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Post-earthquake solid waste management strategy (for the City of Vancouver and the surrounding area)

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ABSTRACT

Southwestern British Columbia, the region of most significant seismic activity in all of Canada, faces a high risk of a major earthquake occurring at any time. Earthquake emergency preparedness plans have been developed for the West Coast Lower Mainland (Lower Mainland). However, the densely populated City of Vancouver and the surrounding area remain in need of a plan for clean-up and restoration of the potentially disaster-stricken region. The necessity of having a post-earthquake solid waste management strategy at the time of an earthquake is evident throughout the study when issues such as public health and safety, short- and long-term economics, and environmental aspects are addressed. The objective of the study is the development of an operational post-earthquake solid waste management strategy that takes into consideration prior knowledge of: 1) emergency routes that need to be cleared immediately following the occurrence of an earthquake; 2) landfill capacities for ultimate disposal of solid waste; 3) availability and feasibility of alternate disposal methods (such as recycling, etc.) in order to maximize diversion of materials from landfills; 4) areas that can be utilized as temporary storage for large amounts of disaster debris and municipal solid waste; 5) contingency plans in the event that regular municipal solid waste collection is interrupted; and 6) availability of and accessibility to heavy debris removal machinery and manpower. The paper presents the rationale for developing a post-earthquake solid waste management strategy for the Lower Mainland; identifies the main problems associated with earthquake-generated solid waste, and how they are further complicated by the unique features of the Lower Mainland; provides a brief discussion of the six founding factors of the operational strategy; and concludes with some preliminary recommendations. The paper is, in essence, a compilation of the progress made thus far in achieving the goal of the study.

INTRODUCTION

Southwestern British Columbia, the region of most significant seismic activity in all of Canada, faces a high risk of a major earthquake occurring at any time. It is beyond the scope of this paper to assess the risk of a major earthquake, or to make any definitive predictions regarding a potential earthquake. Instead, the paper states several key assumptions about the potential earthquake, which are directly applicable to post-earthquake solid waste management.

Earthquake damage estimates are available for Southern California, Alaska, and Japan, as well as other areas around the world. This information emphasizes that the resulting quantities of disaster debris are unmanageable by conventional means of solid waste management. Based on an earthquake damage projection study (CMHC, 1990), the damage in the West Coast Lower Mainland (Lower Mainland) caused by a major earthquake is expected to be quite devastating. Managing the consequences of such severe damage will pose a massive problem in the Lower Mainland..

Despite the existence of earthquake emergency preparedness plans, the densely populated City of Vancouver and the other areas within the Lower Mainland lack plans for clean-up and restoration of the potentially disaster-stricken region. Without a clean-up strategy in place, or at least giving consideration to the issues that are bound to be raised following an earthquake, an ad-hoc response will inevitably cause a number of problems for the future. The problems will be either irreparable, or rectifiable only at substantial costs. Under such conditions, as observed in cities that have faced such a predicament, the initial solution will be to landfill the debris. However, the quantities of debris involved are immense. The landfill capacity will either be entirely depleted even before the problem of the disaster debris disposal is solved, or the life expectancy of the landfill for municipal solid waste (MSW) disposal will be substantially shortened. As a result, a problem of MSW disposal for the future will be created, and the problem of disaster debris disposal will still remain unsolved. Furthermore, the absence of a contingency plan, in the event that regular MSW collection is disrupted, will pose more problems. Contamination of earthquake debris with domestic waste will increase as time passes without collection. Such a situation will make the disposal of disaster debris even more difficult by seriously limiting the disposal options. In addition, a significant disruption in MSW collection poses increased health and safety hazards to the general public.

Purpose of the study and objectives of the paper

Presently, a study is being conducted in an attempt to rectify the situation presented above. The objective of the study is to develop an operational strategy to optimize the solution to the post-earthquake solid waste management problem, and mitigate disaster impacts.

To meet the objective of the study, the problems associated with earthquake-generated solid waste must be investigated and identified in the Lower Mainland. A range of solutions must be proposed and considered.

