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GEOLOGIC CONSIDERATIONS FOR URBAN PLANNING IN SEISMIC ENVIRONMENT *

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ABSTRACT

Even though it is desirable to visualize the performance of an entire metropolitan centre during earthquake occurrences as part of local hazards mitigation programme, yet these centres still remain vulnerable to major seismic activity. Geological considerations lack in urban planning and do not account for hazards mitigation. This may also be due to the involvement of several interdependent activities, like services, functions, life line elements, etc. The failure of anyone of these can make the entire metropolitan area inoperative. It is recommended that multidisciplinary teams should undertake zoning studies for use in the future growth areas of Indian urban centres.

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INTRODUCTION

Several residential areas in a number of urban centres in the developing countries are getting very thickly populated with the onset of industrialisation since World War II. Industrial growth in India too has resulted in steady migration of people from rural areas to metropolitan Centres. Bangalore, Bombay, Calcutta, Delhi and Madras are expected to be very very large (population wise) metropolitan centres by the year 2000 when nearly one-fourth of the total population of the country would be living in cities with more than one million population (Table 1).

Those living in highly congested metropolitan centres, in contrast to those in the rural area, are exposed to most critical natural hazard risk such as earthquakes. A few very large size (magnitude greater than 8) earthquakes have occurred in Indian region in 1897, 1905, 1934 and 1950 in which several thousand lives were lost. Fortunately none of those occurred in the vicinity of a metropolitan area. The increasing growth of population density is creating problems whereby a very localised earthquake in an urban setting can cause a major catastrophe such as was not possible a few decades back. The pressures of population growth in the urbanization are causing expansion into areas which are more difficult to develop safely than those of earlier times.

The increasing vulnerability of high density metropolitan areas highlights the necessity of geological considerations by designers in natural hazards mitigation programmes. The present advances in earthquake engineering, like testing and analysis of individual structures and in the art of predicting earthquakes, based on monitoring of precursors, can significantly reduce the earthquake risk. However, it is a question of feasibility and implementation of earthquake hazard reduction programmes to suit the economic convenience of various developing countries. It is in this important context where state-of-the-art knowledge in seismic-zonation or micro-zonation can contribute significantly.

VULNERABILITY OF URBAN CENTRES

The planning and design of an urban centre in itself is a highly complex problem due to the involvement of several interdependent activities, services, functions and facilities. Because of the interdependence of these facilities, the failure of any single component can severely affect the functioning of the other, resulting into chaos.

The consideration of geological inputs for designing a relatively safe human-built environment in a region of high seismicity requires still greater skills in using the raw data and state-of-the-art research in the basic seismic investigations of the geo-science and engineering (Fig. 1). Since safety from earthquake disaster is only one of a multitude of crucial issues a designer is confronted with, the consideration of geological and engineering inputs must be so dovetailed to a form that includes the most essential and important information for designers and architects involved in construction and land use planning.

There has been considerable research and development in the functioning of individual elements of the urban environment, such as independent studies on life lines, land use, building design, contingency planning, and public policy, but no work has been done in approaching the problem from a balanced urban planning point of view to mitigate earthquake vulnerability of large metropolitan areas. Several large Indian cities lie in active seismic zones and it is well known that these cities are not well prepared for a large seismic event. The architect and planner should possess a basic understanding of and take an active role in both primary categories of strategies for earthquake hazard mitigation, namely, (1) Structural design for seismically resistant buildings, and (2) Zonation of land use based on risk and hazard. The importance of the first category of hazard mitigation has long been recognized and most widely used aseismic approach in the building professions. The second category has more recently been explored as a major method of mitigating earthquake hazard. Research in this area, and recognition of its validity as an additional line of defence against earthquake, is increasing.

Another area in which the planning and design practitioner plays an important role deals with the existing hazardous, older buildings problem. They have participated in the rehabilitation of existing buildings, and their strengthening, for many years and it is only recently that this critical aspect of urban seismic safety has been realized. Whether it is called "redesign, retrofitting, renovation, rehabilitation, renewal, recycling, remodeling, restoration, preservation, conservation, revitalization, reuse" or by any other name, the reconstruction of the existing building stock has become a very important part of an architect's responsibilities. The existing, older building problem will receive more attention in our urban areas in the future.

