The Effect of the January 13, 1993, Earthquake on the Mona Campus, UWI: The Case for an Earthquake Vulnerability Reduction Programme

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Abstract

On January 13, 1993, an earthquake of magnitude 5.4 on the Richter scale centred at latitude 18.06 ^{0}N and longitude 76.77 ^{0}W damaged several buildings on the Mona Campus of The University of the West Indies (UWI). The location of the earthquake on a segment of the Wagwater Fault belt confirmed that this fault can be expected to generate moderate to large earthquakes in the future. The proximity of the Fault to the Mona Campus, and the damage suffered in this moderate earthquake raises serious questions as to whether the campus can survive a large earthquake without a crippling loss of lives, buildings, infrastructure and equipment.

The effects of the recent earthquake indicate that an earthquake loss reduction programme is urgently needed for the Mona Campus. This programme should have as its major objectives, saving of lives, reducing damage and ensuring rapid recovery. The necessity of such a programme must be viewed in the context of the uncertain climate now prevailing in the re-insurance industry. It is likely that Caribbean territories will have to bear greater and greater proportions of the risk associated with natural hazards. A loss reduction programme will therefore result in considerable saving of money should a large earthquake occur. Such a programme will also set an example in disaster mitigation for the Region and will support the objectives of the International Decade for Natural Disaster Reduction.

This paper summarizes the damage caused by the January 13 earthquake and examines the implications for future earthquakes. It then proposes the outline of a loss reduction programme for the Mona Campus.

Introduction

The Mona Campus of the UWI is located on six hundred acres nestled between Long Mountain and the Port Royal Mountains (Figure 1). It has a combined student and staff population of approximately seven thousand, five hundred and fifty. The campus also houses the teaching departments of the University Hospital of the West Indies and the staff housing estate - College Common.

The earthquake of January 13, 1993, which shook the campus at about 12:11 PM local time, was the largest felt in eastern Jamaica since 1907 (Grandison, pers. comm.). The epicentre was located on the Wagwater Fault belt at latitude 18.06 ^{0}N and longitude 76.77 ^{0}W or approximately three kilometres north of the Mona Campus. The seismic data obtained from this earthquake suggests that the Wagwater Fault is capable of generating a large earthquake. Shepherd et al. (1988) also concluded that the Wagwater Fault is seismically active, and Ahmad (1993) and Grandison (1993) support this conclusion.

The tremor caused widespread damage in the Kingston - St. Andrew area. The most intense damage from ground shaking was concentrated over the river terrace deposits in August Town where several private dwellings were badly damaged. Elsewhere, minor structural damage to engineered buildings was reported. On campus, the Faculty of Natural Sciences and the main administrative buildings were worst affected.

