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TECHNO-LEGAL REGIME FOR EARTHQUAKE RISK REDUCTION IN INDIA

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SUMMARY

India has a large stock of seismically unsafe buildings coming down from many generations. Even at the present time, many buildings are added every year without earthquake resisting measures. The main reason is the absence of regulatory mechanisms, either for planning of settlements or in the building bye-laws. Earthquake resisting measures were developed as early as 1962 in the form of standard design criteria and in 1967 as an earthquake resisting building construction code of practice. Since, these are not mandatory by law, the construction in the informal sector proceeds without considering the safety provisions. An Expert Group set up by the Ministry of Urban Development, Government of India looked into the issues of disaster prevention, mitigation and preparedness and worked out a Vulnerability Atlas of India giving the hazard maps, as well as seismic risk tables for buildings in every district of the country and also proposed a Techno-legal Regime for planning of settlements and seismically safe building construction in the formal as well as informal sectors. The paper presents these issues, which are quite common in most developing countries.

INTRODUCTION

It is well recognised that the earthquake risk consists of two separate factors, namely the occurrence of 'seismic hazard' and 'the vulnerability' of the elements of the habitat both physical and socio-economic, impacted by the 'hazard'. Whereas the seismic hazard may be : very severe, severe, moderate or mild, as measured by its Magnitude or Intensity or Peak Ground Acceleration likely to occur in any location, its impact on the physical elements like housing, community buildings, service buildings and infrastructure, may be amplified due to local soil conditions on which the structures are built. Also, the damage vulnerability of the physical elements will be variable, some construction types like Adobe and un-reinforced masonry will be highly vulnerable to even moderate seismic Intensities, the others like reinforced masonry, crate like shear wall buildings, and well designed reinforced concrete and steel framed buildings will escape collapse or even heavy damage under severe seismic Intensities.

Most developing countries in Asia, Africa and Latin America, like India have a large stock of highly vulnerable housing and community buildings. When impacted by even moderate earthquakes of 5.7 to 6.5 Magnitude earthquakes (Richter Scale), large numbers of buildings collapse leading to loss of lives, (human as well as cattle) loss of limbs and belongings rendering the people homeless and destitute. Formulation of a Techno-Legal Regime towards achieving reasonable earthquake risk reduction in a short time and at economical cost is an effort made in India in the last four years after the IDNDR Yokohama Conference organised by UN-DHA in 1994. A brief account of various components of the Techno-legal framework and action plan there under is presented in the paper.

FUNCTIONAL STRUCTURE FOR EARTHQUAKE RISK REDUCTION

The occurrence of earthquake can neither be prevented nor predicted in precise terms of its Magnitude, Time of occurrence and Place of its Focus. Geological and geophysical sciences and records of seismic occurrences in the

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past and present have enabled us to map the zones of active seismicity and provided guidance on the future probable maximum earthquake Magnitudes and Intensities in such zones. Thus seismic zoning maps are established along with suitable zone factors to be taken into design for safety of structures.

So also damage observations in earthquake occurrences around the world have produced data on assessment of vulnerabilities of various types of building, and structures under various earthquake Intensities. Hence, earthquake resistant design and construction procedures have been established for earthquake protection which are being updated in various countries of the world including India. But in spite of this know-how that has become available worldwide, through various national, regional and international conferences and educational and training programmes, the disastrous consequences of the earthquake occurrences are recurring even under very moderate Magnitudes. The main reasons could be the following:

i. National policies, by and large, are historically directed towards post-disaster response involving search, rescue, relief and reconstruction and not towards pre-disaster prevention, mitigation and preparedness.
ii. There is lack of awareness in the masses that whereas earthquake occurrence is *natural*, but its disastrous impact can be avoided altogether or reduced to minimum level by application of appropriate design and construction measures.
iii. Architects who have the primary function of 'designing' buildings, as a community are still insensitive to important, rather crucial role they can play in safer building plans and specifications.
iv. Most engineers still erroneously believe that earthquake resistant measures will involve too much extra costs.
v. Lack of awareness in policy planners prevents integration of disaster mitigation strategies in development plans.
vi. Rapidly rising population is resulting in expansion of human settlements in hazard prone areas.