Some of the major Indian cities or metropolitan centres located in active seismic zones and subject to moderate or severe earthquake activity (being located in seismic zones III, IV or V as designated by IS: 1893-1975, Ref. 1) are given in Table 2. Other important cities like Bhopal, Jamshedpur, Madras and Ranchi which though not located in seismically active areas, will none the less be affected by 'long period' damage patterns resulting from the occurrence of major earthquakes in other highly active areas far away. Also not listed are those major coastal cities like Visakhapatnam, located in a comparatively lesser earthquake prone area but still vulnerable to tsunami damage caused by earthquakes originating thousands of kilometers away.

It is thus apparent that a huge population is at risk in the metropolitan areas when the planners are dealing with urban development. The recent earthquake studies in the USA indicate that the occurrence of a severe earthquake in a localized high density population in the urban area would result in collosal disaster with staggering casualties and high death ratio (Ref. 5.)

URBAN DESIGN AND PLANNING

In the early days of the evolution of urban design and planning it was found that many decisions overlooked the fundamental principles due, in part, to the fact that the urban environment is a complex and tightly knit fabric composed of many interdependent activities, facilities and functions. The failure of one element may affect the functioning of others severely. Therefore the urban designers and planners are becoming sensitive to the fact that their decisions must be developed from a balanced and holistic programme to include the design professions, public policies, social and economic concerns when dealing with intricate relationships found in metropolitan areas.

The profession of urban design focusses on three dimensional physical planning and design of the urban environment. Botsai, et al (Ref. 2) describe the fundamental objectives of urban design to synthesize and develop three dimensional solutions to:

(i) the physical, spatial arrangement of all urban activities including their nature, location, type, scale, density, and circulation patterns,

(ii) the physical three-dimensional from of urban activities through the interaction of design determinates with climate, topography, natural hazards, and other environmental relationships,

(iii) the physical organisation of urban linkages relating to community and social requirements exemplified by buildings, transportation systems, communication networks, re-development, energy utilization, land use, local government programmes, and

(iv) the quality of urban living which recognizes and measures the positive attributes of physical development in terms of public health and life safety.

URBAN PLANNING AND EARTHQUAKES

Participation of Organisations : The participation of the government, local communities, social organizations, etc. plays a very important role in the various programmes of hazard reduction. However, a recent study shows that the response of these organisations varies considerably both in the level of preparedness as well as in their ability to participate in the programmes to mitigate earthquake effects. A few organizations ignore the potential risk of earthquakes, others might be unable to apply known information to effective policy and programme implementation, still a few others may have changed building practices to mitigate earthquake disasters.

Design Aspects : The design characteristics of urban centres should be reviewed in the light of potential hazards of earthquakes. The land use, building codes and topologies, infrastructure design, life line systems, internal city structures, local city laws, construction materials and practices and insurance can be so knit as to increase a community's resilience to the disastrous effects of earthquake. Urban planning policies for emergency and preparedness programmes can minimize catastrophies, past-earthquake planning programmes for reclamation, redeveloping and resettling can accelerate the recovery phase of a community.

A study (Ref. 3) of the case history of earthquakes of 1971 (San Fernando, USA) and 1972 (Managua, Nicaragua) indicates significant interaction between urban design concerns and the vulnerability of cities to earthquakes and post-earthquake recovery. It is inferred that it is an urban planning problem and not solely an earthquake engineering or earthquake prediction problem.

Multidisciplinary Approach : It would be appropriate to work out a range of urban design and planning skills in a multidisciplinary manner and use them as integrating factors in reducing the risks assumed by metropolitan centres rather than to attempt to mitigate the problem by strengthening isolated structure. The urban design and planning require a balanced approach to the problem through joint cooperative efforts by the design profession and local administration in order to develop and implement a coordinated effort in earthquake hazards reduction programmes.

