09139,	Nisha Kashyap	09140
2.	Didwin Tikker -	Ashish Rana	09115,	Pankaj Syal	09143
3.	Har -	Pulkit Goel	09153,	Rishi Kumar	09152
4.	Tikker-Brahmana -	Ravi Ranjan	09132,	Sharbh	09158
5.	Kanoh –	Kavita Dhiman	09129,	Manik Bali	09130
6.	Mehare –	Ishan Sharma	09126,	Animesh Gupta	09107
7.	Salooni –	Vipul Prakash	09170,	Sagar Sharma	09169
8.	Barsar –	Sahil Sharma	09155,	Manish Vashishth	09149
9.	Panjgraon –	Prakash Lenka	09163,	K.Someshwar Reddy	09178
10.	Lathyani	Suman Kumar	09146,	Abhinav Kumar	09174
11.	Bhatta	Siddhartha Khuraijam	09172,	Divyesh Mohan	09168
12.	Manjheli	Mohit Shukla	09134,	Anjan Mahajan	09108
13.	Jaleri	Raman Hardeep Singh	09150	Ankush Kumar	09111
14.	Nadaun	Priyanka	09147,	Shanya Sambyal	09157
15.	Basdi – Kohala	Dinesh kr	09103	Akshit Gupta	09104
16.	Kuthera	Nikhil Srivastava	09179,	Shiva Barwal	09159
17.	Chabutra – Khas	Ankit Sharma	09119,	Ankit Kumar	09109
18.	Tira – Sujanpur	Kamal Verma	09127,	Nawang Chhonzer Negi	09137
19.	Lamblu-	Praveen Kr. Singh	09175,	Nitish Thakur	09142
20.	Bhoranj-	Yogendra Singh Bais	09164,	Arun Kr Verma	09165
21.	Dhamrol-	Vijay Pratap Singh	09148,	Negin Gurung	09138
22.	Jahu-	Garima Sood	09121,	Akriti Kothiala	09512
23.	Kalanjri-	Abhinav Kumar	09144,	Harikishan Meena	09123
24.	Dhanwana-	Mayank Suman	09133,	Amit Meena	09106
25.	Daroghan-	Udit Singh Gaur	09120,	Vivek Sharma	09177
26.	Darkoti-	Bhaira Ram Godara	09141,	Munish Sadhu	09162
27.	Tauni Devi-	Mayank Kumar	09114,	Pravesh Kumar Rathore	09101
28.	Samirpur-	Avinash Thakur	09116,	Mukesh Kumar	09135
29.	Awah Devi-	Samarika Kulshreshtha	09425,	Vipin Kumar	09173
30.	Bhota-	Prinsul Kumar Niranjan	09160,	Chandni	09118
31.	Mair-	Ajay Kumar	09128,	Sajan	09122
32.	Dangar-	Prateek	09113,	Pramod	09117
33.	Patta-	Sachin Sharma	09167,	Aman Gupta	09105
34.	Ladror-	Ravi Ranjan	09112,	Himanshu Dikshit	09124
35.	Karhota-	Ashutosh	09125,	Kuldeep Sharma	09161
36	Mundkhar	Chand Kamal	09102	Ajay Shyam	07161

The following was the format given to students to be filled up during survey

Carry out survey of building (Frame/ Load bearing/Composite -Both under construction and constructed):

Location of survey: Period of construction:

Site selection - Flat/sloping

Plans and elevations (sketches/photographs) with Number of storeys, approx. dimensions:

Structural and architectural details; Common structural irregularities (Photographs/ illustrations)

Table 8

S.No	**Irregularity**	**Yes/No**	**Remarks(if yes)**
1.	Re-entrant corner	Yes	(Type of re-entrant column)
2	Diaphragm		
3	Out of plane offsets		
4	Non parallel system		
5	Stiffness irregularity		
6	Mass irregularity		
7	Vertical geometry		
8	Staircase connectivity		
9	Bracing in roof		
10	Dampness (specify		
11	Opening from corner >		
12	Total Opening / wall		
13	Seismic band – plinth,		
14	Crack – thickness and		
15	Reinforcement		

