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Preliminary Study of Seismic Risk in New Westminster, British Columbia

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ABSTRACT

This paper presents preliminary estimates of structural damage in buildings in New Westminster, B.C., resulting from the ground motions specified for design in the National Building Code of Canada (NRC, 1995). These ground motions are due to crustal earthquakes only and have a probability of exceedance of 5% in 50 years. For shaking levels corresponding to MMI=VII and MMI=VIII, the preliminary studies indicate structural damage would range from 0%-5%, and 5%-10%, respectively, of the replacement cost.

INTRODUCTION

New Westminster was founded in 1859 and was the capital of colonial British Columbia until 1866. It overlooks the Fraser River, about 20 km east of Vancouver. Its population in 1996 was 49,350. The city, with about 8,000 buildings, occupies an area of 15 km squared.

New Westminster can be affected by both crustal earthquakes in the Continental North American Plate and a large subduction earthquake that may be generated by the Juan de Fuca Plate, which is subducting under the continental plate. In the present study, preliminary estimates of damage in buildings in New Westminster are made for a level of ground shaking consistent with the ground motions specified for design in the National Building Code of Canada (1995). These ground motions are due to crustal earthquakes only and have a probability of exceedance of 5% in 50 years.

The ground motions have been calculated for firm ground. The effects of other soil conditions on the ground motions are still under study. In this preliminary damage estimate, the effects of soil conditions are bracketed by considering a range in the intensity of shaking that would be likely to include substantial soil effects.

The New Westminster damage study is part of a major research project on seismic risk in Southwestern British Columbia.

ASSESSMENT OF DAMAGE

The damage caused by an earthquake depends on the intensity and duration of shaking. There are various ways of characterizing the level of shaking at a site, but for this preliminary study, the shaking is characterized by the Modified Mercalli Intensity (MMI) Scale. The levels in this scale are defined by different levels of damage to buildings and the ground.

In this study, the distribution of MMI is calculated from the peak ground accelerations. The peak ground acceleration for firm ground in New Westminster with a probability of exceedance of 5% in 50 years is calculated to be 0.196 g. An MMI somewhat greater than VII estimated using Newmann's equation (1933). To include in a preliminary way the effects of soil conditions in the New Westminster area, damage was estimated for both MMI=VII and MMI=VIII. The damage descriptions corresponding to these two levels of shaking intensity are given in Table 1.

Structural Damage

Structural damage is defined here as one of the seven damage states shown in Table 2. Each damage state is defined by a range in damage factors which represent damage as a percentage of replacement cost. For example, moderate damage is defined in Table 2 as corresponding to 10%-30% of replacement cost, with an average factor called the Central Damage Factor (CDF) of 20%. The CDF is used to characterize the damage in this study.

The buildings in British Columbia were grouped into 31 different prototypes for the overall risk study. These prototypes fall into 7 general classes: wood, steel, concrete, masonry; tilt up, precast concrete, and mobile homes. A building inventory for New Westminster was compiled using the database provided by the City Planning Department. Guidelines were established for relating building descriptions in the New Westminster database to the prototype structures. To validate these guidelines, about 1,000 of the approximately 8,000 buildings in the city were checked individually by field investigators. The results of this investigation showed ten different prototype buildings prevalent in New Westminster.

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For a given level of shaking, the damage will depend on the vulnerability of the building, which in turn depends on the kind of construction and the material used in the construction. The vulnerability of a building to a given level of shaking, say MMI=VII, is specified by giving the probability of achieving the different levels of damage defined in Table 2 in that particular building. The probabilities differ from one building type to another. Probabilities of different levels of damage were developed for each of the buildings in Table 3 (Bell, 1998).

The procedure for estimating losses will be illustrated for building prototype SFCWHR (Steel Frame with Concrete Wall, High Rise). The damage matrix for this building prototype is given in Table 4, which shows the central damage factors and the probabilities of their occurrence. The damage will be calculated for MMI=VII. The central damage factors are multiplied by the corresponding probabilities for MMI=VII and the products are added up to give the total level of damage as a percentage of replacement cost. This is called the Mean Damage Factor (MDF) for the building and is the damage that would be expected if the postulated level of shaking occurred. This is similar to that approach recommended for damage estimation by ATC-13 (ATC, 1985).