The pattern of location of urban centres, expansion, structure and management must be considered against the disastrous effects of earthquakes and classified to include ground shaking, ground displacement along fault zones, landslides, soil-structure interaction and water inundation by earthquake waves or dam failures.

MICROZONATION IN URBAN PLANNING

Till recently, damages from earthquakes were socially understood as a fact of life, a reflection of individual choice, or a product of God's will. But lately it is being realized that these damages are not factual but are, instead, a problem. The distinction between fact and problem is that problems have solution whereas social facts have no solution. The patterns of distribution of earthquake effects and losses have enabled scientists to better understand the interactive causes of earthquake losses which imply a more systematic approach to reducting the growing hazards from earthquakes. A set of solutions to be interactive causes of earthquake losses is being worked out. These solutions are aimed at altering the cycle of increasing potential for catastrophic losses. Microzonation has a large and effective contribution in solving earthquake problems and thereby providing the urban planners a very significant information.

The aim of microzonation is to estimate the location, recurrence interval, and relative severity of future seismic events in an area so that the potential hazard can be assessed and the effects can be mitigated or avoided. The various comprehensive programmes for earthquake hazard reduction in urban centres can be designed and implemented according to this concept. Such studies have the potential to make public aware of risks from geological hazards, enhance design and application of practicable land use subdivisions and zoning programmes, enhance regional application of appropriate building design and practice, enhance responses for emergency planning, enhance socially the responses to earthquake warnings, and make public aware of planning for compatible reconstruction after an earthquake.

Microzonation techniques provide a potentially important tool for design professionals and urban planners seeking physical solutions to earthquake hazards vulnerability of cities from an urban design focus. Microzoning maps can provide the initial 'check points', among others, in the general, overall configuration or redevelopment of metropolitan areas and the corresponding suitable location of life line systems. Before the planner looks in to the alternative three-dimensional solutions the codes and ordinances, he can consult the microzoning maps for the preliminary information.

In an earthquake hazards mitigation programme, urban planning may lead to somewhat different location, design configuration and management of cities than the currently practised types. The urban design practices coordinated with microzonation techniques can provide the basis for locating the developmental area in metropolitan centres which are vulnerable to potentially damaging earthquake (Ref. 4,5).

CONCLUSION

Geological inputs are being increasingly used in the design and planning of urban centres in the quest for reducing earthquake hazard. Urban planning in terms of earthquake disaster mitigation is a new and emerging field. As a discipline, it involves a multi-disciplinary approach in solving all sorts of present and future problems as compared to the three-dimensional design of major metropolitan centres. Utilisation of (i) geological inputs in the design of urban centres and (ii) comprehensive policies in urban planning may have significant and adequate effect in their application to earthquake safety concerns. An effective use of the techniques of microzonation enables the designer and planner of urban centres to improve upon their designs and policies in reducing earthquake hazards. However, it is essential to determine priority areas for conducting microzonation studies in respect of earthquake effects. Those areas, where population growth has yet to take place, should be given priority over the ones, which are very thickly populated, in the selection of areas for microzoning studies. It is much cheaper to prevent incompatible development and expansion than to strengthen or repair or correct the existing dwellings or facilities.

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TABLE 1, THIRTY-FIVE LARGEST URBAN AGGLOMERATIONS RANKED SIZE 1900, 1950, 2000.