1. Foundation: Material and method of construction with sizes
2. Wall typology:

- Wall system: Load bearing/ Framed / Composite construction
- Constituent materials: Mud/ Masonry units-Brick/ Stone, Mortar type/ Timber/ RCC (show photographs)
- Components: Common sizes /thickness and local nomenclature
- Construction methodology: Sequence of construction, Details of bonding/ Interlocking, Equipment/ Tools used, Reinforcement detailing (should be supported by photographs/sketches)

3. Roof typology: (different variants, support by Photographs/sketches)

- RoofSystem:Sloping–Trussed/Rafters/Hipped/Gable;Flat-Tiles on girder/RCC;Rigid/flexible
- Materials - Heavy/light:
- Construction methodology (Roof):
- Interconnection of different members, Placing of tiles; Anchorage with walls

4. Floor system: Materials –

- Materials - Heavy/light:
- Construction methodology:
- Interconnection of different members, Placing of tiles, Anchorage with walls

5. Availability of design/ Construction skill: Constructed by owner/ Involvement of professional Architects/Engineers/Mason/Bender/Carpenter.
6. Cost of construction: Approximate prevailing rates per square meter
7. Performance during past earthquakes (year of earthquake)

5.1 Owner's Guide – An owner's guide have been developed for non-engineered buildings in hindi. This guide advises on the appropriate measures to be taken during construction in terms of provision of seismic bands at plinth, sill, lintel and roof, bracing in the roof truss, provision of construction joint to counter vertical irregularity, provision of detached staircase, opening distance from the inside corner of the wall, construction joint to counter plan irregularity. The guide also highlights the issue of cement sand ratio to be used for construction as 1:4 and cement: sand: aggregate as 1:1.5:3 (nominal M20 Mix grade)

6. **Developing Don'ts for the various key players in the construction process** - such as Supervisor, Junior Engineer, Sub Divisional Officer and Executive Engineers with the studies of deficiencies and irregularity in practice.

The survey was carried out in the both within town limits and outside the town limit. The survey highlighted the issue of building being constructed with the non-provision of earthquake resistant in non-engineered buildings.

6.1 The reasons for non-provision of earthquake resistant guidelines for within town limits are as follows

- **a.** Owner / mason are not aware of the earthquake resistant guidelines and the same are not been implemented.
- **b.** Owner / mason are aware of the earthquake resistant guidelines and the same are not implemented to reduce the cost at the risk of owner's life and property.
- **c.** Masons are aware of the earthquake resistant guidelines and the same are not implemented because owner insisted on reduced building cost at the risk of his/her own life and property.
- **d.** Owner is aware of the earthquake resistant guidelines and the same has not been implemented because of casual attitude of mason to reduce his labour and material cost at the risk of owner's life and property.

Scenario **(a)** can be handled in the following way
Any particular non engineered building is constructed with material Brick/stone, sand, aggregate cement, steel and water. Out of all these building material only cement and steel is the material which is sold as an organized sector product through the involvement of specified dealer at various locations in Himachal Pradesh. This cement and steel is either purchased by the mason (in case of small quantities)/owner (in case of large quantity). Hence it can be the responsibility of the dealer who will have two ways communication with the representative of product manufacturer (field officer) and state government representative (Junior Engineer). The engineers and field officer of cement and steel companies should ensure that the minimum number of irregularities exits in the building.

The dealers shall maintain record of the purchaser of cement and steel and would further give the feedback to their respective cement and steel companies. The companies can then further give the report at regular interval to the state disaster management authority about the proper utilization of their product in the benefit of the society.

Scenario (**b)** can be handled by imposing the solution of scenario **(a)** and sensitizing the owner with the past performance of building in the various earthquakes. The mason to be advised not to repeat such attitude for the other building to constructed with further warning by the engineer.

Scenario **(c)** can be handled by imposing the solution of scenario **(a)** sensitizing the owner with the past performance of building in the various earthquakes.

Scenario **(d)** can be handled by imposing the solution of scenario **(a)**. The mason to be advised not to repeat such attitude for the other building to constructed with further warning.