Buildings were grouped in Blocks, as defined by the Planning Department database. For a given MMI, each building is assigned its corresponding MDF by prototype. MDF was then averaged over each block, weighted by area. The Geographical Information System (GIS) software, MapInfo, was used to produce maps of the geographical distribution of damage for MMI=VI and MMI=VIII. This range in shaking was adopted to include soil effects in a preliminary way.

Nonstructural Damage

The methodology for assessing nonstructural damage is similar to that used for structural damage except that the damage probability matrices are different. In addition, two types of nonstructural damage were evaluated: displacement-sensitive damage and acceleration sensitive damage. Partition walls, plumbing and piping are very susceptible to damage due to deformations of the building, whereas mechanical equipment and furniture is sensitive to the accelerations in the building.

PRELIMINARY RESULTS OF STUDY

The building inventory is presented on a block-by-block basis in Fig. 1. This inventory is the basis for damage estimation. The distributions of structural damage in New Westminster on a block-by-block basis for both MMI=VI and MMI=VIII are shown in Fig. 2. The damage is defined in terms of percentage of replacement cost using 3 ranges: 0%-0-5%; 5%-10%;. 10%-30%.

Damage estimates for ground shaking consistent with the design motions in the National Building Code of Canada (1995) are mainly in the range of 0%-5% for MMI=VII and firm ground conditions. On softer sites, the intensity is likely to be MMI=VIII and damage estimates are mainly in the range 5%-10%. Most of the damage is sustained by wood-frame residential and masonry buildings.

Nonstructural damage for MMI=VII is shown in Fig. 3. Displacement-sensitive damage is shown on the left, and acceleration-sensitive damage, on the right. The damage, averaged on a block-by-block basis, is in the range 5%-10% of replacement cost.

ACKNOWLEDGEMENTS

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Table 1. Earthquake Intensities in New Westminster Study

Modified Mercalli Intensity	Description of Effects
VII	Damage negligible in buildings of good design and construction; slight to moderate in well-built ordinary structures; considerable damage in poorly-built structures. Some chimneys broken.
VIII	Damage slight in specially designed structures; considerable damage in ordinary substantial buildings with partial collapse. Damage great in poorly-built structures. Fall of chimneys, factory stacks, columns, monuments, walls. Heavy furniture overturned.

Table 2. Structural Damage States in Terms of Percent of Replacement Cost

Damage State	Damage Factor Range (%)	Central Damage Factor (%)
1 – None	0	0
2 – Slight	0 – 1	0.5
3 – Light	1 – 10	5
4 – Moderate	10 – 30	20
5 – Heavy	30 – 60	45
6 – Major	60 – 100	80
7 – Destroyed	100	100

Table 3. Prevalent Building Types in New Westminster

Wood	WLFR	Wood Light Frame, Residential
	WLFCI	Wood Light Frame, Commercial/Institutional
	WLFLR	Wood Light Frame Low Rise
Steel	SBFLR	Steel Braced Frame Low Rise
	SBFMR	Steel Braced Frame Mid Rise
	SFCWLR	Steel Frame Concrete Walls Low Rise
Concrete	CFLR	Concrete Frame with Concrete Walls Low Rise
	CFHR	Concrete Frame with Concrete Walls High Rise
Masonry	RMLR	Reinforced Masonry Shear Wall Low Rise
	URMLR	Unreinforced Masonry Bearing Walls Low Rise
Tilt Up	TU	Tilt Up

Table 4. Damage Probability Matrix (DPM) for a Steel Frame with Concrete Walls, High Rise (SFCWHR) Building. (All values are percentages.)