The situation can be remedied by adopting an overall functional structure of earthquake risk reduction and implementing it through an appropriate techno-legal regime. Such a structure will involve the following components:

i. Earthquake Hazard Mapping and Seismic Zoning of the country.
ii. Vulnerability assessment of the various building types.
iii. Risk assessment of the built environment
iv. Building Codes and Technical Guidelines for earthquake resistant design and construction.
v. Legislation for planning of habitat from seismic safety view point, land use zoning, and enforcement thereof.
vi. Improvement of building bye-laws of municipalities and other local-body areas for mandatory implementation.
vii. Human Resource Development through education and training of architects and engineers and hands-on training of artisans.
viii. Transfer of technology to local rural and urban levels through demonstrative constructions.

Whereas items (i) to (iv) are of scientific and technical nature which could be pursued with some help from government sources of funds, items (v) to (viii) depend on government commitment and have to be in the official policy for action with necessary financial support. Concerning these matters, an inter-disciplinary Group of Experts [3] was set up by the Ministry of Urban Development, Government of India on Natural Disaster Prevention, Preparedness and Mitigation having bearing on Housing and Related Infrastructure. The main outputs of the Group relating to Techno-legal regime for implementation of earthquake risk reduction in India are briefly described in the following paras.

[3] *Chairman – Anand S.Arya (Earthquake Engineering)*
Members – G.S.Mandal (Cyclones), V.C.Thakur (Geology & Tectonics), Prem Krishna (Wind Engineering), N.Lakshmanan (Wind & Cyclones), S.K.Chaudhuri (Floods).
Member Convenor- T.N.Gupta (Architecture)

VULNERABILITY ATLAS OF INDIA

Seismic zoning Maps

The Vulnerability Atlas of India 1997 shows the areas prone to earthquake, wind and flood hazards through Statewise maps including Union Territories. The intensities of the hazards are also clearly marked alongwith the boundaries of the districts which are the administrative units for hazard management. These maps are drawn on a scale of 1:2.5 million. The earthquake hazard maps are based on the seismic zoning map of India given in IS:1893- 1984, in which there are five macro level zones based on probable maximum seismic intensities, IX or more, VIII, VII, VI and V or less, respectively. On these maps the seismotectonic features are also marked alongwith the epicentres of the earthquakes with Magnitude 5.0 or more, giving the year of its occurrence as per Catalogue of Earthquakes prepared by India Meteorological Department. For example seismic zoning map of the State of Andhra Pradesh is shown in Fig. 1. Similarly, the wind and flood hazard maps are based on available databases.