6.2 Presently the state government does not own any responsibility in terms of structural strength and safety of building outside in the areas outside the town limit where No objection certificates are not required. In such areas the engineers from Rural Development Department can be considered as state government representative as mentioned in section 6.1. The same above four scenarios as mentioned in section 6.1 are likely to be possible outside the town limits with scenario **(a)** more prominent.

All the above mentioned solution has been arrived at with an objective to ensure safe construction rather only ensured knowledge to the mason. Trained Mason may or may not ensure quality and safe construction but owners will rarely risk their life for money if sensitized effectively. Any sensitized owners will get their buildings constructed from those trained mason who would ensure safe and quality buildings.

7. Evaluation of the existing norms vis-à-vis the practices being followed in district Hamirpur.

Fig 3 a

Fig 3 b

Fig 3 c

Fig 3 d

Fig 3 e

Fig 3 f

Fig 3 g

Fig 3 h

Non provision of Seismic bands in different buildings

Fig 4 a

Fig 4 b

Provision of Seismic bands in some buildings

Fig 5 a

Fig 5 b

Fig 5 c

Fig 5 d

Fig 5 e

Fig 5 f

Fig 5 g

Fig 5 h

Reentrant corner in different buildings

Fig. 6a Regular buildings

Fig 7 a

Fig 7 b

Fig 7 c

Fig 7 d

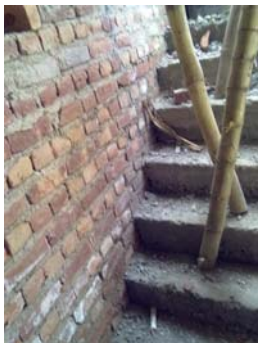

Fig 7 e

Fig 7 f

Staircase connectivity to building

Fig 8 a

Fig 8 b

Fig 8 c

Opening from corner or opening to opening < 2ft

The summary of survey carried out by the students is as following

a. The students were not able to find all six types of buildings as desired. Hence the particular group at the places did the survey of only selected types of buildings.
b. Although the 3rd yr student were undergoing the course on Earthquake Resistant design of structures. There have been some short comings in terms of the specific directional photographs that were desired for the particular irregularity that existed in the buildings.
c. All the irregularities did not existed in all the building as expected.
d. All the details of the building could not be determined due to the privacy by the owners, non-exposure and non-approachability of the particular structural component.
e. It is not possible to exactly quantify which irregularities are prominent and which was not. Although qualitatively – most of the irregularities i.e. Stiffness irregularity, Mass irregularity, Vertical geometry irregularity, Staircase connectivity to building, Bracing in roof construction, Dampness (specify location), Opening from corner > 2ft, Total Opening / wall length, Seismic band – plinth, lintel, Roof are the irregularity that need more attention.
f. Out of plane offset were not a prominent feature in masonry construction but are of concern in RCC construction.
g. It has been seen that the distance between door and window opening less 2 ft are of major concern incase of school which has large window opening due to higher light requirements.
h. The distance between the windows in the most of the buildings is observed to be of lesser concern although opening to wall ratio are observed to large in some case than as specified in the guidelines.

8. Website of building survey database of Distt. Hamirpur

The website consists of database of the various building surveyed in the district Hamirpur was developed to provide the details of the construction being followed in different places of the hamirpur. The survey details are given in section 5 of this report. The website is developed using

- HTML 5.0 for displaying various elements in the webpage
- CSS 3.0 for arranging the various elements and making them compatible for different resolutions and multiple browsers.
- As a server language PHP is used alongwith mysql for storing data
- AJAX is being used to make website dynamic.

The home page and the database page are developed as shown in Fig. 9a and Fig. 9b.

The website provides the summary of the percentage deficiency / irregularity in the various surveyed buildings (Fig. 9c).

