Chapter 7 :

Recommendation to Formulate a Comprehensive Urban Disaster Prevention and Management Plan

Chapter 7. Recommendations to Formulate a Comprehensive Urban Disaster Prevention and Management Plan

7.1. Introduction

7.1.1. Review of Seismic Damages to the City of Tehran

In chapter 4, damages were estimated for various items. Here major damages are reviewed. Damages to residential building and human casualties were estimated as Table 7.1.1. The damage of bridges was estimated as Table 7.1.2. Damages to major public facilities were estimated as Table 7.1.3.

Table 7.1.1 Building Damages and Human Casualties

	Ray Fault Model	NTF Model	Mosha Fault Model	Floating Model	Current Condition
Building Damage	483,000	313,000	113,000	446,000	Number of Buildings
Building Damage Ratio	55%	36%	13%	51%	876,000
Damage Cost (% of GDP) (Re-construction cost of residential buildings)	22.7%	14.30%	5.16%	20.38%	Gross GDP (1998) 109 Billion US$
Number of Dead People	383,000	126,000	20,000	302,000	Population
Death Ratio	6%	2%	0.3%	5%	6,360,000

Note: Damage cost is calculated by using published GDP(1998) at price of US$50,000 per building (government official exchange rate 1US$=Rls.3,000)
Human casualties are case for of night-time and no rescue operation.

Table 7.1.2 Damage of Bridges

Fault Model	Ray Fault Model	NTF Model	Mosha Fault Model	Floating Model
Collapsed	6	0	0	0
Unstable	5	7	0	10

Table 7.1.3 Damages to Public Facilities

	Number of Damage and Damage Ratio (%)																	
	Govern-mental Facility		Police		Traffic Police		Fire-Fighting		Hospital		Elementary School		Inter-mediate school		High School		Higher Education Center (University)	
Ray Fault Model	18	(40)	27	(43)	7	(52)	28	(52)	56	(50)	623	(57)	369	(54)	340	(52)	66	(42)
NTF Model	11	(25)	18	(28)	5	(35)	21	(38)	33	(29)	376	(35)	250	(36)	242	(37)	61	(39)
Mosha Fault Model	4	(8)	7	(11)	2	(16)	7	(12)	11	(9)	133	(12)	81	(12)	75	(12)	18	(12)
Floating Model	16	(36)	26	(41)	6	(48)	28	(53)	50	(44)	558	(51)	350	(51)	331	(51)	76	(48)

7.1.2. Outline of General Approach and Conclusion

In order to mitigate an urban earthquake disaster, comprehensive measures are required for the following four stages:

- Prevention stage, to plan for the mitigation of damage in the event of an earthquake;
- Emergency stage, to mobilise effective and efficient evacuation and rescue/relief operations and other essential activities after an earthquake;
- Rehabilitation stage, to reactivate urban functions and lifelines as soon as possible, without compromising the safety of people; and
- Reconstruction stage, to rebuild a stronger Tehran that is able to sustain the effects of earthquake occurrences.

The Study Team considers that the most effective and proper way to address the reality of Tehran being at risk of an earthquake disaster involves the following:

1) Enhancement of legal measures,
2) Establishment of clear organisational structures for policy-making and for the execution of these policies,
3) Financial arrangements for required prevention, emergency, rehabilitation and reconstruction measures,
4) Formulation of a Comprehensive Urban Disaster Prevention and Management Plan, and
5) Formulation of Action Plans and Programs.

Table 7.1.4 shows contents of consideration of the Study. Table 7.1.5 shows summary of existing conditions, issues, and recommendations for Urban Seismic Disaster Prevention.

Table 7.1.4 Contents of Consideration

Subject	Contents of Consideration	Section No in this Report
Legal Measures	Chronology of Legislated Measures for Natural Disasters in Iran	7.2.1.
	The National Committee for Natural Disaster Reduction (NCNDR)	7.2.2.
	Ministry of the Interior: Executive Agency for Natural Disaster Management	7.2.3.
	Issues on Legal Measures	7.2.4.
	Recommendation to Enhance Legal Measures	7.2.5.
Organisational Structure	Present Organisational Structure for Natural Disaster Reduction Policy-Making	7.3.1.
	Issues Regarding the Present Organisational Structure	7.3.2.
	Proposed Organisational Structures	7.3.3.
Financial Measures	Allocated Natural Disaster Reconstruction Fund	7.4.1.
	Additional Financial Measures	7.4.2.
Comprehensive Urban Disaster Prevention and Management Plan	Past Trends of Related Studies and Activities in Iran	7.5.1.
	Required Fields of Comprehensive Urban Disaster Prevention and Management Plan	7.5.2.
	Required Fields to Formulate Policy and Objectives	7.5.3.
	Damage Estimation and Hazard Map (Seismic Microzoning)	7.5.4.
	Formulation of Prevention Plans ● Prevention Plan for Ground-based Disaster ● Fire Prevention Plan ● Evacuation Plan with Facilities Development ● Prevention Plan for Building Damage (details are compiled in Chapter 8) ● Prevention Plan for Lifelines ● Prevention Plan for Damages to Transportation Facilities ● Reinforcement Plan for Urban Structures ● Organisation Plan for Urban Disaster Prevention and Management ● Guideline and Manual for Disaster Prevention Awareness ● Earthquake Disaster Study and Research Plan (details are compiled in Chapter 9)	7.5.5.
	Emergency Operation Plans ● Disaster Task Force System and Organisational Structure ● Fire Fighting Plan ● Rehabilitation of Heliport ● Evacuation Plan ● Maintenance Plan for Emergency Roads and Evacuation Road Network Functions ● Emergency Rescue Operation Plan and Law ● Relief Operations and Medical Service Plan and Law ● Evacuation Area Plan ● Emergency Water Supply Plan ● Emergency Food Supply Plan ● Other Emergency Goods Supply Plan ● Preventive Measures for Epidemics, Cleanliness, and Health Care ● Locating Dead Bodies, Preparing Morgues, Burials and Burial Grounds ● Rehabilitation of Educational Function ● Distribution Plan of Monetary Donations for Disaster Victims ● Acceptance Plan of Donation for Disaster	7.5.6.
	Rehabilitation and Reconstruction Plan ● Road and Transportation Rehabilitation Plan ● Urban Infrastructure (Lifelines) Rehabilitation Plan ● Rehabilitation and Reconstruction Plan of Social and Public Service Facilities ● Housing Damage ● Socio-Economic Revitalisation and Stabilisation Plans	7.5.7.
Formulate Action Plans and Programs		7.6.

Table 7.1.5 Matrix of Existing Situation/Issues/Recommendation for Tehran Urban Seismic Disaster Prevention (1)

<table>
<tr><th></th><th>Period /Sector</th><th>Existing Situation</th><th>Issues</th><th>Recommendation</th></tr>
<tr><td rowspan="3">Legislation</td><td>Before disaster stage</td><td rowspan="3">NCNDR is only legislated at present. The other required prevention and mitigation measures and organisation for urban natural disaster damages are not legislated yet.</td><td>Lack / unclear prevention measures for urban natural disaster damage before earthquake.</td><td rowspan="3">1. Comprehensive and integrated prevention measures on the three stages should be clearly defined on the proposed ‘Comprehensive Urban Seismic Disaster Prevention Plan for Tehran’.
2. Roles and functions of each related government agencies and private sectors for the required prevention measures on each stages should be clearly demarcated and stated with financial and organisational background by legislated measures.</td></tr>
<tr><td>Emergency stage</td><td>Unclear / duplicated / lack of indispensable task for emergency measures between government agencies and private sectors.</td></tr>
<tr><td>Rehabilitation/ reconstruction stage</td><td>Unclear rehabilitation / reconstruction measures and task distribution to public and private sectors.</td></tr>
<tr><td rowspan="5">Organisation</td><td>General</td><td>Systematic organisation for policy making and execution has been established as follows,</td><td>Functions and members of Provincial Committee of NCNDR and Provincial NDTF are duplicated.</td><td>Function of Provincial NCNDR could be substituted by Provincial NDTF.</td></tr>
<tr><td>Policy Making/ Inter Ministerial Coordination</td><td>1. NCNDR was established to formulate the national policy for natural disaster prevention.</td><td>National policy is set under the inter-ministerial coordination by NCNDR, which is organised by the minister of Interior.</td><td>For the policy making under the ministerial coordination, The president of Iran is proposed to be the head of NCNDR supported by the Minister of Interior (deputy for the committee) and the present secretariat office in Ministry of Interior.</td></tr>
<tr><td>Execution before disaster stage</td><td>2. NDTF system for central / regional levels is established to execute all of required prevention measures.</td><td>There is no Seismic Disaster Prevention and Management Plan, and no appropriate organisation to implement and manage the plan exists in the country</td><td>1. Appropriate organisation should be established to prepare “Urban Seismic Disaster Prevention and Management Plan for Tehran” under direct control of Tehran Mayor.
2. To implement the proposed plan, sufficient organisation should be established or improved within Tehran Municipality.</td></tr>
<tr><td>Execution on emergency stage</td><td></td><td>Lack / unclear community levels of disaster task forces to tackle to the huge scale of urban disaster emergency operation (evacuation, rescue, fire-fighting, food / water supply, etc.).</td><td>For huge scale of urban disaster damage on Metropolitan Tehran, community level, residential block and family level of Disaster Task Force Units and Groups are proposed to establish.</td></tr>
<tr><td>Execution on rehabilitation / reconstruction stage</td><td></td><td>Unclear measures for rehabilitation of lifelines and reconstruction of more than a half of collapsed public and private buildings.</td><td>Disaster Task Forces on each lifeline agencies and companies are proposed to establish. The present organisation for urban reconstruction should be improved for huge scale of estimated reconstruction demand.</td></tr>
</table>

Table 7.1.5 Matrix of Existing Situation/Issues/Recommendation for Tehran Urban Seismic Disaster Prevention (2)

	Period /Sector	Existing Situation	Issues	Recommendation
Financial	Before disaster stage	Funds and budgets have not been properly allocated for prevention measures.	Funds / budgets and plan for prevention measures is not cleared to improve weak structure of public and private buildings, road / urban structures, lifelines and emergency facilities / goods before disaster damages.	Proper budget to implement three staged measures should be identified and allocated on the proposed 'Comprehensive Urban Seismic Disaster Prevention Plan for Tehran'.
	Emergency stage	Funds and budget has not been properly allocated for emergency facilities and goods.	Funds / budget and plans for emergency operation is not cleared to improve emergency facilities and goods.	
	Rehabilitation / reconstruction stage	Reconstruction Funds for public facilities / road / lifelines and collapsed private buildings has been allocated.	The allocated funds for reconstruction could not be enough for the estimated reconstruction demand.	
Prevention		Prevention plan for urban natural disaster is not formulated in Iran.	Lack of prevention and mitigation plans and measures for urban natural disaster for Tehran and others.	1. Formulation of 'Comprehensive Urban Seismic Disaster Prevention Plan for Tehran' is recommended to be the top priority.
		Training / drill for natural disaster is held on the national disaster day.	Community / establishment levels of natural disaster drills is not well organised on the plan.	2. Implementation of prevention and mitigation measures of urban disaster damage before disaster is recommended on the above-formulated plan.
Emergency		Emergency operation plan for Tehran is formulating by Red Crescent Society of Iran.	Red Crescent Society of Iran is taking major roles for emergency operation but their capability is not enough for the huge scale of Metropolitan Tehran Urban Disaster.	3. Urgent action or action program to improve school building and disaster center (municipality / district offices, police / traffic police, fire-fighting station. etc.) is recommended based on the above-formulated plan.
		Financial resources for the emergency operation plan are arranging.		
Rehabilitation and Reconstruction		Housing Foundation (Ministry of Housing and Urban Development and Islamic Revolution) has experience of urban natural disaster reconstruction on Manjil earthquake.	The estimated magnitude of urban disaster damages of Ray Fault model will be huge, which is over several ten times larger than that of Manjil earthquake.	

7.2. Recommendation of Legal Measures

In the Islamic Republic of Iran, natural disaster prevention and management measures have not yet been actively legislated. In the future, all the required institutional and implementation measures requires to either prevent or manage natural urban disasters should be legislated with a clear designation of roles and tasks of related government agencies, NGOs, and the private sector, under a formulated National, Regional and Urban Disaster Prevention and Management Plan.

7.2.1. Chronology of Legislated Measures for Natural Disasters in Iran

The first legal measure for natural disaster mitigation in Iran was the establishment of the Civil Defence Organization in 1958. This was followed by the enactment of the Flood Mitigation and Reconstruction Law in 1969. With the Islamic Revolution in 1978, the Civil Defence Organization was dissolved, and its functions were transferred to the Basij Mostaz' afin (the Revolutionary People' s Union).

A new fundamental law to establish the National Committee for Natural Disaster Reduction (hereinafter referred to as NCNDR) was approved and legislated by the Islamic Consultative Assembly in 1991, after the Manjil Earthquake occurrence and the declaration of International Decade for Natural Disaster Reduction (1990-2000) by the United Nations.

7.2.2. The National Committee for Natural Disaster Reduction (NCNDR)

The NCNDR was established to handle information exchange, scientific research, and formulation of alternative prevention and mitigation plans of natural disasters, such as floods, drought, agricultural calamities, and earthquakes, under the direction and supervision of the Minister of Interior.

With the establishment of the NCNDR, the following activities were set into motion:

1) Formulation and establishment of sub-committees, dealing with:
   - Comprehensive studies and research on natural disasters,
   - Measures for warning systems and declaring a state of emergency, and
   - Quick emergency response and compensation for damage
2) Allocation of budget by the PBO
3) Organisation of Provincial Committees for NDR
4) Presentations of results by the sub-committees to the National Committee every six months
5) Procedure for undertaking the identified roles and tasks
6) Dispatching of some of the NCNDR staff to the PCNDR

The organizational structure for policy making of preventive measures was legislated in accordance with the results of the above-mentioned activities.

The National Committee for NDR has formulated and enacted the following:

- Technical standards for sand and gravel exploration in river channels,
- Criteria for land-use and development zoning along the coast and rivers,
- Compensation for damages by floods,
- Guidelines for the general directors of NDR,
- Building code under Standard No. 2800,

- Regulations for earthquake-resistant building design, and
- Instruction for technical and safety measures, which are supervised by municipalities and other executive organisations

On the other hand, the Disaster Task Force system, meant to execute measures with proper organisational structure for the emergency, rehabilitation and reconstruction stages of natural disasters, has not yet been legislated.

7.2.3. Ministry of the Interior: Executive Agency for Natural Disaster Management

The Ministry of the Interior is officially assigned to the task force to oversee and coordinate all activities for the mitigation of natural disasters. In this connection, government bodies/agencies at the provincial, district or municipality, and sub-district levels are organised into the Provincial Disaster, District Disaster, and Sub-District Disaster Task Forces under the General Provincial Governor, Head of Districts, and Head of Sub-Districts, respectively.

The Disaster Task Force under the Ministry of the Interior, which is the central coordinator of disaster management in Iran, commenced its activities in March 1991 and is mainly responsible for the following items:

- Disaster prevention,
- Damage mitigation,
- Emergency relief and rescue operations,
- Rehabilitation, and
- Reconstruction

7.2.4. Issues on Legal Measures

There is limited implementation of legislated and other measures for natural disaster prevention and management in Iran, which is caused by the lack of a National, Regional and Urban Natural Disaster Prevention and Management Plan.

7.2.5. Recommendation to Enhance Legal Measures

All the required institutional, organisational, financial, and implementation measures for prevention and management before and after an earthquake, or any other natural disaster for that matter, are recommended to be legislated with detailed task distribution identified for each measure.

Measures and tasks should be clearly identified and explained in the disaster prevention and management plans of national, regional and urban areas.

7.3. Recommendation for Organisational Structure

The Ministry of the Interior has the primary role of mobilising disaster prevention and management functions, which should principally be carried out by the two organisational systems of policy-making and execution.

7.3.1. Present Organisational Structure for Natural Disaster Reduction Policy-Making: the NCNDR

The NCNDR was enacted as the policy-making organisation for natural disaster reduction by the Islamic Consultative Assembly in 1991. In accordance to its executive by-laws, a Coordination Committee, 9 Special Sub-Committees, and 27 Provincial Committees were formed. A regular committee meeting is held tri-monthly, presided over by the head of committee. The organisational structure of the NCNDR is presented in Figure 7.3.1

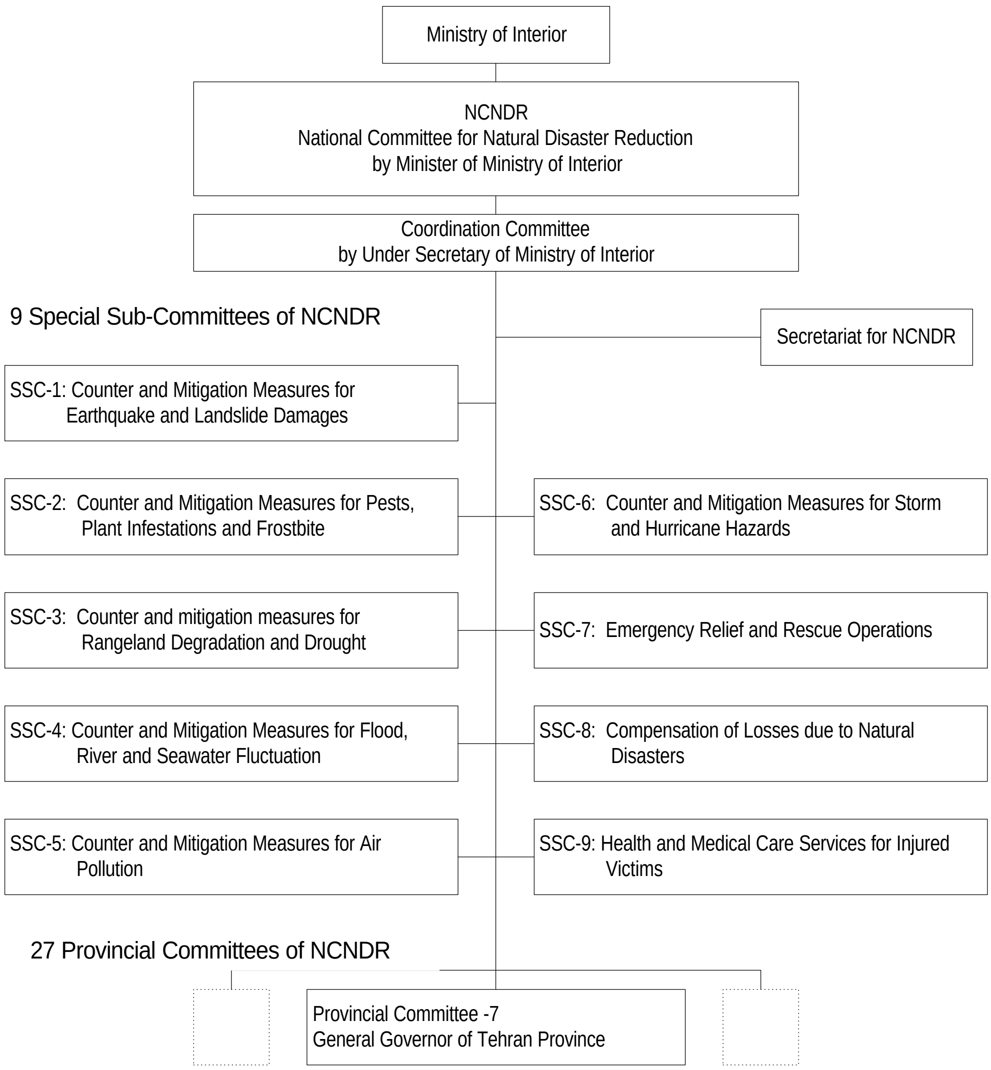


Figure 7.3.1 Present Organisational Structure for Policy- Making: the NCNDR

Source: Ministry of Interior

Table 7.3.1 Member Organization of National Committee for Natural Disaster Reduction

Organisation		NCNDR	SSC-1	SSC-2	SSC-3	SSC-4	SSC-5	SSC-6	SSC-7	SSC-8	SSC-9
Ministry of Interior	MOI	Main Body	M	M		M	M	M		M	M
Environment Protection Department	EPD	Director	M				H		M		
Forestry and Rangeland Organisation	FRO	Director									
Geological Survey of Iran	GSI		M			M					
Institute of Environmental Study, Tehran University	IESTU						M				
Institute of Geophysics, Tehran University	IGTU	Director	M				M	M			
Institute of Meteorology Iran	IMI	Director		M	M	M	M	H			
International Institute Earthquake Engineering and Seismology	IIEES		M						M		
Iran Atomic Energy Organization	AEO		M	M			M				
Islam Republic of Iran Central Bank	IRICB									M	
Islamic Revolution Housing Foundation	IRHF		M								
Islamic Republic of Iran TV/Radio	TV/R		M	M	M	M	M	M	H	M	M
Ministry of Agriculture	MOA	Minister		H	M	M		M		M	
Ministry of Commerce	MOC	Minister									
Ministry of Corporative										M	
Ministry of Culture and Higher Education	MCHE		M				M	M	M		
Ministry of Defence and Armed Forces	MDAF								M		
Ministry of Economics and Finance	MOEF									M	
Ministry of Energy	MOE	Minister	M	M	M	H					M
Ministry of Health	MOH	Minister		M			M		M		H
Ministry of Heavy Industry	MOHI						M				
Ministry of Housing and Urban Development	MHUD	Minister	H			M				M	
Ministry of Jihad of Construction	MOJC	Minister		M	H	M		M	M	M	M
Ministry of Mine and Metal	MOMM						M				
Ministry of Petroleum	MOP						M				
Ministry of Post and Telegraph and Telephone	MPTT				M	M		M	M		
Ministry of Road and Transportation	MORT	Minister				M			M		
Military Forces		Director									
National Welfare Organisation									M		M
Plan and Budget Organisation	PBO	Director								H	
Police and Military Commanders	PMC								M		
Port and Shipping Organisation	PSO							M			
Red Crescent Society of Iran	RCSI	Director							H		M
Social Security Organization	SSO									M	
Tehran Medical Education University											M
Tehran Municipality			M				M		M		

Note:
NCNDR: National Committee for Natural Disaster Reduction
Special Sub-committee 1: Counter and mitigation measures for earthquake and landslide damages
Special Sub-committee 2: Counter and mitigation measures for pests, plant infestations and frostbite
Special Sub-committee 3: Counter and mitigation measures for rangeland degradation and drought
Special Sub-committee 4: Counter and mitigation measures for flood, river and seawater fluctuation
Special Sub-committee 5: Counter and mitigation measures for air pollution
Special Sub-committee 6: Counter and mitigation measures for storm and hurricane hazards
Special Sub-committee 7: Emergency relief and rescue operations
Special Sub-committee 8: Compensation of losses due to natural disasters
Special Sub-committee 9: Health and medical care services for injured victims
H: Head Organisation, M: Member Organisation

(1) Members of the NCNDR

The NCNDR are consisted of nine ministries and seven organisations. Details are summarised in Table 7.3.1.

(2) Coordination Committee

The Coordination Committee is headed by the under secretary of the Ministry of the Interior. The committee apprises its members of any proposed agenda; it also prepares presentation materials for the NCNDR meetings.

(3) Special Sub-Committees

The nine Sub-Committees were organised in 1993 to deal with the major issues and specific themes for Cabinet discussion. Details are summarised in Table 7.3.1.

Regular sub-committee meetings are held every month. Experts and consultants are invited to these meetings. Each sub-committee is responsible for a specific aspect of mitigation, as indicated below. Each one has to come up with a task description, which is basically a collection and compilation of information, research and planning and training and coordination exercises, and submit those to the NCNDR.

There are also 27 Provincial Committees, which are headed by the respective General Provincial Governors.

(4) Present Organisational Structure of the Disaster Task Force: DTF

Required functions for the emergency, rehabilitation and reconstruction stages of disaster are undertaken by the Disaster Task Force (DTF). Details of the organisation is shown in Figure 7.3.2.

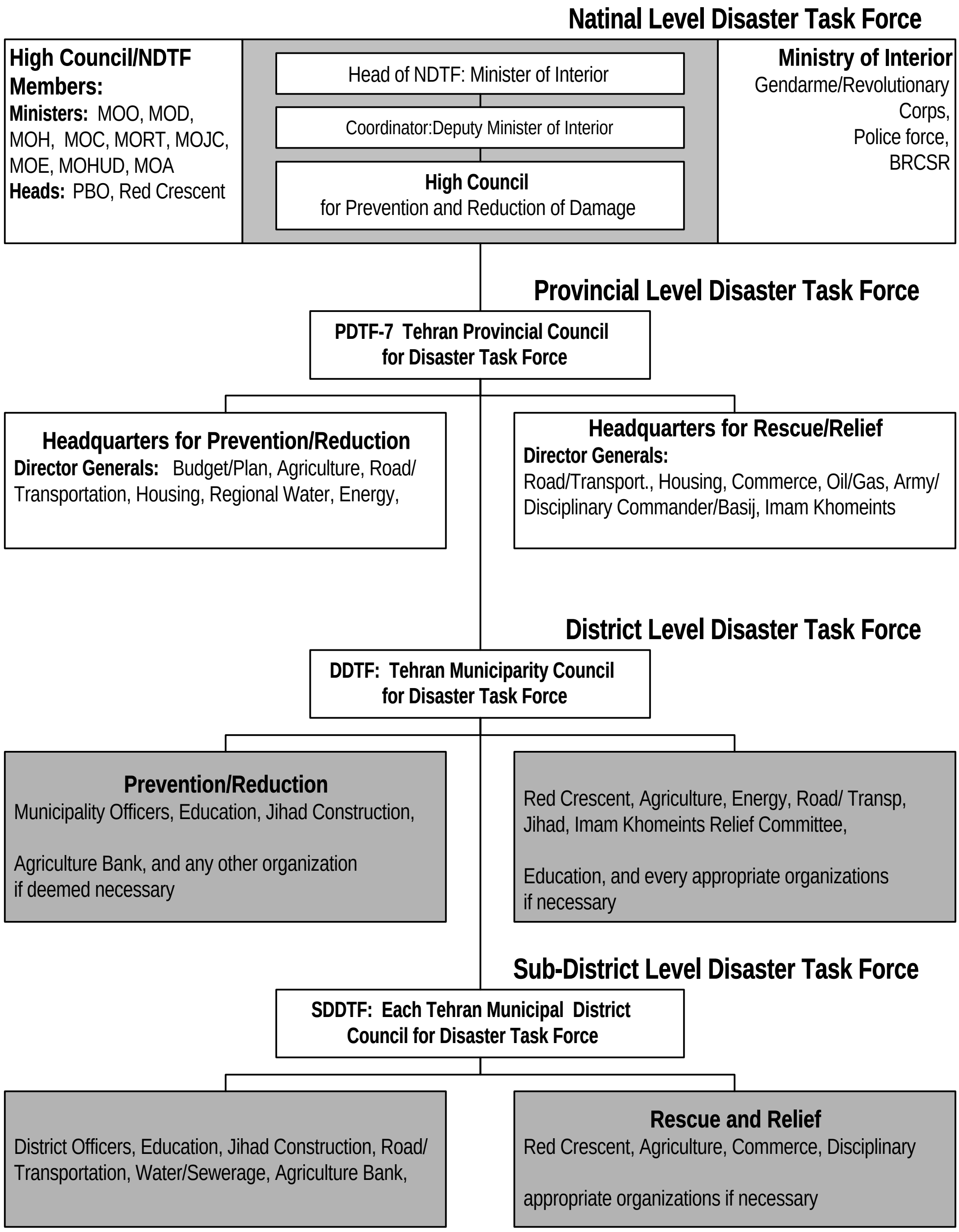


Figure 7.3.2 Present Detailed Organizational Structure of Disaster Task Force

Source: Ministry of the Interior

(5) National Level: NDTF

The High Council for Prevention and Reduction of Disasters of the NDTF convenes tri-monthly and the Minister of the Interior can call a special session.