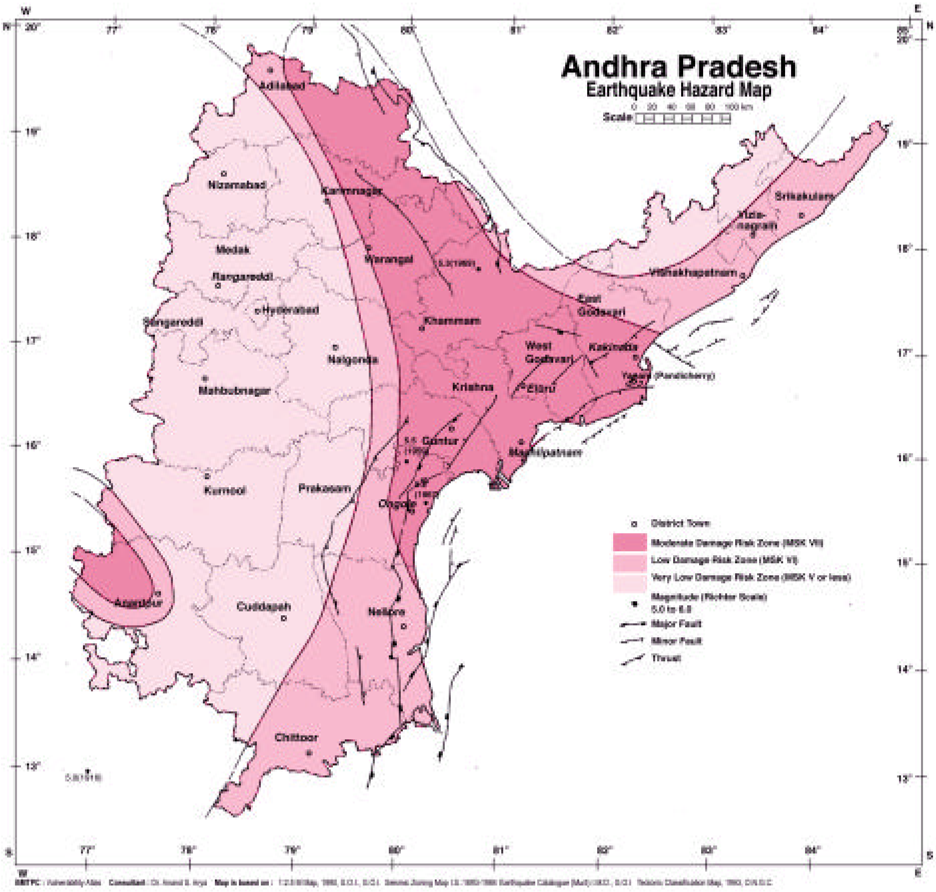

Figure - 1

Seismic Risk to Buildings

The Atlas also presents Districtwise tables for various States and Union Territories of India for which building type data-base was taken from the Census of India 1991, analysed and regrouped suitably for assessing their vulnerabilities to different intensities of the hazards and specifying the damage risk. Each Table shows the percent area of the district likely to be subjected to a particular Intensity of earthquake, the number of housing units of various types classified by wall material and the roof type, and the number of buildings of each type. The damage risk to the buildings has been indicated as very high (VH), high (H), medium (M), low(L) and very low (VL) which have been clearly explained in the Atlas for each hazard type. As an example, the damage risk to housing in District East Godavari in the State of Andhra Pradesh is shown in Fig. 2.

It may be mentioned that this type of damage risk was only defined internationally under MSK seismic intensity scale given below which was used as such.

Very High Damage Risk (VH) - Total collapse of buildings

High Damage Risk (H) – ***Gaps in walls; parts of buildings may collapse; separate parts of the building lose their cohesion; and inner walls collapse.***

Moderate Damage Risk (M) – Large and deep cracks in walls, fall of chimneys on roofs.

***Low Damage Risk (L)* – Small cracks in walls; fall of fairly large pieces of plaster, pantiles slip off; cracks in chimneys, part may fall down.**

Very Low Damage Risk (VL) – Fine cracks in plaster; fall of small pieces of plaster.

However, in the absence of any such scales for the wind and flood damage risk, these were specifically developed by the Group and made applicable to the existing building stock.