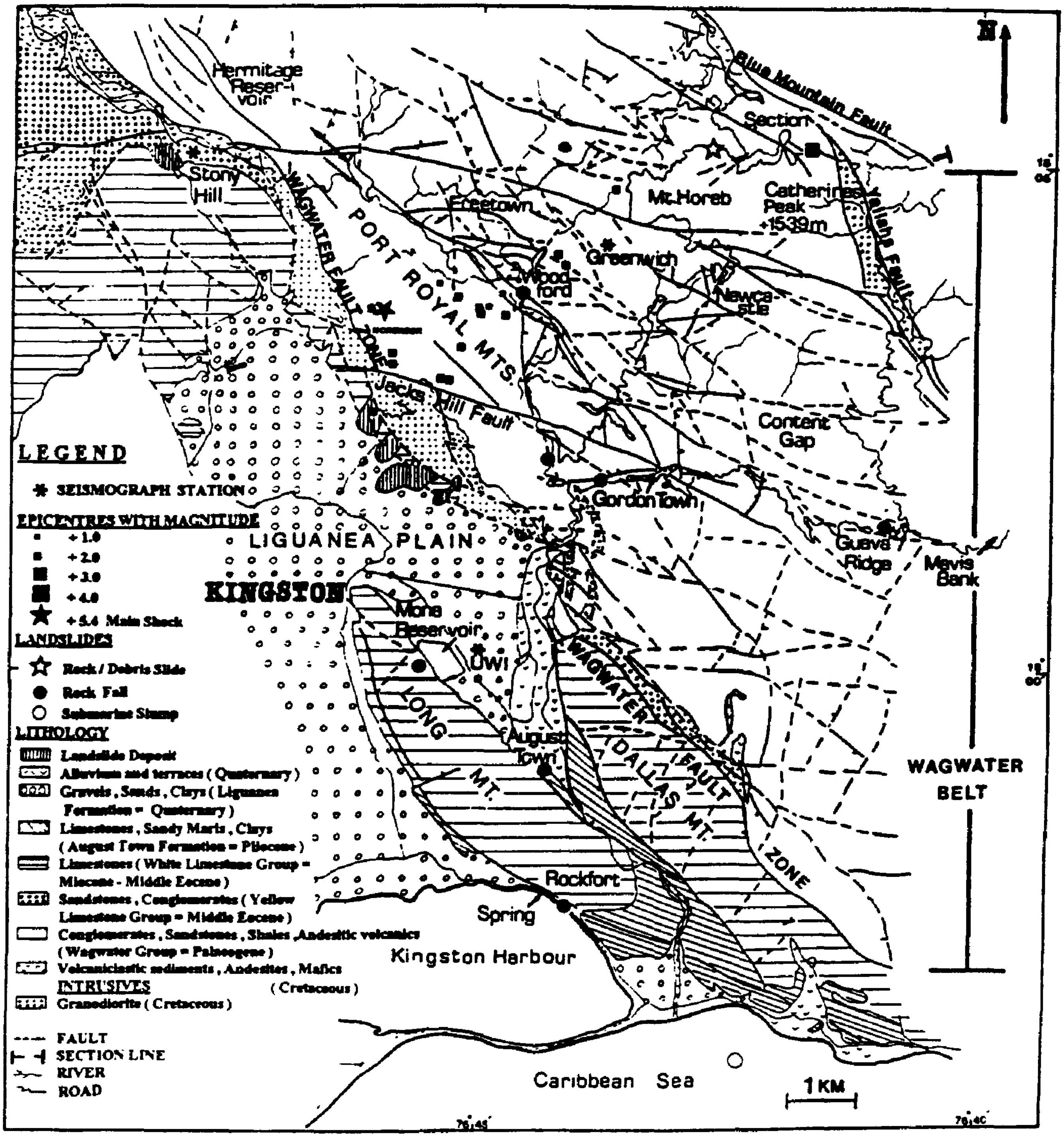

Figure 1: The geology and structure of the UWI Mona Campus and surrounding areas, with epicentre of the January 13, 1993 earthquake shown. (From Ahmad, 1993).

At the time of writing this paper, the total cost of damage to the Mona Campus is still not known. Repairs so far have cost two million dollars ($J 2.0m), ($27 = $US1) but these are still being carried out. Replacement of broken laboratory glassware and equipment will cost at least one hundred and fifty thousand dollars ($J150,000.00).

The Geology of the Mona Campus

The campus is underlain by the Pleistocene Liguanea Formation, consisting of lenses of gravels, sands and clays (Geological Sheet 25). Its maximum thickness is unknown, but is of the order of several hundred feet (Geological Sheet 25). Running in an arc roughly northwest to southeast to the north and east of the campus, the Wagwater Fault Zone demarcates the Tertiary bedrock formations from the Liguanea Alluvium (Figure 1). This geology is problematic from three points of view. First the Wagwater Fault can cause strong earthquakes. Second, the alluvial deposits can cause amplification of ground acceleration and third, the nature of the alluvium, combined with the high water table characteristic of the Liguanea Plain makes it susceptible to liquefaction. This combination of factors by itself offers a strong argument for a vulnerability reduction programme for the Mona Campus.

Response to Earthquake

Fortunately the earthquake struck in the semester break when classes were suspended. The response is best described as disorganized. Some staff and students evacuated buildings immediately the shaking stopped, while others had to be encouraged to leave. The lights in the Assembly Hall building went out. As there are no windows on the upper floors, staff were forced to feel their way out in total darkness, in many cases over furniture and ceiling tiles which had fallen, as no emergency exit lights functioned on the second floor. There were no instructions about when it was safe to re-enter buildings, so staff wandered back in eventually at their own discretion and risk.