Damage Data (CDF)	VI	VII	VIII	IX	X	XI	XII
0.00	15.0	2.0	***	***	***	***	***
0.50	65.0	15.0	5.0	1.0	***	***	***
5.00	20.0	80.0	65.0	5.0	1.0	1.0	***
20.00	***	3.0	30.0	79.0	50.0	5.0	1.0
45.00	***	***	***	15.0	47.0	77.0	64.0
80.00	***	***	***	***	2.0	17.0	35.0
100.00	***	***	***	***	***	***	***

***Very small probability

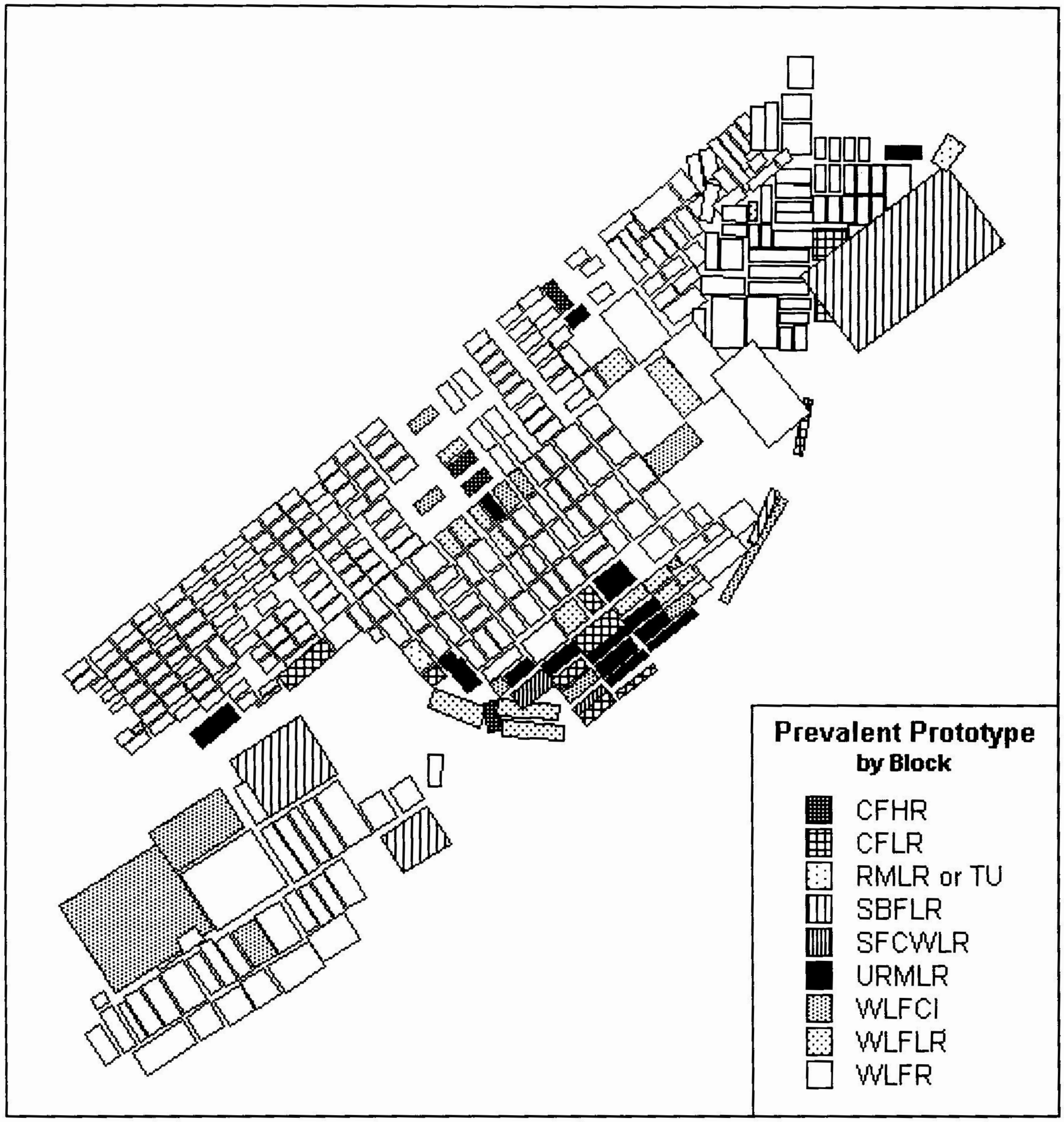

Fig. 1. Distribution of prevalent building types in New Westminster, on a block-by-block basis.

Structural Damage, MMI=VII **Structural Damage, MMI=VIII**

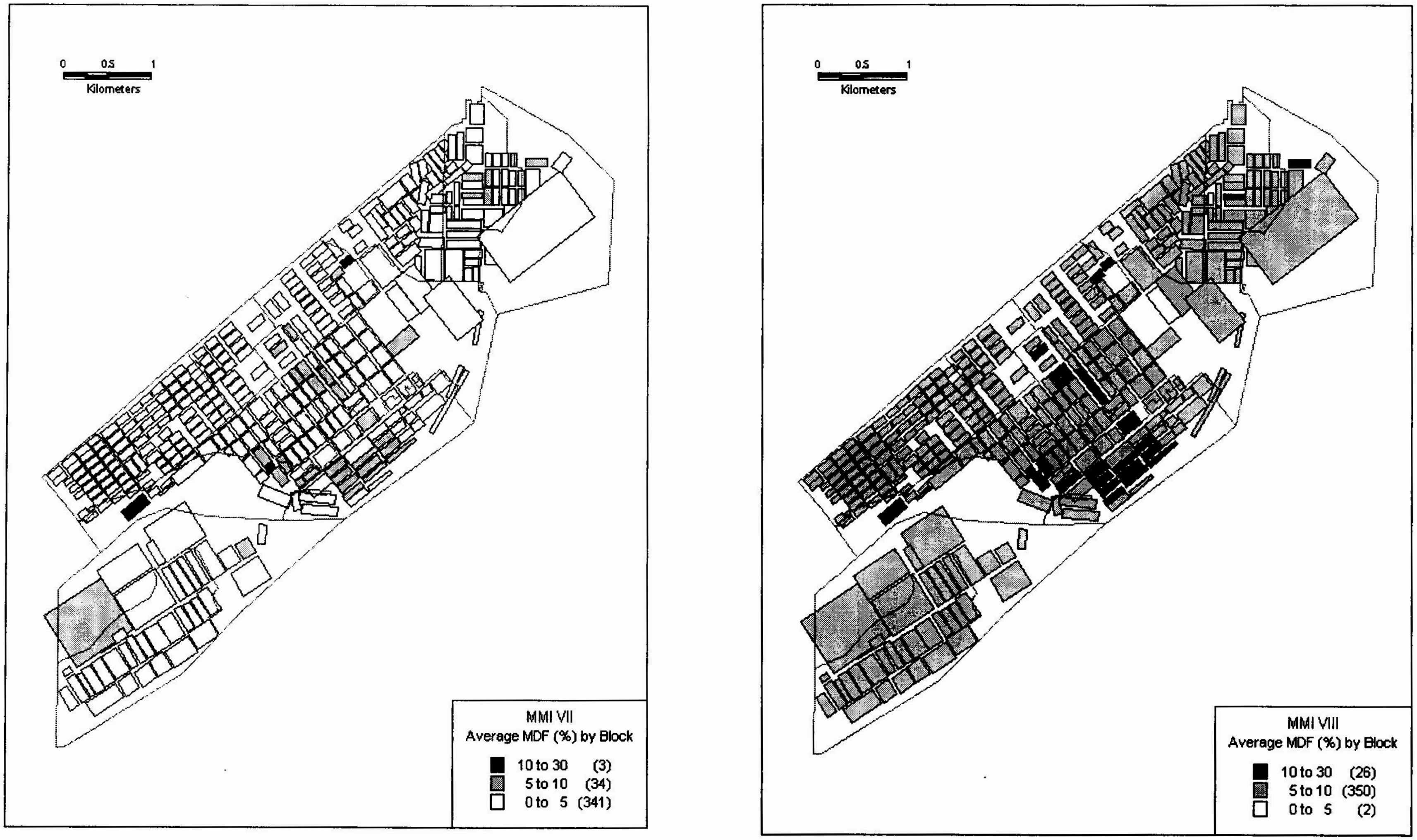

Fig. 2. Distributions of building damage in New Westminster for Modified Mercalli Intensities, MMI=VII and MMI=VIII.

Nonstructural Damage, MMI=VII
Displacement Sensitive

Nonstructural Damage, MMI=VII
Acceleration Sensitive

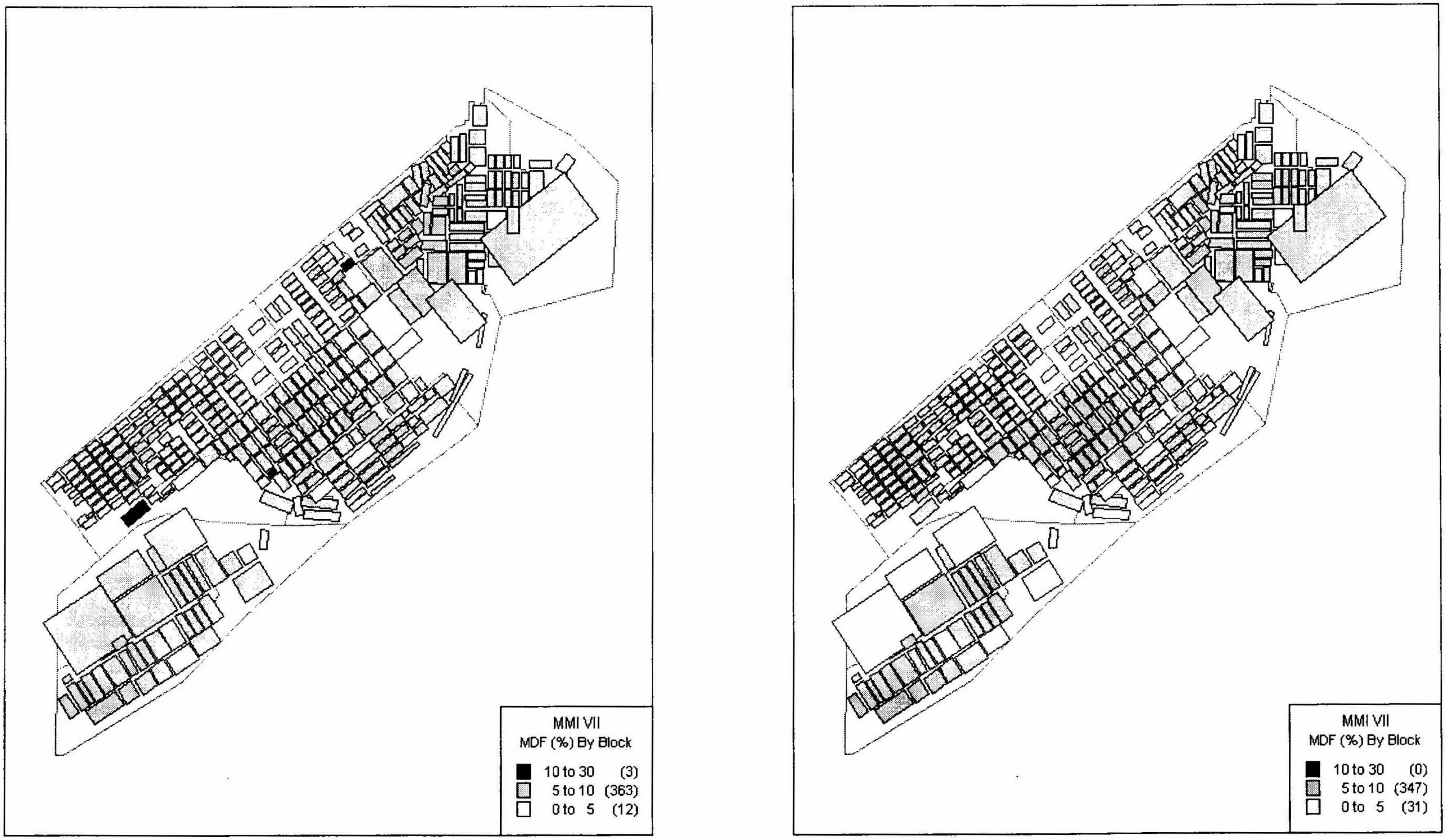

Fig. 3. Distribution of nonstructural damage.