Figure 2: Damage risk to housing

Table No. : AP.05 — ANDHRA PRADESH — EAST GODAVARI

Wall and Roof Combination		Census Houses		Level of Risk under										
		No. of Houses	%	EQ Intensity MSK				Wind Velocity m/s				Flood		
				≥ IX	VIII	VII	≤ VI	55 & 50	47	44 & 39	33	Prone	Protected **	Outside ***
				Area in %				Area in %				Area in %		
						60.2	39.8	65.1		34.9		18.3	15.3	66.4
CATEGORY - A														
A1. Mud Wall														
All roofs sloping	Urban	57,930	5.07											
	Rural	190,900	16.71											
	Total	*248,830*	*21.79*			M	L	VH		M		VH	M	L
A2 Unburned Brick Wall														
a) Sloping roof	Urban	4,930	0.43											
	Rural	60,390	5.29											
	Total	*65,320*	*5.72*			M	L	VH		M		VH	M	L
b) Flat roof	Urban	285	0.02											
	Rural	275	0.02											
	Total	*560*	*0.05*			M	L	VH		M		VH	M	L
A3. Stone Wall														
a) Sloping roof	Urban	960	0.08											
	Rural	5,825	0.51											
	Total	*6,785*	*0.59*			M	L	VH		M		VH	M	L
b) Flat roof	Urban	380	0.03											
	Rural	925	0.08											
	Total	*1,305*	*0.11*			M	L	H		L		VH	M	L
Total - Category - A		**322,800**	**28.26**											
CATEGORY - B														
B. Burned Brick Wall														
a) Sloping roof	Urban	84,995	7.44											
	Rural	344,645	30.17											
	Total	*429,640*	*37.62*			L	VL	H		M		H	L	VL
b) Flat roof	Urban	61,065	5.35											
	Rural	30,165	2.64											
	Total	*91,230*	*7.99*			L	VL	M		L		H	L	VL
Total - Category - B		**520,870**	**45.60**											
CATEGORY - C														
C1. Concrete Wall														
a) Sloping roof	Urban	3,510	0.31											
	Rural	13,500	1.18											
	Total	*17,010*	*1.49*			VL	NIL	H		M		L	VL	VL
b) Flat roof	Urban	9,545	0.84											
	Rural	7,620	0.67											
	Total	*17,165*	*1.50*			VL	NIL	L		VL		L	VL	VL
C2. Wood Wall	Urban	3,495	0.31											
(all roofs)	Rural	17,890	1.57											
	Total	*21,385*	*1.87*			VL	NIL	VH		M		H	M	VL
C3 Ekra Wall	Urban	60	0.01											
(all roofs)	Rural	115	0.01											
	Total	*175*	*0.02*			VL	NIL	VH		M		H	M	VL
Total - Category - C		**55,735**	**4.88**											
CATEGORY - X														
X1 - GI and other Metal Sheets	Urban	245	0.02											
	Rural	500	0.04											
(all roofs)	*Total*	*745*	*0.07*			NIL	NIL	VH		M		H	M	VL
X2 Bamboo, Thatch	Urban	33,335	2.92											
Grass, Leaves etc.	Rural	208,695	18.27											
(all roofs)	*Total*	*242,030*	*21.19*			NIL	NIL	VH		H		VH	M	L
Total - Category - X		**242,775**	**21.26**											
GRAND TOTAL		**1,142,180**	**100**											

Multi-Hazard Prone Areas

Analysing the hazard prone areas in the Vulnerability Atlas of India, it was seen that there are a large number of districts which can be subjected to one or more of the major natural hazards either occurring individually in different years or at different times of the year, or even occurring simultaneously. For this purpose, the following criteria were used: area prone to earthquake intensity MSK VII or more; area prone to cyclone; and area prone to flood (protected or unprotected). It was also considered that the probability of earthquake and cyclone occurring together is very remote and may not be considered. But earthquake and flood, cyclone and flood could occur simultaneously. Analysing the hazard prone areas on this basis, it was found that 139 Districts out of total 451 Districts are prone to the risk of earthquake and floods, and 35 Districts are prone to cyclone and flood acting simultaneously. There are 45 districts in which cyclone and earthquake may each occur but individually. Effectively, a total 190 districts are prone to the multi hazard situations. An example of District East Godavari with multiple hazard situation is shown in Fig. 3.