Inspections were carried out by the University's Maintenance Department over the next few days, and local engineers were called in to carry out an initial rapid inspection on the afternoon of January 13. Engineers from the Faculty of Engineering at the St. Augustine campus were also asked to inspect damage and to make appropriate recommendations.

Damage to the Mona Campus

Damage to buildings was widespread but in most cases not severe. The engineers from the Faculty of Engineering, Dr. A. K. Sharma and Mr. Keith Sirjue inspected the campus between January 17 and 18 and reported the following damage:

Teaching Departments

a) In the De La Beche Building, which houses the Departments of Geology and Geography, several block walls and columns exhibited distress as a result of the earthquake.
b) Block walls in the Department of Botany were extensively cracked.
   Beams and roof slabs exhibited cracking.
   In addition, most departments reported cracks to walls, and some breaking of window panes.

Bursary - Registry Buildings

a) All four corner walls of the Council Chamber were severely cracked and had to be replaced.
b) Damage to infill walls in the Registry-Bursary complex and failure of one of these walls.

c) Cracks in a beam in the Registry and spalling of concrete.

Libraries
i) Extensive cracking of walls and fins, and cracking of cross-beam joining fins in the Main Library. Cracks in walls of Science Library.

Teaching Hospital
i) Cracks in several walls of the Department of Pathology.

Infrastructure
i) A 75 kV three phase transformer was damaged due to loss of cooling fluid.

Halls of Residence.
i) Minor cracks reported.

College Common Residences
i) Minor cracks reported.

Apart from damage to the buildings outlined above, there was also damage to the contents of buildings. In addition, movement and toppling of furniture, ceiling partitions, lamp shades, laboratory glassware and chemicals could have resulted in injury to the occupants of these buildings. In the Science Library shaking and overturning of shelves caused several hundred books to topple.

Some of the observed damage was evidence of poor workmanship or design and in one case poor engineering practice. Sharma and Sirjue (1993) list the following as giving cause for concern because they suggest distress to the main structural elements of buildings, failure of which could result in catastrophic consequences:-

a) The De La Beche Building appears to have been inadequately designed for earthquake loadings and should be analyzed with a view to retrofitting

b) The cracking of a beam and concrete fins in the Main Library apparently resulted from the direct linking of the extension to the building to the existing building, poor engineering practice which can alter adversely the response of each component building to ground motion

c) The shear cracks in the floor and roof of the Chemistry Department and the Radiology Department require further analysis

d) The shear cracks in the Department of Botany are indicative of overstressing. Remedial measures are indicated.

The Need for a Vulnerability Reduction Programme

The probability of a large earthquake being generated by the Wagwater or other onshore faults necessitates a thorough review of the preparedness of the Mona Campus. The performance of the structural and non-structural elements of various buildings in the recent earthquake suggests that much work needs to be done in terms of reducing the vulnerability to a future earthquake. Two major considerations render the development of a vulnerability reduction programme a matter of urgency. The first is the proximity of the Mona Campus to the Wagwater Fault. The southernmost section of the fault passes within one kilometre of the campus. High intensities can therefore be expected from earthquakes generated along this fault. The second factor is the probability of amplification of ground acceleration across the alluvial deposits on which the campus is built. Such amplification is known from other earthquakes, e.g. the effects of the Michoacan, Mexico, earthquake of

September 1985 in Mexico City, (Singh et al., 1989). Shepherd and Aspinall (1980) estimate that amplifications of three to four times that on bedrock could occur in the Liguanea Formation under favourable conditions. Proximity to the fault and amplification of ground acceleration is likely to cause greater damage to structures than would normally be expected.

Prediction of likely problem areas is possible from reviews of earthquake damage elsewhere and from experiences of previous earthquakes in Jamaica. Based on these, the following areas are suggested for attention.

The Registry/Bursary complex

The irregular I - shape of this building is the type of design which is known to react badly to earthquakes (Adams, personal communication). The "soft" first floor which forms the undercroft is also known to react poorly to earthquake stresses, (Esteva and Blasco, 1989). Further complications are introduced by the fact that the southernmost section is an extension to the main building. This can set up differential movement which can cause additional damage to buildings if extensions are not properly engineered (Sharma and Sirjue, 1993).

Older Buildings

Older Buildings, such as some in the Faculty of Natural Sciences, apparently were not adequately designed for earthquake loading and risk severe damage if not strengthened.

New Additions

The structural linking of new additions to existing buildings can cause damage to both buildings. This was demonstrated in the case of the Main Library.

Infrastructure

Electrical cables, the new fibre optic cable, transformers, water pipes, gas lines, hazardous materials stores, are all susceptible to earthquake damage.

Laboratories

Laboratories are particularly susceptible to loss of equipment, hazardous materials spills and fires. People working in the laboratories at the time of an earthquake risk severe burns from chemicals, some of which may be boiling, as well as from fires caused by rupturing of gas lines. This in addition to the "normal" hazards of toppling furniture, breaking glass, etc.

External Threats

Threats external to the campus which should be taken into account in any vulnerability analysis include:-

a) Breaching or overtopping of the Mona Reservoir
b) Damage to the building housing the National Water Commission hazardous materials store
c) Rock falls/debris flows from Long Mountain
d) Fuel spills and fire hazard at nearby petrol station.

Economic Considerations

The replacement value of the property at Mona is approximately two billion Jamaican dollars. This includes the campus, the housing estate at College Common, the teaching departments at the University Hospital of the West Indies, and the building contents. Insurance premiums have doubled over the last year, but even at this level of increase it has been difficult for the campus to obtain coverage. One reinsurance company which accepted fifty per cent of the risk last year has accepted only fifteen per cent this year. The Mona administration anticipates considerable difficulty in obtaining coverage for next year, as well as another doubling of rates. It seems likely that the insurers will offer coverage for perils such as fire and theft, but will refuse to cover natural hazards.

If the Mona Campus is indeed forced to insure itself, the need for a vulnerability programme becomes even more urgent. The cost of repairing damage from Hurricane Gilbert (1988) was about seventy-five million dollars (J$ 75m). This figure is not complete, as some of the historic wooden buildings which were destroyed have not been replaced. Whereas Gilbert did most damage to roofs and building contents, an earthquake will cause greater structural damage, and more damage to infrastructure. One can therefore expect a higher cost from a large to strong (M 6-7) earthquake than from Hurricane Gilbert. There is, of course, a significantly higher risk of loss of life, and injuries. Loss of buildings, equipment and contents from secondary hazards such as fires and hazardous materials leaks and spills must also be taken into account. Consider too, that there is no fire fighting capability on the campus. The nearest fire station, some eight kilometres away will almost certainly not be able to respond immediately after an earthquake. The potential for loss from an earthquake and secondary hazards might therefore be from one to two hundred million dollars ($J100-200m), depending on the size of the earthquake, its epicentral location and the time of impact.

While an analysis of the cost versus benefits to the University of a loss reduction programme is beyond the scope of this paper, it is instructive to look at a simple example. A laboratory in the Chemistry Department lost glassware valued at $2695.65. This slid from the working bench and shelves. For about $350.00 all the shelves and workbenches could have been fitted with one inch high strips which would have prevented the equipment sliding off. Benefits in this case go beyond mere economics. Burns from chemicals and cuts from broken glass would also be minimized by this simple retrofit. Although all savings from retrofitting would not be of this magnitude, it is safe to say that most retrofitting would cost less than the damage likely to be incurred without it.

Planning considerations

The next compelling argument for a vulnerability reduction programme is the protection of the campus population. Since a proportion of this population is resident on the campus, and with the increasing use of the plant for a variety of purposes during the semester and summer breaks, the potential exists for loss of life and injuries at all times. The primary objective of the programme, therefore, must be to raise the level of awareness of the population so that loss of lives and injuries can be prevented or minimized.

Another objective of the loss reduction programme must be the anticipation of disruption likely from an earthquake, and shortening of recovery time. After the January 13 tremor it took about one week for a reliable power supply to be re-established in some areas of the campus. This resulted in considerable loss of worktime for those buildings on the damaged circuit which had no auxiliary power. If a larger earthquake causes more widespread loss of power during, say, examinations, this will seriously affect theory and laboratory examinations. Such a contingency must be planned for. Interruption of examinations will be problematic in any case, especially for those papers which are common across the three campuses. Clear guidelines must be worked out for resitting of examinations interrupted by an earthquake. From the evidence of the January 13 tremor, it seems that rehousing of laboratory examinations might be necessary if a large earthquake occurs. But even without destruction of buildings, inspection, clean-up and temporary repairs can be expected to incur several weeks of lost time. The Science Library estimates that it required about two weeks to return to normal after the recent earthquake - and this did not include repairs of damage to the building.

Other planning considerations must include housing of the campus' resident population and provision of basic services after a damaging earthquake. Will foreign students be sent home? If so at whose expense? How will health and welfare enquiries be handled? For how long can the campus be closed without causing irretrievable loss of time for the academic year? If this time is exceeded will students be asked to repeat this entire year? How will the campus cope if the Registry-Bursary complex suffers major damage and loss of records? Are there adequate back-up systems in place for student records, accounts etc.? How vulnerable is the new fibre-optic network and peripheral instrumentation linked to the supercomputer to an earthquake and how will its loss affect the campus, given that this network will carry most of the campus' teaching and research data and administrative records? These and similar questions must be answered in planning for earthquakes.

UWI's Responsibility to the Wider Community

The role of UWI as an opinion leader in the society increases its responsibility to set an example in matters such as loss reduction and employee safety. Of equal importance is the fact that Jamaica's Earthquake Unit is housed on the campus. Its ability to function effectively will be critical to the provision of data necessary to emergency response after an earthquake. Its ability to collect data from the earthquake is also essential to building a data base which will eventually allow a better understanding of the earthquake hazard and which will allow forecasting and planning based on scientific data.

Recommendations

The University Administration has already recognized the need for an emergency management and vulnerability reduction programme (Carby, 1993). There is, however, necessity for action to be urgently taken to implement this programme. Such a programme must include the following elements:-

a) Taking of appropriate policy decisions necessary to facilitate development of an earthquake vulnerability reduction programme.

b) Vulnerability analysis of buildings and systems to establish probable losses from earthquakes of various magnitudes. This should also include cost benefit analyses which will quantitatively justify the programme.

c) Appropriate retrofitting of structural and non-structural elements where necessary. A phased programme starting with simple techniques such as placing restraining wires across laboratory shelves and proper anchoring of furniture can be easily carried out immediately, with larger and more complex retrofitting jobs awaiting the structural analysis.

d) Design of buildings to the building code and use of proper engineering practices during construction.

e) Development of earthquake hazard map for campus.

f) Predictions of disruption likely for various size earthquakes at various times of year, e.g. during registration, during examinations etc. This will form valuable input for planning.

g) Training of staff in personal preparedness, and institution of regular earthquake drills.

h) Training of first response teams in search and rescue, first aid, fire fighting, rapid damage assessment.

i) Development of capacity for post-earthquake data collection, including deployment of portable seismographs and field teams immediately after the earthquake.

j) Development of contingency plan including procedures for rapid inspection and placarding of buildings and procedures for health and welfare enquiries for campus population.

k) Maintenance of emergency lighting systems and safety equipment, and clear marking of exits.

l) The question of laboratories merits special consideration because of the threats from secondary hazards. It may be that special training is required for students of the Faculty of Natural Sciences, this geared towards protecting themselves if an earthquake occurs during practicals. Wearing of appropriate safety equipment must be rigidly enforced, and installation of non-skid surfaces on benches and anchoring of equipment wherever possible should be assigned high priority.

Summary

The expertise needed to successfully develop and implement an earthquake vulnerability reduction programme already exists within the University. The programme could be approached as a multi-disciplinary one involving the Faculty of Engineering, the Department of Geology and the Earthquake Unit, the Department of Economics and the Maintenance Department. One of the benefits of this programme would be the development of a pool of expertise able to carry out similar programmes throughout the Region. Methodology used could be disseminated to other institutions in need of such a programme. The International Decade for Natural Disaster Reduction provides an ideal focus for such an activity, which would have the added benefit of achieving some of the objectives of the Decade.

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