Presented in this paper are the purpose, scope, and assumptions of the study; issues associated with earthquake-generated solid waste; factors to be considered during the development of the post-earthquake solid waste strategy, and how they are affected by the unique features of the Lower Mainland; and preliminary conclusions and recommendations.

Scope

The scope of the study addresses two post-earthquake solid waste streams: 1) disaster debris, and 2) municipal solid waste. The first waste type is especially problematic due to the immense quantities involved. This category includes structural and non-structural debris (mainly inert and wood material) generated by earthquake ground motions. The main adversity of the second waste type is the increased health and safety hazard to the general public. This category includes typical MSW (i.e., garbage generated by the general public); MSW resulting from altered consumption of goods following the earthquake (e.g., increased canned goods and bottled water); and solid waste generated as an indirect effect of the earthquake (e.g., food spoilage due to power failure).

The study applies to earthquakes resulting in damage that generates one or both of the solid waste streams mentioned.

Two-tiered strategy

Response and recovery from an earthquake occurs essentially in two stages: 1) initial immediate response, when rescuing human life is the primary objective; and 2) subsequent post-emergency recovery, when human life is no longer in jeopardy. Therefore, the two-tiered strategy must consist of temporary quick debris removal solutions, and longer-term economically and environmentally driven approaches to solid waste management, which includes debris removal.

Assumptions

Developing a post-earthquake solid waste management strategy necessitates making several assumptions.

1) Type of earthquake to affect the Lower Mainland
A large subduction earthquake is expected to occur off the west coast of Vancouver Island. The next version of the National Building Code (NBC) will reflect the probable subduction motions. However, seismic design in the Vancouver area is controlled by crustal earthquake motions, because of the estimated distance from the potential subduction source. Therefore, the type of earthquake to profoundly affect the Lower Mainland is a crustal earthquake.

2) Magnitude and intensity of earthquake
The magnitude and intensity of the expected earthquake are based on the NBC 1995 design earthquake. The design earthquake has a 10% probability of occurrence in 50 years (i.e., has a recurrence interval of 475 years). The corresponding ground motions in the Vancouver area are assessed to be 0.23 g (i.e., 0.23 times the acceleration due to gravity) on firm ground, and 0.29 g on soft ground. There is no direct correlation between a ground motion value and an earthquake magnitude or intensity. However, common practice in the Vancouver area is to use magnitude M = 7. The intensities associated with such an earthquake are on the order of VII - VIII on the Modified Mercalli Intensity (MMI) scale.

3) Location of epicentre
It is impossible to estimate the epicentre location of a potential earthquake with reasonable accuracy, particularly due to the lack of active faults in the Vancouver area. The location of the epicentre will be such as to result in the assumed ground motions. According to the report by CMHC (1990), the epicentre will be relatively far removed from densely populated regions.

4) Type of damage
Damage caused by the earthquake will result from ground shaking and ground failure; the earthquake will not be augmented by a damaging tsunami.

Bridges that have undergone seismic retrofitting in compliance with the most recent NBC 1995 will not sustain major damage. Bridges built in compliance with earlier versions of the NBC and not retrofitted, will sustain damage with partial or complete failure. Failure will occur either along the bridge spans or access routes.

The effect of the earthquake on buildings will be as described by the Modified Mercalli Intensity scale. For MMI = VII, the damage will be negligible in buildings of good design and construction; slight to moderate in well-built ordinary structures; considerable in poorly-built structures; some chimneys will be broken. For MMI = VIII, the damage will be slight in specially-designed structures; considerable in ordinary substantial buildings with partial collapse; great in poorly-built structures; chimneys, factory stacks, columns, monuments, and walls will fall; heavy furniture will be overturned. In addition, significant amount of damage will be non-structural in nature (e.g., to the contents of the building structures). Unreinforced-masonry-type structures will sustain severe damage or full collapse.

Damage to roads will consist of horizontal and vertical displacement of soil foundations due to earthquake ground-wave motions. Both concrete and asphalt road structures will be affected.