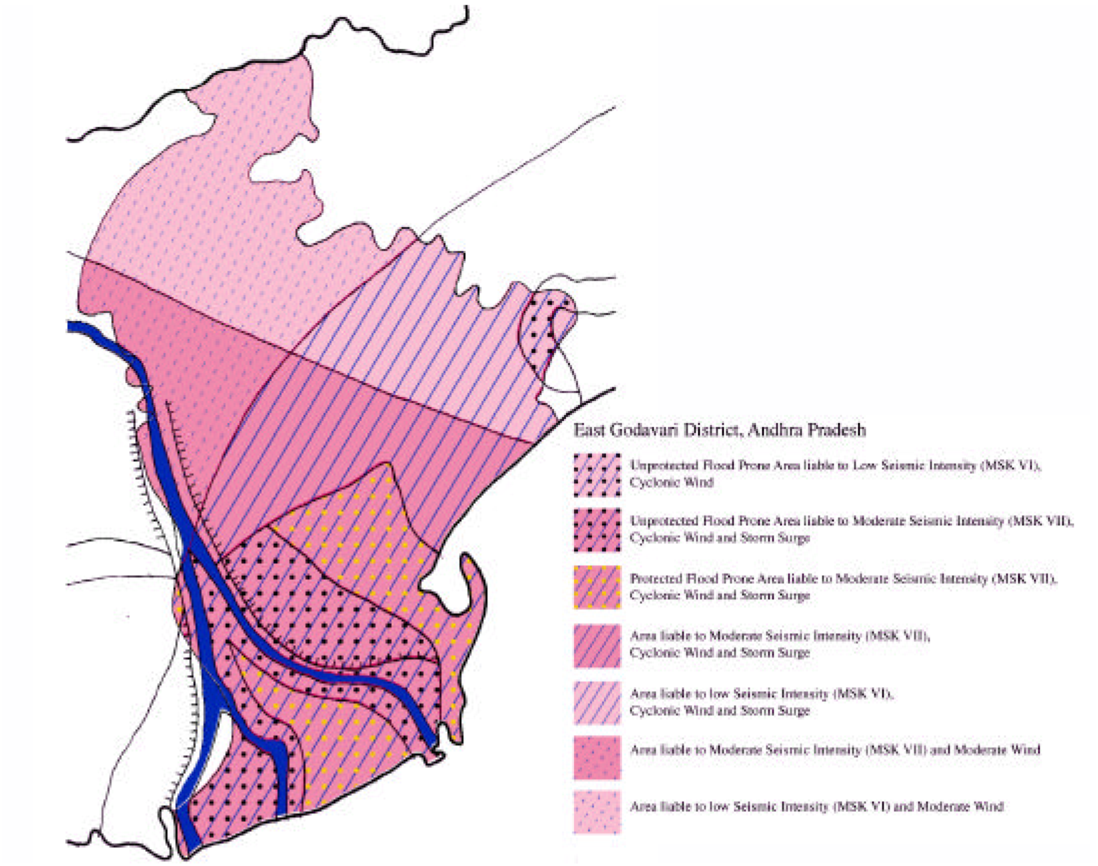

Figure 3 : Multi hazard zones in East Godavari District, Andhra Pradesh

It will, therefore, be necessary that the existing housing stock as well as the new construction in such districts will have to be reviewed for safety from more than one hazard and special designs will need to be worked out to suit such situations. This work will require further studies by R&D institutions to take a holistic view in the design.

LEGISLATION FOR NATURAL DISASTER REDUCTION

Study of the Maharasthra Regional & Town Planning Act 1966 and the National Capital Regional Planning Board Act of 1985 showed that there was no consideration of natural disasters in siting and planning of the settlements. It was also found that the bye-laws of local bodies do not specifically require the safety of the habitat or the buildings from the natural disasters including earthquakes. In the building Bye-laws, from the view point of the safety of the buildings, normally, a stability certificate is required. These deficiencies in enforcement methods prevented the consideration of earthquake impact in settlement planning. and designing of buildings thereby resulting in the rise in number of unsafe settlements and the buildings posing a fearful scenario of risk in future.

In view of these findings, *hazard prone areas* were defined, and additional phrases or clauses were suggested with reference to Maharashtra Regional and Town Planning Act as *model (*see Annexure 1*)*. Additionally, to help the planners, *guidelines on land use zoning in hazard prone areas* were formulated (see Annexure 2). Also the additional requirements for safety of buildings have been worked out to be included in the building bye-laws of local bodies, as a part of which a building information schedule (a simple check list to be ticked by the person submitting the building plan for approval) has been prepared (see Annexure 3).

IMPLEMENTATION OF TECHNOLOGICAL REGIME

Based on the results and findings as above, the following Action Plan is being adopted for implementation of the Techno-Legal Regime in India:

1. Restructuring *the National Policy* on disaster management reflecting the holistic approach involving prevention, mitigation and preparedness in pre-disaster phase with appropriate additional funding, alongwith the existing policy of the *post-disaster relief and rehabilitation* under crisis management.
2. *Creating awareness* for disaster reduction amongst policy makers, decision makers, administrators, professionals (architects, engineers and others at various levels) financial institutions (banks, insurance, house financing institutions) and NGOs and Voluntary organisations.
3. *Amending the legislative and regulatory instruments* (state laws, master plans, development area plan rules, building regulations and bye-laws of local bodies) alongwith capacity building in the enforcement mechanisms at different levels.
4. *Capacity building* at local and regional levels for enforcement of the regulations and building byelaws.
5. *Creating awareness* for improving preparedness amongst the communities, using media, school education, and the national network of the Building Technology in the Districts Centres.
5. *Ensuring use of disaster resistant construction* techniques in all housing and institutional building works to be undertaken under the Central and State development schemes.
6. *Making mandatory*, the use of disaster resistant codes and guidelines related to disaster resistant construction in the construction of houses and buildings in all sectors of the society by law or through incentives.
7. *Promoting the study of natural disaster* prevention, mitigation and preparedness as subjects of education in architecture and engineering curricula for human resource development.