When disaster occur, the National Disaster Task Force coordinates and takes command of required emergency operation, rehabilitation and reconstruction measures, in cooperation with the related technical ministries and agencies.

The members comprising the NDTF and their activities during disaster and non-disaster times are described in Table 7.3.2. It is noteworthy that the NDTF is managed by the director of the BRCSR in times of non-disaster, but in case of disaster, the Deputy Minister of the Interior takes over.

Table 7.3.2 Present Detailed Tasks of National Disaster Task Force

Organisation	Non-disaster period	Disaster period
Office for Coordination and Study of Safety and Reconstruction of the MOI	Organise study, research, and plan teams for disaster management, prevention, and mitigation, and to supervise natural disaster executive bodies	Provide logistical support to the provincial and district DTFs and compensation for damage, rehabilitation and restoration activities
Ministry of Housing and Urban Development/Housing Foundation	formulate a reconstruction plan in the aftermath of a natural disaster and a building code for future seismic resistance	coordinate and execute the reconstruction plan and to supply housing for damaged rural areas (not for urban areas)
Ministry of Energy	The Ministry is responsible for management and disaster mitigation with respect to rivers, dams, and the Caspian Sea water level	
Ministry of Jihad and Construction	The ministry is mandated to supervise watersheds, forests and rangelands	
Ministry of Health, Ministry of Road and Transportation, and Ministry of Agriculture	Collectively, these ministries play substantive roles in the emergency, rehabilitation, and reconstruction stages.	
Plan and Budget Organisation (PBO)	The functions of this organisation are to approve and control the disbursement of the government budget during the prevention, emergency, rehabilitation, and reconstruction stages.	
Red Crescent Society of Iran	Educate and train rescue teams and youth groups, and to procure emergency supplies (medicine, food etc.)	Provide quick response and region-wide rescue, relief, and first-aid services
Basij (Civil Defence Organisation for mobilisation)	This is a non-governmental organisation, which undertakes emergency services.	
Other Agencies in the Ministry of Interior (MOI)	The police force, gendarme and revolutionary corps, and the Bureau for Research and Coordination of Safety and Reconstruction Affairs (BRCSR) are also involved in emergency operations and other relief measures.	

(6) Provincial/District Level: PDTF/DDTF

Provincial Disaster Task Force (PDTF) groups are organised to manage disasters of provincial and national scales. They are headed by the General Provincial Governor, with instruction from the NDTF. Headquarters for Disaster Prevention and Reduction and Rescue and Relief are organised under the PDTF.

District Disaster Task Force (DDTF) groups are organised to manage district and provincial level disasters under the command of the mayor or governor of each municipality or district, with instruction from the PDTF and NDTF. Centres for Disaster Prevention and Reduction and Rescue and Relief are also organised under the DDTF.

Sub-District Disaster Task Force (SDDTF) groups are organised by district mayors of municipalities or heads of sub-districts, with instruction from the PDTF and DDTF. Task force groups for Disaster Prevention and Reduction and Rescue and Relief are also organised under the SDDTF.

The PDTF, DDTF, and SDDTF should collect and compile primary information on the location and magnitude of natural disasters as well as the required primary and secondary emergency operations. The information must be reported to the NDTF headquarters as soon as possible. All information and reports should pass through the DDTF and PDTF to the NDTF from the district and sub-district groups of disaster prevention and reduction and relief and rescue task forces.

The NDTF should decide upon and issue an alert from three levels: national, provincial and local, based on the damage information provided by the PDTF/DDTF.

The DDTF and SDDTF should also function as sub-headquarters for actual emergency operations, including quick damage information, with the support of sub-district mayors. Presently, the Tehran Municipality is positioned as the DDTF.

7.3.2. Issues Regarding the Present Organisational Structure

(1) Issues Regarding the Assessment and Recommendations for the National Disaster Prevention and Management System

The Office for the Coordination and Study of Safety and Reconstruction Affairs of the MOI conducted a UNDP-supported assessment of the present natural disaster prevention and management system in Iran. Dr. S. H. Bahraini of the Faculty of the Environment, Tehran University, headed the study. The results of the study were published in Report No. 11/6, dated July 1998, entitled, " National Scheme for Prevention and Management of Natural Disasters."

The issues raised by the study, including its findings and recommendations, regarding the present institutional system for natural disaster prevention and management are as follows:

1) Lack of integration and comprehensiveness of the present laws in all natural disaster stages (prevention, emergency, rehabilitation and reconstruction);

2) Ineffective administrative system for disaster prevention and management;

3) Inadequate coverage of actual disaster areas by the present hierarchical execution system;

4) Unclear designation of roles and tasks of related ministries and authorities for disaster prevention and management measures;

5) Duplication and/or interference of tasks by the related ministries and authorities, resulting in inefficient execution and loss of momentum in the execution of operations,

6) Lack of systems to organise local communities for quick emergency rescue operations after an earthquake;

7) Lack of systems to organise local and international NGOs;

8) Inability of the Red Crescent Society of Iran to manage a large-scale, regional disaster, in terms of mobilising rescue teams, supplies and equipment;

9) Hampering of earthquake disaster prevention and management momentum and awareness.

(2) Issues identified by the Study Team

a. National Level

The functions and roles of the NCNDR and NDTF are principally to make policies and execute them. However, their policy-making and before-and-after-a-disaster executive functions, which are also required to prevent, mitigate and manage natural disasters, have not been clarified as shown below.

	Policy-making	Execution
Before a Disaster	NCNDR	NDTF of NCNDR?
After a disaster	NCNDR or NDTF	NDTF

Both designated functions of the NCNDR and NDTF are actually handled by just one BRCSR director in the MOI, which is contradictory to the principle of orderly organisational systems for natural disaster prevention and management.

Roles and tasks for members of the NDTF are not clearly identified and designated, owing to a lack of a national disaster prevention and reduction plan.

b. Provincial Level

The present system provides two organisational structures of the Provincial Sub-Committee of the NCNDR and the PDTF in each province. However, the headquarters of Prevention and Reduction are organised under the PDTF, whose function duplicates, and sometimes contradicts, the functions of the Provincial Sub-Committee of the NCNRD.

c. District Level

The DTF of the city of Tehran presently exists at the district level. However, the city continues to accumulate an increasing amount of capital functions, such as government offices, economic centres, and social and cultural centres, among other things. Consequently, there are fears that the scenario earthquake in the city of Tehran will result in heavy damage and wreak havoc on the indispensable capital functions of Iran.

It is, therefore, the opinion of the Study Team that the mere district-level of the DTF for the municipality is inconsistent and unsuitable, considering the actual concentration of capital functions in the city of Tehran.

d. Sub-District Level

The 22 districts of the city of Tehran, which have an average population of around 300,000, are also classified as sub-district level DTFs. This classification is also deemed as inconsistent and unsuitable, compared with their present accumulated population and capital functions.

e. Local Levels

A self-mobilised emergency operation at the community level could be the most effective and indispensable system, especially for primary damage information collection, quick rescue and relief operations, evacuation guides, and small-scale fire fighting. However, such a system does not yet exist.

7.3.3. Proposed Organisational Structures

Proposed organisational structure is shown in Figure 7.3.3.

(1) Designate Appropriate Roles and Functions for the Present Policy-making and Executive Organisations

Roles and functions for disaster prevention and management on the national level should be clearly defined and designated to the NCNDR, NDTF and related government agencies through legislative measures.

a. Reorganisation of the NCNDR into an Inter-Ministerial Policy-making Body

It is recommended that the NCNDR be reorganised as an inter-ministerial, "before disaster" and "after disaster" policy-making body. In this case, it is proposed that the President of Iran act as Chairman, especially in cases of national disasters, and the Minister of the Interior, as the Deputy Chairman, with the MOI acting as Secretariat. The NCNDR should be comprised of 14 ministries and other government organisations and institutes.

It is further proposed that the NCNDR legislate laws based on the recommended urban earthquake, disaster prevention and management policy.

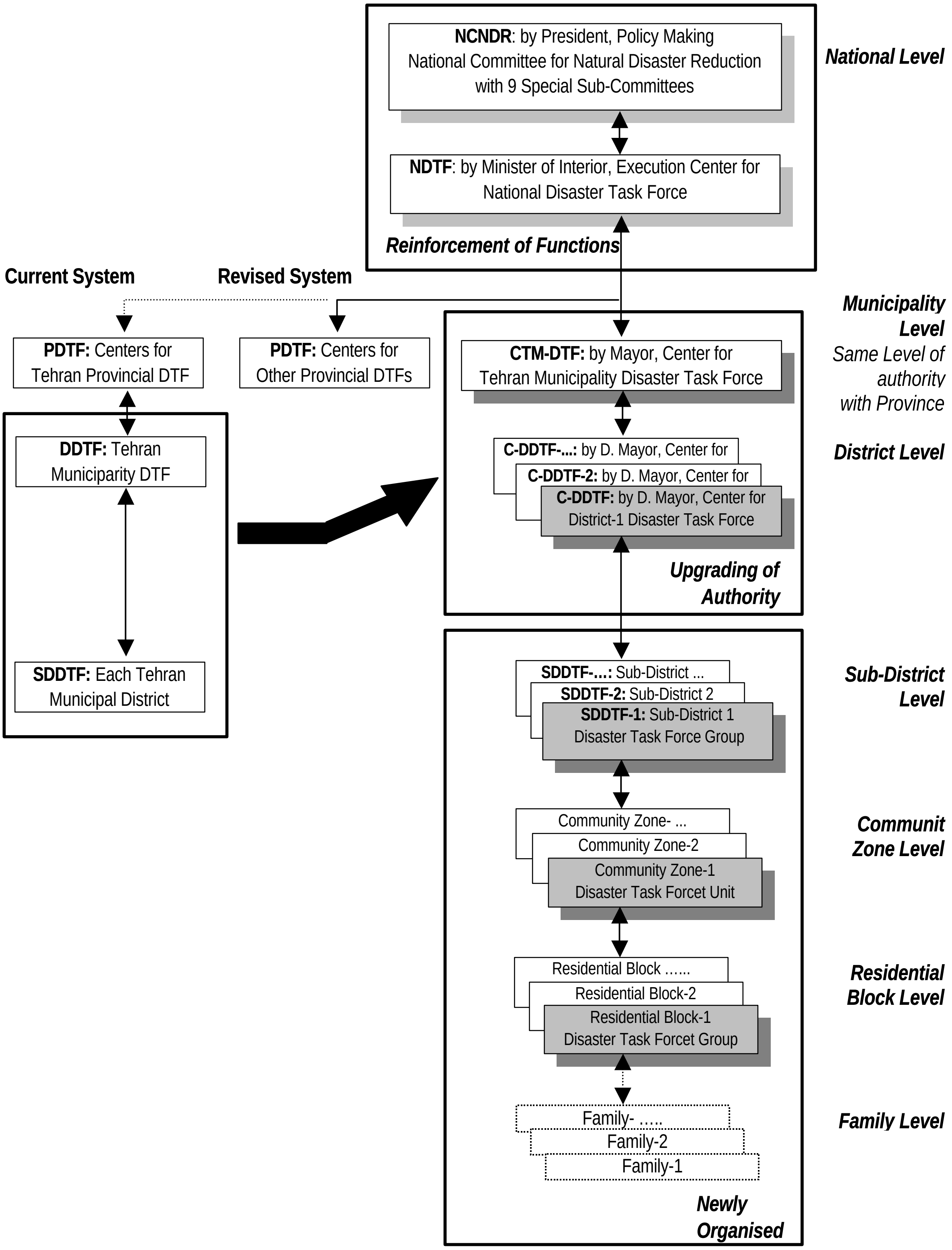


Figure 7.3.3 Proposed Organisational Structure

Source: JICA Study Team

b. Preparation of a National Disaster Prevention Plan Based on the Output of the Nine Special Sub-Committees of NCNDR

The nine sub-committees conduct research and planning to support the policy-making function of the NCNDR. Since that is the case, they might as well formulate a national disaster prevention plan for their respective sector. Furthermore, it is proposed that their collective output be utilised to formulate a National Disaster Prevention Plan. The regulations and guidelines drawn up by the earthquake and landslide sub-committee to formulate regional and urban disaster prevention plans are recommended to support the existing instruction on disaster prevention given to local governments.

c. Transfer of the Function of the 27 Provincial Committees of the NCNDR to the Provincial Disaster Task Force.

The PDTF Disaster Prevention and Reduction Headquarters of the PDTF can substitute the work of the 27 Provincial Committees, thereby eliminating any duplication of function.

d. The NDTF as a Comprehensive Executive Body

It is recommended that the NDTF assume the roles required as an executive body under the policy-making function of the NCNDR before and after a disaster.

Under the National, Regional, and Urban Disaster Prevention and Management Plan, each DTF member ministry, organisation and institute should be provided with a detailed description of tasks and mandate to execute appropriate measures without duplication before and after natural disasters and with proper financial support.

(2) Proposed Organisational Structure for the Disaster Task Force of the Tehran Municipality

a. Upgrading of the Tehran Municipality to a Provincial Level Disaster Task Force

The metropolitan function and the national capital functions are concentrated in the Tehran Municipality. It is recommended that Tehran be upgraded to a Provincial Level Disaster Task Force.

b. Upgrading of 22 Municipal Districts to District Level Disaster Task Force

Under the Tehran Municipal Disaster Task Force, it is proposed that a District Level Disaster Task Force be organised in each of the 22 municipal districts.

c. Establishment of Sub-District Disaster Task Force

A sub-district is an intermediate designation between a district and a community zone. It is composed of 10 to 20 community zones with 7,000 to 10,000 households and populations of 30,000 to 45,000. It is proposed that zones be located within a 2-km walking distance from each other. It is also recommended that Sub-district Disaster Task Force groups be organised in every 5 to 10 sub-districts in each municipal district.

d. Establishment of Community-based, Self-Mobilised Disaster Task Force System

A community-based, self-mobilised task force is recommended for each community zone (census zone or primary school zone) and residential block. This task force can provide an essential and effective mechanism as follows:

- Collection of primary damage information,
- Guide and assistance in evacuation and initial rescue operations of victims trapped under collapsed houses,

- Extinguishing of fires before spreading, and
- Engagement in other activities to reduce damage

For mitigation and management of huge urban disasters, a hierarchical (to a certain extent), community-based, self-mobilised task force system is required. The system should be headed with personnel who have undergone complete training and participated in simulation drills.

e. Adoption of a Hierarchical Disaster Task Force Structure at the Community Level

For urban disaster prevention and management of the Tehran Municipality, a hierarchical organisational structure of community level Disaster Task Force groups, including municipality, district, sub-district, community zone and residential block level, is recommended.

(3) Functions of Each Level of Task Force of the Tehran Municipality

a. Disaster Task Force Centre for the Tehran Municipality (CTM-DTF)

This centre is proposed for establishment under the Mayor of the Tehran Municipality, who should be responsible for the issuing orders and implementing actual measures for the prevention and management of earthquake disasters, as follows:

<u>Before the disaster:</u>

1) Development and establishment of a DTF Municipal centre: the building complex, including facilities and functions, are as follows:

- Command and operation centre,
- Information and communication centre with emergency network system,
- Research centre with seismograph network and damage simulation system,
- Awareness and training centre for disaster prevention and mitigation, and
- Planning and coordination centre for disaster prevention.

In addition, the centre is to organise yearly disaster prevention training sessions, including taking inventory of supplies.

2) Formulation of Comprehensive Urban Disaster Prevention and Management Plan for the Tehran Municipality

Upon the order of the NCNDR, the Tehran Municipality is to formulate an urban disaster prevention and management plan to mitigate damage caused by natural disasters.

3) Implementation of Preventive Measures

Preventive measures proposed for implementation include the following:

- Improvement and reconstruction of weak urban structures and land use,
- Reinforcement and reconstruction of structurally weak school buildings,
- Reinforcement and reconstruction of structurally weak emergency centre buildings (government offices, municipality/district/sub-district offices, hospitals/health care centres, fire fighting stations, traffic police stations, and police stations),
- Development and establishment of disaster management centres for 22 districts, sub-districts, and community zones with emergency facilities (including municipal emergency supply storage and distribution centres, road maintenance centres, evacuation areas, etc.),
- Reinforcement and establishment of emergency road network (including evacuation network),
- Improvement of management and monitoring system for hazardous facilities, and

- Improvement of security measures and upgrading of seismic resistance of lifeline networks (especially of gas networks to minimise secondary disasters)

After the Disaster

1) Simulation of earthquake disaster damage based on data recorded by a network of seismographs that should be installed,

2) Collection of information on the scale of damage from reports by District DTFs (including the capacity of each Disaster Task Force and required additional support),

3) Review of emergency operation plan based on the results of the simulation and on primary information on damage,

4) Report to and request of the NDTF on the following:

- Report primary information on the disaster,
- Request the implementation of the Fundamental Law for Large Scale Earthquake Disaster, and
- Request deployment of supporting emergency operations (rescue/relief/first aid /traffic control/emergency goods and supplies/security measures)

5) Decision-making, order and announcement of emergency evacuation and damaged zones based on the collected information on the disaster,

6) Order the utilisation of designated public facilities for evacuation and primary gathering areas,

7) Order the mobilization of emergency tasks to designated agencies (Red Crescent, fire fighters, traffic police, police, etc.),

8) Order the operation of community-based emergency tasks for all community DTFs,

9) Order the removal of debris and obstacles from the emergency road network by the designated road maintenance sections of the municipality, districts and sub-districts,

10) Order the supply of required emergency goods by the municipality, 22 districts, sub-districts, community emergency storage and Red Crescent Society, (Clarify who will be supplying emergency goods)

11) Issue a request or order that lifeline service providers activate their emergency backup systems, and

12) Request the preparation of temporary housing and tents.

b. District Disaster Task Force Centre (C-DDTF)

A District Disaster Task Force Centre should be established in each district office. Main role and responsibility of the centre is actual operation of preventive and management tasks against disasters as indicated below.

Presently, providing service coverage to the 22 districts involves the challenge of aiding districts lacking uniformity in total area (808 to 7,260 ha), built-up area (234 to 2,654 ha) and population (56,000 to 640,000).

Before the Disaster

1) Formulate an Urban Disaster Prevention and Management Plan in each district,

2) Arrange or develop DTF District centres at the district offices,

3) Arrange and develop District Depots of Emergency Supplies,

4) Order to arrange or develop evacuation areas for each sub-district or community zone and temporary assembly points for evacuation in each community zone under the Urban

Disaster Prevention Plan with financial arrangement by the Municipality,

5) Organise the community-based DTF group system in each community zone unit and residential group,

6) Train and educate leaders of community DTFs of Community Blocks and Zones and raise citizen awareness on disaster prevention,

7) Organise yearly disaster prevention training on National Disaster Day,

8) Develop and establish a communication and announcement system among community zone units, groups and citizens to relay evacuation orders given by the Municipality DTF centre or other pertinent organisations, and

9) Coordinate and implement residential and urban redevelopment projects to strengthen weak residential and urban structures and to improve areas with limited emergency vehicle access. These projects should be identified and developed through the Urban Disaster Prevention and Management Plan.

After the Disaster

1) Relay evacuation orders from the Municipality DTF centre to the citizens in each community zone by means of an improved loudspeaker or other emergency system,

2) Collect and compile the following primary damage information from community level DTFs through Sub-District DTFs and report this information to the Municipal Centre:

Human Casualties:	Number of evacuees, slightly injured, seriously injured, dead, and people trapped under collapsed buildings,
Building Damage:	Number of completely collapsed, heavily damaged, and damaged structures
Lifeline Damage:	Damages to water, electricity, gas supply, and telecommunication networks,
Other Damage:	Fires, explosions, bridge collapses, impassable or obstructed roads, etc.

3) Assess the capacity of the District DTF itself to carry out emergency operations and report to the Municipal DTF centre any additional emergency support and goods required,

4) Order to prepare or open evacuation areas and to supply emergency goods

c. Sub-District Disaster Task Force Group (SDDTF)

The chairmen and deputy chairmen of Sub-district DTF groups are appointed district officers by the District DTF.

Each SDDTF should be organised into units that will be in charge of information collection and distribution, fire fighting, rescue, first aid, evacuation planning and coordination, and food and water supplies. Members of these units should be appointed from among the heads of the Community Zone DTF units.

An SDDTF mainly performs intermediate functions between those of the district centre and community zones, as shown below.

Before the Disaster:

1) Coordinate with residents to develop an evacuation area (1 to 2 m^2/resident),

2) Construct emergency storage facilities in evacuation areas stocked with rescue equipment, first aid equipment and medicine, fire fighting equipment, loudspeakers,

water, food, cooking equipment, clothes, etc.,

3) Prepare and improve SDDTF centres in existing public facilities (with emergency communication systems, mobile phones, meeting rooms, etc.)

4) Identify and prepare an intermediate storage location for emergency goods in the present public area, and

5) Organise yearly disaster prevention training (including taking inventory of stored goods).

After the Disaster:

1) Relay information and orders from district centres or community zones,

2) Prepare and subdivide the evacuation area according to evacuees from each community zone,

3) Organise SDDTF units for rescue and relief, first aid, and goods supply operations to seriously damaged community zones based on damage reports,

4) Organise SDDTF fire fighting units to put out small-scale fires reported by community zones,

5) Receive, store and distribute emergency goods from the municipality and district emergency goods distribution centre to community zones, and

6) Prepare food and distribute potable water to evacuees in and outside the evacuation area.

d. Community Zone DTF Units

Community zones are neighbourhood units within a 500 to 800 m walking distance from each other. They are almost the same size as census zones or primary school zones, made up of approximately 10 residential blocks, 470 dwelling units and populations of 2,100. These community zones can serve as primary evacuation units.

Census zones or primary school zones should be reviewed and re-designated into community zones, which should be considered as evacuation zones, based on the shape of the area in question and physical barriers in the communities.

A DTF Unit should consist of a chairman, deputy chairman and chiefs or members of taskforce groups. They should be appointed from among the heads of residential blocks in the zone and should be in charge of information collection and distribution, fire fighting, rescue, first aid, evacuation planning and coordination, and food and water supply.

The residential block in a community zone is the appropriate group to lead evacuees to the designated evacuation area. The Disaster Task Force group in a residential block is also composed of the same taskforce groups of the community zone. All taskforce members are composed of heads of households living in a residential block.

Tasks for the DTF Units and Groups are as follows:

Before the Disaster:

1) Coordinate site selection with residents and prepare evacuation area or temporary evacuation area (primary assembly points: 0.5 m^2/resident),

2) Organise yearly disaster prevention training, including the following items:

- Preparation and opening of the Community Zone DTF centre,
- Maintenance of information and records on evacuees, injured, deaths, and missing persons,
- Compilation and report of damages to SDDTF/DDTF,
- Inspection of stored emergency goods,

- Evacuation and guidance,
- Rescue and first aid,
- Extinguishing of initial and small fires,
- Education on proper actions to take during an earthquake, and
- Preparation and supplying of emergency water and food

Emergency goods that should be inspected include rescue equipment, first aid equipment and medicine, fire fighting equipment, loudspeakers, potable water, food, and cooking equipment.

3) Promote and enhance family emergency preparedness measures, such as:

- Storing water and food for emergency use,
- Sorting out supplies or possessions to take if evacuated,
- Preparing evacuation of handicapped family members,
- Checking of gas valves and other utilities, and
- Securing homes and property in event of evacuation

After the Disaster:

1) Collect information on building damage, human casualties and missing persons, status of fires and hazardous facilities, road conditions (road obstacles) etc. from the information taskforces of all residential blocks,

2) Transmit information and orders given by the district centre or community block unit,

3) Prepare and subdivide primary evacuation areas by evacuees of each residential block,

4) Organise and deploy community-based rescue operations and first aid groups, following reports by residential block information chiefs on seriously injured victims and people trapped under collapsed buildings,

5) Organise and deploy community-based, volunteer fire fighters to extinguish small fires or initial fire outbreaks reported by information chiefs of residential blocks, and

6) Prepare and supply potable water and food for evacuees in and outside the primary evacuation area.

(4) Establishment of Planning and Implementing Department for Urban Seismic Disaster Prevention and Management Plan within Tehran Municipality

In the course of the study, it had been clarified that Tehran Municipality does not have appropriate planning and implementing section for disaster prevention, mitigation and management against strong seismic disaster. Figure 7.3.4 shows proposed organisation chart of Tehran Municipality including Disaster Prevention and Management Department. This department should be responsible for preparation of " Urban Seismic Disaster Prevention and Management Plan" and afterward implementation of the plan. As mentioned in section 7.3.3, (3)a., Tehran Municipality should be upgraded to Provincial level, which is in District level at present, and establish CTM-DTF in the Disaster Prevention and Management Department. Proposed new organisation and its roles and functions can be found in section 7.3.3.

In Section 7.5, preparation of the Master Plan for Urban Seismic Disaster Prevention and Management is proposed, and necessary items for the plan is explained in detail.

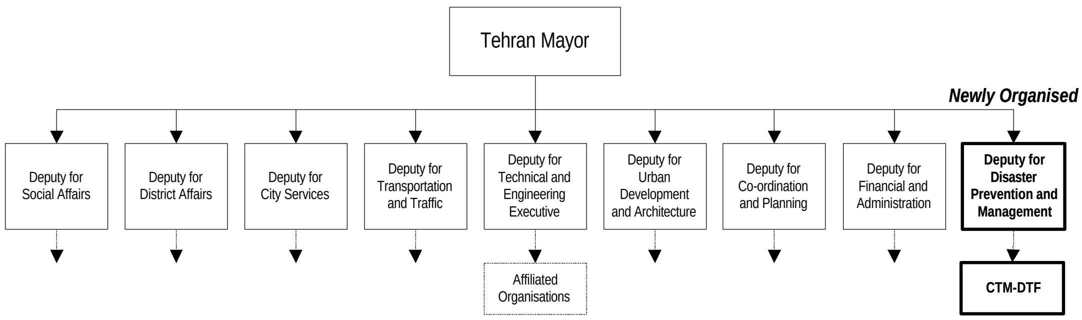


Figure 7.3.4 Proposed Organisation of Tehran Municipality

7.4. Recommendation of Financial Measures

Implementation of the required disaster prevention and management measures, which are identified in the recommendations for Urban Disaster Prevention and Management Plan of the Tehran Municipality, should be supported by financial measures both before and after the disaster.

These required financial measures should be supported by legislative measures, which describe the available financial resources, responsible agencies, distribution procedures and any conditions and criteria.

7.4.1. Allocated Natural Disaster Reconstruction Fund

Reconstruction funds for damaged public facilities and private buildings by natural disasters has been allocated as follows:

(1) Reconstruction Fund for Public Facilities

Presently, the allocated Reconstruction Fund for infrastructure and public buildings damaged by natural disasters is in the amount of 700.62 billion Rials (approximately US$ 85 million).

Based on the damage analysis of the Ray Fault scenario earthquake, 1,400 (54%) educational facilities, 56 (50%) public hospitals, 28 (52%) fire stations, and 40% of government offices will collapse. Reconstruction costs for school buildings alone will require more than 3 trillion Rials (2.15 billion Rials/school X 1,400 schools = 3 trillion Rials), an amount which is approximately 4 times the allocated fund.