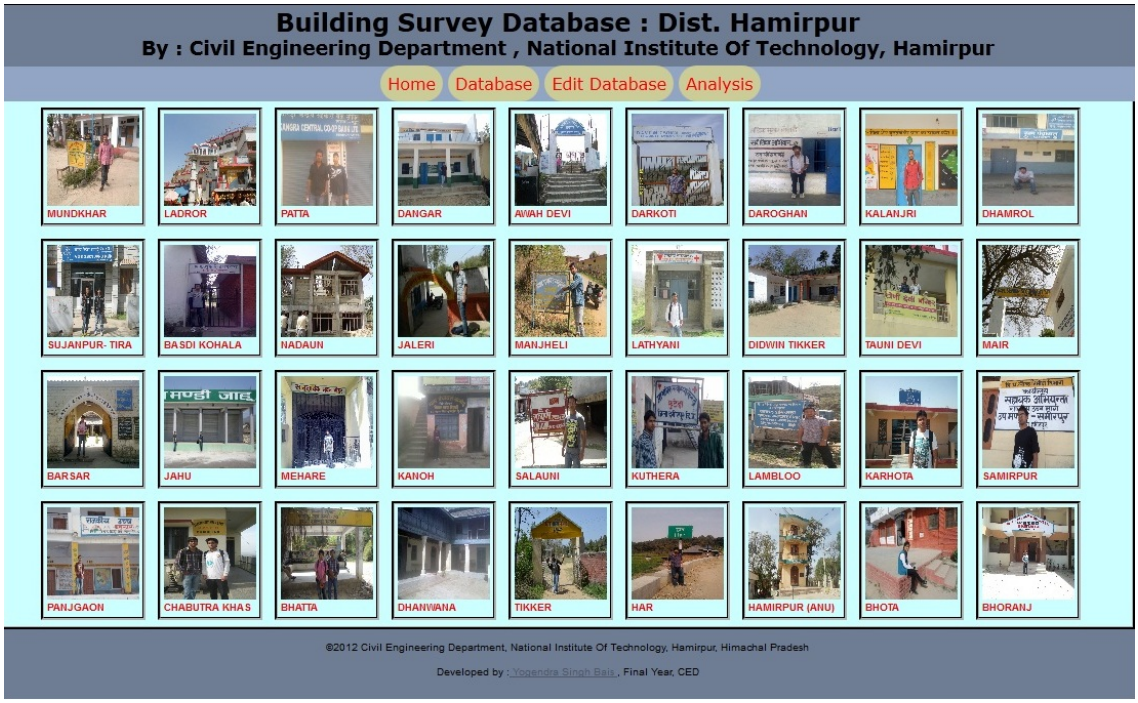

Fig 9 a Typical view of Home page of building survey database website

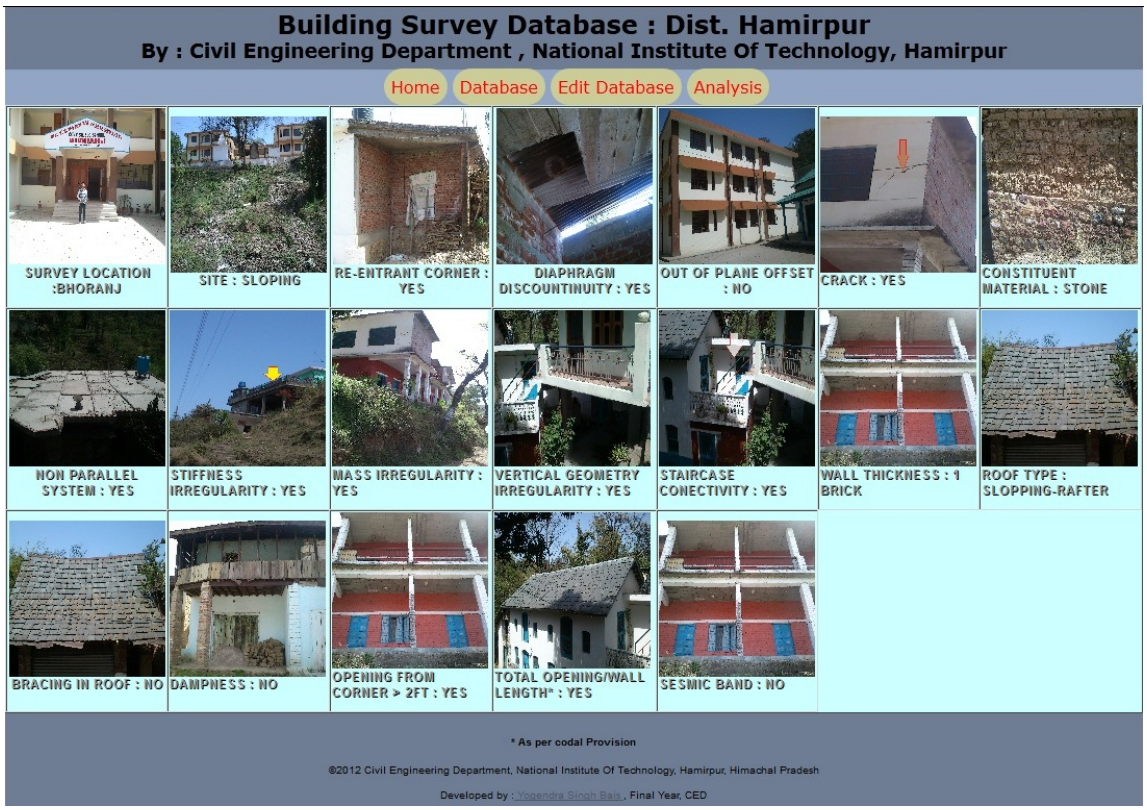

Fig 9 b Typical view Database page of