Rank	Agglomeration/ Country	Pop. 1900	Agglomeration/ Country	Pop. 1950	Agglomeration/ Country	Pop. 2000
1	London, Britain	6.48	NYC/NE New Jersey, USA	12.4	Mexico City, Mexico	26.3
2	New York, USA	4.24	London, UK	10.4	Sao Paulo, Brazil	24.0
3	Paris, France	3.33	Shanghai, China	10.3	Tokyo/Yokohama,Japan	17.1
4	Berlin, Germany	2.42	Rhein-Ruhr, FDR	6.9	Calcutta, India	16.6
5	Chicago, USA	1.72	Tokyo/Yokohama, Japan	6.7	Greater Bombay, India	16.0
6	Vienna, Austria	1.66	Beijing, China	6.7	NYC/NE New Jersey,USA	15.5
7	Tokyo, Japan	1.50	Paris, France	5.5	Seoul, Republic of Korea	13.5
8	St.Petersburg,Russia	1.44	Tianjin, China	5.4	Shanghai, China	13.5
9	Philadelphia, USA	1.42	Buenos Aires, Argentia	5.3	Rio de Janeiro, Brazil	13.3
10	Manchester, Britain	1.26	Chicago/NW Illinois,USA	5.0	Delhi, India	13.3
11	Birmingham, Britain	1.25	Moscow, USSR	4.8	Buenos Aires,Argentina	13.2
12	Moscow, Russia	1.12	Calcutta, India	4.4	Cairo/Giza/Imbaba,Egypt	13·2
13	Peking, China	1.10	Los Angeles, USA	4.1	Jakarta, Indonesia	12.8
14	Calcutta, India	1.09	Osaka/Kobe, Japan	3.8	Baghdad, Iraq	12.8
15	Boston, USA	1.08	Milan, Italy	3.6	Teheran, Iran	12.7
16	Blasgow, Scotland	1.07	Rio de Janeiro, Brazil	3.5	Karachi, Pakistan	12.2
17	Liverpool, Britain	0.94	Mexico City, Mexico	3.1	Istanbul, Turkey	11.9
18	Osaka, Japan	0.93	Philadelphia, USA	3.0	Los Angeles, USA	11.2
19	Constantinople Turkey	0.90	Greater Bombay, India	2.9	Dacca, Bangladesh	11.2
20	Hamburg, Germany	0.90	Detroit, USA	2.8	Manila, Philippines	11.1
21	Shanghai, China	0.84	Sao Paulo, Brazil	2.8	Beijing, China	10.8
22	Buenos Aires,	0.81	Naples, Italy	2.8	Moscow, USSR	10.1
23	Budapest	0.79	Leningrad, USSR	2.6	Bangkok/Thonburi, Thailand	9.5
24	Bombay, India	0.78	Manchester, UK	2.5	Tianjin, China	9.2
25	Ruhr, Germany	0.77	Birmingham, UK	2.5	Paris, France	9.2
26	Rio de Janeiro,Brazil	0.75	Cairo/Giza/Imbaba, Egypt	2.5	Lima-Callo, Peru	9.1
27	Warsaw, Poland	0.72	Boston, USA	2.3	London, UK	9.1
28	Tientsin, Dhina	0.70	Shenyang, China	2.2	Kinshasha, Zaire	8.9
29	Canton, China	0.67	West Berlin, FDR	2.2	Rhein-Ruhr, FDR	8.6
30	Newcastle, Britain	0.62	San Francisco/Oakland, USA	2.0	Lagos, Nigeria	8.3
31	St. Louis, USA	0.61	Leeds/Bradford, UK	1.9	Madras, India	8.2
32	Pittsburg, USA	0.60	Glasgow, UK	1.9	Bangalore, India	8.0
33	Cairo, Egypt	0.60	Jakarta, Indonesia	1.8	Osaka/Kobe, Japan	7.7
34	Naples, Italy	0.56	Hamburg, FDR	1.8	Milan, Italy	7.5
35	Brussels,Belgium	0.56	Wien, Austria	1.8	Chicago/NW Illinois, USA	7.2
	Total	46.21	Total	144.2	Total	422.8

Source : Chandler and Fox, pp. 323-330
U.N, Department of Internation Economic and Soil Affairs (1985), Tabl A-12, pp. 144-147

Table 2 Seismic Zones & Population Data for Some Important Indian Towns

Town	Seismic Zone	Population[+] 1941	Population[+] 1981
Agra	III	284 149	770 352
Ahmedabad	III	595 210	2 515 195
Amritsar	IV	391 010	589 229
Bombay	III	1 695 168	8 227 332
Calcutta	III	2 108 891	9 165 650
Dehradun	IV	78 228	293 628
Delhi	IV	659 857	5 713 581
Gorakhpur	IV	98 977	306 399
Imphal	V	99 716	155 639
Kanpur	III	487 324	1 685 308
Ludhiana	IV	111 639	606 250
Patna	IV	196 415	916 102
Simla	IV	23 320	70 479
Surat	III	171 443	912 568
Varanasi	III	263 100	798 057

[+]Census of India, Registrar General and Census Commissioner of India, New Delhi.