CONCLUSIONS

From the matter presented in the paper above, it may be seen that in spite of seismic zoning maps and building codes having been available in India for the last about 40 years, the progress on the implementation has been unsatisfactory for want of mandatory regulatory measures. It is also noted that for effective earthquake risk reduction actions are to be taken by various sectors of the society starting with the Central and the State Governments, Planners and Designers, and local officials by implementing the codes and guidelines including Land-Use Planning. This requires development of suitable regulatory measures and enforcement thereof. India has developed such a Techno-Legal Regime and various actions are being taken accordingly, which will achieve earthquake risk reduction in the country.

ACKNOWLEDGEMENT

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2. IAEE Committee (1986), *Guidelines for Earthquake Resistant Non-Engineered Construction*, The International Association for Earthquake Engineering.
3. IS: 1893 (1962), *Criteria for Earthquake Resistant Design of Structures*.
4. IS: 4326 (1967), *Earthquake Resistant Design and Construction of Buildings – Code of Practice*.

Annexure 1

AMENDMENT PROPOSED TO THE MAHARASHTRA REGIONAL AND TOWN COUNTRY PLANNING ACT OF 1966

It is considered that amendments are required to be made in Section 2 of Chapter 1, Sections 13 & 14 of Chapter II, Section 22 of Chapter III, and Section 43 of Chapter IV as reproduced below. The amendments to be made are shown in ***Bold Italics***.

<u>Section 2 of Chapter I</u> - This should include the definitions of Natural Hazard and Natural Hazard Prone Areas, as given below:

(16 a) Natural Hazard

The probability of occurrence, within a specific period of time in a given area, of a potentially damaging natural phenomenon.

16 b) Natural Hazard Prone Areas

Areas likely to have (i) moderate to very high damage risk zone of earthquakes, as shown in Seismic Zones III, IV and V specified in IS:1893; OR (ii) moderate to very high damage risk of cyclones areas along the sea coast of India prone to having wind velocities of 39 m/s or more as specified in IS:875(Part 3);OR (iii) significant flood flow or inundation, in river plains (unprotected and protected) as indicated in the Flood Atlas of India prepared by the Central Water Commission) or as identified through local surveys in the Development Plan of the area, OR (iv) one or more of these hazards.

<u>Section 13 and 14 of Chapter II</u>

13. Subject to the provisions of this Act and the rules and regulations made thereunder, a Regional Board shall, with a view to securing planning development and uses of land in a Region, carry out a survey thereof, prepare an existing landuse map thereof ***including natural hazard prone areas*** and other maps as are necessary for the purpose of preparing the Regional Plan. ………………………………

Annexure 2

LAND USE ZONING IN HAZARD PRONE AREAS - GUIDELINES

(Extract applicable to Earthquake Hazard)

Scope of Guidelines – (a) Areas planned under Master Plan/Development Plan; (b) areas not covered under Development Plan viz. Small size local municipalities/bodies.

Definitions – (a) *Natural Hazard :* The probability of occurrence, within a specific period of time in a given area, of a potentially damaging natural phenomenon; (b) *Natural Hazard Prone Areas :* Areas likely to have moderate to high intensity of earthquake, OR cyclonic storm, OR significant flood flow or inundation, OR land slides/mud flows/ avalanches, OR one or more of these hazards.

Objectives – (a) to regulate land use in hazard prone areas with a view to minimise damage caused to the habitat (b) to determine the locations and extent of areas likely to be adversely affected by the hazard; (c) to evolve development pattern of such areas to minimise losses; (d) to restrict indiscriminate development of unprotected areas to specify conditions for safer development.

Identification of Earthquake Prone Areas: - (a). Areas under seismic zone III, IV and V as specified in IS:1893 based on intensities VII, VIII, IX or more; (b) In these zones, the areas which have soil conditions including the level of water table favourable to liquefaction; (c) Under these zones, those hilly areas which are identified to have poor stability conditions, or mud flow or avalanches could be triggered by earthquake.