building survey database website

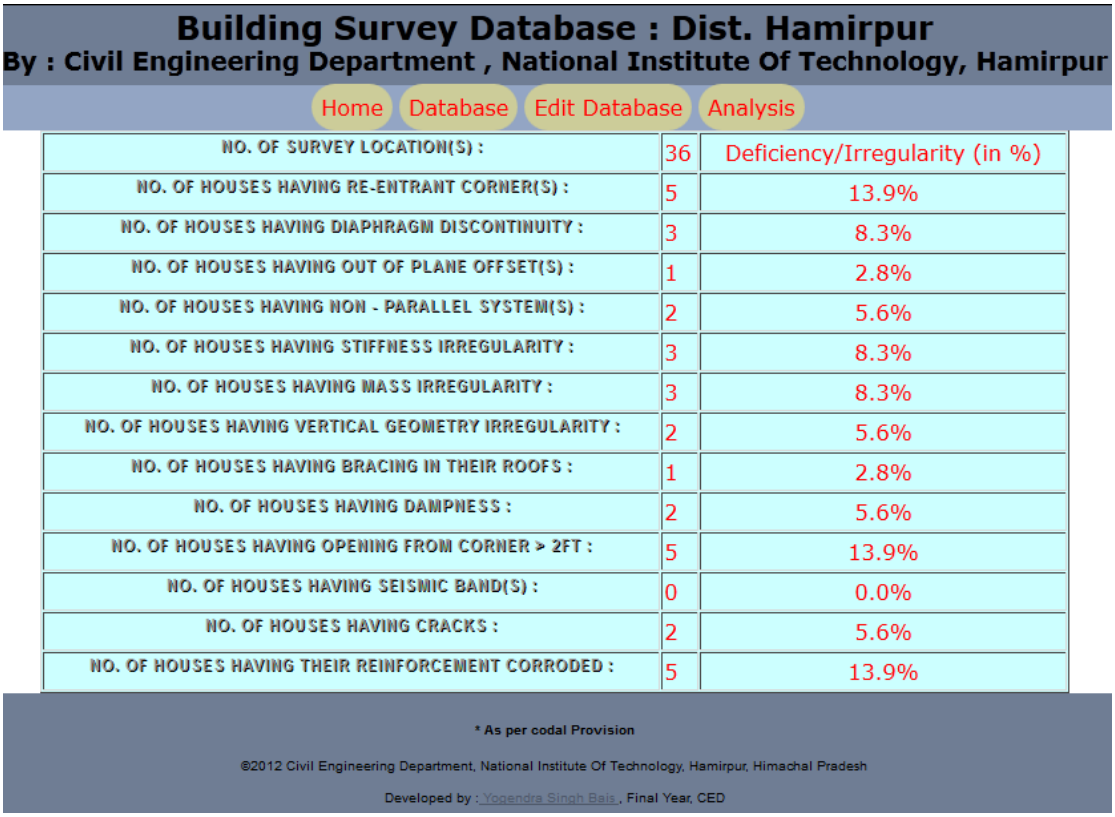

Fig 9 c Typical view Analysis page of building survey database website

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