It is recommended that 1) experts conduct a diagnosis to evaluate the seismic resistance of existing building structures, in order to identify vulnerable structures, and 2) necessary reinforcement and reconstruction tasks should be undertaken. These are safety measures recommended for the mitigation of building damage and human casualties not only for the present, but also for the future.

(2) Reconstruction Fund for Private Buildings

The allocated Reconstruction Fund for private houses and commercial buildings damaged by natural disasters totals 550 billion Rials (approximately US$ 67 million). The financing system available to citizens is a bank loan without interest.

Based on the Ray Fault scenario earthquake, approximately 55% (500,000 buildings and 750,000 dwelling units) of all residential buildings in the city will be damaged. Reconstruction cost for heavily damaged housing, excluding commercial buildings, will require more than 100 trillion Rials (US$ 13 billion). The assumption used to arrive at this calculation is as follows: 150 million Rials/dwelling unit X 750,000 dwelling units = 113 trillion Rials.

Preventive measures to reinforce and reconstruct vulnerable houses are not only recommended to reduce building damage, but also to minimise the estimated large number of human casualties (400,000 deaths).

7.4.2. Additional Financial Measures

It is recommended that financial measures be allocated as much as possible for preventive measures (before a disaster), which could be identified in the Comprehensive Urban Disaster Prevention and Management Plan.

Financial measures should be developed to finance the following major disaster preparedness actions before a disaster strikes the city:

1) Reinforce or reconstruct structurally vulnerable schools,

2) Reinforce or reconstruct structurally vulnerable emergency centres, such as government offices, hospital/health care centres, fire stations, traffic police stations, and police stations,

3) Reinforce or reconstruct other structurally vulnerable public facilities,

4) Reinforce or reconstruct bridges with weak foundations that are situated on the designated emergency and evacuation road network,

5) Improve (widen) narrow roads of the designated emergency and evacuation road network,

6) Develop emergency communication network between DTF centres,

7) Develop Municipality, District, and Sub-District DTF centres,

8) Prepare gathering areas, evacuation areas, and temporary housing areas for evacuees,

9) Establish emergency goods depots and distribution centres for the municipality and 22 districts, and storage for sub-districts and community zones,

10) Install a safety valve system for natural gas supply network to mitigate secondary disasters,

11) Improve other lifelines for seismic resistance,

12) Make special loans available to reinforce and/or reconstruct vulnerable housing and private buildings, and

13) Redevelop the urban area, paying special attention to weak urban structures and building areas, as follows:

- Poor and/or narrow roads (hampering emergency vehicle access and operation)
- High-density populated areas with vulnerable housing structures

7.5. Recommendation for a Comprehensive Urban Disaster Prevention and Management Plan

The Tehran Municipality has had the potential and experience of earthquake and landslide disasters, and it remains at risk of reliving forecasted disaster damages. Thus, the formulation of a Comprehensive Urban Seismic Disaster Prevention and Management Plan is recommended for the Tehran Municipality.

Required, proper and comprehensive measures for preventive, emergency, rehabilitation and reconstruction efforts to mitigate urban earthquake disasters should be well-coordinated and integrated in the Urban Seismic Disaster Prevention and Management Plan. The development of the Plan is considered the most urgent action to take before a disaster occurs.

Urban seismic disaster prevention and management is one of the most important administrative mandates of municipal governments, and hence, a Seismic Disaster Prevention and Management Plan is to be formulated under the initiative of the Tehran Municipality. However, Tehran Municipality does not have appropriate implementing body for the proposed plan, therefore, it is strongly recommended to reorganise and strength organisation body for proper implementation of the proposed plan.

7.5.1. Past Trends of Related Studies and Activities in Iran

Together with international technical cooperation agencies, some government agencies have conducted disaster prevention studies and activities, as shown below. However, a Disaster Prevention and Management Plan has not yet been actually formulated on regional and district levels.

1) Comprehensive seismic potential and landslide study in the different provinces,
2) Preparation of the Atlas of Landslides in each province,
3) National Committee for Natural Disaster Reduction ordered to formulate the Urban Disaster Prevention Plan of Tehran at the end of 1999,
4) The 8th Seminar for Earthquake Prediction by MOHUD, Centre for Natural Disaster of Iran (in the Housing Foundation) and Ministry of Regional Planning of Germany,
5) Regional Training Workshop for Case Study of Floods and Earthquake Damage Reduction by MOI and UNESCO in1998,
6) Formulation of National Preparedness and Mitigation Plan for Natural Disasters supported by UNDP,
7) Comprehensive Seismological Study by UNDP and IIEES (English report is still unavailable),
8) Conference for Earthquake Data Evaluation by IIEES 22-27 Nov. 1992,
9) The 1st Training Workshop for Disaster Management by MOI, MOF and UNDP 14-20 Sept. 1992,
10) International Conference on Seismology and Earthquake Engineering, IIEES, 1st Conference in 1990, 2nd Conference in 1995, 3rd Conference in 1999.
11) The 1st International Conference for Natural Disaster in Urban Areas by Tehran Municipality 11-13 May, 1991.

7.5.2. Required Fields of Comprehensive Urban Disaster Prevention and Management Plan

Formulation of a Comprehensive Urban Disaster Prevention and Management Plan for the Tehran Municipality could efficiently utilise the results of the JICA Study on Seismic Microzoning for Greater Tehran. The Plan should cover the following aspects:

1) Policy and objectives
2) Damage estimation and hazard map (seismic microzoning)
3) Plan for preventive measures
4) Plan for emergency measures
5) Plan for rehabilitation and reconstruction measures

7.5.3. Required Fields to Formulate Policy and Objectives

The following fields should be clearly defined and stated at the onset:

1) Objectives of the Plan
2) Legislative background and institutional identification for the Plan
3) The fundamental law for the Urban Disaster Prevention and Management Plan for the Tehran Municipality should be legislated, if it is not available
4) Program of activities and intervals to review the Plan
5) Information and dissemination campaign to introduce the Plan to related agencies and citizens
6) Research and training programs to fully absorb the rationale of the Plan and, thus, facilitate its execution

7.5.4. Damage Estimation and Hazard Map (Seismic Microzoning)

The required premises to formulate the Plan are the existing conditions and damage estimation, which are covered almost entirely by the JICA Study Team, as follows:

1) Natural conditions
2) Socio-economic conditions
3) The supplied and input data of lifelines and public facilities and hazardous facilities were macro-base data, which was not appropriate for the damage analysis of the Study. The data needed to be improved before it was used in the Study.
4) Potential earthquakes
5) Damage estimation (human casualties, buildings, public facilities, lifelines, and hazardous facilities)
6) Location map of natural disaster prone and hazardous areas

7.5.5. Formulation of Prevention Plans

Prevention plans should cover all aspects required to prevent an earthquake disaster, as follows:

(1) Prevention Plan for Ground-based Disaster

The plan should cover landslides, soft ground, liquefaction, residential areas and cut and fill slope of roads. Hazardous areas in the city that have been identified and assessed include the following:

1) Landslide disaster area: located on the northern mountain skirts. Residential areas, oil tanks, road, and newly planned raw water transmission pipes are located in the identified area.

2) Soft ground area: not found in the city.

3) Liquefaction disaster area: some areas with liquefaction potential are found in the southern end of the city.

The plan should include the following items:

a. Landslide Damage Protection Plan for Precipice and Steep Slope Areas

1) Inspection and monitoring program for identified potential disaster area,

2) Designation of landslide hazard zone (including development control regulations for the zone), and

3) Enforcement program of landslide hazard zone.

b. Residential and Urban Development Control for Landslide Hazard Zone

1) Legislation and enforcement of the regulation for new residential subdivision and development in landslide hazard zones,

2) Regulation of preventive efforts by the existing residents in a landslide hazard zone (building a retaining wall, slope drain, etc.), and

3) Monitoring and patrolling program to identify existing conditions, development activities, and any illegal practices, and to monitor preventive efforts by residents themselves.

c. Disaster Prevention Plan for Soft Ground

For soft ground, adequate design standards for seismic resistance should be applied for the development of heavy public works, medium- and high-rise buildings, and hazardous facilities.

d. Disaster Prevention Plan for Liquefaction Hazard Zone

For liquefaction hazard zones, there should be adequate monitoring and maintenance of existing structures, including those underground. Measures for liquefaction mitigation should be considered and applied in future development.

e. Prevention Plan for Landslides on Steep Roadside Slopes

For steep roadside slopes, assessment, patrol and preventive efforts and programs are required for identified landslide hazard areas.

(2) Fire Prevention Plan

The Plan should cover fire outbreaks, extinguishing fire at the earliest possible time, and protecting against its spread. These are discussed hereafter.

a. Prevention of Fire Outbreak

A fire prevention program utilising a multimedia approach can heighten the awareness of the citizenry and establishments about what causes fire and how to prevent its outbreak:

Publicity Campaign on Fire Preventive Measures by Families

The DTF should start a multimedia campaign using themes like " The Dangers of Earthquake Fire Outbreaks" and " How to Avoid Outbreaks of Fire" and giving tips on the following matters:

- Correct usage of gas/fire equipment
- Emergency guidance to shut off gas lines and electricity
- Introduction of automatic shut-down systems for gas supply and fire equipment
- Safe storage of hazardous materials (combustible and flammable),
- Fire extinguisher importance and instructions on how to use it, and
- The importance of storing water in the house for emergency use

Plan for Prevention of Outbreak of Fire in Establishments

For especially hazardous facilities, legislative measures involving regulations, registration, monitoring, penalties, etc. are urgently required for establishments that store, produce, and utilise hazardous materials.

Preventive measures for hazardous facilities should cover the following:

1) Prevention Plan for Hazardous Facilities

The following legislative measures are required for establishments that produce, store and utilise hazardous materials:

- Seismic resistant structural design code
- Seismic resistance improvements to equipment and machinery
- Regulations for storage and transportation of hazardous materials
- Preventive measures for spillage and outbreak of fire
- Periodic inspection by experts authorised by the government to determine safety measures instituted by establishments
- Organisations of company emergency personnel that can handle on-site incidents like fires, explosions, etc.

2) Prevention Plan for Gas Leak

Gas companies should devise their own fire-fighting plan. Under the plan, training and fire drills, extinguishing fire, emergency work, and communication/reporting should be frequently carried out to master the required emergency operations and to determine any need to revise the plan.

For the existing gas pipeline network, an inspection is required to determine whether construction methods and materials used are in accordance to government standards and regulations. The present manual safety valve system should be urgently changed to an automatic one to minimise secondary disasters due to gas leakage.

3) Prevention Program for Other Hazardous Materials

Storing, producing, and utilising radioactive, gunpowder, and toxic materials should be controlled to minimise secondary disasters.

The following items should be legislated:

- Seismic resistant structural design code,

- Counter measures against flammability, and
- Stored supplies for emergency operations and rehabilitation

4) Prevention Program for Chemical Products

Periodical inspection and guidance programs are required for educational facilities, hospitals and research institutes, which use chemical products.

5) Other Establishments

Each establishment should be required to carry out the following measures:

- Formulate own fire fighting program,
- Regular fire fighting and evacuation drills, and
- Seminar to raise awareness on fire prevention

b. Plan to Extinguish Initial Outbreaks of Fire

In Tehran, most residential and building structures are made of fire-resistant materials, such as brick, stone, and steel. With regards to building conditions, Tehran is not at risk of a conflagration in an earthquake disaster. However, small fires will simultaneously break out in many places as a result of the collapse of an estimated 500,000 residential buildings.

The following measures are required to extinguish initial outbreaks of fire, thus mitigating damage:

Organisation of Community-based Volunteer Fire-fighters for Initial Outbreaks of Fire

Community-based volunteer fire fighters organisations provide quick response. Therefore, they are considered as most effective to extinguish initial outbreaks of fire. A program to organise and enhance this volunteer group is required, covering the following aspects:

- Recruitment of volunteer fire-fighters among residents and dividing them into groups;
- Delineation of main and supporting coverage area for each group, and
- Instilling a sense of responsibility among members

Deployment Program and Tasks of Community-based Volunteer Fire-fighters

Members should first educate their own families about fire and fire prevention. Afterwards, they can organise to train their neighbours the proper and safe way to extinguish initial outbreaks of fire.

Fire Fighting Equipment for Community-based Volunteer Groups

Municipality and district offices should provide the necessary equipment and storage facilities to the community-based fire fighters. Ideally, the storage area should be located beside the designated evacuation area.

c. Plan to Prevent the Spread of Fire

Special emergency fire fighting operations are required in case of an earthquake disaster to manage the simultaneous outbreaks of fire in many locations.

Specially-organised Fire Fighting Teams for Earthquake Disaster:

- Formation of small teams for deployment to a number of fire sites,
- Utilisation of the designated emergency roads by fire trucks, and
- Deployment program of supporting forces

Upgrading of Fire Fighting Capacity

- Increase the number of fire fighters,
- Reserve fire engines,
- Improve the storage facilities and equipment of community-based volunteer fire fighter groups, and
- Improve fire stations (over half of the stations are predicted to collapse), and
- Improve the communication network.

Development and Training of Fire Fighters

Some of the well-trained members of the volunteer fire fighter groups could be used as temporary support staff of the regular fire fighting force.

(3) Evacuation Plan with Facilities Development

After an earthquake disaster, all residents in a disaster area should be evacuated to a safe area. Before an earthquake event, municipality and district offices should formulate an evacuation plan, covering evacuation zoning, site selection and development of gathering and evacuation areas, route selection and improvement of evacuation routes.

a. Evacuation Zoning

A zoning plan is proposed according to the hierarchical evacuation system that fits the following emergency stages:

Initial Stage:

A Community Evacuation Zone (neighbourhood zones within 500-800 m walking distance) should be coordinated to organise the proposed Community DTF Unit.

A safe assembly point and/or temporary evacuation area should be provided in the zone with emergency goods storage.

The present sizes of primary school zones and census zones are appropriate for use as community evacuation zones. However, a review of the present shape of zones is proposed in order to fit the purpose of an evacuation area.

Mid Stage:

A sub-district evacuation zone (zones within 2 km walking distance) should be coordinated to organise the proposed Sub-District DTF.

An evacuation area with a SDDTF centre and emergency goods storage should be provided.

Post Disaster:

District offices should have an executive function to be able to provide for the welfare of evacuees and of those whose houses have collapsed.

A tent village or temporary housing should be provided for each district.

b. Site for Assembly Points and Evacuation Areas and Evacuation Route Selection

Site selection for assembly points, evacuation areas, and tent villages or temporary housing should be coordinated with the area demand, land availability, suitability and accessibility as follows:

Assembly Point (Temporary Evacuation Area)

The required space for assembly points is estimated based on the standard of more than 0.5 m^2/resident (0.5 m^2 X residents in zone = 0.4 to 4.0 ha).

The following public facilities in a community could be identified as the most appropriate candidates for assembly points. However, almost all public facilities are presently non-seismic resistant structures (over 50% are estimated to suffer from almost total collapse) and do not possess enough open space. Community parks and open spaces are not evenly distributed throughout residential areas in the city. Multi-purpose open space developments for assembly points are proposed for the southern districts, where there is presently a lack of public open space.

- Public facilities with seismic resistant structures (primary schools, cultural/community centres, religious facilities), and
- Community parks and open spaces.

Evacuation Areas

An evacuation area is to serve as haven in cases of emergency and should also be prepared to accommodate overnight stays for evacuees and for those rendered homeless by disasters. Evacuation areas will be highly in demand, given that 55% of the residential buildings will almost totally collapse and, of the remaining 45%, more than half will be damaged to a lesser, but still serious, extent.

Required space for evacuation areas is estimated based on the following conditions:

- Temporary evacuation area (one week) – 1 m^2/refugee
- Extended-stay evacuation area (more than one week) – 2 m^2/refugee

The required net evacuation space should exclude unusable space, including building areas, roads, ponds etc. Candidate facilities for evacuation areas could be major urban and recreational parks bigger than 10 ha not located adjacent to areas where hazardous facilities are located.

There are no appropriate public open spaces to serve as evacuation areas in the sub-districts of Tehran's central and southern districts. It is proposed that necessary land acquisition and preparation take place in order to provide safety evacuation areas for evacuees.

Tent Villages and Temporary Housing

Tents or temporary housing should be provided to each family left homeless by the collapse of their home, which cannot be reconstructed or rehabilitated quickly. The area of tents or temporary houses should be sufficient only to accommodate emergency family life.

Long-term temporary housing supply in Japan has the following characteristics:

Floor space:	25 m^2/ family
Planned coverage:	1/3 of the homeless family
Provided period:	Started construction within 20 days after disaster until less than 2 years

Based on these assumptions, the land requirement for the estimated 750,000 homeless families will be approximately 19 sq. km. of net temporary housing area, which will be 25 sq. km of gross temporary housing area. Public lands for temporary housing are not available, especially in the central and southern districts. Site selection for the temporary housing should be coordinated with planned and designated future residential expansion areas in and outside the present city boundary under the City Development Master Plan.

Evacuation Routes

All of the identified areas for assembly, evacuation, and temporary housing should be linked by evacuation routes and an emergency road network to ensure safe evacuation, emergency operations and supply of necessary goods. The evacuation route should have roads wider than 20 m or pedestrian ways wider than 15 m.

In the highly populated southern districts, wider roads are not yet well organised and networked.

c. Designation, Land Preparation and/or Expropriation for Assembly Points and Evacuation Areas and Routes

Designation of evacuation areas should be coordinated with related government agencies in charge of the selected public open space and facilities and with private owners of other selected areas. Appropriate community and public facilities and open space for evacuation areas should be assessed and selected along with necessary reinforcement and/or reconstruction plans. Land expropriation and urban reconstruction measures to prepare proper evacuation areas will be required in the southern and central districts. Appropriate community and public facilities and open spaces do not exist in the area..

Evacuation route improvement and widening, including urban reconstruction and replacement of brick and block enclosures with hedges to maintain the functions of evacuation route (collapsed enclosures obstruct routes), should also be coordinated with local residents and communities.

d. Site and Facilities Development

For each evacuation area, emergency lifeline services (potable water, sewage, telecommunications) and storage areas for emergency goods and equipment should be planned and developed.

(4) Prevention Plan for Building Damage

Human casualties by an earthquake disaster in Tehran will be mainly caused by the estimated building collapse. Improvement measures for structurally weak public and private facilities are recommended to minimize the estimated human casualties.

Collapsed structurally weak block or brick enclosures and falling objects from building will also add to the number of human casualties and affect emergency and evacuation road networks.

The following measures to improve building structures and others are recommended:

a. Housing Improvement

Measures to Prevent Estimated Damage

As often emphasised, around 55% of total residential buildings in the municipality are predicted to suffer almost total collapse. The rest will have some minor damage.

Designation and Plan Formulation of Urban Reconstruction Zone

Before an earthquake disaster, the identification of urban reconstruction zones and plan formulations are recommended. These formulated plans could be implemented to strengthen the seismic resistance of structurally weak housing. The designated urban reconstruction zones and plan could be utilised immediately and revised after the formulation of the urban reconstruction plan.

The designation of urban reconstruction zones is recommended in order to address the needs of community zones with poor housing and weak urban structures:

- Estimated, heavily damaged, weak residential building areas
- High density residential areas with small dwelling units (within the legislated and designated urban reconstruction zone, all rehabilitation and reconstruction activities should be regulated until finalisation of the urban reconstruction plan.)
- Lack of public space to develop proper open spaces, educational facilities and other community service facilities
- Weak road networks for emergency operations, owing to narrow streets in residential areas

Proper Enforcement of Regulation for Reconstruction or Reinforcement of Housing with Financial and Tax Incentives

Proper enforcement of regulations for building codes and seismic resistance standards is required for the design approval stage and the inspection stage. The regulation enforces to avoid the presence of weak housing structures in the reconstruction and rehabilitation stage. Modification of the present enforcement system, based on the advice of the consultant hired by an applicant, will be recommended.

For high-standard, seismic-resistant housing reconstruction, property tax and/or reconstruction loan incentives are recommended.

Expansion of Allocated Reconstruction Fund for Housing and Commercial Buildings

The worst-case scenario earthquake predicts approximately 500,000 collapsed residential buildings and 750,000 homeless families. Also, more than half of the remaining 400,000 residential buildings may have some minor damage, which will require heavy or partial rehabilitation. The reconstruction cost for 750,000 homeless families could be roughly over 100,000 billion Rials., which is around 180 times of the present allocated amount of 550 billion Rials.

It is proposed to utilise the present allocated reconstruction fund as soon as possible, before an earthquake disaster, to reconstruct weak housing structures.

b. Public Facilities Improvement

Social and public service facilities could be categorised into three groups as follows from viewpoints of disaster prevention and management:

- Facilities to be used for Disaster Task Force and centres during a disaster
- Facilities to be used for emergency evacuation
- Other public and social service facilities

Prevention and Improvement Plan for Disaster Task Force Centres

There are estimated 300 public and social service facilities. These include government offices, police stations, traffic police stations, fire fighting stations, and public hospitals. These facilities could be categorised for the Disaster Task Force centres as follows:

- Government offices: Municipal/District DTF headquarters and road maintenance centres for each sub-district
- Police stations: centres for security measures of ordered evacuation areas
- Traffic police stations: centres for traffic and access control of emergency roads
- Fire fighting stations: centres for fire fighting operations and support of rescue/relief operations

- Public hospitals: centres for medical and health services

Approximately 140 facilities (half of the listed facilities) are estimated as collapsed almost completely by the Ray Fault Model scenario earthquake. The expected functions and tasks of each centre cannot be carried out with these heavily damaged building. Therefore, these buildings need to be reinforced or reconstructed for seismic resistance before the earthquake event.

The headquarters of ministries, which are almost all located in the north and south centre of the city's heavily damaged districts, are excluded from the facility list. The nation's capital functions could not be sustained if these ministries and commercial/financial centres are heavily damaged because of weak structures. Before an earthquake occurrence, an assessment of all public facilities should be made by an expert, and recommendations made to reinforce or reconstruct for seismic resistance should be carried out.

Table 7.5.1 Estimated Building Damage for Centres of Disaster Task Forces

District	Government Office			Police Station			Traffic Police Station			Fire Fighting Station			Public Hospital			Total		
	Damaged No.*1	Facility No.*2	Damaged Ratio	Damaged No.*1	Facility No.*2	Damaged Ratio	Damaged No.*1	Facility No.*2	Damaged Ratio	Damaged No.*1	Facility No.*2	Damaged Ratio	Damaged No.*1	Facility No.*2	Damaged Ratio	Damaged No.*1	Facility No.*2	Damaged Ratio
1	2	9	18%							0	1	10%	0	2	15%	2	12	17%
2	1	2	30%	1	3	23%	0	2	20%	2	4	38%	1	3	20%	4	14	27%
3	0	1	20%	3	15	21%				2	4	43%	2	5	30%	7	25	26%
4				1	5	20%				1	4	33%	2	7	27%	4	16	26%
5	0	1	20%	1	2	40%	1	2	60%	2	4	40%	1	4	23%	5	13	36%
6										2	4	40%	5	14	35%	7	18	36%
7	3	7	37%	4	12	35%	1	1	50%	1	1	60%	6	12	48%	14	33	41%
8	1	2	40%	1	1	50%	0	1	40%	2	2	75%	3	5	54%	6	11	54%
9	1	3	43%	1	2	45%							1	2	45%	3	7	44%
10	1	2	60%				1	2	60%	2	3	50%	5	10	53%	9	17	54%
11	1	1	70%	5	5	90%	1	1	60%	4	6	67%	7	10	70%	17	23	73%
12							1	1	100%	2	3	60%	4	7	60%	7	11	64%
13				1	1	50%				1	3	37%	1	2	65%	3	6	48%
14	2	5	48%	2	4	48%	0	1	40%	1	2	50%	7	12	54%	12	24	51%
15	4	9	48%	1	3	40%	1	2	55%	2	3	73%	2	2	80%	10	19	55%
16										1	1	60%	4	6	70%	5	7	69%
17	1	1	70%	2	2	75%				1	1	100%	2	2	80%	5	6	80%
18				1	2	70%				1	1	100%	4	6	65%	6	9	70%
19										1	1	60%				1	1	60%
20	1	2	65%	4	5	84%				2	2	90%	1	1	90%	8	10	82%
21				0	1	40%				1	2	45%				1	3	43%
22										1	2	30%				1	2	30%
N*	6	22	27%	10	38	27%	3	6	42%	11	26	40%	19	52	36%	48	144	33%
S*	12	23	52%	17	25	66%	4	7	61%	18	28	63%	37	60	62%	88	143	61%
T	18	45	40%	27	63	43%	7	13	52%	28	54	52%	56	112	50%	136	287	47%

Note: Damaged No.*1 is the number of heavily collapsed facilities, Facility No.*2 is the listed number of facilities with building structure information. N* is the sum and average of the northern districts 1 to 8 and 22. S* is the sum and average of the southern districts 9 to 21.

Source: Number of facilities is supplied by 22 district offices, JICA Study Team

Prevention and Improvement Plan for Educational Facilities

More than 2,500 educational facilities in Tehran are evenly and densely distributed in local communities, and they could, in theory, serve as the most suitable locations for community evacuation. However, standards for educational facilities in Iran do not call for these facilities to have an appropriate amount of open space to serve as primary evacuation community assembly points, much less for seismic resistance that would give the facilities the ability to survive an earthquake disaster. It is estimated that 54% of listed school buildings will be heavily damaged.

Reinforcement or rebuilding of structurally weak schools, which should be assessed and identified by an expert, are recommended in order to provide appropriate school building structures for coming generations and to provide appropriate emergency evacuation spaces for local communities during a disaster.

It is recommended that, before an earthquake event, the above proposals be planned and implemented as much as possible.

c. Agreement to Replace Block and Brick Enclosures with Hedges

Brick and block enclosures are commonly utilised as private property boundaries in Tehran. In an earthquake disaster, brick and block enclosures will not only collapse and cause human casualties, but also disturb emergency operations by obstructing roads with their debris.

In Japan, it is encouraged that brick and block enclosures be replaced with hedges under community agreements and with government financial support, in order to avoid human casualties and minimise road obstructions.

This system of community agreements and government financial support to replace the hazardous brick and block enclosures is also recommended for Tehran.

d. Regulation for Building Set-Back, Wall Materials/Finishing, and Signboard

Within the old quarter and city centre areas, almost all private and public traditional buildings are not properly set back, and some buildings have overhangs, originally planned to provide shade to pedestrians, that are located directly above pedestrian walkways.

In an earthquake, building collapse and falling wall and window materials will cause secondary disasters and human casualties.

It is recommended that regulations for the set-back of buildings and appropriate securing measures for walls and windows be formulated as part of the Urban Development Zoning Plan in the near future.

(5) Prevention Plan for Lifelines

The supply of water, power, natural gas and telecommunication services could be categorised as lifelines and infrastructures for socio-economic activities in Metropolitan Tehran. As estimated by the Study, each of these facilities will suffer enormous damage, which should be quickly prevented on a priority basis by the responsible agencies, as follows:

a. Prevention Plan for Municipal Water Supply

There will be an estimated 4,000 damaged points along the 8,520 kilometre-long municipal water supply network according to the Ray Fault Model. This damage will be concentrated in the southern district (88% of total points), especially in the southern-central districts (75% of total points) as mentioned in section 7.5.6(9). The estimated damage to the water supply network has been estimated on the macro data of water pipeline length, which was provided by the Tehran Province Water and Sewage Company.