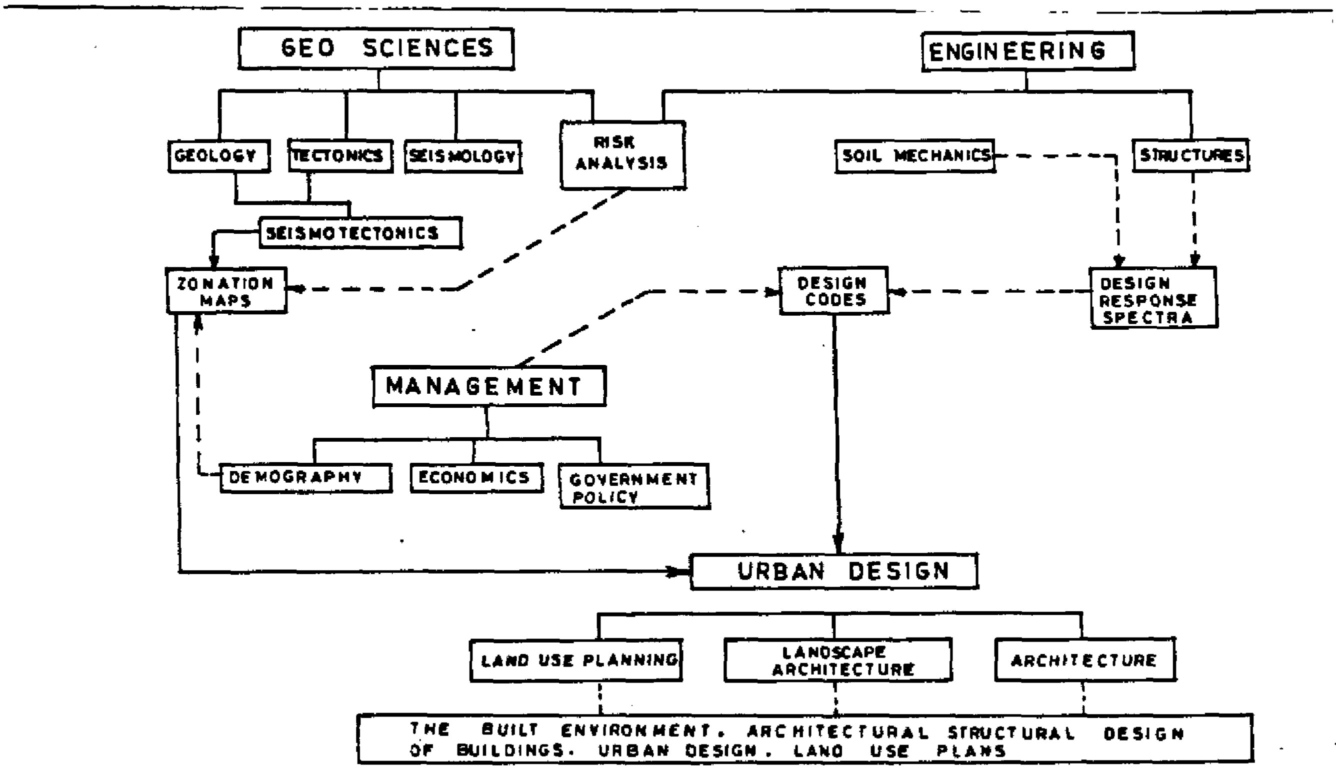

FIG. 1 _ FLOWCHART OF INTERDISCIPLINARY RELATIONS IN EARTHQUAKE HAZARD MITIGATION PROGRAMME FOR URBAN CENTRES. (MODIFIED FROM LAGORIO AND WANG, 1981)