5) Severity of damage
Damage as a percentage of replacement cost (reflecting the assumed ground motions) will be 5.7% in areas with firm ground, and 6.6% in areas with soft ground. Given a number of further assumptions, and utilizing the available data, a minimum of 50 million of tonnes of disaster debris will be generated as a result of the assumed earthquake.

6) Spatial distribution of damage
Damage will vary within the Lower Mainland. The most significant damage will be restricted to a number of isolated areas throughout the Lower Mainland. There will be a higher frequency of damage occurrence in areas on soft soils and/or with poor construction. There will not be general devastation everywhere.

7) Laws and regulations
Transportation and solid waste disposal laws and regulations will be suspended or amended during the initial state-of-emergency phase, when human life is at stake, and search and rescue crews are in full operation. In an attempt at a speedy restoration to normalcy, all laws and regulations will be reinstated during the recovery phase, directly after the state of emergency is terminated.

ISSUES AND FOUNDING FACTORS

Post-earthquake solid waste issues

In terms of solid waste, the single most problematic consequence of earthquakes is the enormous quantity of waste generated. The amount of earthquake-generated solid waste requiring management causes tremendous strain on all available resources, from manpower to equipment to disposal options to funds. Managing earthquake-generated solid waste is complicated by contamination of inert, and relatively easily handled waste with unknown and/or hazardous substances. Earthquakes increase the quantities of waste not generated under normal circumstances, such as food spoilages due to power failures.

Earthquake events disrupt regular MSW collection. Earthquakes also alter consumption of food products, and thereby, alter the pattern of waste generation (e.g., increased quantities of containers, which are recyclable).

Unique features of the Lower Mainland affecting post-earthquake solid waste issues

The geology in the Lower Mainland is quite diverse, ranging from stiff soils and bedrock to saturated, liquefiable soft soil deposits. The latter soil type is expected to cause substantial problems during the earthquake, concentrating most heavily affected areas that undergo greatest damage.

Furthermore, the Lower Mainland is a mountainous region, whose many steep slope are inhabited by people. Earthquakes are renowned for causing slope failures and landslides, which result in the most devastating damage.

Transportation issues greatly hinder the access to and removal of earthquake-generated solid waste. The geography of the Lower Mainland is such that access to the only municipal landfill within the area depends on the functionality of bridges. Transportation over water is also possible, provided that barges and other ocean vehicles are available.

The Lower Mainland has never suffered a major earthquake at any time during its existence as a densely populated urban centre. Structures dating back to the turn of the century still stand, and are utilized today. This is very much in contrast to such areas as Los Angeles and San Francisco in Southern California. There, construction is newer, building standards have been more stringent, and building practices are more seismically conscious due to the high frequency of occurrence of large earthquakes.

Founding Factors of the Operational Strategy

1) Emergency routes
Disaster Response Routes have been identified, and posted with appropriate signs within the Lower Mainland. Immediate debris removal will be required on these routes in the interest of saving lives, and protecting property following the earthquake. The fastest way to accomplish this will be to plow the streets clear of debris and abandoned vehicles, off to the side, or perhaps, into smaller, connecting streets. These accumulations of debris and vehicles will constitute the first (short-term) temporary storage sites. These materials will then be available for separation, collection, and transportation to more organized temporary storage facilities or final disposal sites.

2) Landfill capacities
Conventional landfilling should be viewed as a final disposal option for disaster debris only when other disposal alternatives are exhausted, not available, or economically prohibitive. Considering present day practices and technology, landfilling is an irreversible solution to the post-earthquake waste disposal problem.

There is only one municipal landfill in operation (Vancouver Landfill at Burns Bog in Delta) within the Lower Mainland. The remaining capacity of the landfill is 20 million tonnes (according to the 1997 forty-year agreement). Another municipal landfill in the vicinity (Cache Creek Landfill, north-east of Vancouver) has a remaining capacity of 3.5 million tonnes, with a seven-year life expectancy. However, the hauling distances from the potential sources of disaster debris (and thus, the transportation costs) present an economic deterrent for using this location as a debris disposal solution.