In the formulation of the prevention plan, the following impacts of estimated damages should be considered (the main objective of the prevention plan should be the uninterrupted connection of all areas to lifelines):

- Reinforcement of row water transmission;

- Reinforcement of water purification plants, reservoirs, pumping stations, and the city's main pipeline network; and
- Reinforcement of distribution pipeline network and fire hydrant system

b. Rehabilitation Plan for Electric Power Supply

The electric power supply network in Tehran is composed of 4,063 km of 20kV high-tension main lines and 11,110 km of 400V distribution lines. 65% of 20kV and 50% of 400V networks are laid underground, which has stronger seismic resistance.

Damage to power lines is estimated at approximately 18.5km (0.12% of the total length); 92% of the estimated damage is expected in the southern district, especially the southern-central districts as follows:

Table 7.5.2 Electric Power Lines and Estimated Damage

		line length (km)		damaged length(km)		Ratio
Northern Districts		7,672	51%	1	7%	0.017%
	Fringe Districts:1-5/22	5,381	35%	0	0%	0.000%
	Center Districts:6-8	2,291	15%	1	7%	0.058%
Southern Districts		7,501	49%	17	93%	0.228%
	Fringe Districts:9/13/14/21	1,282	8%	1	8%	0.115%
	Center Districts:10-12/15-20	6,219	41%	16	85%	0.251%
Municipality Total		15,173	100%	18	100%	0.121%

Note: Ratio is percentage ratio of damaged length / total length of line.
Source: JICA Study Team

The Electric Power Company should formulate a prevention and improvement plan, especially for weak overhead sections of the power distribution and city main network as follows:

- Improvement of electric poles or change to underground cable box system,
- Upgrading and strengthening of the city main network to be seismic resistant
- Upgrading and strengthening of sub-stations and transformers to be seismic resistant

c. Prevention Plan for Natural Gas Supply

The present natural gas pipeline network in the municipal area is composed of high pressure (250 psi) and middle pressure (60 psi) steel pipeline and low-pressure polyethylene pipeline. Approximately 7,000 km of the present gas pipeline will be damaged at 540 points, which was estimated based on the lifeline damage analysis as follows:

Table 7.5.3 Gas Pipeline by District/Area and Estimated Damage

		pipeline (km)		damaged points		d.p./km
Northern Districts		3,449	49%	80	15%	0.023
	Fringe Districts:1-5/22	2,249	32%	20	4%	0.009
	Center Districts:6-8	1,201	17%	60	11%	0.050
Suthern Districts		3,605	51%	450	85%	0.125
	Fringe Districts:9/13/14/21	1,235	18%	90	17%	0.073
	Center Districts:10-12/15-20	2,370	34%	360	68%	0.152
Municpality Total		7,054	100%	530	100%	0.075

Change entry in table above to "Southern Districts"
Note: damaged points / km* is number of damaged points per kilometre of pipeline.
Source: JICA Study Team

The Natural Gas Company should formulate the prevention and improvement plan, including security measures, to avoid secondary disasters as follows:

Security Measure:
A new automatic safety valve system (from the present manual valve) with seismometer and telemeter network is proposed to avoid secondary disaster and to simulate and estimated seismic damages for quick and proper emergency responses before disaster occurrence.

Preventive Measure:
Improvement and upgrading of pipeline joint system to make it seismic resistant. Establishment of a wireless communication system between headquarters, branch offices and key facilities is also proposed.

d. Prevention Plan for Telecommunication Network

The telecommunication network in Tehran is a dual system of 10,360 km of telephone lines and mobile phones. Presently, the majority of subscribers are covered by a cable telecommunication system.

Telephone lines consist of 681 km of optical fibre, 8,404 km of copper cable, and 1,275 km of cable with conduit. Majorities of telephone lines are laid underground except connection lines to subscribers. According to the Ray Fault Model, the estimated damage to telecommunication lines is 12.8 km, which is around 0.12% of the total length of the network. Earthquake damages for the mobile system and exchange facilities was not estimated because the data available was limited.

The Telecommunication Company should be formulated a prevention and improvement plan of the telecommunication network based on a revised damage analysis that takes into account a proper database.

To promote and enhance the mobile phone system, it is recommended that the emergency telecommunication system for DTFs and citizens be strengthened.

Table 7.5.4 Telecommunication Network and Estimated Damage

		length of line (km)		damaged length(km)		ratio*
Northern Districts		5,226	50%	1	9%	0.02%
	Fringe Districts:1-5/22	3,539	34%	0	0%	0.00%
	Center Districts:6-8	1,687	16%	1	9%	0.06%
Suthern Districts		5,138	50%	12	91%	0.23%
	Fringe Districts:9/13/14/21	1,237	12%	1	9%	0.09%
	Center Districts:10-12/15-20	3,901	38%	11	82%	0.27%
Municpality Total		10,364	100%	13	100%	0.12%

Note: Ratio is percentage ratio of damaged length/total length of telephone line
Source: JICA Study Team

(6) Prevention Plan for Damages to Transportation Facilities

A prevention plan to minimise disaster damages to transportation facilities should cover roads, bridges, railways and commuter rails, and airports should be based on an adequate database. Road and bridge damages are estimated in the damage analysis study.

All of the above transportation modes are indispensable to mobilise and deploy experts and manpower for emergency operations and to transport emergency goods after an earthquake event.

A road and bridge improvement and reinforcement plan should be formulated for emergency roads and evacuation road networks. The works should be based on detailed diagnoses of their seismic resistant condition by experts. Designated emergency road networks should link the DTF centres, evacuation areas, emergency goods storage and distribution centres, regional roads and airports, etc.

(7) Reinforcement Plan for Urban Structures

According to the results of the damage analysis, the Ray Fault Model earthquake will almost destroy residential and other buildings, especially in the central and southern districts of Tehran,. In the area, seismically vulnerable building structures weak urban structures on narrow roads are prevailing. In these areas, there is also a significant lack of adequate public space for evacuation.

A reinforcement plan of urban structures is required in order to avoid and mitigate the estimated heavy damages in the specific districts due to an earthquake disaster. The seismic resistant strengthening of urban structures should cover the following fields:

- Designation of reinforcement district and areas,
- Designation and improvement of emergency roads and evacuation road networks,
- Designation and preparation of proper evacuation areas (including site expansion, building reinforcement of schools, and development of multi-functional public open space to serve as evacuation areas),
- Seismic resistant reinforcement and rebuilding of public facilities, which would serve as DTF centres,
- Implementation of urban reconstruction projects for the above areas (including highly populated small-scale and structurally weak residential areas).

(8) Organisation Plan for Urban Disaster Prevention and Management

For the estimated large-scale urban earthquake disaster, the Tehran Municipality should establish systemised and hierarchical Disaster Task Forces, including community disaster task forces before and after disaster occurrence, which is recommended in section 7.3, Recommendation for Organisational Structure.

Required facility development plans for each DTF should cover the need for emergency communication devices, emergency goods and equipment, emergency potable water supply tanks and systems, and emergency vehicle and helicopters/pads, etc.

(9) Guideline and Manual for Disaster Prevention Awareness

Tasks to upgrade disaster prevention awareness are currently taken on mainly by the Red Crescent Society of Iran. However, the estimated disaster damage will have great impacts on all citizens, communities, and establishments in the Tehran Municipality.

Disaster prevention awareness could be upgraded and its momentum maintained to prevent and mitigate disaster damages on a family and community basis.

Guidelines and manuals on disaster prevention awareness should include the following aspects:

- Diffusion of scale and danger of earthquake disaster in Tehran,
- Diffusion of disaster prevention measures on a family and establishment basis, and
- Diffusion of emergency response activities to minimise damage on a family and establishment basis

Implementation of awareness raising programs are proposed as follows:

- Each level of DTFs in the municipality supported by emergency operation bodies such as the Red Crescent Society, Fire Fighting Dept., Traffic Police, Police, etc.
- Curriculum in social science and emergency drills in elementary, intermediate and high schools
- Periodical training and drills on disaster prevention and emergency response operations and activities.

Community-based training activities are proposed in section 7.3.3(3)d.

(10) Earthquake Disaster Study and Research Plan

Earthquake disaster study and research activities on active faults conditions are required to establish an earthquake disaster database in the DTF municipality centre and to improve the disaster prevention plan.

In addition, establishment of a ground and earthquake motion monitoring system with damage simulation models is recommended. The system allows the DTF centre to input earthquake event details and obtain quick information necessary for the formulation of informed emergency operation plans immediately after an earthquake event. The proposed items are as follows:

- GIS database system to support disaster prevention and management planning,
- Earthquake damage simulation system to aid in the implementation of proper emergency operations, and
- Research activities with national and international research institutes (on ground conditions and movement, seismic resistance of existing public facility building structures, housing, bridges, research on human activities in emergency and evacuation circumstances, etc.)

7.5.6. Formulation of Emergency Operation Plans

Plans for required emergency measures should cover the following:

(1) Disaster Task Force System Organisational Structure

It is proposed that a hierarchical organisational structure for the Municipality, District, Sub-District, Community Zone, and Residential Block Disaster Task Force System be established through legal measures in the Tehran Municipality.

1) Deployment plan of officers and municipal and district staff to the required task force groups,
2) Include plans for deployment and organisational structure of officers and staff to the required municipal, district, and sub-district level task force groups during office hours and after office hours,
3) Mobilisation plan of municipal staff to emergency task force,
4) Before the disaster, assignment of all municipal and district government staff to specific task force groups at a specific office or meeting place,
5) Disaster Task Force personnel plan,
6) Emergency equipment and machinery procurement and storage plan,
7) Request procedure to dispatch Disaster Task Force to Tehran Province and surrounding provinces and districts,

8) Request procedure to dispatch emergency relief and rescue operation personnel and organisations to Red Crescent Society and other emergency relief groups,

9) Plan for data collection on primary damage, reporting, and announcement.

Objectives of the plan are to identify and carry out quick and proper emergency measures based on accurate primary disaster information. This plan should include a chain of reporting and method and system for data and information collection. The required primary information and data are as follows:

- Earthquake disaster,
- Damage conditions (HQ facility/lifelines, building damages, obstacles on emergency roads, fire outbreaks/status, and human casualties),
- Activities of citizens,
- Condition and progress of evacuation activities,
- Condition and activities of fire fighting operation,
- Condition and activities of municipality and District Task Force groups,
- Condition and activities of rescue operation,
- Condition and activities of first aid and relief operation,
- Other required measures, and
- Collection of earthquake data and information from related earthquake research institutes.

Notification and announcement of the disaster and damages to citizens is a required measure to maintain order and stability. The following plans will be required for the notification/announcement measure:

- Development of information centre,
- Development of wireless communication system,
- Items of information collection and announcement, and
- Advice and counselling for citizens, particularly disaster victims.

(2) Fire Fighting Plan

a. Data Collection

An accurate data and information collection system, including an information and command centre, TV monitoring, roving helicopters and reports from related agencies, is indispensable to the launching of a proper fire fighting operation.

The required information items for fire fighting are as follows:

- Fire outbreak and spreading condition,
- Assessment of necessity of rescue and evacuation operations,
- Conditions of roads and bridges,
- Conditions of operation, mobilization, equipment, and vehicles of fire fighting teams, damage conditions of communication equipment and systems,
- Damage condition of Disaster Task Force centres and related facilities, and
- Activities of citizens

Active public relations and announcement of the collected information are required to maintain order and stability and to dispel the anxiety of citizens.

b. Target and Priority Characteristics

The developed fire fighting operation plan should include target and priority characteristics as follows:

- General protection measures,
- Prioritised protection measures, and
- Concentrated protection measures

Preparation of evacuation routes for evacuees should also be considered.

c. Fire Fighting Operations

After an earthquake occurrence, normal and scheduled activities of fire fighting agencies should be changed to emergency mode as follows:

- Emergency summons to all fire fighting staff and voluntary groups,
- Organise planned emergency teams and emergency patrol and monitoring,
- Enact measures to support fire zones such as designating alert zones, preparing evacuation routes, giving warnings for evacuation, directing fire engines to proper routes and to water sources by helicopter, and designating and preparing for a fire outbreak,
- Prepare emergency fuel tank for emergency operations,
- Organise emergency teams of community-based volunteer fire fighters, and
- Request fire fighting support from surrounding provinces and districts; supply report of conditions and required support duration, activities, coverage area, forces, equipment, access routes, meeting point, and communication.

(3) Rehabilitation of Heliport

The Red Crescent Society owns helicopters and uses them for emergency monitoring and rescue activities. The traffic police also use their helicopter for monitoring traffic conditions.

The use of helicopters provides effective and quick emergency services, such as transportation of emergency goods, personnel and the injured, and a convenient mode to monitor disaster conditions. For the future, helicopters and heliports will be required for the Centre of Tehran Municipal Disaster Task Force (CTM-DTF).

Heliports and operation of helicopters should be rehabilitated for emergency operation as soon as possible, before major earthquake disaster occurs.

(4) Evacuation Plan

After the first ground shaking of a major earthquake, residents should be evacuated to safe areas in accordance with the formulated evacuation plan and drills carried out previously. This is to avoid and minimise human casualties from secondary disasters and building collapse caused by aftershocks.

The evacuation plan should explain the following:

- Principle and execution of recommendation and instruction of evacuation,
- Means to transmit the recommendation and instruction,
- Guidance of evacuation,

- Compilation of damage information (number of evacuees, injured and missing, building damage, fire, and road conditions), and
- Reporting of compiled damage information to heads of district, municipal, and national level Disaster Task Forces and related task force centres.

(5) Maintenance Plan for Emergency Roads and Evacuation Road Network Functions

After an earthquake disaster, the road maintenance section of sub-districts, which is responsible for daily road maintenance, should be responsible for the maintenance of designated emergency roads and evacuation road network functions.

a. Maintenance of Evacuation Road Network by Road Maintenance Section of Municipality, Districts and Sub-Districts

- Inspection of designated evacuation road condition,
- Removal of obstacles on roads and access restoration using all possible means,
- Selection of substitute roads when there is danger of fire or explosion along the original route,
- Provision of signboards for selected substitute route, and
- Maintenance of the emergency road network

Designation and selection criteria for emergency roads are as follows:

- Arterial road linking to the regional road network outside the municipality,
- Arterial road of adequate width,
- Arterial road required and effective for quick rehabilitation of urban functions, and
- Proper density of emergency roads, which should consider the accumulation of urban functions

b. Inspection and Maintenance Activities

- Inspection of emergency route road and bridge conditions by the road maintenance section of each sub-district,
- Removal of obstacles on roads by the road maintenance section to allow emergency traffic,
- In the case of bridge collapse along designated emergency roads, bypasses should be selected and signboards should be provided to point out the substitute route.

(6) Emergency Rescue Operation Plan and Law

Tasks for rescue and relief operations should be clearly defined and assigned to the community-based Task Force groups, the Red Crescent Society of Iran, the Fire Fighting Department and other rescue experts to reduce the estimated number of human casualties.

a. Principles for Rescue Operations

The following principles for rescue operations should be followed: set-up rescue operation units to cover the estimated human casualties; organise strategic rescue task force groups in districts where a high number of casualties is concentrated, carry out first aid, and clearly define the task to rescue those trapped under collapsed buildings.

b. Rescue Operations at the Initial Stage

Activities at the initial stage include the following: determine the condition of roads, capacity of medical care facilities, required rescue operation zones, and the estimated number of human casualties and those trapped under collapsed buildings. Order the mobilisation of community-based rescue activities to get detailed information on human casualties and missing family members per building. Order the activation of strategic rescue operations by the Red Crescent Society and Fire Fighting Department for the seriously damaged southern municipal zones. Prepare and enact first aid and emergency procurement of emergency medicine, goods, and equipment.

c. Rescue Operation at Mid Stage

Transfer the rescue forces from less damaged northern districts to heavily damaged southern districts. Transfer the injured from first aid stations to medical facilities. Collect information on the capacity of medical facilities.

d. Rescue Operation at the Late Stage

Transfer all injuries from first aid stations and temporary medical service facilities to medical facilities. Request ambulances from other provinces and districts. Investigate the whereabouts of those that are still missing and determine danger areas. Compile names, hospitals, addresses of identified fatalities, injured, and missing persons. Notify and announce fatalities by TV and radio.

(7) Relief Operations and Medical Service Plan and Law

The plan will provide first aid treatment to evacuees (including pregnant women) when ordinary functions of medical service facilities are suspended as a result of a disaster.

Implementation of the plan should cover the following six aspects:

- Organisation of first aid teams whose members should come from medical and health care organisations of the municipality/public sector, Red Crescent Society, and medical hospitals of the private sector
- Scope of medical and obstetrical services: medical services including diagnosis, medicine/goods supply, treatment/operation, and transfer to hospital and obstetrical services including support for delivery, treatments, and goods supply.
- Deployment of first aid teams following the planned procedure, including dispatching order for first aid teams of each medical care organisation.
- Setting-up of temporary first aid service in health centres, district offices, Red Crescent Society locations, fire fighting stations, evacuation areas, and other areas.
- In-patient System: first level medical service in temporary first aid locations, moved to second level by vehicle/helicopter, and second level medical service in medical service facilities.
- Procurement of medical service goods and equipment

(8) Evacuation Area Plan

The objective of the plan is to provide temporary shelter to evacuees, whose houses are damaged by the earthquake. This plan should include the following aspects: qualifying accommodated persons, responsible agencies, manner of implementation, and funding.

a. Conditions for accommodated evacuees

- Those given orders to evacuate their homes; and

- Those rendered homeless because of damaged or collapsed buildings.

b. Responsibility: Mayor of Tehran Municipality

The Mayor of the Tehran Municipality should take responsibility for evacuation as follows:

- Financial arrangement to prepare evacuation areas in coordination with the NDTF, and
- Decision-making and order to evacuate in coordination with the NDTF

c. Implementation: District Mayors

District Mayors will implement and open required primary and secondary evacuation areas for damaged sub-districts or community zones under the evacuation order.

Primary evacuation area

In Japan, primary evacuation areas, which should be provided for each community zone, usually utilise public primary and intermediate schools, community halls or other public facilities with strong structures resistant to seismic events. However, the predicted building damage ratio in Tehran is over 55%, which could be understood to mean that public facilities will be unusable as evacuation areas. Appropriately, distributed public facilities with strong seismic resistant buildings are not available in each community zone. Parks and open spaces will be candidates for primary tent evacuation areas. In the southern districts, additional public open spaces are required to accommodate the estimated number of evacuees.

After the opening of the evacuation area, all important details pertaining to the evacuation area, i.e., location and time of opening, number of evacuees, forecasted period, and required emergency goods supply, should be reported to the Municipal Disaster Task Force centre by the district DTF. In Japan, the operation period of an evacuation area is legislated at not more than 7 days after a disaster. After 7days, operation of the evacuation area could be expanded, but, principally, evacuees should be removed to temporary housing or villages.

Secondary evacuation area

A secondary evacuation area is used to transfer evacuees from a primary evacuation area, when there is danger of fire or explosion of hazardous facilities or difficulty of operation of emergency water and goods supply. Regional- or district-level parks are usually utilised as secondary evacuation areas, which are required for sub-district or district level communities.

d. Expense and Cost of Operation

The Government of Iran and Tehran Municipality should bear all operation costs and expenses under the legislated financial measures.

(9) Emergency Water Supply Plan

The following facilities contribute to the municipal water supply system of Tehran:

- Surface water sources: Karaj, Lar, Latiyan dams (605 Mm^3/annum, 70%)
- Ground water sources: 200 deep wells (250 Mm^3/annum, 30%)
- Raw water transmissions: 176 km to water treatment plants,
- Water treatment plants: 4 existing (16.7 m^3/s)/1 under construction (15 m^3/s)
- Treated water mains: 147 km pipelines with 5 pumping stations to reservoirs,
- 50 reservoirs (1.55 Mm^3) and 26 reservoirs with pumps,
- Municipal water distribution pipeline: more than 8,500 km.

Damage to water distribution pipelines is estimated to occur at approximately 3,900 points, mostly located in the southern districts. However, water supply throughout the municipality will be cut off because of a number of damaged pipelines, except for parts of Districts 1 and 22.

Principally, the damage analysis of Tehran's water supply network should be reassessed further, in order to provide an accurate database of water supply pipeline information for the Urban Disaster Prevention and Management Study in the future.

Table 7.5.5 Municipal Water Distribution Pipeline and Damaged Points

		Pipeline (km)		Damaged points	
Northern Districts		3,957	46%	500	13%
	Fringe Districts:1-5/22	2,727	32%	200	5%
	Center Districts:6-8	1,230	14%	300	8%
Southern Districts		4,560	54%	3,400	87%
	Fringe Districts:9/13/14/21	1,220	14%	500	13%
	Center Districts:10-12/15-20	3,340	39%	2,900	74%
Municpality Total		8,517	100%	3,900	100%

Source: Tehran Province Water and Sewerage Company and JICA Study Team

For areas where municipal water supply could be cut off in case of a disaster, emergency water supply systems should provide the required minimum potable water for evacuees and residents, as explained below.

a. Initial Stage

Data collection and compilation of damage to dams, intakes, raw water transmissions, treatment plants, main municipal water pipelines and pumping stations, reservoir with pumps, distribution pipes based on task distribution.

1) Assessment of potential cut-off areas and possible amount of water supply by the existing municipal water supply system,

2) Emergency adjustment by valve control for areas with limited water sources,

3) Emergency water supply,

4) The Mayor of Tehran should be responsible for emergency potable water supply for evacuees and residents in areas cut off from municipal water supply,

5) Temporary emergency water supply points and systems include:

- Existing reservoirs,
- Fire hydrants (though they are not appropriately distributed throughout the entire municipal area),
- Tank lorry (they cannot serve individual homes/buildings), and
- Preparation of temporary or permanent water tanks with supply system in evacuation areas

6) Standard ration of water per person should be more than 3 litres/person/within 7 day limit (standard in Japan)

7) Request to the surrounding provinces and districts for emergency water supply manpower/machinery,

8) Information dissemination of water supply cut off conditions/zones, emergency water supply service/locations by the use of vehicles with loudspeakers, and

9) Entire operation cost is the responsibility of the municipality (or province).

b. Available Resources for Emergency Water Supply

In the event of a disaster, old shallow wells (less than 50m deep) and most qanats (except 2 qanats of Kowsar, 286 l/s, and Opper Naseryeh, 166 l/s) could not be used as emergency potable water sources in Tehran because they are almost totally polluted by sewage, due to the lack of an urban sewage system.

About 200 deep wells (average depth: 130 m) and 50 water reservoirs (total capacity: 1.55 Mm^3) could serve as water sources for 1.5 months for all citizens (based on the ration of 5 l/person/day). The 26 municipal pump reservoirs could be most important emergency water sources after an earthquake disaster.

Seismic resistance assessment and improvement measures for water reservoirs and emergency power supply systems to operate water pumps will be required.

(10) Emergency Food Supply Plan

The responsibility of emergency food supply is currently taken on by the Red Crescent Society of Iran, which is planning to expand their stocks of emergency goods, including food items. However, with the estimated damage coverage of more than half of over 4 million evacuees located in the entire city area, the Red Crescent Society alone will not be able to provide emergency food supply to them.

A 3-stage emergency food supply system is recommended considering capacity for required volume, period and distribution coverage.

a. Emergency Food Supply-1 by Community-based Task Force Group: 1st day

The establishment of a community-based emergency goods storage system is recommended for all evacuation areas in community zones, sub-district centres, and district centres (financed by the municipality). Furthermore, families should be encouraged to keep a stock of emergency goods themselves in order to promote a disaster preparedness mind frame.

Just after an earthquake occurrence, the community-based emergency goods storage system in each evacuation area could easily cover the required food supply for evacuees. On the other hand, the existing single supply system by the Red Crescent Society will have risks and difficulties to adequately cover the damaged areas and provide for evacuees in evacuation areas, which will be spread over the entire municipal area. In addition, rehabilitation work of emergency road networks (including that which would facilitate food supply) will take a few days. Meanwhile, traffic of private cars will hinder emergency operations on designated emergency roads, which should be well controlled by traffic policemen.

b. Emergency Food Supply-2 by Red Crescent and District/Municipality DTFs: Half Week (Until Activation of Regional and National Emergency Goods Supply)

Expansion of Red Crescent logistic centres and development and establishment of municipal emergency goods supply depot and distribution centres, including food are recommended. Those are constructed at existing traffic nodes of regional roads, railways and airports to the east, south, and west of the city boundaries. A few days after an earthquake occurrence, the municipal-based emergency food storage system could be tapped as the proper system to provide the required food supply through the community-based emergency food supply system to the estimated thousands of evacuees. This makes sense because the food and food processing industries located in the Tehran Municipality would not be able to sustain an adequate food supply in earthquake disaster.

Distribution of stored emergency food through regional depots and food supply industries from other regions will take a few days to arrange and to transport to municipal emergency depots in Tehran.

c. Emergency Food Supply-3 by National, Municipality, and District DTFs: half month

It is recommended that a nationwide food supply system (including information management, food processing, and transportation and distribution) be established. And it is recommended that emergency food receiving system for international emergency food aid. The municipal emergency goods depot and distribution centres and community-based emergency food supply systems takes important role. Distribution and supply systems should be supported and reinforced by government agencies and well-organised NGO activities.

(11) Other Emergency Goods Supply Plan

Other emergency goods are necessary for daily life activities. These include medicine, other first aid supplies, tableware, bedding, clothes, etc. A similar system and plan as that for emergency food supply are recommended for the supply and distribution of other emergency goods.

(12) Preventive Measures for Epidemics, Cleanliness, and Health Care

This plan should contain quick and proper measures to guard against epidemics, to maintain cleanliness, to dispose of dead livestock, to remove obstacles for mobility, and to monitor food hygiene, as described below, for the purpose of preventing environmental deterioration in damaged areas.

a. Plans for Preventive Measures Against Epidemics

Organised examination teams and prevention teams should perform the following tasks:

Examination Team:

- Examination of disease and diagnosis of health for early detection
- Guidance of preventive measures
- Temporary vaccination
- Education and information campaign on preventive measures
- Treatment/operation/isolation of patients

Prevention Team:

- To disinfect and maintain cleanliness
- To exterminate harmful insects and rats

Procurement, storage and inspection of required medicines, disinfectants, insecticides, etc. should be planned. These items should be inspected to maintain the appropriate demand and quality for residents within each health care centre.

b. Plans for Cleanliness Measures

The plan should cover garbage disposal and sewage disposal.

The garbage disposal plan should contain initial and secondary measures as follows:

Initial Measures

- Site selection for temporary garbage collection based on public land ownership and absence of negative environmental impact

- 5 to 10 sites for each district (based on demand and/or population)

Secondary Measures

- Garbage transfer from temporary collection sites to solid waste disposal facilities by temporary workers and machinery

A sewage disposal plan should cover all the designated evacuation areas and temporary housing/tent villages. A huge number of temporary toilets with underground tanks would be required for each area based on the demand of an estimated 3 to 3.5 million evacuees according to the Ray Fault Model scenario earthquake.

In order to address this concern, it is recommended that underground sewage tanks and some public toilets to be constructed before the earthquake for use in the designated evacuation areas.

c. Disposal Plans for Dead Livestock

Principally, livestock and pets that die during the disaster should be disposed of by owners. If the owners are unable to do it, the municipal government should collect and dispose of them. The proposed procedure of disposal is as follows:

- Dispatch inspection officers of infectious disease prevention to reported livestock site;
- Provide measures of disinfection and sanitation; and
- Collect and bury dead carcass in designated area.

d. Monitoring Plans for Food Hygiene

After an earthquake disaster, power failures and water supply shortages could cause food decomposition and water pollution.

Municipal governments and health care centres should organise and dispatch monitoring teams for food hygiene and water pollution after disaster strikes.

(13) Locating Dead Bodies, Preparing Morgues, Burials and Burial Grounds

In case of the Ray Fault Model scenario earthquake, approximately 400,000 deaths are estimated when rescue operations are not carried out. A maximum of approximately 100,000 of these deaths could be prevented, that is potential victims could be rescued, by community-based rescue operations (60%), by emergency squads of the Red Crescent and other agencies (25%), and by emergency rescue experts (15%).

Formulation of the plan for locating bodies and for morgues and burials should consider the magnitude of human casualties.

a. Locating Dead Bodies

The required proper information to search for missing persons should be compiled based on accurate community-based information, including detailed location of bodies in buildings.

The estimated human casualties are not only concentrated in the city centre and southern districts (92% of estimated deaths), but also dispersed throughout the entire municipality area. The search for the 300,000 to 400,000 victims over the entire area cannot be managed solely by rescue operation agencies. It will depend heavily on community-initiated efforts by the proposed Community Disaster Task Force Group in each community zone and residential block.

b. Preparation of Morgues

It is recommended to set up a plan for morgues in each district or sub-district. At almost of Districts 7 to 17, there would be heavy residential building damage. 50 to 82% of residential buildings are completely damaged. Open spaces, which serve as evacuation areas, do not exist and the residents would most likely be evacuated outside the districts. For these districts, it is recommended that morgue sites should be set at outside district boundaries, near evacuation areas.

Morgue sites, facilities and coffins should be prepared and provided by district offices with financial support from the municipal government.

c. Burials and Preparation of Burial Grounds

The municipal government is to prepare the required burial grounds (an estimated 75 to 100 ha), which would be subdivided amongst the national cemeteries (Behesht Zahra and others) in the southern part of the municipality.

Joint burials could be organised by district offices with assistance from the municipal government.

(14) Rehabilitation of Educational Function

The Ray Fault Model scenario earthquake predicts that approximately 70% of educational buildings in the southern districts will be almost totally collapsed, 40% in the northern districts, and 54% in the entire city. Therefore, it is urgently recommended that schools with weak structures be either reinforced or reconstructed following an expert assessment. Furthermore, the schools should be strengthened to withstand repeated seismic events as much as possible. The reinforced school building could then be used as evacuation facility for local communities in case of an emergency.

Recovery of educational functions will be difficult based on the estimated high collapse ratio of school buildings, more so in the southern districts. Schools are already operating on a double shift the area because of the current shortage of school buildings. To compound this problem, after an earthquake disaster, some existing and rehabilitated school buildings will have to be converted to evacuation facilities for local communities during the emergency period.

After the emergency period, all school buildings that survived the disaster should be cleared of evacuees and cleaned to restart schooling, and those still homeless would have to be moved to temporary housing or tent villages.

For heavily damaged school buildings, temporary schools should be provided on public land near the site of the original school or near temporary housing or tent villages.

Presently, a reconstruction fund, in the amount of 700.62 billion Rials. (US$ 85.5 million), is allocated for infrastructure and public facilities.

Table 7.5.6 Estimated Building Damage for Educational Facilities

District	Elementary School			Intermediate School			High School			University			Total		
	Damaged No.*1	Facility No.*2	Damaged Ratio (%)	Damaged No.*1	Facility No.*2	Damaged Ratio (%)	Damaged No.*1	Facility No.*2	Damaged Ratio (%)	Damaged No.*1	Facility No.*2	Damaged Ratio (%)	Damaged No.*1	Facility No.*2	Damaged Ratio (%)
1	24	67	36%	12	37	34%	18	44	42%	4	13	33%	59	161	37%
2	37	106	35%	37	101	37%	35	96	37%	9	24	36%	118	327	36%
3	15	38	39%	13	39	34%	17	48	35%	13	41	32%	58	166	35%
4	22	76	29%	20	63	32%	17	59	28%	5	17	30%	64	215	30%
5	17	45	38%	21	48	44%	18	48	37%	2	6	25%	57	147	39%
6							1	3	20%				1	3	20%
7	24	49	50%	17	35	49%	16	33	47%	9	19	48%	66	136	49%
8	33	58	56%	19	32	61%	25	39	63%				77	129	59%
9	14	33	41%	11	26	41%	10	25	42%	2	5	46%	37	89	41%
10	29	39	75%	15	20	77%	13	18	74%	0	1	40%	58	78	75%
11	59	70	84%	40	53	75%	30	42	71%	10	13	74%	138	178	78%
12	8	11	73%	8	11	69%	10	16	64%	2	4	58%	28	42	67%
13	33	65	50%	23	45	51%	11	22	51%	2	3	57%	68	135	51%
14	24	42	57%	11	19	60%				1	1	50%	36	62	58%
15	109	149	73%				1	1	60%				109	150	73%
16	45	59	75%	31	39	79%	27	35	77%				102	133	77%
17	25	30	82%	10	12	87%	18	23	77%				53	65	81%
18	33	50	66%	27	37	72%	21	28	75%	3	5	68%	84	120	70%
19	15	18	82%	17	22	77%	6	9	67%				38	49	77%
20	55	73	76%	33	43	76%	43	52	82%	4	6	67%	135	174	77%
21	3	4	80%	2	3	77%	5	8	64%				11	15	71%
22	1	1	60%	1	4	28%							2	5	34%
N*	173	440	39%	141	359	39%	145	370	39%	42	120	35%	501	1289	39%
S*	450	643	70%	228	330	69%	195	279	70%	24	38	64%	897	1290	70%
T	623	1083	57%	369	689	54%	340	649	52%	66	158	42%	1,398	2,579	54%

Note: Damaged No.*1 is the number of heavily damaged facilities, Facility No.*2 is the number of facilities listed with building structure information. N* is sum and average of the northern Districts 1 to 8 and 22, and S* is the sum and average of the southern Districts 9 to 21.

Source: Number of facilities is supplied by 22 district offices; JICA Study Team

(15) Distribution Plan of Monetary Donations for Disaster Victims

The NCNDR should prepare standards and criteria for monetary donations from the national government to surviving victims of urban and regional natural disasters by a legislation process. The National and Tehran Municipal Disaster Task Forces should be responsible for the preparation of the distribution plan.

(16) Acceptance Plan of Donation for Disaster

Once news of the disaster is reported by national and international news agencies, donations will start pouring in from within and outside the country.

The Tehran Municipal Disaster Task Force, which could be supported by the National Disaster Task Force, should prepare a mechanism that could handle this enormous task and inform the same to international agencies, foreign embassies, news agencies, and the media.

7.5.7. Rehabilitation and Reconstruction Plan

The objectives of the rehabilitation and reconstruction plan are to repair damaged public and social service facilities and infrastructure and to improve and upgrade urban seismic disaster prevention functions for the future.

Plans for required rehabilitation and reconstruction measures should include the following:

- Rehabilitation plan for road and transportation facilities,
- Rehabilitation plan for urban infrastructure,
- Rehabilitation and reconstruction plans for social service and public facilities, and
- Socio-economic revitalisation and stabilisation plans.

It is recommended to incorporate incentives, such as tax exemptions, in the financing plan for reconstruction of private housing and industries, and for revitalisation of trade and goods circulation.

(1) Road and Transportation Rehabilitation Plan

Responsible agencies for road construction and maintenance should inspect and rehabilitate facilities damaged by the earthquake disaster, with a focus on the following:

a. Slope Protection

Fixing of facilities and landslide rehabilitation plans for the northern mountain area is required.

b. Roads and Bridges Rehabilitation Plan of Emergency Road Network

The plan for damaged bridges and road sections blocked by obstacles and landslides should describe how to perform a ‘ quick-search’ of such areas, the required rehabilitation work and describe the agencies responsible for the removal of road obstacles.

In case quick rehabilitation for damaged and interrupted road sections is difficult, bypass routes should be set up and communicated for emergency vehicle access

c. Recommended Preventive Measure

For damaged bridges, reconstruction and/or reinforcement work to improve their seismic resistance is recommended, along with urgent structural assessment by an expert.

(2) Urban Infrastructure (Lifelines) Rehabilitation Plan

The supply of water, power, natural gas, and telecommunication network systems could be categorised as lifelines and infrastructures for socio-economic activities in Metropolitan Tehran. As estimated by the Study, each of these facilities will suffer enormous damage, which should be quickly rehabilitated on a priority basis by responsible agencies as follows:

a. Rehabilitation Plan for Municipal Water Supply

In case of the Ray Fault Model earthquake scenario, there will be an estimated 4,000 damaged points on the 8,520 kilometre long municipal water supply network. Damages will be concentrated in the southern district (88% of total points), especially in the southern-central districts (75% of total points). The estimated damage of the water supply network has been focused on the macro data of water pipeline length, which is provided by the Tehran Province Water and Sewage Company.

The rehabilitation should consider the impacts of estimated damages in the formulation of the plan as follows (the main objective of the rehabilitation plan should be the uninterrupted connection of all areas to lifelines):

- Inspection and rehabilitation task distribution plan for each water supply district, zone and area;
- Inspection work, rehabilitation work and changing or adjustment of water supply zone to maintain uninterrupted connection to lifelines; and
- Report of power failure information to the responsible agency

b. Rehabilitation Plan for Electric Power Supply

The Electric Power Company should quickly organise rehabilitation teams based on the formulated rehabilitation plan for earthquake damage as follows:

- Preparation of emergency order and guidelines for all employees (after office hours, all employees should be assigned to work in the branch offices located in their area of residence),
- Inspection of damaged condition and difficulty of rehabilitation,
- Setting of rehabilitation priority based on the impact of service coverage,
- Review of formulated rehabilitation plan and preparation of implementation program for rehabilitation work by damage information and assessment,
- Coordination of implementation plan with the Disaster Task Force groups,
- Inform damage condition and rehabilitation plan to I.R.I. TV and radio and other forms of mass media for dissemination.
- Deployment of required rehabilitation manpower with orders to the branch offices outside the municipality, and
- Procurement and transportation of required material and machinery for rehabilitation

c. Rehabilitation Plan for Natural Gas Supply

Around 7,000 km of the existing gas pipeline will be damaged covering around 540 points, which was estimated based on the lifeline damage analysis.

The Natural Gas Company should organise a Disaster Task Force and implement a rehabilitation program based on the seismic disaster management plan, which should be formulated before the occurrence of an earthquake disaster as follows:

Emergency Operation-1:
Information collection from devices, damage simulation and transmission, information exchange between related agencies, damage information and data to be transmitted through vaporiser or supply factory to Disaster Task Force centre.

Emergency Operation-2:
Review of formulated emergency operation and rehabilitation plan considering primary data of earthquake damage. Priority for rehabilitation should be provided for 1) matters relating to human lives, 2) intensive rescue/relief operation zone, and 3) lifelines.

Emergency Operation-3:
In case of occurrence of an earthquake of seismic intensity (MMI) more than 5, order branch offices and related companies in and outside the municipality for mobilisation and deployment for emergency rehabilitation. Such orders should be broadcast repeatedly by I.R.I. TV and radio.

Emergency Operation-4:
Order to arrange and transfer required materials, equipment and machinery from branch offices and related companies in and outside the municipality. The arrangement of these goods should be planned based on stored inventory.

Emergency Operation-5:
Answers to public concerns and information on implementing safety measures and required activities for citizens should be disseminated through I.R.I TV and radio and by loudspeakers of rehabilitation vehicles.

Emergency Operation-6:
Preventive measures for secondary disasters should be carried out, i.e., valves to supply districts and zones should be shut off if there is potential for leakage.

Emergency Operation-7:
Rearrangement of gas supplies zones to minimise areas affected by the interruption of supply.

Emergency Operation-8:
Implementation of rehabilitation work should be based on a cooperation system with relating agencies and companies of the Municipal Disaster Task Force groups, road management and traffic management agencies, infrastructure management companies, and mass communication companies.

d. Rehabilitation Plan for Telecommunication Network

After an earthquake occurrence, the telecommunication system will be forced to operate beyond its capacity, as it facilitates communication and information exchange between related agencies and Task Force groups and among families, relatives and friends.

Emergency communication measures for Disaster Task Force groups includes that these groups activate their own wireless communication system with supporting mobile system. DTF groups should not depend on cable telecommunication system in their emergency operations to avoid the risk of communication interruption (disconnection).

Quick rehabilitation and a substitute system for the telecommunication network is required for indispensable emergency measures to revive the sense of security of citizens.

Telecommunication Company Disaster Task Forces should be quickly organised to implement rehabilitation measures before an earthquake occurs. These measures should be based on the formulated rehabilitation plan as follows:

Emergency Measures

- Telephone line control

Just after a disaster, a majority of available telephone lines should be designated as lines solely to be used for emergency calls, emergency operations, and communication between Disaster Task Force groups. This measure serves to prepare for the potential breakdown of telephone lines, owing to the large demand that is beyond its capacity to serve.

- Damage data collection and protection measure and rehabilitation program:

Measures to protect damage expansion are required as soon as possible. The rehabilitation program should include deployment plans, including manpower, materials, equipment and machinery.

- Initial emergency operation

Power supply for telecommunication machinery by own power generator and mobile power generator. Provide bypass circuit by radio communication devices.

- Secondary emergency operation:

Changing of damaged lines; switching of circuit to minimize cut-off area; providing temporary bypass circuits and lines by temporary cable; providing emergency mobile telephone exchange; providing temporary public telephones.

- Broadcasting of guidelines for telephone use:

Regulation, monitoring, and control of frequency and calling time; priority to provide lines for emergency calls; and providing temporary offices.

Rehabilitation Measures

Rehabilitation work should be planned and implemented on a priority basis as follows:

- Rehabilitation priority-1:

Disaster Task Force members (Office of the President, Head Quarters of ministries, municipality, districts, police, traffic police, fire fighters, Red Crescent, transportation/goods circulation, other forces), earthquake and meteorological research institutes/centres, and the Electric Company.

- Rehabilitation priority-2:

Natural Gas Company, Water and Sewage Company, I.R.I TV and Radio and other mass communication companies, banks, and state companies other than those listed in priority-1.

- Rehabilitation priority-3:

Other than those listed in priority-1 and -2

(3) Rehabilitation and Reconstruction Plan of Social and Public Service Facilities

Social and public service facilities could be categorised into three groups, as follows, from the viewpoints of disaster prevention and management:

- Disaster Task Force and centres during the disaster period
- Evacuation facilities and areas for emergency period
- Other public and social service facilities

a. Rehabilitation and Reconstruction Plan for Disaster Task Force Centres

For damaged Disaster Force centres, the formulation of rehabilitation and reconstruction plans are proposed to help these centres to resume their functions as follows.

Government Offices:	HQ of Municipal/District DTF and road maintenance centres for each sub-district
Police Station:	centre for security measures of ordered evacuation areas
Traffic Police Station:	centre for traffic and access control of emergency road
Fire Fighting Station:	centre for fire fighting operations and for support of rescue/relief operations
Public Hospital:	centre for medical and health services

In case of the Ray Fault Model scenario earthquake, approximately 140 facilities (half of the listed facilities) will be totally collapsed. Due to these heavy building damages, the expected functions and tasks of each centre should be supported by provided reinforcement to the centre buildings and/or providing temporary facility construction, if necessary. Coordination of service coverage with surrounding centres should also be outlined.

For damaged centres responsible for capital functions, a substitute system of government administrations, commercial, and economic centres should be implemented, under the consideration of damage conditions, to carry out these functions.

b. Rehabilitation and Reconstruction Plan for Educational Facilities

Of the 2,500 listed schools, 54% of them are estimated to be heavily damaged.

Reinforcement and/or reconstruction of damaged schools, which should be assessed and identified by an expert, are recommended to provide adequate and safe school building structures to future generations.

Rehabilitation of educational functions for each school will be difficult. The high collapse ratio of school buildings are estimated, especially in the southern districts, where schools are already operating on a double shift schooling system because of the shortage of school buildings.

For the above estimated damage condition, a rehabilitation and reconstruction plan of educational facilities and systems should be urgently formulated in coordination with the formulated urban reconstruction plan and urban development master plan of the Tehran Municipality. This plan should include the development of temporary schools and deployment of temporary teachers,

(4) Housing Damage

The rehabilitation and reconstruction plan for damaged housing will be required to cover the following aspects and procedures:

a. Diagnosis of Structural Damage by Experts

As often emphasised, approximately 55% of total residential buildings in the municipality are predicted to suffer almost total collapse. The rest will have some minor damage. A rapid assessment by experts should be conducted to determine the possibility of continued use of buildings and the required rehabilitation measures to strengthen building structures. The result of the diagnosis should form the framework for formulation of the housing reconstruction and rehabilitation plan, including fund allocation and temporary housing and tent village development.

b. Designation and Plan Formulation of Urban Reconstruction Zone

Before an earthquake disaster, it is recommended that urban reconstruction zones be identified and a plan be formulated, which could be developed and implemented to strengthen the seismic resistance of urban structures. The plan could be utilised immediately and revised for the post earthquake urban reconstruction plan formulation.

Designation of urban reconstruction zones is recommended to cover the community zones with weak urban structures and poor housing as follows:

- Lack of public space to develop proper open spaces, educational facilities and other community service facilities
- Weak road networks for emergency operations, owing to narrow streets in residential areas
- Heavily damaged weak residential building areas

- High-density residential areas with small dwelling units. Within the legislated and designated urban reconstruction zone, all rehabilitation and reconstruction efforts should be regulated until finalisation of the urban reconstruction plan.

c. Proper Enforcement of Regulations for Housing Reconstruction and Rehabilitation Financial and Tax Incentives

Proper enforcement of regulations for building codes and seismic resistance standards is required not only for the design approval stage but also for the inspection stage, because weak housing structures in the reconstruction and rehabilitation stage should be avoided. Modification of the present enforcement system, based on the advice of the consultant hired by an applicant, will be recommended.

For high-standard, seismic-resistant housing reconstruction, property tax /or reconstruction loan incentives are recommended.

d. Expansion of Allocated Reconstruction Fund for Housing and Commercial Buildings

The worst-case scenario earthquake predicts approximately 500,000 collapsed residential buildings and 750,000 homeless families. In addition, more than half of the remaining 400,000 residential buildings may have some minor damage, which will require heavy or partial rehabilitation. The reconstruction cost for 750,000 homeless families could be roughly over 100,000 billion Rials, which is about 180 times the present allocated amount of 550 billion Rials.

It is proposed to utilise the present allocated reconstruction fund as soon as possible, before an earthquake disaster, to reconstruct weak housing structures.

e. Support and Arrangement to Supply and Distribute Construction Material

There will be huge demand for the reconstruction (750,000 dwelling units) and rehabilitation (more than 300,000 dwelling units) of structures. The present manufacturing industries, importation system and supply and distribution system for construction materials should be drastically improved and expanded to cover the expected huge demand for reconstruction and rehabilitation.

f. Promotion and Enhancement of Construction

For the large-scale reconstruction and rehabilitation demands, supporting measures are required not only for construction materials, but also for promotion and enhancement of construction industries. There is also a need to upgrade construction techniques and skills.

(5) Socio-Economic Revitalisation and Stabilisation Plans

This plan should focus on supporting self-revitalization of socio-economic activities for disaster victims by granting grace periods, reductions, or exemptions from tax payments; financing for rehabilitation of housing and commercial building reconstruction; and rehabilitation of goods transportation and circulation, as indicated hereafter.

a. Tax Incentive for Evacuees

Tax incentives such as grace periods, reductions, and exemption from national and municipal tax payments should be legislated and enacted, based on the assessed level of damage sustained by evacuees.

b. Financial Incentive for Reconstruction and Rehabilitation Activities

It will be required to expand the present Reconstruction Fund, which amounts to 550 billion Rials (US$ 67 million) of bank loans without interest, and, based on the estimated demands, to use in the reconstruction and rehabilitation of collapsed and damaged private housing and commercial buildings.

Financial incentive measures to reconstruct private industries are also proposed in order to revitalise the industrial and economic activities of the nation and city.

c. Rehabilitation of Consumer Goods Supply and Circulation

Measures to reactivate consumer goods supply and circulation should look to stabilize supply by normalising price and volume to meet market demands, thus avoiding panic. These measures include the following:

- Supply required consumer goods by municipality: check and inventory required consumer goods, coordinate additionally required consumer goods with ministries and wholesalers and manufacturers.
- Monitor and control consumer prices: survey and monitor consumer prices, urging maintenance of the appropriate consumer price, enforce counter measures for retailers and wholesalers who take advantage of the emergency.
- Announce consumer goods information: available items and volume of consumer goods, appropriate price and location of retail shops to protect consumers and to prevent panic buying.

7.6. Recommendation to Formulate Action Plans and Programs

Action plans and programs covering a period of five years should be selected and formulated from a long list of plans and programs, which, in turn, should be drawn up based on the proposed Comprehensive Urban Disaster Prevention and Management Plan (CUDPMP) for the Tehran Municipality, by the following process:

1) Preliminary Estimation of Restoration Cost for Earthquake Damages

Preliminary cost of rehabilitation and reconstruction efforts and damage amount by item, based on damage analysis of the reviewed microzoning should be estimated in the process of formulating the CUDPMP.

2) Preliminary Cost Estimation for the Identified Plans and Programs

Preliminary costs to implement the identified plans and programs in the long list of the CUDPMP should be estimated by short, mid and long term measures.

Cost-benefit ratios of the plans and programs should be assessed with the estimated damage amount and rehabilitation and reconstruction cost.

3) Comparative Evaluation of the Identified Plans and Programs

The identified plans and programs should be comparatively evaluated from the point of views of urgency, range of positive impact to reduce damage, and importance to national policy.

4) Identification of Available Financial Resources for Preventive Measures

Available financial resources for the 5-year development plan should be identified to implement preventive measures in the short term.

5) Priority Assignment to the Listed Plans and Programs

A preliminary, short-term implementation schedule of the identified plans and programs should be coordinated and adjusted, based on the results of evaluation and the limitation of financial resources.

6) Formulation of Action Plans and Programs

The selected plans and programs should be included in an overall action plans and programs formulated with detailed plans and 5-year short-term implementation schedules.

The formulated action plans and programs should also be assessed based on economic analysis and preliminary environmental impacts.

Chapter 8 :

Recommendation on Structural Design

Chapter 8. Recommendation on Structural Design

This chapter describes the recommendation for legal measures to improve structural design and improvement measures for weak structures in the city of Tehran. Moreover, some ideas of countermeasures, which should be based on structural aspects in the earthquake disaster prevention plan, are presented. These are divided into "urgent measures" and "long-term measures".

Once danger is recognised, countermeasures should be taken as soon as possible, i.e. within five years. Countermeasures will become ineffective after this period. In this report, the measures, which should be concretely implemented within five years, are defined as " urgent measures," and those which need a longer time frame are defined as " long-term measures."

8.1. Improvement Measures for Building Codes and Structure (Long Term Measures)

8.1.1. Introduction

Urban infrastructures are changing day by day. A goal of disaster prevention is closely dependent on current economic activities. Once the urban structure is upgraded or newly identified knowledge is accumulated, the goal should be modified. Economically or technically incapable matters will be easily introduced in the future.

Important items that need to be upgraded include the following:

- Establishment of database for building, superstructure and infrastructure
- Goal of disaster prevention
- Earthquake-resistant design code; and
- Calibration of seismic assessment technique and system

Proposed measures for building design standards and seismic resistant codes should also be revised periodically based on the following conditions:

1) Urban expansion and structural change
2) Socio-economic growth (upgrading of investment capability)
3) Upgrading of construction methods and skills,
4) New seismic resistant technology, and
5) Revised earthquake scenario.

For the review of the earthquake scenario, the experience of seismic damage in a nearby area can produce new findings, and the outlook on earthquakes must be changed accordingly.

Let us look back to the earthquake occurrences in Japan and the history of measures that had been enacted. A list of the major earthquakes in Japan and the resulting events are shown in Table 8.1.3, at the end of this chapter. Design code for earthquake-resistant structures were demanded after the large 1923 Kanto Earthquake of magnitude 7.9 for the first time. The code was revised after the 1994 Sanriku Haruka-oki Earthquake of magnitude 7.5. The design criteria had to be further revised a great deal after the the Kobe Earthquake with magnitude 7.2 in 1995.

8.1.2. Recommendation for Earthquake-Resistant Design Code

In this section, suggested code specifications are described on the following viewpoints, 1)the present specifications of Iran are analysed in comparison to the specifications of Japan, 2) the relation between the scenario earthquake and the present specifications in Iran is described, and the problem is clarified, 3) problems on structural vibration characteristic are discussed.

(1) Strict Compliance and Enforcement of Code

Roughly speaking, if the present earthquake-resistant code of Iran were strictly followed, the most of structures in the Study area could withstand the earthquake excitation of the scenario earthquake. However, that is not the case for most buildings. A large majority of buildings are not compliant with the present earthquake-resistant code. Most of these buildings, shops and dwellings were developed before 1960, in the central and southern districts. In fact, very little consideration was paid to structural engineering aspects during the construction.

Therefore, it is very important that buildings are built according to the earthquake-resistant code and that the Tehran Municipal Government strictly enforces the code. The following are further proposed:

- Continuous education of engineers; and
- Strict and proper enforcement of the codes on design approval and in building inspection after construction.

(2) Comparison of Structural Seismic Design in Iran and Japan

In Japan, after the Kobe Earthquake in 1995, idea of two types of earthquake motions were introduced in assessing the aseismic capacity of civil engineering structures. The contents are summarised in Table 8.1.1.

Table 8.1.1 Two Types of Design Earthquake Motion in Japan

	Level I earthquake motion	Level II earthquake motion
Definition	Likely to strike a structure once or twice while it is in service. Inter-plate earthquakes in the ocean area are included in this type.	Very unlikely to strike a structure during the structure's life time, but when it does, it is extremely strong. Earthquakes generated by inland faults are included in this type.
Demanded Performance	The level in which structures are not damaged when these motions strike. It is demanded that every structural member be in the range of elasticity.	The level in which an ultimate capacity of earthquake resistance of a structure is assessed in plastic deformation range. It is demanded that every structural member be in the range of allowable ductility factor and that the entire structural system should not collapse, even with the plasticity of part of the structural member.

The design earthquake motion according to the present code of Iran is explained below:

> *Iranian Code for Seismic Resistant Design of Buildings, Iranian Building Code Series, BHRC Publication No.82 1st. ed. Feb. 1988 2nd ed. Oct. 1990.*

In the code, the " seismic design coefficient" is provided. This corresponds to an earthquake motion, which is called level I in the earthquake-resistant code of Japan.

a. Design Earthquake Level I

The design seismic coefficient of the average bridge of Tehran is calculated on a trial basis. Seismic coefficient C for Equivalent Static Analysis Method is calculated by Equation 1.

Equation 1: $C = \frac{A \bullet B \bullet I}{R}$

where:

A: Design base acceleration

B: Response coefficient of the building obtained from the design response spectrum

I: Importance factor of the building

R: Behaviour coefficient of the building

<u>Value *A*</u>

The value of A is decided as equal to 0.35, assuming that the average bridge of Tehran has the " high seismic relative hazard."

<u>Value *B*</u>

The value of B is calculated by Equation 2.

Equation 2: $B = 2.0\left(\frac{T_0}{T}\right)^{2/3}$

where:

T: Fundamental natural period

T_0: Figure according to the type of soil

The value of B is decided as equal to 2.0, assuming that T = 0.5 sec and that T_0 = 0.5 of " Soil type III" . The value of B reaches the highest value in the provisions. In the code, soil types are defined as follows:

<u>Soil Types</u>

I: a) Igneous rocks, hard and stiff sedimentary rocks and massive metamorphic rock
b) Conglomerate beds, compact sand and gravel and stiff clay bets up to 60 meters from the bedrock

II: a) Loose igneous rocks, friable sedimentary rocks, foliated metamorphic rocks and the rocks which have been loosened by weathering
b) Conglomerate beds, compact sand and gravel and stiff clay beds where the soil thickness exceeds 60 meters from the bedrock

III: a) Rocks which have been disintegrated by weathering
b) Beds of gravel and sand with weak cementation and/or uncemented, unindurated clay where the soil thickness is less than 10 meters from the bed

IV a) Soft and wet deposits resulted from high level of water table
b) Gravel and sand beds with weak cementation and/or uncemented, unindurated clay where the soil thickness exceeds 10 meters from the bedrock.

