Appendix 2

EVALUATION OF THE EARTHQUAKE PERFORMANCE OF ORDINARY BUILDINGS IN KATHMANDU VALLEY

BUILDING PERFORMANCE TYPE

Ordinary buildings in Kathmandu Valley were classified into five types, based on earthquake performance. Type 1 is the worst and Type 5 the best:

Type 1: Adobe, stone, brick in mud, adobe & stone, stone & brick in mud
Type 2: Non-reinforced masonry made of brick in mud, brick in lime, brick in cement, brick in mud & brick in cement
Type 3: Reinforced concrete ordinary-moment-resistant-frames (OMRF)
Type 4: Reinforced concrete intermediate-moment-resistant-frames (IMRF)
Type 5: Reinforced concrete special-moment-resistant-frames (SMRF)

Using data from The Study on Earthquake Disaster Mitigation in The Kathmandu Valley, Kingdom of Nepal (NSET, 2001), the building stock in Kathmandu Valley was classified as shown in the following table:

Building Types in Kathmandu Valley According to Structural Performance

Building Type	Structural System		Percentage of Buildings	
	Type	Definition		
1	AD	Adobe (earth blocks in mud).	19%	34%
	ST	Stone in mud.	7%	
	AD-ST	Adobe combined with stone.		
	ST-BM	Combination of stone and brick in mud.	8%	
2	BM	Non-reinforced masonry with brick in mud.	18%	43%
	BL	Non-reinforced masonry, brick in cement mortar.		
	BC	Non-reinforced masonry, brick in lime mortar.	21%	
	BM-BC	Non-reinforced masonry combination of BM-BC.	4%	
3	RC-OMRF	Reinforced concrete structure and infill masonry walls, without earthquake-resistant design. Most of the 3- or more-storey buildings.	15%	23%
4	RC-IMRF	Reinforced concrete structure and infill masonry walls, with moderate level of earthquake-resistant design. Mainly 1 or 2-storey buildings.	8%	
5	RC-SMRF	Reinforced concrete structure and infill masonry walls, with special design for earthquake resistance. A few hospitals and other buildings.	<1%	<1%

DEFINITION OF STRUCTURAL SYSTEMS

Non-reinforced-masonry bearing-walls system:
A load-bearing system in a building without seismic design in which its bearing-walls do not meet the special detailing requirements for ductile behaviour. This system is only suitable for Seismic Zone 1. In Nepal, most of the hospitals of this kind were constructed by combining clay bricks with mortar cement.

Ordinary moment-resisting-frame-system (OMRF):
A load-bearing system in a building without seismic design in which its moment-resisting-frame does not meet the special detailing requirements for ductile behaviour. This system is only suitable for Seismic Zone 1.

Intermediate moment-resisting-frame-system (IMRF):
A load-bearing system in a building with a seismic design, in which its moment-resisting-frame has moderate ductile behaviour and complies with the requirements of Seismic Zone 2.

Special moment-resisting-frame-system (SMRF):
A load-bearing system in a building with high-performance seismic design, in which its moment-resisting-frame is specially designed to create ductile behaviour and comply with the requirements of Seismic Zones 3 and 4. Although this system should be adopted for RC frame structures in Nepal, its use is currently an exception.

DAMAGE ESTIMATION IN KATHMANDU VALLEY BUILDINGS

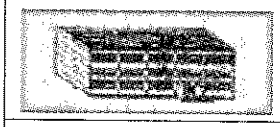
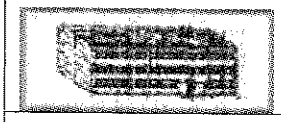
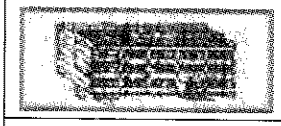
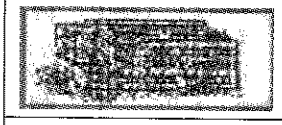
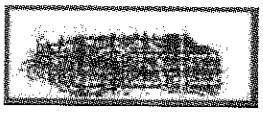
By combining the size and classification of building damage, as defined by the European Micro-seismic Scale for different earthquake intensities, with expected losses and building stock distribution, a gross damage estimation was made for 250,000 buildings in Kathmandu Valley. The results are shown in the following tables:

Estimated Number of Buildings Damaged in Kathmandu Valley

Earthquake Intensity	No Damage	Damage Category				
		Negligible to Slight	Moderate	Substantial to Heavy	Very Heavy	Destruction
VI	201,688 (80.68%)	37,725 (15.09%)	10,088 (4.04%)		<500 (< 0.2%)	
VII	140,225 (56.09%)		69,438 (27.78%)	35,663 (14.27%)	4,675 (1.87%)	
VIII	-	140,226 (56.1%)		69,438 (27.78%)	35,663 (14.27%)	4,675 (1.87%)
IX	-	144,901 (58%)			69,438 (27.75%)	35,663 (14.25%)

Although building performance varies in Kathmandu Valley, building classification was made as simple as possible and according to the criteria used in the European Micro-seismic Scale.

Damage Classification According to European Micro-seismic Scale

RC Frame Structures	Masonry Structures	Damage Category	Damage Description
		NEGLIGIBLE TO SLIGHT	No structural Slight non-structural
		MODERATE	Slight structural Moderate non-structural
		SUBSTANTIAL TO HEAVY	Moderate structural Heavy non-structural
		VERY HEAVY	Heavy structural Very heavy non-structural
		DESTRUCTION	Very heavy structural

Expected Loss of Buildings According to Damage Categories

Damage Category	Negligible to Slight	Moderate	Substantial to Heavy	Very Heavy	Destruction
Expected Losses	0 – 5%	5 – 15%	15 – 40%	40 – 80%	80 – 100%

Expected loss of buildings is estimated as a percentage of costs, as follows:

Expected loss of buildings = damage direct-cost / building cost.

Percentage of Buildings Damaged

MMI = VI **Damage Categories**	**Building Type**			
	1	**2**	**3**	**4**
Negligible to Slight	Many (10-60%)	Few (1-10%)	Few (1- 10%)	
Moderate	Few (1–10%)	Few (1–10%)		

MMI = VII **Damage Categories**	**Building Type**			
	1	**2**	**3**	**4**
Negligible to Slight		Some (5- 30%)	Some (5- 30%)	Few (1- 10%)
Moderate	Many (10- 60%)	Many (10-60%)	Few (1- 10%)	
Substantial to Heavy	Many (10-60%)	Few (1–10%)		
Very Heavy	Few (1–10%)			

MMI = VIII **Damage Categories**	**Building Type**			
	1	**2**	**3**	**4**
Negligible to Slight			Some (5-30%)	Many (10-60%)
Moderate		Some (5-30%)	Many (10-60%)	Few (1- 10%)
Substantial to Heavy	Many (10-60%)	Many (10-60%)	Few (1–10%)	
Very Heavy	Many (10-60%)	Few (1–10%)		
Destruction	Few (1–10%)			

MMI = IX **Damage Categories**	**Building Type**			
	1	**2**	**3**	**4**
Negligible to Slight				Some (5 – 30%)
Moderate			Some (5 – 30%)	Many (10-60%)
Substantial to Heavy		Some (5 – 30%)	Many (10-60%)	Few (1- 10%)
Very Heavy	Many (10-60%)	Many (10-60%)	Few (1- 10%)	
Destruction	Many (10-60%)	Few (1–10%)		