There is only one privately owned demolition, landclearing, and construction (DLC) landfill of consequence, in terms of capacity, in operation in the Lower Mainland (Ecowaste Industries Ltd.). The DLC landfill accepts only inert materials, and provides a separate compost facility for yardwaste. The remaining permitted DLC landfill capacity is approximately 2.5 million tonnes.

Landfilling alone will not provide a complete debris disposal solution. The overwhelming volumes of material generated in the earthquake would deplete present landfill capacities long before all the disaster debris is disposed of. Utilizing the entire available landfill capacity in the Lower Mainland would satisfy only about a half, or a third of the disposal demand generated by the earthquake.

3) Availability and feasibility of alternate disposal methods
The goal of alternative disposal methods is to divert as much waste as possible from the landfill. In an earthquake event, the goal is also to manage the quantities of solid waste generated by the earthquake in excess of the available landfill capacity. A simultaneous objective of alternate disposal methods is to restore beneficial uses to waste materials generated during an earthquake. A number of conventional and innovative alternatives can be utilized. These are briefly summarized below.

The success of the recycling program in the Los Angeles area following the 1994 Northridge earthquake demonstrates that recycling of disaster debris is a feasible solution. The main components of disaster debris that can be recycled include concrete, metals, asphalt, brick, gypsum, and wood, and yardwaste through composting. Extensive organization and coordination, and initial economic investment are required to set up the debris recycling infrastructure. However, once in full operation, it is a cost-effective, environmentally conscious diversion alternative to landfill disposal. In addition, the earthquake recycling infrastructure can be used in future programs to save revenue through direct costs, and the future cost of landfilling by avoiding disposal.

Ocean dumping is currently utilized as a disposal alternative for certain waste materials, but requires permitting by Environment Canada. Stringent criteria apply to the deliberate disposal at sea, restricting the type and volume of waste material. Presently, the main materials disposed of in British Columbia are limited to dredged sediments, clean excavation soils, and dredged wood waste from forestry sites. Certain inert disaster debris may also be suitable for ocean disposal, if it meets the criteria of the ocean disposal permit. Alternatively, the criteria may need to be re-evaluated, and where appropriate, altered to provide for the disposal of inert disaster debris.

Concrete and dirt (soil) constitute the largest portion (on mass basis) of earthquake-generated debris. Figures emerging following the 1994 Northridge Earthquake indicate that this type of material accounts for 50 - 90% of disaster debris. The nature of this material may be appropriate, and structurally comparable for building, re-building, or reinforcing sea and river dykes, and river bank protection. Material used for this purpose must not be contaminated with other types of debris, and must be well sorted. Current practice of dyke construction and river bank protection dictates mainly utilization of well-graded, easily compactable soils, with limited application of crushed concrete.

Although limited in application in North America, artificial reef construction uses concrete as its most preferred building material (D'Itri, 1985). Scrap metal from ships or cars has also been employed for this purpose (Waldichuk, 1988). While enhancing fish habitat, which is the primary objective of artificial reef construction in other parts of the world (mainly in East Asia), many reef projects in the United States have solid waste disposal as a secondary or even primary objective (D'Itri, 1985). Many vehicles are destroyed in an earthquake, and earthquake debris consists mainly of concrete. Therefore, these materials should be considered for artificial reef construction as a diversion alternative.

Landfilling of disaster debris can also be conducted in man-made or natural cavities in the earth's surface or subsurface. There exists a number of open excavation sites in the Lower Mainland, which have been created by prior mining activities. Using inert disaster debris to back-fill these cavities (in a responsible, environmentally sensitive manner) would result in substantial savings in capacity of the engineered municipal landfill.

Provided that the Burnaby Incinerator is functioning following the earthquake, much of the putrescible waste can be incinerated. In the event that the Burnaby Incinerator is out of commission, all perishable waste will need to be landfilled.

4) Temporary storage areas

In order to effectively manage disaster debris, in terms of cost, disposal capacity, and environmental sensitivity, temporary storage areas will be required. Based on the earthquake experience from Southern California, it takes years to remove and dispose of disaster debris. Temporary storage sites are especially necessary for processing and separation of co-mingled debris. Thus, potential sites should be large enough to facilitate several waste piles, sorting equipment, and vehicles transporting the debris. Accessibility is also an essential consideration. Temporary waste stockpiles should not conflict with, or be located near areas designated for temporary shelters for people. A special provision should be made for temporary storage of hazardous materials. Temporary hazardous waste storage sites should have restricted access, and be protected from the elements. Potential disaster debris storage sites to consider include empty fields and parks; parking lots; tennis courts; sites of collapsed buildings; curbsides and streets (not essential as access routes); the landfill; large empty warehouses (preferred location for storing hazardous waste).

5) Contingency plans for regular municipal solid waste collection

Interruption in regular municipal solid waste collection leads to increased contamination of inert disaster debris, and increased health and safety hazard to the general public. The public should be informed about how to handle their domestic waste, and when collection can be expected to occur in the event that the disruption is prolonged for an extended period of time. In the absence of regular collection, residents should be encouraged to store their putrescibles in cool, enclosed places for as long as possible. Such strategy will promote minimization of solid waste generation, as well as promote reuse of waste materials as appropriate. Temporary storage sites for domestic waste can also be established.

6) Availability of and accessibility to heavy debris removal machinery and manpower

The main adversity to affect debris removal will be inaccessibility due to breaks in transportation routes. Transportation route interruptions may be in the form of bridge failures, large earth displacements along roads, and road blockage by disaster debris. Heavy debris removal equipment, once located, can be transported over land, or alternatively, over water on barges, or by air using military air lifting equipment. Similarly, debris can be transported over land, or loaded onto barges. Availability of and accessibility to heavy machinery and qualified manpower can be facilitated by prior knowledge of equipment and manpower sources. These sources include private owners, contractors, and government agencies (including the military) within the Lower Mainland, as well as throughout British Columbia, the Prairie Provinces, and the neighbouring States.

SUMMARY AND CONCLUSIONS

There is a high risk of a devastating earthquake in the Lower Mainland. The consequence of such an earthquake will cause an unprecedented problem. To achieve efficient and effective solid waste management, it is imperative that an operational strategy be developed prior to the occurrence of the earthquake. In the absence of a plan, there is reason to believe that less than optimal solutions will be implemented. It is the objective of this study to minimize the effects following the disaster, and optimize the course of action undertaken to solve the post-earthquake solid waste management dilemma. The scope of the study is identified as pertaining to two waste streams: disaster debris and MSW. In this paper, key assumptions regarding the potential earthquake, and its devastating effects on the Lower Mainland are made. The vast quantities of disaster debris; potential contamination of inert materials with hazardous substances; generation of atypical waste; and disruption of regular MSW collection are the main problems associated with earthquake-generated solid waste. The key features unique to the Lower Mainland that augment the post-earthquake solid waste management problem are the geology, topography, and geography of the region. Absence of severely damaging seismic events in the Lower Mainland further compounds the disaster debris dilemma. Landfilling all of the earthquake-generated solid waste is not an option in the Lower Mainland. The quantities of disaster debris, and the capacity of landfills dictate that diversion alternatives be used. The alternate solid waste management techniques that may be utilized, or should be considered in the Lower Mainland include recycling and composting; ocean dumping; sea and river dyke construction; artificial reef construction; landfilling of man-made or natural, surface or subsurface cavities; and incineration, if facilities are operational. Temporary storage sites will be required for stockpiling and processing disaster debris. These sites should be pre-selected and evaluated prior to the earthquake event. Special provisions will be necessary for stockpiling and disposing of hazardous materials. To ensure the highest level of public health and safety during post-earthquake conditions, provisions for handling of domestic waste need to be communicated to the general public. Access to heavy debris removal equipment and manpower can be facilitated by transportation over water or by air in addition to, or in place of land transport. Pre-planning is the key to success in earthquake recovery and restoration.

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