<u>Value *I*</u>

The value of I is decided as equal to 1.2, for " Group 1" buildings. In the code, classification of buildings is defined as follows:

<u>Building Classification</u>

Group 1: Buildings of great importance
Group 2: Buildings of average importance
Group 3: Buildings of lesser importance

<u>Value *R*</u>

The value of *R* is decided as equal to 6.0. As for *R*, a value of 4-8 is taken according to the " structural system" and " lateral force resisting system." The value of 6.0 corresponds to " steel moment resisting space frame" for the table " moment resisting space frame system."

<u>Value *C*</u>

Therefore, the seismic design coefficient is:

$$C = \frac{0.35 \times 2.0 \times 1.2}{6} = 0.14$$

The seismic code of a foreign country was applied before the Iranian Code for Seismic Resistant Design of Buildings was published. Also in that case, the seismic design coefficient value, which slightly exceeds 0.1, is used except for the Vali-asr-Chamran Bridge. (See Table 8.1.4 shown at the end of this chapter)

The method of earthquake-resistant bridge design for Tehran is provided in the above stated code (*Code of Practice for Seismic Resistant Designs and Computation of Bridges, Tehran Municipality, Technical and Development Division, July 1995*).

The following behaviour coefficients by pier types in this code are shown in Table 8.1.2.

Table 8.1.2 Behaviour Coefficients of Bridge by Pier Type

Pier Type	Behaviour Coefficient (R)
Wall-type reinforced concrete piers	3.0
Single column piers or piers that behave like single column piers	4.0
Multi-column or frame-type piers	6.0

The value of *R* = 4.0 is used for " single column piers or piers that behave like single column piers."

Therefore, the " seismic coefficient for equivalent static analysis method" *C* will be 0.21.

$$C = \frac{0.35 \times 2.0 \times 1.2}{4.0} = 0.21$$

<u>**Consideration**</u>

In Japan, after Kanto Earthquake in 1923, road bridge specification was introduced as the first edition. The seismic coefficient was defined as 0.2. The above calculated C = 0.21 corresponds to the coefficient. Based on various earthquake experiences, the coefficient is modified. In the current regulations, about 0.3 is applied as the value of " seismic coefficient for equivalent static analysis method," in general. Therefore, the value 0.2 is small.

The ground of Tehran is hard compared to the ground of Japan and the earthquake motion of Tehran can be characterised by a rather high frequency domain compared to the usual earthquake motion of Japan. Therefore it can be concluded that there is not too much difference between the earthquake-resistant levels of both nations when " seismic coefficient for equivalent static analysis method" is compared with the value of " soil type I" in Japan.

Moreover, the main reason why the value of the seismic design coefficient is small can be attributed to the behaviour coefficient of the building, *R*, which is located in the denominator of the Equation 1. It is said that the " United Building Code (UBC, code of the USA)" is referred to in this equation.

The Iranian Code for Seismic Resistant Design of Buildings comments as follows:

" The behaviour coefficient of the building represents the building' s capability to absorb energy, and reflects numerous factors including materials, damping, type of structure and ductility capacity of the building" .

It is recognized that this coefficient represents energy absorption and hysteresis damping after plasticity of the material. In short, the concept of elastic-plasticity design may be introduced into the code without enough deliberation.

If ductility is expected, approximately 8.0 is needed as an allowable ductility factor, μ, when a designer tries to achieve the effect of an $R = 4$ value as the behaviour coefficient of the building. However, the structures that have an allowable ductility factor, μ, of 8.0 may be very few in the city of Tehran.

b. Design Earthquake Level II

Elastic-plasticity design concept came to be recognised strongly in Japan after the Kobe Earthquake. It is also emphasised with Vision-2000, which SEAOC published.

The earthquake motion set of the scenario earthquake applied in the Study is small compared to the earthquake motion provided as a level II earthquake, but the evaluated building damage in Tehran is still serious. This result suggests that the attention to the level I earthquake should be given priority before considering the elastic-plasticity design.

There is possibility of a larger earthquake than that predicted in the Study. In fact, a very large earthquake motions have been observed in Iran (Tabas etc.) in the past. Another design system can be prepared for important facilities, in order to protect the functions of Tehran as a capital city. However, easy application should be avoided, for example, revision of behaviour coefficient of the building *R*.

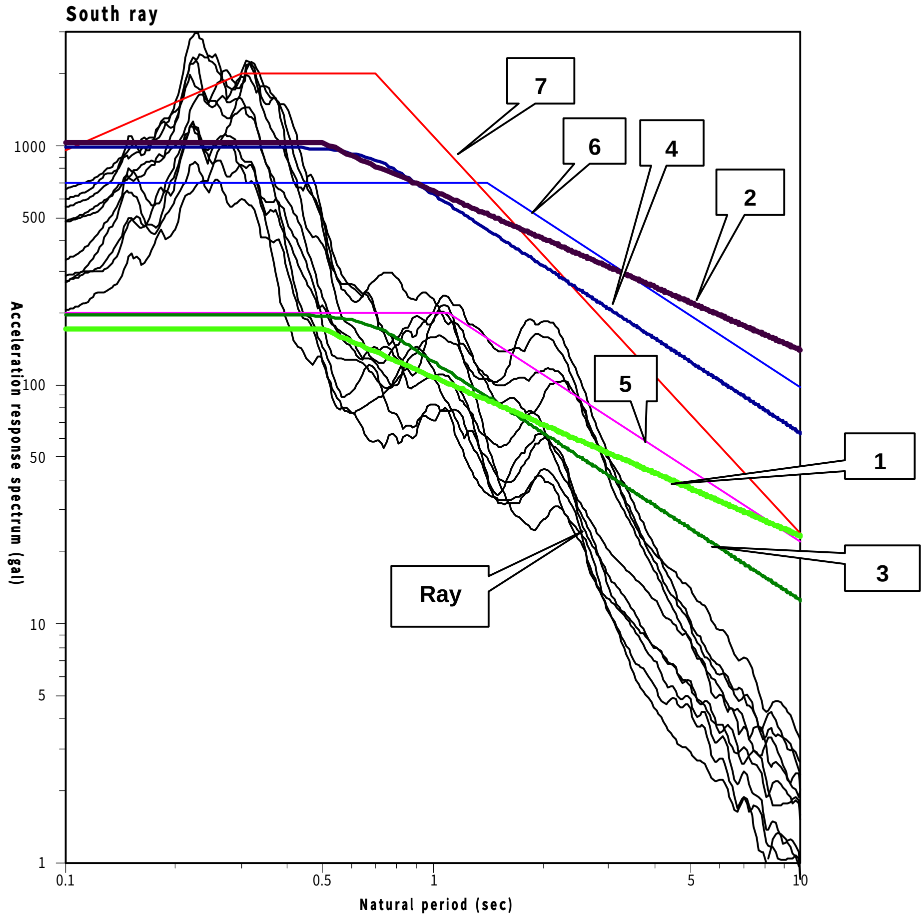
In addition, brittle fracture of RC columns caused by lack of shear reinforcement is important problem. The problem must be solved before the application of elastic-plasticity design concepts. Technological innovation to structural details should be achieved.

(3) Consideration Concerning Scenario Earthquake and Design Earthquake

In this section, response spectra were analysed and influence to structures by the earthquake motion was evaluated.

a. Spectral Characteristics of Current Design Code

The concept of " a scenario earthquake" is introduced in the Study. That is, the fault due to which Tehran may be most affected is selected, and the earthquake motion that is caused by this fault is analysed. The fault that may produce the biggest influence to Tehran is the Ray Fault. The response spectra of the earthquake for the Ray Fault model are shown in Figure 8.1.1. Here, dumping factor h is assumed as 5%. The current design spectra for earthquake resistant design standard in Iran and Japan is also shown to comparison.



Analysed spectrum

'Ray' Response spectrum due to the scenario earthquake 'South Ray' (h=5%)

Design spectrum

1: Iranian Code for Seismic Resistant Design of Buildings (Iran), R=6

2: Iranian Code for Seismic Resistant Design of Buildings (Iran), R=1

3: Building Standard Law (Japan), for allowable unit stress calculation

4: Building Standard Law (Japan), for calculation of retained horizontal strength

5: Design Specifications for Highway Bridges, Part V, Seismic Design (Japan) for (L1)

6: Design Specifications for Highway Bridges, Part V, Seismic Design (Japan) for (L2) Type I

7: Design Specifications for Highway Bridges, Part V, Seismic Design (Japan) for (L2) TypeII

Figure 8.1.1 Response spectrum of Ray Fault Scenario Earthquake and the Design Spectra Provided by Various Earthquake Resistant Design Codes

Note: In case of Ray Fault scenario earthquake, dumping factor h is assumed as 5%.

1) Design spectrum provided by 'Iranian Code for Seismic Resistant Design of Buildings (Iran)' for R = 6

The seismic design code of Iran revised in 1999, 'Iranian Code for Seismic Resistant Design of Buildings', provides for the design spectrum through Equation 1.1. The case for R = 6.0, is shown, which is for condition of elastic range deformation of general structures.

$$C = \frac{A \bullet B \bullet I}{R} \qquad \text{(Eqn. 1.1)}$$

where

A = design base acceleration

B = response coefficient of the building obtained from the design response spectrum

I = importance factor of the building

R = behaviour coefficient of the building

A is assumed to be 0.3 considering the region has "high relative seismic hazard."

B is given by Equation 1.2. ($B \leq 2.5$)

$$B = 2.5\left(\frac{T_0}{T}\right)^{2/3} \qquad \text{(Eqn. 1.2)}$$

where,

T = fundamental natural period

T_0 = figure according to the soil type

T_0 will be assigned the value 0.5, since most of the Study area corresponds to soil "Type II". Definition of the soil type is explained in section 8.1.2 (2).

I will be assigned the value 1.2. This value corresponds to building classification "Group 1". Definition of the building classification is explained in section 8.1.2 (2).

2) Design spectrum provided by 'Iranian Code for Seismic Resistant Design of Buildings (Iran)' for R = 1

The seismic design code of Iran revised in 1999, 'Iranian Code for Seismic Resistant Design of Buildings', provides for the design spectrum through Equation 1.1. The case for R = 1.0, is shown, which is for condition of elastic-plastic range deformation of general structures.

3) Design spectrum provided by 'Building Standard Law (Japan)' for allowable unit stress calculation

Seismic design code of Japan 'Building Standard Law' provides for the design spectrum through Equation (1.3). The case for C_0 = 0.2 is shown, which is for condition of elastic deformation of general structures.

$$C_i = ZR_t A_i C_0 \qquad \text{(Eqn. 1.3)}$$

where,

C = the seismic shear coefficient

Z = the seismic zone factor (Z = 1.0 for metropolitan areas)

R_i = vibration characteristic factor

A_i = vertical distribution factor (A_i = 1.0 for the first floor)

C_0 = the standard shear coefficient

R_i is obtained by the equation (1.4)〜(1.6)

T<Tc

$$R_i = 1 \qquad \text{(Eqn.1.4)}$$

Tc ≤ T<2Tc

$$R_t = 1 - 0.2\left(\frac{T}{T_c} - 1\right)^2 \qquad \text{(Eqn. 1.5)}$$

2Tc ≤ T

$$R_t = 1.6\left(\frac{T_c}{T}\right) \qquad \text{(Eqn. 1.6)}$$

T_c = value according to the soil type

T_c = 0.4 Type I

T_c = 0.6 Type II

T_c = 0.8 Type III

T_c will be assigned the value 0.4 since most of the investigation area corresponds to Type I.

4) Design spectrum provided by Building Standard Law (Japan) for calculation of retained horizontal strength

The seismic design code of Japan, the “ Building Standard Law,” provides for the design spectrum through equation (1.3). The case for C_0 = 1.0 is shown, which is for condition of elastic deformation of general structures.

5) Design spectrum provided by ‘ Design Specifications for Highway Bridges, Part V, Seismic Design (Japan) (seismic design based on seismic coefficient method (L1))’

The seismic design code of Japan, ‘ Specifications for Highway Bridges, Part V, Seismic Design’ , provides for the design spectrum S through equation (1.7), is shown, which is for condition of elastic deformation (seismic coefficient method (L1)).

$$S = c_Z c_D S_0 \qquad \text{(Eqn. 1.7)}$$

where,

c_Z = modification factor for zone; for regional division A, c_Z =1.0

c_D = modification factor by damping constant, it shall be calculated by Equation 1.8 in accordance with the mode damping constant h_i

$$c_D = \frac{1.5}{40h_i + 1} + 0.5 \qquad \text{(Eqn. 1.8)}$$

S_0 = standard acceleration response spectrum (gal) used to verify the result of seismic design based on the seismic coefficient method; it shall be a value in accordance with the ground classification and the natural period T_i of vibration mode.

Soil type I

$T_i < 0.1$	$S = 431\ T_i^{1/3}$	$S \geq 160$
$0.1 \leq T_i \leq 1.1$	$S_0 = 200$	
$1.1 < T_i$	$S = 220 / T_i$	

This spectrum implicitly assumes an earthquake of return period of 75 years. It is assumed that average term in service is 50 years and possibility of occurrence of a earthquake during the term is 50 %, i.e. 25 years of fluctuation.

6) Design spectrum provided by ‘ Specifications for Highway Bridges, Part V, Seismic Design (ductility design method (L2), type I)’

The seismic design code of Japan, ‘ Specifications for Highway Bridges, Part V, Seismic Design’ , provides for the design spectrum, S_{I} , through equation (1.9) is shown, which is for condition of elastic-plastic range ((ductility design method (L2), type I)).

$$S_{\mathrm{I}} = c_Z c_D S_{\mathrm{I0}} \qquad \text{(Eqn. 1.9)}$$

where,

C_Z = modification factor for zone; for regional division A, C_Z =1.0

C_D = modification factor by damping constant; it shall be calculated by Equation 1.8 in accordance with the mode damping constant h_i

S_{I0} : standard acceleration response spectrum (gal) of Type I; it shall be a value in accordance with the ground classification and the natural period, T_i, of vibration mode.

Soil type I

$T_i \leq 1.4$	$S_{\mathrm{I0}} = 700$
$1.4 < T_i$	$S_{\mathrm{I0}} = 980/T_i$

This spectrum implicitly assumes an earthquake of about 400 years of return period.

The background of this spectrum is explained in ‘ Specifications for Highway Bridges, Part V, Seismic Design’ as follows:

> The Type I design lateral force coefficient, the design lateral force coefficient stipulated in the earlier Seismic Design Specifications (February 1990), reflects a seismic force that hypothesises a large-scale marine earthquake occurring on the boundary between plates: a category of earthquake that occurs rarely. The earthquake motion generated in the Tokyo area by the Great Kanto Earthquake of 1923 is cited as an example of this type of earthquake motion, and it has been incorporated into seismic design based on the ductility design method. Because strong motion observations were not performed at the time of the Great Kanto Earthquake, it is impossible to perform earthquake motion evaluations based on scientific evidence such as strong motion records, but the acceleration at the surface of the ground is estimated at between 0.3 and 0.4 g, using the distance decay equation, etc. Although it varies in different ground types according to the natural period or damping characteristics of each bridge, the acceleration generated in a bridge when a certain vibration occurs in the ground is generally about two to three times the acceleration in the ground. Therefore, if it is assumed that a bridge exhibits elastic behaviour under earthquake motion between 0.3 and 0.4 g, the acceleration generated in the bridge will be between 0.7 and 1 g. Thus, the Type I design lateral force coefficient has been established based on the ductility design method.

7) Design spectrum provided by ‘ Specifications for Highway Bridges, Part V, Seismic Design (ductility design method (L2), type II)’

The seismic design code of Japan ‘ Specifications for Highway Bridges, Part V, Seismic Design” provides for the design spectrum, $S_{II,}$, through equation (1.10) is shown, which is condition for elastic-plastic range (ductility design method (L2), type II).

$$S_{II0} = c_Z c_D S_{II0} \qquad \text{(Eqn. 1.10)}$$

where,

c_Z = modification factor for zone; for regional division A, $c_Z = 1.0$

c_D = modification factor by damping constant; it shall be calculated by Equation 1.8 in accordance with the mode damping constant h_i

S_{II0} = Standard acceleration response spectrum (gal) of Type II, it shall be a value in accordance with the ground classification and the natural period T_i of vibration mode.

Soil type I

$T_i < 0.3$	$S_{II0} = 4463\ T_i^{2/3}$
$0.3 \le T_i \le 0.7$	$S_{II0} = 2000$
$0.7 < T_i$	$S_{II0} = 1104\ T_i^{5/3}$

This spectrum was provided based on the seismogram recorded during the Kobe Earthquake of 1995. Analyses conclude that the estimated return period of this earthquake will exceed 1000 years.

The background of this spectrum is explained in “ Specifications for Highway Bridges, Part V, Seismic Design” as follows:

> The Type II design lateral force coefficient, which is based on acceleration strong motion records actually obtained at ground surface during the Kobe Earthquake of 1995, was established by categorising its acceleration response spectra for each ground category. In brief, during the Kobe Earthquake, the acceleration was high at the Kobe Maritime Meteorological Observatory (Ground type I), at the JR West Japan Takatori Station (Ground type II), and in the ground around the Higashi Kobe Bridge (Ground type III), and earthquake motion acceleration that destroyed structures was observed. This regulation presents the values of the design lateral force coefficients obtained by first calculating the acceleration response spectra of the earthquake motions that were observed, smoothing particularly conspicuous peaks in the spectra, then correcting the spectra found in this way based on damping constants for each of the natural periods described above.

b. Comparison of Each Spectrum

The following characteristics on spectrum are observed in Figure 8.1.1:

The design spectrum is classified into three categories:

1) Design spectrum, which should be adopted in elastic range deformation

- Design spectrum for R=6, provided by seismic standard (Iran), Curve 1).
- Design spectrum for C_0 = 0.2, provided by building standard law (Japan), Curve 3).
- Design spectrum of seismic design based on seismic coefficient method (L1), provided by bridge standard (Japan), curve 5).

2) Design spectrum, which should be adopted in elastic-plastic range deformation
   - Design spectrum for R=1, provided by seismic standard (Iran), Curve 2).
   - Design spectrum for C_0 = 1.0, provided by building standard law (Japan), Curve 4).
   - Design spectrum of ductility design method (L2), type I, provided by bridge standard (Japan), Curve 6).
3) Spectrum of the maximum earthquake motion that is estimated on findings presently obtained.
   - Design spectrum of ductility design method (L2), type II, provided by bridge standard (Japan), Curve 7).

The response spectrum for the Ray Fault scenario earthquake hardly exceeds the spectrum for the " Specifications for Highway Bridges" (ductility design method (L2), type II) at any period, and the shape of both response spectra resemble each other. The tendency is feasible because the assumed scenario earthquake fault is very close in proximity to the city of Tehran. In addition, the magnitude of the earthquake fault of both is almost equal.

c. Consideration

Here, the response spectrum due to the Ray Fault scenario earthquake and the design spectrum of the Iranian seismic criterion are examined. If the buildings are constructed based upon the design code, the damage properties are estimated on the consideration.

For the range T< 3 sec

The response spectrum due to the scenario earthquake exceeds the design spectrum (R = 6.0, curve 1) for the case of natural period is shorter than 3.0 seconds. Therefore, it is considered that the members of most buildings designed by the equivalent static analysis method exceed elasticity for the Ray Fault scenario earthquake.

For the range T > 0.5 sec

The response spectrum due to the scenario earthquake does not exceed the design spectrum (R = 6.0, curve 1) too much for the range where the natural period T is greater than 0.5 seconds. Therefore, if the structure is kept within the range of structural ductility, it does not become an overall collapse.

Here, it is examined whether to keep the members within the range of structural ductility for the scenario earthquake if the buildings are designed in an elastic manner, based on the equivalent static analysis method.

The response of the elastic-plastic system can be simply examined by using Newmark' s assumption, " the energy which the elastic system absorbs is equal to the energy which the elastic-plastic system absorbs" .

When the input earthquake motion causes the maximum response acceleration I_s, a yield seismic intensity, which is required for the elastic-plastic system with allowable ductility ratio, $_a$, is obtained by Equation 1.11.

$$I_R = \frac{I_S}{\sqrt{2\ _a - 1}} \qquad \text{(Eqn. 1.11)}$$

where,

I_R = Yield seismic intensity, which is required for elastic-plastic system

I_S = Maximum response acceleration by elasticity assumption

$_a$ = Allowable ductility ratio

I_R = 2.24 is obtained when $_a$ =3.0 is assigned to the Equation 1.11.

If allowable ductility ratio is maintained as 3.0, 2.24 times the yield seismic intensity is allowable for the response acceleration to behave in accordance to the elasticity assumption.

To the right of 0.5 sec along the horizontal axis in Figure 8.1.1, the response spectrum due to the scenario earthquake does not exceed 2.24 times the design spectrum of the Iranian seismic criterion (R = 6), excluding only a few ranges. Therefore, it is concluded that if allowable ductility ratio, $_a$, is maintained as 3.0, the structure whose natural period is longer than 0.5 seconds will not collapse, even though members may yield partially.

For the range T < 0.5sec

To the left of 0.5 sec along the horizontal axis in Figure 8.1.1, the response spectrum of the scenario earthquake reaches from 5 to 10 times the design spectrum of the Iranian seismic criterion (R = 6). This indicates that a structure designed according to the equivalent static analysis method will be collapsed.

Furthermore, the response spectrum of the scenario earthquake exceeds the design spectrum of the Iranian seismic criterion (R =1.0) in this range. This indicates that when structures designed by the equivalent static analysis method are examined by dynamic analysis using the elastic-plastic model and the design spectrum of the Iranian seismic criterion (R =1.0), these structures require reinforcement.

These considerations are a common feature for shallow, inland type earthquake. Same phenomenon was observed in the Kobe Earthquake of 1995. In general, low-rise dwellings and many shops in both Kobe and Tehran have a natural period of 0.5 sec or less. Therefore, the huge quantity of damage to low-rise dwellings, which were estimated in the Study, agrees to the consideration on natural properties.

The scenario earthquake disaster assessment reflects the severest condition, which can be assumed, based on the present day findings. On the other hand, the conditions of earthquake-resistant design should be approved based on economic limitations and agreed upon level of craftsmanship and quality. Careful consideration of the design spectrum is required in consideration of these issues.

It is emphasised that the existing seismic design code of Iran is not necessarily enough for low-rise dwellings and many commercial buildings, which have the natural period of 0.5 seconds or less.

Moreover, ductility issue is much more serious than that of the design spectrum. In this chapter, it was assumed that an allowable ductility ratio is maintained at 3.0 or more. However, column-beam joints of general low-rise dwellings and many shops in Tehran do not have a high enough ductility ratio. Most buildings have neither effective shear walls nor braces.

(4) Vibration Characteristics of Structures in Tehran

The ambient vibrations of typical buildings of the city of Tehran were measured in the Study. The vibration characteristics of the structures of Tehran were evaluated as a result. Especially, results for construction with the natural period of 0.5 sec or less are important in consideration of the design code.

The results of ambient vibration measurement for the buildings are shown in Figure 8.1.2 to Figure 8.1.4.

The Fourier analysis is applied to the ambient vibration result, and the relation between the lowest period and the height of the building within the predominant period is shown by O and .

The mark O is a period obtained from the measurement value for the longitudinal direction. The mark is a period obtained from the measurement value for the transverse direction. Each of these corresponds to the first natural period, which originates in the natural mode in each direction.

The solid curve shows the first natural period calculated by equations that is provided in the seismic design code of Iran.

For Steel Frame Buildings

$$T = 0.08H^{\frac{3}{4}} \qquad \text{(eqn. 1.12)}$$

For Reinforced Concrete Buildings

$$T = 0.07H^{\frac{3}{4}} \qquad \text{(eqn. 1.13)}$$

For cases except above

$$T = 0.09\frac{H}{\sqrt{D}} \qquad \text{(eqn. 1.14)}$$

where

T: Predominant periods (sec)

H: Building height (m)

D: Building width to be measured (m)

Permanent Committee for Revising the IRANIAN Code of Practice for Seismic Resistant Design of Buildings (STANDARD 2800): IRANIAN Code of Practice for Seismic Resistant Design of Buildings, BHRC Publication NO.253 1997

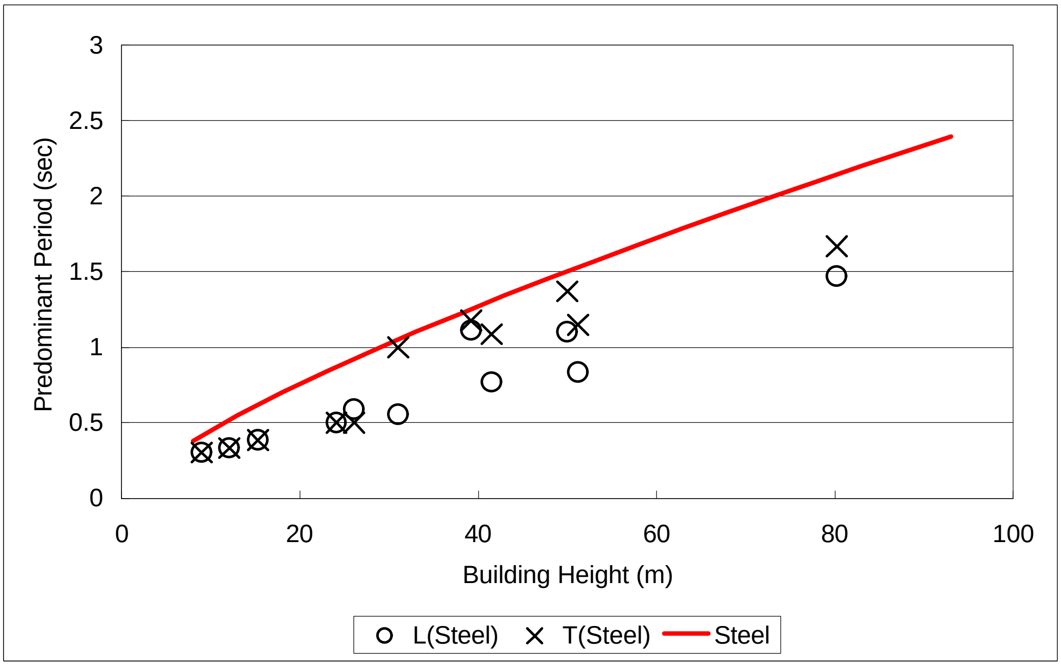


Figure 8.1.2 Relation between the lowest period and the height of the building (Steel)

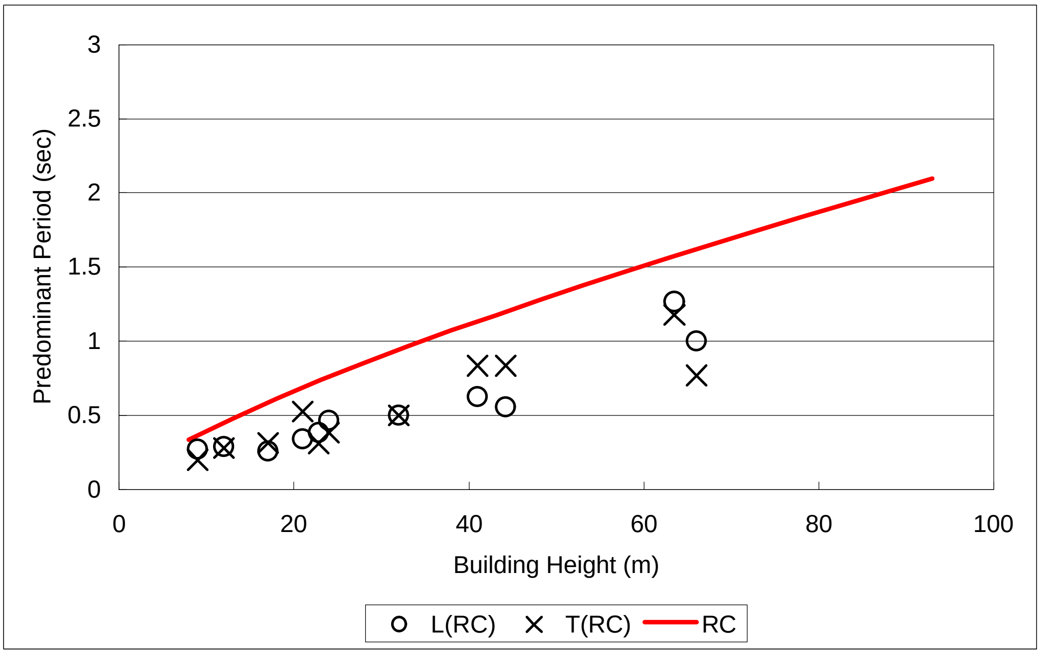


Figure 8.1.3 Relation Between the Lowest Period and the Height of the Building (RC)

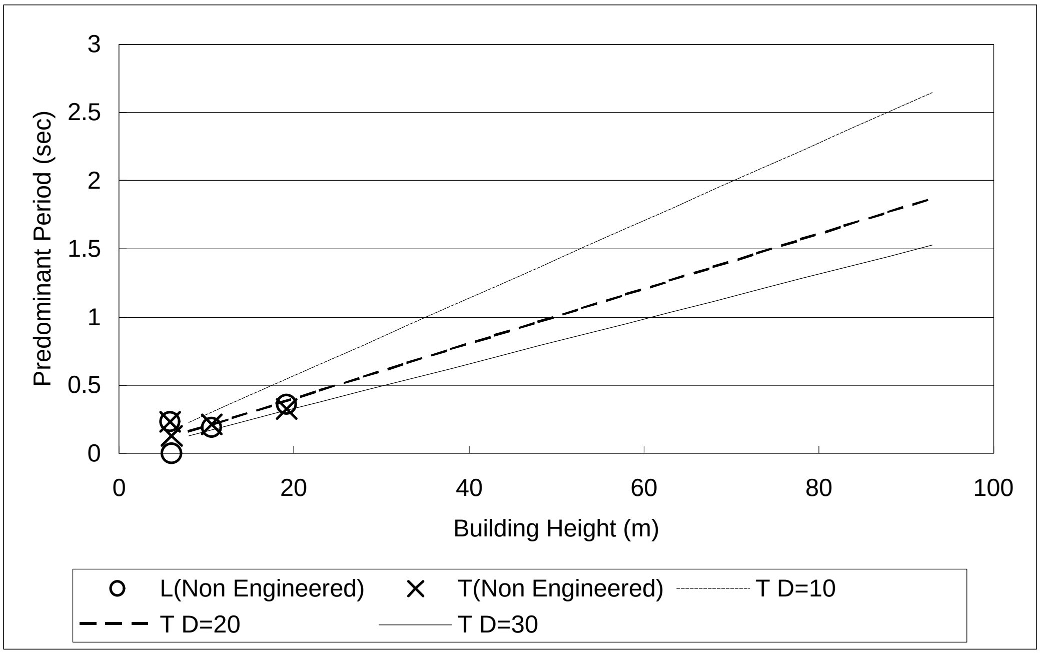


Figure 8.1.4 Relation between the Lowest Period and the Height of the Building (Non-Engineered)

Note: TD is width of buildings to be measured.

a. Steel Framed Buildings

Figure 8.1.2 shows measurement values of steel frame buildings. The characteristics are as follows:

1) The period in the transverse direction is longer than the period in the longitudinal direction, excluding five examples. The exception applies for buildings of less than 27 m in height.
2) Sections of columns and beams are not strong enough. Moreover, arrangement of brace is different for building direction.
3) It is considered that the rigidity against a horizontal force differs very much depending on existence of structural brace. In general, to allow for a window opening, etc., bracing is omitted. The same is true for the building's front panel. Otherwise, bracing is limited to the corners of the structure and the K shape brace is installed. Therefore, the rigidity in the longitudinal direction is lower compared to the rigidity in the transverse direction, and the natural period in the longitudinal direction becomes longer as a result.
4) The measured natural period is shorter than the first natural period calculated by the seismic design code of Iran (equation 1.12).

b. RC Framed Buildings

Figure 8.1.3 shows the measurement values of RC framed buildings. The characteristics are as follows:

1) There is a difference in the period values in the longitudinal direction and the transverse direction. In addition, longer-period direction is not clear.
2) Section of column and beam is not strong enough. In addition, infill brick walls and RC walls are enclosed by the columns and the beams.

3) It is considered that neither the column nor the beam influences the rigidity against a horizontal force very much. Moreover, the walls influence the rigidity against a horizontal force. Furthermore, arrangement of the walls is different for individual buildings.

4) The measured natural period is shorter than the first natural period calculated by the seismic design code of Iran (equation 1.13).

c. Non-Engineered Buildings

Figure 8.1.4 shows measurement values of Non-Engineered buildings. The characteristics are as follows:

1) There does not exist non-engineered buildings exceeding 20 m in height.

2) There is no difference in the period values in the longitudinal and transverse direction.

3) It is considered that there is no stiffener, such as shear walls, in either direction.

4) The measured natural periods almost exactly correspond to the first natural period calculated by seismic design code of Iran (equation 1.14).

d. Consideration

The natural period is shorter than 0.5 seconds for steel framed buildings that are lower than 25 m in height, for RC framed buildings that are lower than 30 m in height, and for all non-engineered buildings. In section 8.1.2 (3) Consideration Concerning Scenario Earthquake and Design Earthquake, the response spectrum is calculated based on the scenario earthquake and this is compared with the design spectra. The conclusions reached are as follows: " It is emphasised that the existing seismic design code of Iran is not necessarily enough for low-rise dwellings and many commercial buildings, which have the natural period of 0.5 seconds or less." With respect to ambient vibration measurement results, steel framed buildings that are lower than 25 m in height, RC framed buildings that are lower than 30 m in height, and all case of non-engineered buildings are applied to the definition.

Moreover, it has understood that the first natural period of the seismic design code of Iran has a tendency to be calculated as longer than the actual natural period. It is considered that this tendency may affect the design of structures in a dangerous manner. The following is considered a cause for why the Iranian code value is different from the actual value:

- It is considered that the code is based on results of actual measurements and on results of structural calculations. The calculation is based on the section parameter of a structural material on the blueprint. However, it is impossible to reflect the failure or quality of construction. This leads to the difference.

- It is considered that some references in foreign countries, which are not suitable to the building condition in Iran, are introduced in examination.

Furthermore, there is some idea that natural period obtained from the ambient vibration measurement is a value at small strain level and an equivalent natural period of actual earthquake becomes longer than result of the measurement. However, this idea is not accurate. Both design spectrum and ambient vibration assumes elasticity.

It is desired to reflect the above-mentioned points when the seismic code is revised.

- The method to generate the parameters that are used in the analysis model must be reviewed.
- The handy method that gives the natural period must be reviewed.
- The design spectrum must be reviewed.

The scenario earthquake disaster assessment reflects almost the severest condition, which can be assumed based on the present day findings.

On the other hand, the conditions of earthquake-resistant design should be approved based on economic limitations and agreed upon level of craftsmanship and quality. Careful consideration of the design spectrum is needed when considering these issues.

Moreover, it is impossible to use a highly refined model and analysis for economical reasons when designing medium or small size buildings. Even for these cases, the fail-safe method for minimum safety securing is needed. The following points are referred to in last paragraph of section 8.1.2 (3) Consideration Concerning Scenario Earthquake and Design Earthquake:

- Many column-beam joints of general low-rise dwellings and many shops in Tehran do not have a high enough ductility ratio.
- Most buildings have neither effective shear walls nor braces.

Full understanding on construction method of column-beam joints, requirement for shear walls or bracing is strongly desired. The Japanese code and a general blueprint provide useful suggestions.

8.1.3. Recommendation to Improve Weak Structural Details

(1) Public Buildings and Dwellings

Many of the buildings under construction in the city of Tehran have steel frames with hollow brick walls. The followings are problems with these types of structures:

a. Insufficient Strength of Column-Beam Joints

Recommendations on column-beam joints can be obtained in the following guideline publications:

Permanent Committee for Revising the IRANIAN Code of Practice for Seismic Resistant Design of Buildings (STANDARD 2800): IRANIAN Code of Practice for Seismic Resistant Design of Buildings, BHRC Publication NO.253 1997

and

National Technical Scheme for the Reconstruction of Earthquake Stricken Areas Computation, Design and Execution of Seismic Resistant Steel Buildings Foundation and Joints

However, when the current state of construction in Tehran is observed, almost all column-beam joints are made by field welding, and the welding point is just the place where bending moment is the largest.

Considering construction environment of the buildings, field welding is influenced by wind, temperature changes, etc. There may be many differences in the quality of the welding and insufficient level of required yield strength. This leads to a situation that individual members might be broken sequentially from the weakest part to the next weakest part when an earthquake strikes.

It is recommended that steel structure industrialised production systems be promoted and enhanced.

b. No Function of brick walls as shear walls.

In Tehran, hollow bricks are used for steel, steel and brick, and masonry structure buildings. Hollow bricks have low density; therefore, their mass is rather light. This contributes to the decreased inertia against an earthquake. Sufficient rigidity and shear strength are not expected. In addition, there are also a number of uncertainties as to the characteristics of walls made of this material. It is considered that hollow brick walls are used to function as shear walls. However, it is clear that hollow brick walls surely do not function as shear walls.

According to results of further examination, prohibiting the use of those bricks might be a necessary and effective action, although it will shock the building industry of Tehran.

In Japan, the brick construction is limited to the buildings that are to be preserved in consideration of historical importance. Compared to the bricks used in Iran, the bricks used in Japan are high density and rather hard; therefore, it is difficult to compare the characteristics of these bricks. However, brick construction cannot satisfy the requirement of resistance in the event of a large earthquake, as compared to a modern industrial method such as that of reinforced concrete structures. Regardless of the choice, it is recommended that Tehran switch to a modern industrial method, for instance, reinforced concrete or steel skeleton construction, etc. As an example, a recent movement in China, where much brick construction exists, a restriction of brick construction has been started in a limited region.

c. Recommendation

Verification by load testing is needed most to obtain an effective solution for the problem of steel column and beam structures. Because the panel structure, which is composed of beam-column joints and infilled hollow bricks, is a particular case, then the experiment result of a foreign country cannot provide a definite verification for Iranian structures. It is, therefore, necessary that an official Iranian organisation conduct an experiment on this case.

For reference, the schematic drawing of deformation at the beam-column joint is shown in Figure 8.1.5. An example of the loading device and result is shown in Figure 8.1.6 and Figure 8.1.7.

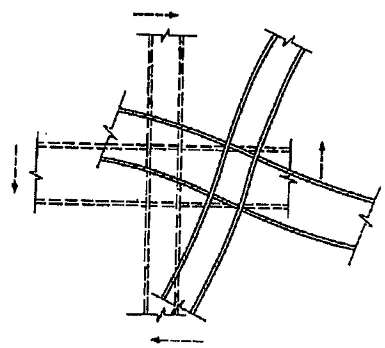


Figure 8.1.5 Schematic Drawing of Deformation at the Beam-Column Joint Connection

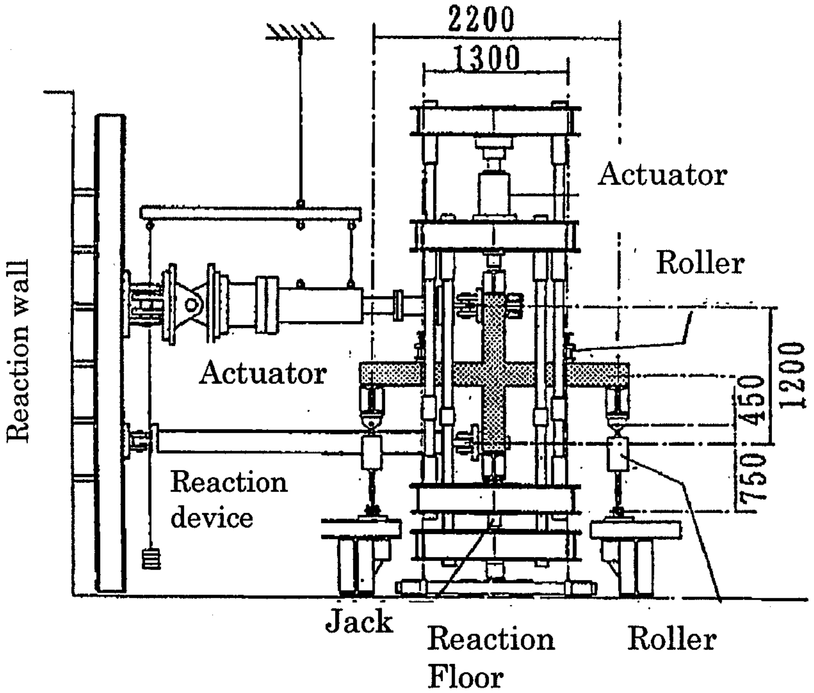


Figure 8.1.6 Example of Loading Device

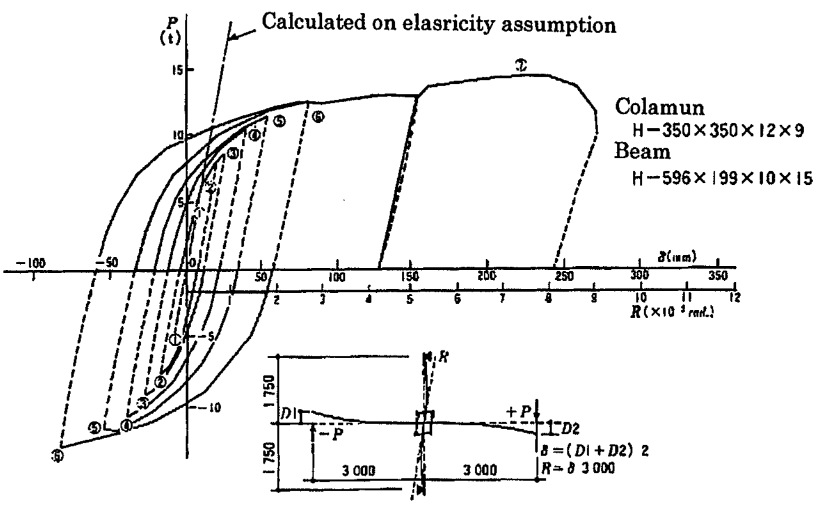


Figure 8.1.7 Result of Loading Device

If a conclusion is drawn that the usual Iranian structures do not entirely satisfy the loading test, it is necessary to develop an improvement plan or technological innovation.

When observing the hysteresis curve shown in the centre of Figure 8.1.8, it can be understood that after the brace experienced buckling under a compression force, the strength of the brace was recovered by enlarging during the alternating load.

Considering the fact mentioned above, the brace can be more effectively reinforced if the buckling of the brace can be prevented. Focusing on this result, in Japan, several kinds of devices, which hinder brace buckling, are developed to expect the effect. For instance, one such device is a jacket filled with mortar that is used to cover the brace. Moreover, low yield point steel is used to obtain enough ductility after yielding, and, in that case, this device achieves the effect of suppressing vibration obtained by hysteresis damping.

It is emphasised that many buildings in Tehran do not have shear walls, and, as a result, enough horizontal resistance and maximum ductility cannot be expected. Therefore, it is realistic to add bracing to reinforce the comparatively old, medium-size buildings that are constructed without applying the latest seismic criterion. It is ideal that columns with adequate section sizes and shear walls be installed. However, improving the bracing can be effective as a provisional countermeasure.

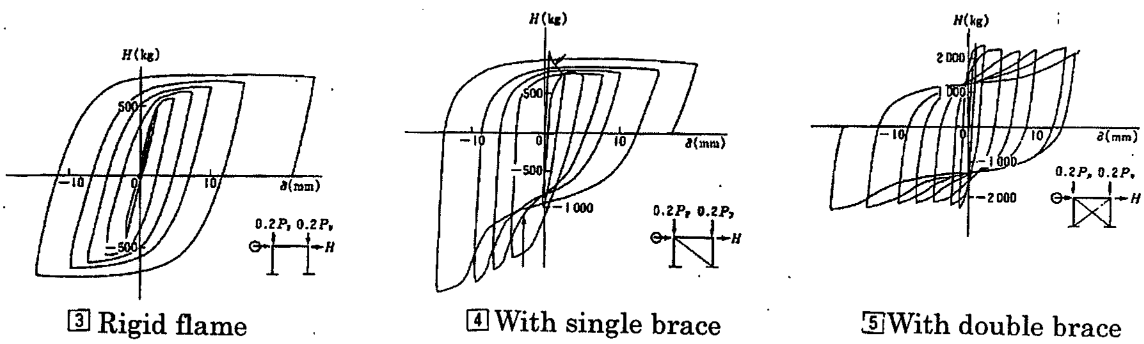


Figure 8.1.8 Effect of Adding Bracing

(2) Bridges

Although the bridges in Tehran are excellently designed and constructed, there are problems in the following areas:

1) Condition of bearing that controls the behaviour of the superstructure is vague.

Most of the bearing material used in Tehran is made of neoprene. Moreover, the condition of movable/fixed bearings is not distinguished in structural details.

It can be emphasised that there are many examples of bridges that have collapsed because of bearing malfunction, including in the Kobe Earthquake.

2) The unseating prevention system is not considered.

3) The shear-reinforcing bar of the pier is not sufficient.

Recommendations:

It is effective to adopt the concept of the unseating prevention system to address problems 1) and 2) above.

It is effective to adopt the concept of the unseating prevention system to address problems 1) and 2) above.

For instance, it is recommended that the unseating prevention system should possess enough seat width and have a connection with the adjoining girder, as described in the "Design Specifications for Highway Bridges, Part V, Earthquake Resistant Design, 1990."

For problem 3), steel lining of the pier column can be effective.

8.1.4. Calibration of Seismic Assessment Technique

Estimated building damage is especially serious. The followings are some issues regarding individual buildings:

- A small number of buildings of high quality could not be distinguished by using the census data and, thus, were not given enough consideration. Damage functions were developed giving priority to the structural types of greater number.
- The damage function proposed in the paper on the Manjil Earthquake is assumed to describe the standard earthquake-resistance of the buildings of Iran. However, further efforts should be made to evaluate the earthquake-resistance of buildings in Tehran more appropriately.
- Some types of building is now increasing in Tehran. These are not representative in the disaster region of the Manjil Earthquake and vulnerability characteristics are different.

A considerable amount of time is required to further investigate and solve the following problems:

- Diagnosis of earthquake-resistant performance in an individual building should be done. It is necessary to accumulate the results of the diagnoses. The frequency distribution chart of I_s-valve of the building in the region should be made.
- The relation between P.G.A. and the rate of building damage after actual seismic damage should be investigated. The reported actual result should then be compared with the estimated damage induced from the frequency distribution mentioned above.

When there is a difference between the observed result and the theoretical value, corrections should be made using a stochastic technique. The stochastic approach of damage function of construction is described in detail in other section.

It is strongly desired that efforts to improve the accuracy of damage functions following the above-mentioned procedure will be continued in the future.

Table 8.1.3 Major Earthquakes and Resulting Events in Japan

1891, October 28 - Nobi Earthquake, M = 8.0
1892 Earthquake Prevention Investigation Association started
1923, September 1 - Kanto Earthquake, M = 7.9
1926 "Road Design Standard" (Department of the Interior) was established
1939 The "Steel Highway Bridge Specifications" (Department of the Interior) was established
1946, December 21 - Nankai Earthquake, **M**8.0
1948, June 28 - Fukui Earthquake, **M**7.1
1952, March 4 - Tokachi-oki Earthquake, **M**8.2
1953 SMAC Strong-Motion Earthquake Record Business Promotion Conference started
1956 The "Steel Highway Bridge Specifications" (Japan Road Association)
1964, June 16 - Niigata Earthquake, **M**7.5
1967 "Guideline Honshu-Shikoku Bridge Design for Earthquake-Resistant Design" was established
1968, May 16 - Tokachi-oki Earthquake, **M**7.9
1969 Coordinating Committee for Earthquake Prediction started
1971 "Guideline Road Bridge Design for Earthquake-Resistant Design" was established
1977 "New Earthquake-Resistant Design Method" (PWRI tentative) was established
1978, June 12 - Miyagi-ken-oki Earthquake, **M**7.4
1979 Earthquake-proof check and reinforcement was executed
1979 "Guideline Railway Structure Design for Earthquake-Resistant Design" (JNR tentative) was established
1980 The chapter of "**V** Seismic design" was added to the "Road and Bridge Specifications"
1982, March 21 - Urakawa-Oki Earthquake, **M**7.1
1983, May 26 - Nihonkai-Chubu Earthquake, **M**7.7
1990 The "Road and Bridge Specifications" were revised
1990 "Design Standard for Railway Structures" (JNR) was established
1993, January 15 - Kushiro-Oki Earthquake, **M**7.8
1993, July 12 - Hokkaido-Nansei-oki Earthquake, **M**7.8
1994, October 4 - Hokkaido-Toho-oki Earthquake, **M**8.1
1994, December 28 - Sanriku-Haruka-oki Earthquake, **M**7.5
1995, January 17 - Hyogo-ken Nanbu (Kobe Earthquake), **M**7.2
1995 Tentative notice and comments for road bridge specifications : "Specification Concerning Restoration of Roads and Bridges Struck by the Hyogo-ken Nanbu Earthquake" was published
1996 "Design Specifications of Highway Bridges, Part **V**, Seismic Design" were revised
2001 "Design Specifications of Highway Bridges, part **V**, Seismic Design" revision work is progressing now

Table 8.1.4 Example of a Bridge in which the Seismic Code of a Foreign Country is Applied

Name of the Bridge	Roads at the Intersection		Seismic Coefficient	Applied Code
	Road –1	Road –2		
S –10	Hemmat	Modarres	0.13	AASHTO
S- 6	Hemmat ramp	Modarres	0.15	AASHTO
Telu	Telu road	Babaie	0.15	AASHTO
Ray	Ahang	Ray	0.2	AASHTO
Pasdaran	Hemmat	Pasdaran	0.14	AASHTO
S –7	Hemmat	Modarres	0.14	AASHTO
S –8	Hemmat	Modarres	0.15	AASHTO
Parastoo	Hemmat	Parastoo	0.14	AASHTO
Kordestan	Hemmat	Kordestan	0.15	AASHTO
Mollasadra	Chamran	Mollasadra	0.13	AASHTO
17 Shahrivar	Ahang	17 Shahrivar	0.12	AASHTO
Shariati	Hemmat	Shariati	0.15	AASHTO
Ozgol	Babaie	Ozgol	0.16	AASHTO
Lavizan	Babaie	Darabad	0.15	AASHTO
Kan river bridge	Karaj special road	Kan river	0.12	AASHTO
Mirdamad	Modarres	Mirdamad	0.1	AASHTO, DIN
Kordestan	Hemmat	Kordestan	0.15	AASHTO
Azadegan	Karaj special road	Azadegan	0.15	AASHTO
Abe –Ali	Babaie	Abe –Ali	0.1	AASHTO,DIN
S –5	Hemmat	Modarres	0.1	AASHTO
Fadaiyan Islam	Besat	Fadaiyan	0.1	AASHTO
Afsarieh	Besat	Afsarieh	0.1	AASHTO
Vali –asr- Chamran	Chamran	Vali –asr	0.35	AASHTO

References for 8.1

Building Guidance Division and Urban Building Division, Housing Bureau, The Ministry of Construction: The Building Standard Law, The Building Centre of Japan, 1995

Code of Practice for Seismic Resistant Designs and Computation of Bridges, Tehran Municipality, Technical and Development Division, July 1995.

Earthquake Engineering Division Earthquake Disaster Prevention Research Centre Public Works Research Institute: Specifications for Highway Bridges, Part V, Seismic Design, Japan Road Association, July 1998.

Permanent Committee for Revising the Iranian Code of Practice for Seismic Resistant Design on Buildings: Iranian Code for Seismic Resistant Design of Buildings, BHRC, 2nd ed. 1999

8.2. Proposed Urgent Measures

In examination of ' urgent measures' for the serious situation of potential seismic disaster in condition for available time and lack of necessary data, there is two types of approach.

- The estimated seismic damage for Tehran presents a very grim picture. In addition, the city of Tehran is still growing and its structures are expected to increase in great numbers. Therefore, there is a need to prepare countermeasures to seismic disaster as soon as possible.
- Detailed seismic activity has not investigated up to this time. This includes the history of the last large earthquake caused by the fault, and the possible re-occurrence of the earthquake. Therefore, it is necessary to devise a schedule after these scenarios have been clarified.

Lessons can be learned from the aftermath of the Kobe Earthquake, Japan, in 1995. Seismic criteria were revised to cover all potential seismic disaster areas. In addition, from 1995 up to the present time, a fundamental check is being done to building structures in Tokyo. Structures that do not satisfy seismic criteria are strengthened accordingly.

8.2.1. Demolish and Rebuild or Strengthen

From an economic point of view, it is unreasonable to rebuild all the structures that cannot withstand an earthquake, although such an action is ideal. It should be carefully decides that whether to rebuild or merely strengthen.

(1) Public Buildings and Dwellings

Since it is impossible to demolish and rebuild all buildings to become earthquake resistant, it is important to limit the target for a rebuilding plan, and to decide the priority level. Some important aspects to consider are as follows:

- Evaluation of the degree of importance of individual public facilities for the rescue and restoration activities after an earthquake;
- Diagnosis of anti-seismic performance of individual public facilities according to building code

In case for dwellings, shops, and private offices, earthquake-proof measures, earthquake-proof measures depend on the judgement of the owner. It is necessary that an official organisation, such as the Municipal Government, encourage diagnosis and strengthening on the structures for anti-seismic performance or earthquake resistance. Strict and proper enforcement of building design codes and seismic resistant codes could be identified as the most important measure, which should be implemented by the municipal government.

(2) Bridges

Only a small number of bridges are estimated to collapse, and a large majority of these unstable bridges are for temporal purpose bridges. Therefore, it is necessary to rebuild these bridges in the near future.

Further examinations of bridges other than the temporary bridges mentioned above should be carried out.

a. Temporary Bridges

It will be necessary to apply the unseating prevention system to temporary bridges, in case of an emergency.

Moreover, it is necessary to rebuild the bridges as soon as possible. The yield strength of these bridges is inadequate considering the traffic volume in Tehran and the current state of the floor slab of these bridges.

b. Other Bridges

It is necessary to continue a more detailed investigation of bridges where a problem is indicated by the seismic damage evaluation. The points, which should be especially noted, are as follows:

- The connection between the adjoining girders is vague; and
- The seat width on the pier cap is not sufficient.

It is necessary to examine the application of the unseating prevention system to the bridge, which corresponds to the above-mentioned conditions.

The design of bridges with a span of four or more should be investigated. For bridges, where shear reinforcement of the pier is not sufficient, strengthening should be carried out.

(3) Lifelines

A systematic record concerning the following items, which form part of the basic data of the damage analysis, did not exist at the time of the Study. A distribution map of the pipeline network, material, and diameter should be compiled for the following services:

- Water,
- Electricity,
- Gas, and
- Telecommunications

First, it is necessary to unify the database format and essential information items. Based upon the information, appropriate damage should be estimated and required measures are determined.

8.2.2. Seismic Retrofitting and Seismic Strengthening

The basic concept of seismic retrofitting is to improve the earthquake-resistance of structures without changing their existing basic framework. Retrofitting should be adopted only when the following provide the advantage over rebuilding:

- The material and construction cost can be limited to the minimum amount.
- The construction period can be limited to the minimum amount.

It is important to clarify the yield strength for seismic intensity before and after execution of seismic retrofitting. It is considered that there is many cases that retrofitting are executed but required resistance, which is defined in the latest seismic design code, is not achieved. Detail consideration is required for the cases.

(1) Public Buildings and Dwellings

The diagnosis of seismic performance is very important. In Japan, diagnosis of seismic performance is usually done before seismic retrofitting, and the seismic intensity I_s-valve is calculated according to the detailed procedure defined by the Japan Architectural Disaster Prevention Society.

In case for public facilities, the diagnosis of seismic performance is performed without exception in order to decide retrofitting to be introduced. Public facilities are used as head quarter of relief activities and disaster management centre. On the other hand, the seismic diagnosis of private buildings lies in the judgement of owners. The municipality should promote and encourage this important exercise.

Examples of construction for seismic retrofitting and seismic strengthening are as follows:

a. Providing Additional Bracing

In case of a structural member of the moment frame does not have enough rigidity, relative displacement in the horizontal direction between each floor becomes excessive. In such a case, it is effective to introduce braces.

In case of there exists a floor of relatively low rigidity or yield strength, destruction is concentrated in the floor. Much damage occurred in the ‘ pilotis’ structure of buildings during the Kobe Earthquake because of the above-mentioned fracture mechanism.

An example is shown in Figure 8.2.1. Here, steel bracing is added to outside walls of school building made of RC.

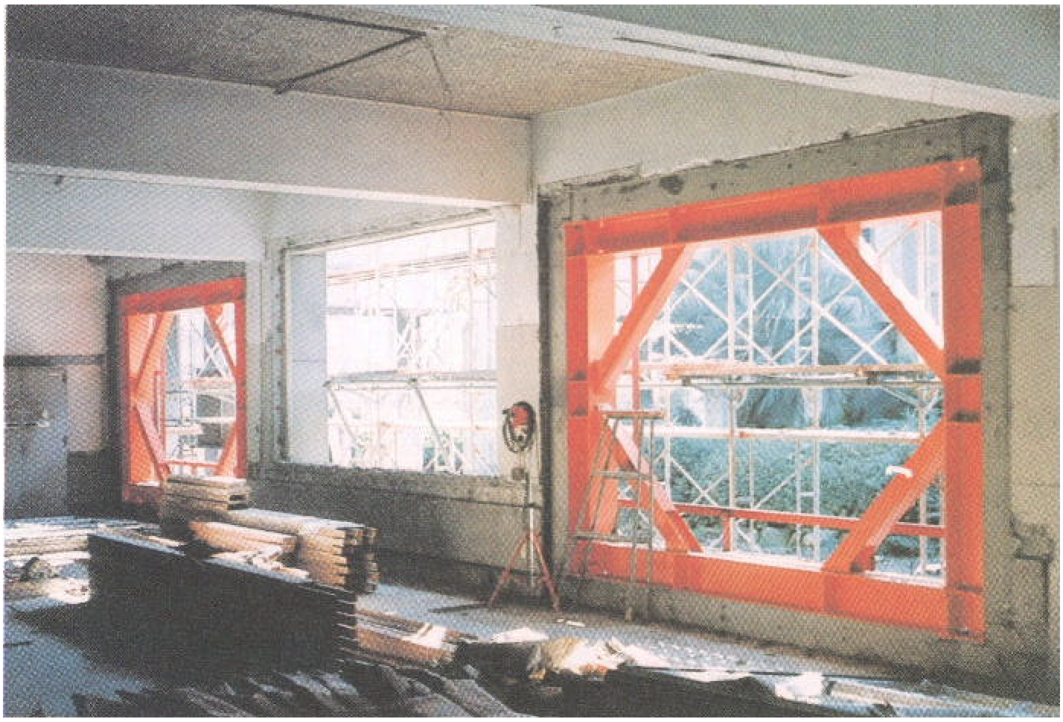


Figure 8.2.1 Steel Bracing Added to a School Building

b. Strengthening of Walls

An increase in the shear wall strength is effective when a structural member of the moment frame does not have enough rigidity.

The schematic drawing is shown in Figure 8.2.2. The shear wall with composite material is fitted to the building made of RC. The case for where the brick wall was strengthened by an RC wall is shown in Figure 8.2.3. This building, which was reinforced just before the Kobe Earthquake, endured that earthquake. The building also had its columns and beams reinforced at the same time (see Figure 8.2.4).

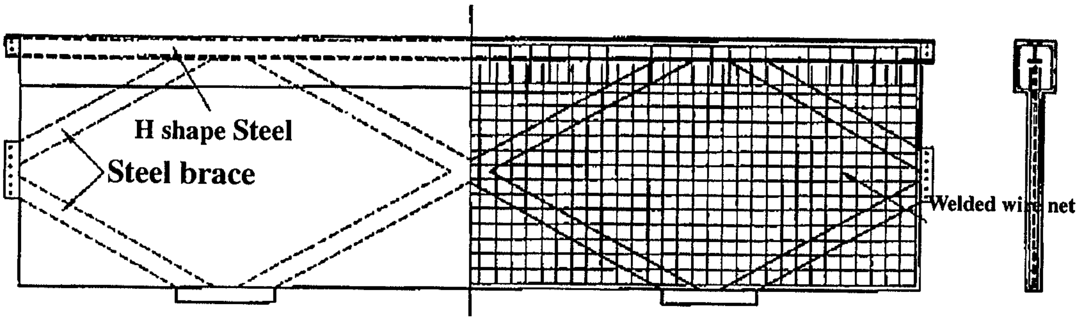


Figure 8.2.2 Schematic Shear Wall with Composite Material

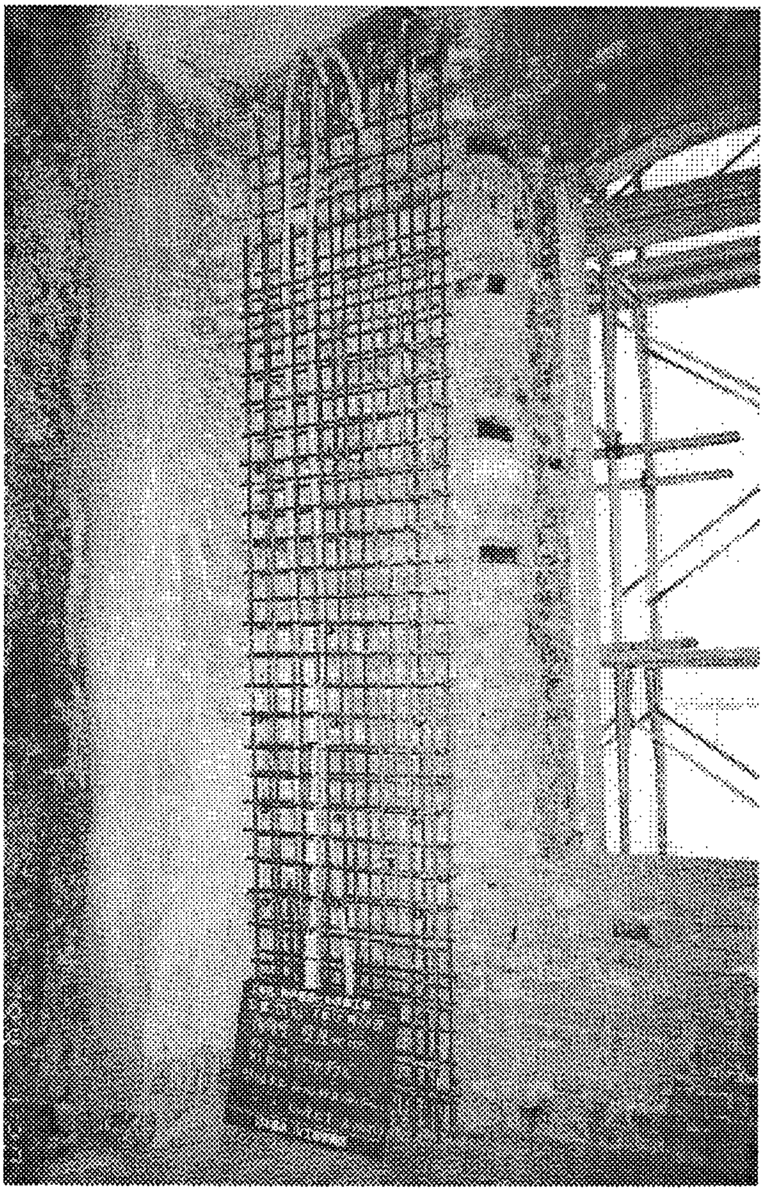


Figure 8.2.3 The Case where the Brick Wall was Strengthened by RC Wall

Figure 8.2.4 Reinforcement of Columns and Beams

c. Steel Lining / Fibre Lining

Buckling occurs in concrete when the RC column does not have enough shear-reinforcing bars. In such cases, a steel plate lining or carbon-fibre lining is effective as shown in Figure 8.2.5.

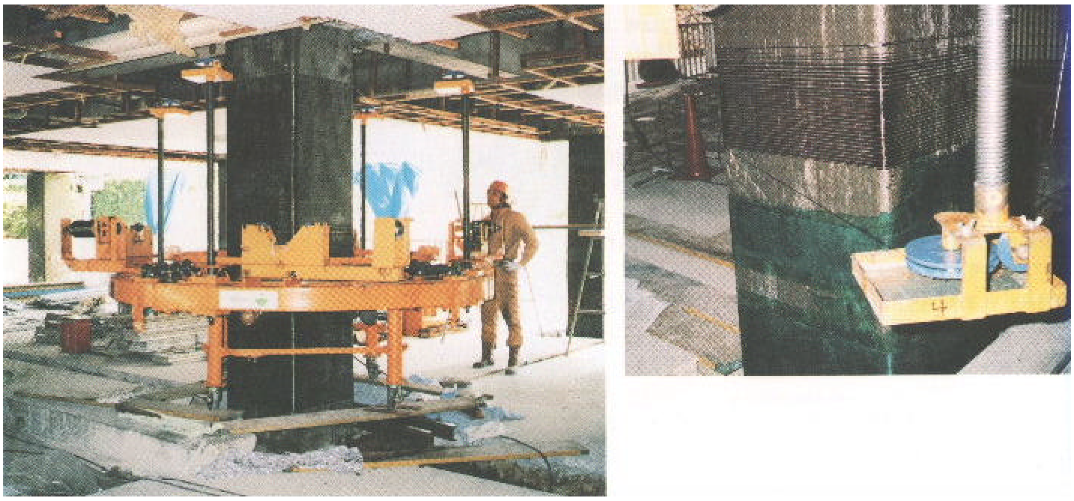


Figure 8.2.5 Carbon Fibre Lining

d. Adding Bracing and Adding a Hysteresis Damping Effect for Vibration Suppression

Fitting an additional brace is effective, even in buildings that have a moment resisting frame, when the relative displacement in the horizontal direction between each floor is excessive. An example of adding bracing to an RC building is shown in Figure 8.2.6.

A schematic drawing of the vibration suppression concept is shown in Figure 8.2.7. The use of an outside pipe to control the buckling of the bracing is more effective to suppress vibration than if an outside pipe is not adopted.

When bracing made of super-low yield point steel is used, the displacement between each floor can be decreased because of the hysteresis damping effect, which is obtained by using a steel brace. This effect is confirmed by the examination of several loading experiments.

This technology is still under development, even in Japan. The construction cost is not low, because each design has to undergo strict examination and dynamic analysis.

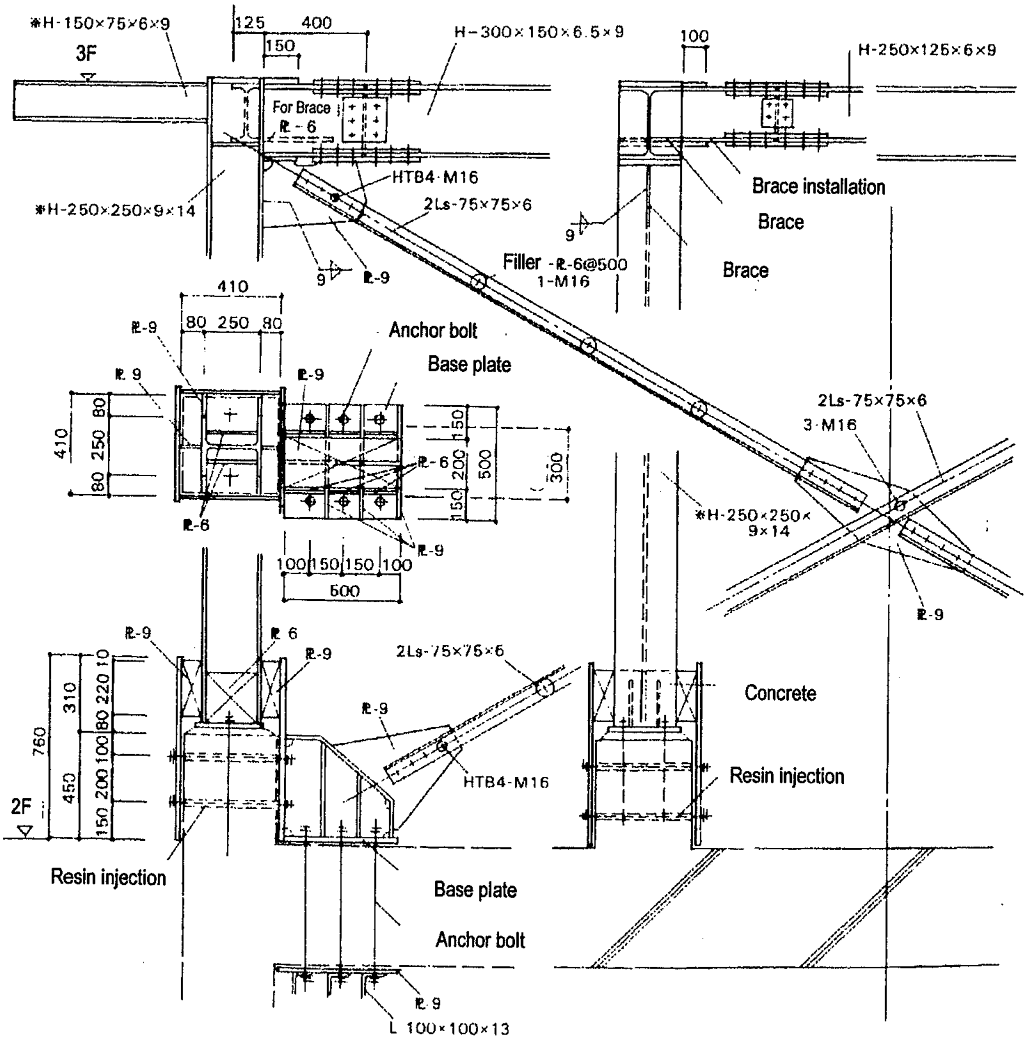


Figure 8.2.6 An Example of Adding Bracing to an RC Building

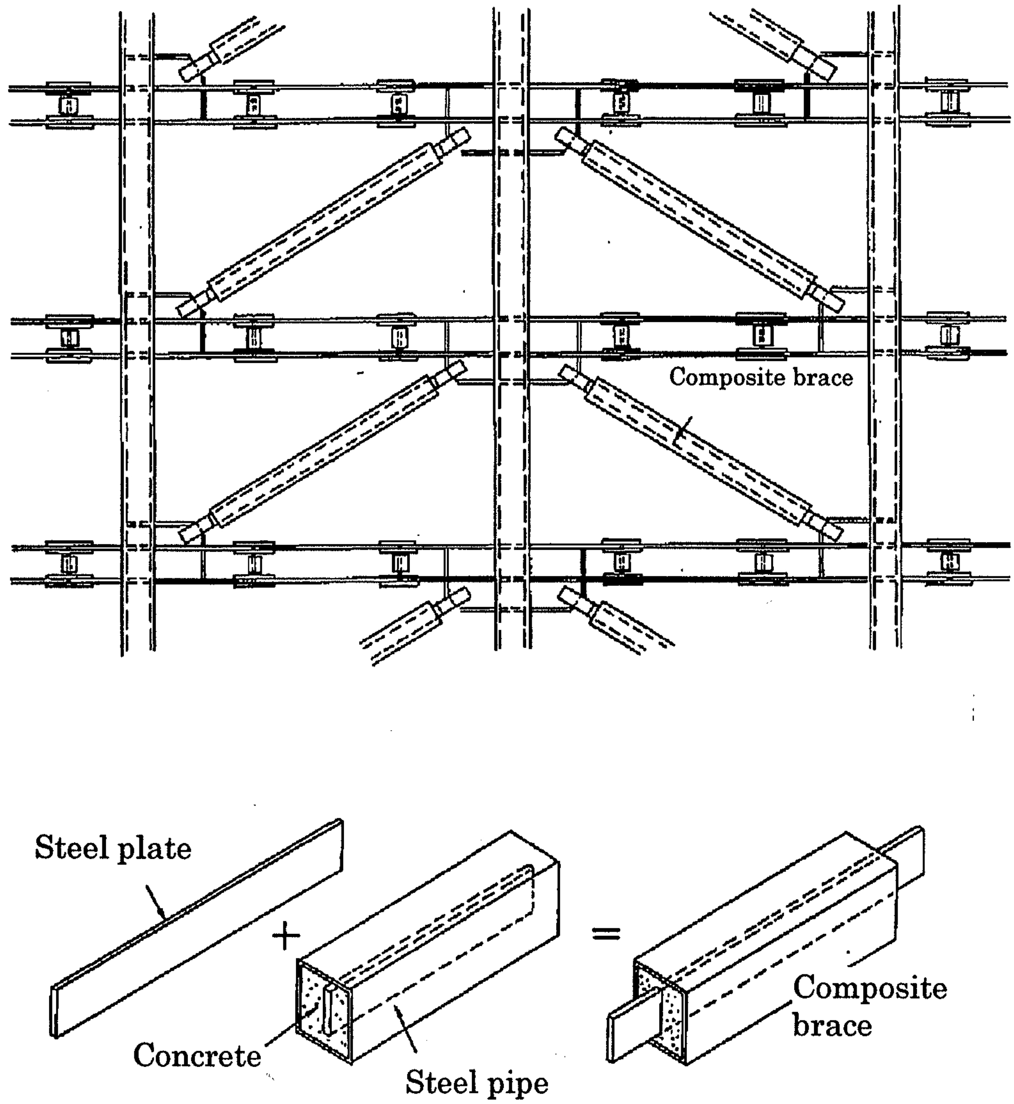


Figure 8.2.7 Schematic Drawing of Vibration Suppression

(2) Bridges

There are not many damaged bridges in the evaluation at this time. It is hoped that a steady pace is maintained in order to advance the strengthening plan. The examples of construction for seismic retrofitting and seismic strengthening are shown below.

a. Unseating Prevention System

In Tehran, most bearings are made of neoprene. There is not much attention paid to the behaviour in the longitudinal direction of superstructures. The mechanical characteristics of the fixed bearing and the movable bearing are not distinguished.

In the 'Design Specifications of Highway Bridges, Part V, Seismic Design, Japan', it is specified that the unseating prevention system must include displacement limitation bearing devices, securing of pier cap seat width, and connection between the adjoining girder. A schematic drawing is shown in Figure 8.2.8 to Figure 8.2.11.

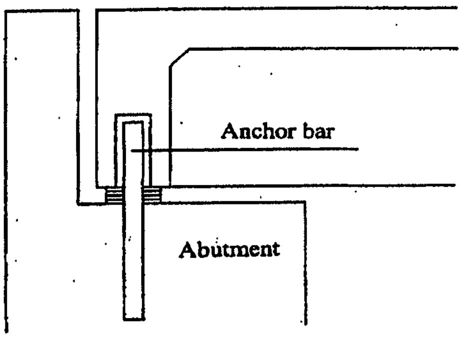


Figure 8.2.8 An Example of an Excessive Displacement-Limiting Structure Connecting the Superstructure with the Substructure

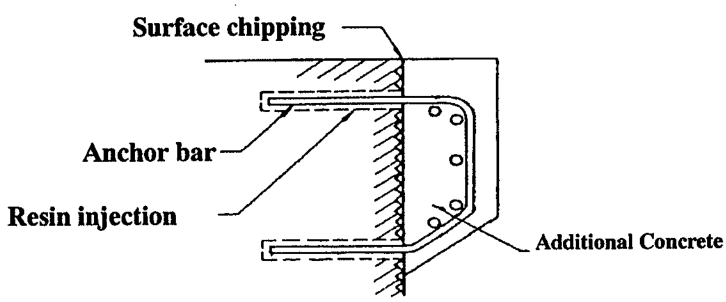


Figure 8.2.9 An Example of Widening the Seat Width of Pier Cap (RC)

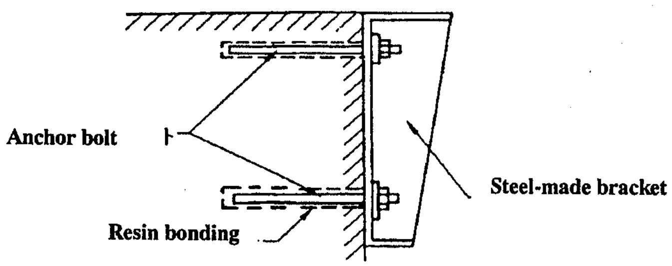


Figure 8.2.10 An Example of Widening the Seat Width of Pier Cap (Steel Bracket)

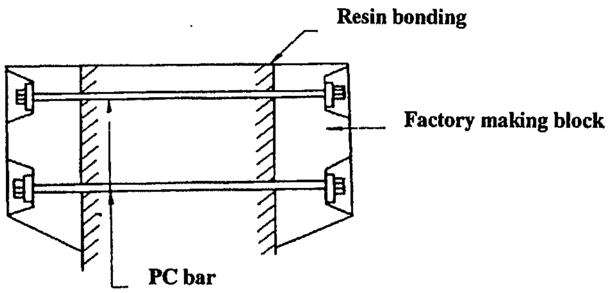


Figure 8.2.11 An Example of Widening the Seat Width on Pier Cap (Factory-made Block)

b. Steel Lining

The shear reinforcement of piers in Tehran is fewer than the required level prescribed in the Japanese code. Shear failure strength becomes lower than the bending peak strength when shear-reinforcement is not sufficient. Therefore, the shear failure generated precedes the bending destruction. This type of defect causes a brittle and sudden destruction.

It is necessary to examine design drawings and investigate the reinforcement bars in bridges with a span of four or more, because, for these cases, the stability of each girder depends on the horizontal yield strength of the pier.

The steel lining shown in the schematic drawing of Figure 8.2.12 is effective in strengthening the pier, which, alone, does not have sufficient shear strength.

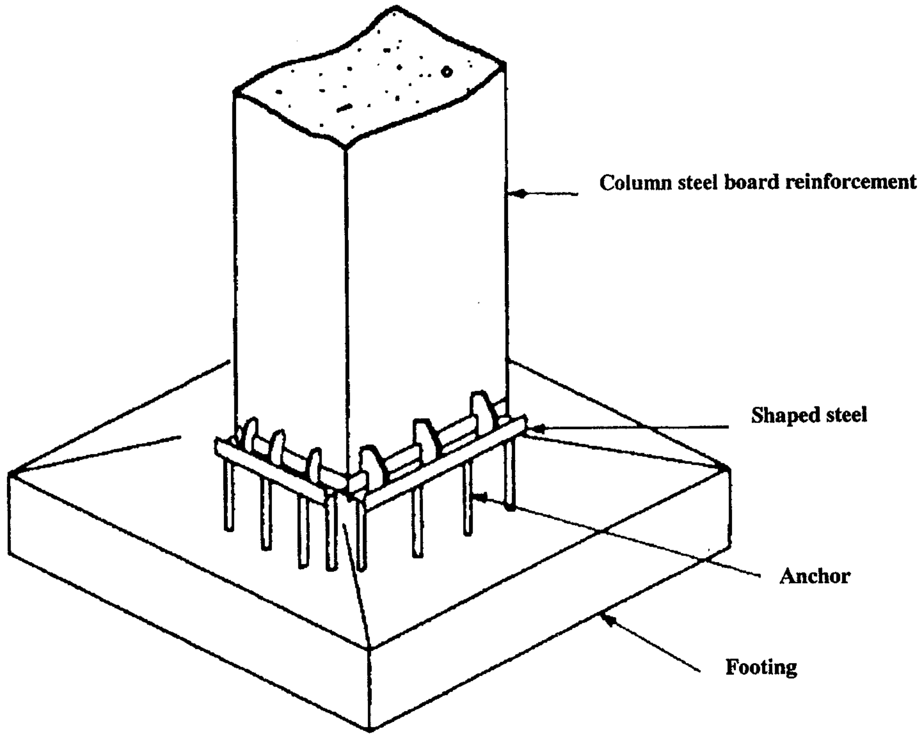


Figure 8.2.12 Schematic Drawing of Steel Lining Reinforcement

Chapter 9 :

Recommendation on Detail Investigation and Evaluation of Seismic Activity

Chapter 9. Recommendation on Detail Investigation and Evaluation of Seismic Activity

It is important for actual disaster prevention planning to estimate the location, magnitude and time of next earthquake.

In this Study, the deterministic approach was applied in the construction of an earthquake scenario. Damages were estimated based upon the scenarios. However, there is little information on earthquake recurrence intervals and the latest earthquake events, and it is difficult to determine when the scenario earthquake will occur. It is strongly desired to investigate characteristics of earthquake source faults and to estimate the time of the next earthquake event. Contents of investigation are summarised in Table 9.1.

Table 9.1 Contents and Procedure for Detailed Investigation and Evaluation of Seismic Activity

Evaluation Items	Investigation Items	Procedure of Investigation
3 dimensional location of active faults	Length	• Interpretation of air photograph • Geological reconnaissance
	Dip	• Seismic Reflection Survey • Observation of micro earthquake activities by seismograph network
Magnitude	Displacement of fault for one event	• Observation of active fault by trenching • Deep boring investigation
	Segmentation	• Inventory survey • Observation of active fault by trenching • Deep boring investigation
Recurrence interval and time until next event	Time of previous two earthquake events	• Inventory survey • Observation of active fault by trenching • Deep boring investigation

The characteristics of earthquake source faults are follows:

North/South Ray Fault

The last event on the North/South Ray Fault occurred in 855. There has been no major earthquake activity in over 1000 years. Earthquake activity on these faults will bring huge earthquake damages, and a detailed investigation and evaluation is required.

North Tehran Fault (NTF)

There is no data in the earthquake catalogue on seismic activities on the North Tehran Fault. Earthquake activity on this fault will bring the next largest earthquake damages (second to the North/South Ray Fault), and a detailed investigation and evaluation is required.

Mosha Fault

The Mosha Fault has been activated repeatedly and major earthquakes have occurred. The latest earthquake occurred in 1830. The Mosha Fault consists of several segments. It is required to evaluate the location and interval for seismic activity of each segment.