Approach for Land use zoning : - (a) Leaving the area unprotected and specifying Land Use Zoning for various development purposes, (b) Using protection methods for the areas as a whole or in the construction of buildings, structures and infrastructure facilities; (c) Prioritising buildings, structures and infrastructures in terms of their importance from the point of view of impact of damage on the socio-economic structure of the society.

Protection of areas from earthquakes: - In those areas where there are no dangers of soil liquefaction or landslides, designing all building structures and infrastructures using relevant Indian Standards; (b) Improving Soils with liquefaction potential by compaction to desired relative densities; (c) Founding buildings and structures on deep bearing piles going to non-liquefiable dense layers; (d) Stabilizing slopes by terracing using retaining walls and breast walls, and ensuring good drainage of water behind hill-slopes; and (e) Any other appropriate engineering intervention.

Annexure 3

BUILDING INFORMATION SCHEDULE

1. Building Address	Plot No.	Scheme/Colony	Town	District		
2. Building function & Location						
2.1 Use	Institutional	Commercial	Industrial	*		
2.2 Importance	Ordinary	Important	Hazardous	*	**IS:1893**	
2.3 Seismic Zone (Design Intensity Used)	V (IX)	IV (VIII)	III (VII)	II(VI)	**IS:1893,**	
3. Design EQ Factor	$\propto o$= …..	I=…..	β=…..	$\propto_h$=…..	**IS:1893**	
4. Foundation						
4.1 Soil type at site (Note 2)	Rocky/stiff	Medium # Soft	Liquefiable	Expansive (B.C.)	**IS:1904**	
4.2 Type of Foundation	Strip	Indiv. Col Fottings/Raft	Bearing Piles	Friction Piles	**IS:1893**	
5. Load Bearing Wall Buildings						
5.1 Building Category	A($\propto_h$ < .05)	B($\propto_h$=.05 to .06)	C ($\propto_h$>.06 & <.08)	D ($\propto_h$=.08 to <0.12)	E ($\propto_h$>0.12)	**IS:4326,**
5.2 Bearing Walls	Brick	Stone	Solid Block	Hollow Block	Adobe	
5.3 Mortar (note 4)	C:S=1: …	C:L:S:=1:….	L:S=1:……	Clay Mud	*	
5.4 Floors	R.C. slabs	Stone slabs on joists	Prefab flooring elements	*		
5.5 Roof structure	Flat like floors/ pitched	Trussed// Raftered/ A Frame/ Sloping RC Slab				
5.6 Roof covering	CGI Sheeting	AC sheeting	Clay tiles/ Slate	Wood Shingle	*	
5.7 Openings in walls	Control used on sizes ? Yes/No/NA	Control used on location? Yes/No/NA	Strengthening around? Yes/No/NA		**IS:4326, IS:13828**	
5.8 Bands Provided	Plinth Band	Lintel Band	Roof/Eave Band	Gable Band	Ridge Band	– do –
5.9 Verticle Bars	At corners of rooms	At jambs of openings			– do –	
5.10 Stiffening of Prefab Floors/ Roofs	R.C. screed & Band	Peripheral band and connectors	Diagonal planks and alround band		**IS:4326**	
6. Steel/RC frame buildings						
6.1 Building Shape	Both axes near symmetrical	One axix near symmetrical/ Unsymmetrical (Torsion considered)				
6.2 Infills/partitions	Out of plane stability check? Yes/No	In Plane stiffness considered? Yes/No			**IS:1893, IS:4326**	
6.3 Ductile Detailing of RC Frames	Beams? YES/NO	Columns ? YES/NO	Beam column Joint? YES/NO	Sheer Walls? YES/NO	**IS:13920**	
6.4 Ductile Detailing of Steel Frames	Beams?YES/NO	Columns YES/NO	Beam Column Joint? YES/NO		**SP6(6)**	

Notes:
1. Encircle the applicable Data point or insert information.
2. Stiff, N> 30; Medium, N=10.3; Soft, N<10; Liquefiable, poorly graded sands with N<15 under Water Table (see Note 5 of Table 1 in IS:1893) where N= Standard Penetration (IS:2131-1981).
3.* means ‘any other, specify.
4.C=Cement, S=Sand, L=Lime

Signature of Applican/Engineer/Architect

Name:

Designation: