



MINISTRY OF WORKS AND TRANSPORT

NATIONAL CONSULTATION ON EARTHQUAKE SAFETY IN TRINIDAD AND TOBAGO

“Impact of Structural Approvals on the Vulnerability of Building Infrastructure”

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NATIONAL CONSULTATION IN EARTHQUAKE SAFETY IN TRINIDAD AND TOBAGO

SALUTATIONS AND INTRODUCTION

Good Afternoon, **Session Chairperson** , Members of the panel, Members of APETT and different engineering associations, Members of various ministries, Members of ODPM and to all fellow engineers colleagues and other distinguished attendees... Greetings.

My name is Marlon Feveck and I will be presenting on the topic- **“Impact of Structural Approvals on the Vulnerability of Building Infrastructure”**, while my colleague Mr. Montano Graham will provide an insight into the typical defects existing in buildings throughout Trinidad and Tobago based on inspections conducted. We are both representatives of the Ministry of Works and Transport (Designs Engineering Branch).

My presentation today is one that will hopefully provide insightful and thought provoking solutions to predominant and recurring threats.

Much of the loss of life in past earthquakes has occurred due to the collapse of buildings. Both modern and traditional buildings suffer damage if there are no earthquake resistant systems within the structure. In general, the buildings constructed with traditional materials such as stone, brick and adobe which are not engineered to be earthquake resistant, suffer high damage.

DEFINITIONS

Some important definitions to bear/keep in mind as we proceed are:-

Definition for Risk

Probability of loss associated with the physical (construction) phase of a construction project (<http://www.businessdictionary.com/definition/construction-risk.html>)

Definition for Physical Vulnerability

Physical Vulnerability is the expected degree of loss to a given element at risk, particularly to built structures, resulting from the occurrence of a hazard of a given magnitude. (Fell 1994, Fell and Hartford 1997)

Quality Control

In engineering, **quality control** or **quality engineering** is a set of measures taken to ensure that defective products or services are not produced, and that the design meets performance requirements. (http://www.wordiq.com/definition/Quality_control)

Essential infrastructure

During a case of emergency i.e. during and after an earthquake the list of infrastructure that may be deemed critical are as follows:

1. Hospitals and health centres
2. Police/Fire stations
3. Transportation facilities e.g. airports, heliports, major road networks and sea ports
4. Key industrial plants should also be considered because these may have a potential to cause a significant secondary disaster

The overall damage of the general and non-structural components varies and will be influenced by the Target Building Performance Levels. These are Collapse Prevention, Live Safety, Immediate Occupancy and Operational and their characteristics can be seen in Table CI-2. Although in both events success is measured by the absence of deaths and serious injuries. Therefore these facilities must adhere to collapse prevention parameters when being designed or retrofitted.

EARTHQUAKES

Hazardous Earthquake Effects

Ground shaking, in itself, is not dangerous. However, the resulting damage to buildings and other structures and the risk of casualties from falling debris can make it extremely hazardous. Some of the earthquake effects that can be harmful to people are:

Collapsing buildings, walls, bridges, falling furniture or objects, shattering glass windows and mirrors. Debris from collapsing structures is one of the principal dangers during an earthquake since the impact of large, heavy objects can be fatal to human beings. Earthquakes sometimes cause glass windows and mirrors to shatter and this is also quite dangerous. Earthquake aftershocks can result in the complete collapse of buildings that were damaged during an earthquake.

Falling electricity lines. Earthquakes can cause electricity poles to fall and live wires to become exposed or to start fires.

Ruptured gas lines and spillage of flammable substances. Earthquake-generated fires can cause widespread destruction after a major earthquake. Escaping gas from broken gas lines and the toppling of containers with flammable substances (e.g. kerosene, household chemicals, etc.) present a significant threat of explosions and fires, which can cause death and destruction of property. Additionally, water pipes are sometimes ruptured during an earthquake and this compounds the problem of controlling such fires.

Rock slides and/or landslides on mountains and hillsides. During an earthquake, large rocks and portions of earth high up in the hills can become dislodged and rapidly roll or slide down into the valleys.

Floods caused by the collapse of dam walls. Earthquakes can cause dam walls to crack and eventually collapse, sending raging waters into surrounding areas and causing severe flooding

Tsunamis. A tsunami is a large sea wave or series of waves that can be generated by an earthquake. Large tsunamis can completely devastate low-lying coastal areas.

Liquefaction. When sediments with high water content are subjected to prolonged shaking, the pressure of the water held in pores in the sediment gradually increases eventually, the sediments lose all cohesive strength and begin to behave as if they were liquids. Building and other structures sink into the ground or overturn and buried tanks and other cavities rise to the surface. This is known as liquefaction. Liquefaction occurred during the earthquake of 1692 in Jamaica and was responsible for the destruction of the town of Port Royal. Over the past few decades, many parts of the Eastern Caribbean have become increasingly vulnerable to liquefaction because of the increased use of reclaimed land for urban development

<http://www.uwiseismic.com/General.aspx?id=16>

Vulnerability of essential buildings and structures

Given the history of construction in Trinidad and Tobago it is extremely difficult to comment with any degree of certainty on the vulnerability of the essential building infrastructure in the event of a serious earthquake. This is so when one considers the fact

that a number of our key facilities (owned by the state) exceed thirty (30) years of age and the importance of earthquake resistant design in Trinidad and Tobago was not appreciated at the time of design.

However, at present there are approval's agencies such as Designs Engineering Branch of the Ministry of Works and Transport, City Corporation of Port of Spain and San Fernando that ensure the satisfactory requirements of earthquake resistant design in buildings are met as part of their functions.

Another key role of the Designs Engineering Branch is to inspect existing buildings that are either:

- A. Occupied by public officers
- B. Considered for rental, purchase or lease by government both locally and internationally
- C. Cinemas, schools, hospitals etc.

Or any other structure at the request from government agencies particularly where the safety of the general public is concerned.

Based on inspections conducted for government rental, approximately 70 percent of the buildings had no structural approval or did not conform to the approved structural drawings. Hence, they were not recommended for rental. At this stage, I would like to now give way to my colleague, Mr. Montano Graham who will provide a synopsis on some of the typical defects identified during inspections of buildings throughout Trinidad and Tobago.

STRUCTURAL APPROVAL ISSUES

Some of the main issues that have been observed not only in the design review stage but during and after construction which would affect the building infrastructure of Trinidad and Tobago based on our experiences are:-

The Design Review Stage

1. Design drawing being submitted for approval after construction has started or is completed.
2. Design calculations not corresponding to design drawings
3. Improper selection of the ductility factor
4. Mathematical errors
5. Inadequate or non-existent lateral load resisting system for the structure
6. Lack of proper detailing

During and Post Construction

1. Serious disparity between the design drawings submitted for approval and the structure being constructed or the structure that is under construction e.g. number of floors/bays, size and material of members, spans and changes in foundation
2. Existing buildings that have never been submitted for approval to the Chief Designs Engineer or any other regulatory body
3. Inadequate or non-existent quality control measures or procedures on site for all kinds of structural systems e.g. Steel- improper welding, wrong bolt size, improper torque of bolts; Concrete- improper compaction/curing procedures (where design strength not achieved), improper placing of steel reinforcement, wrong reinforcement used (high tensile steel specified but mild steel used) or using reject steel.

Engineered structures:

Structures that are designed and constructed as per proper standard engineered practices should have undergone the formal process of approval by the municipal or other pertinent authority. The approval process is supposed to require involvement of an architect/engineer in the design and construction for ensuring compliance to the existing building code and planning laws. The building codes with earthquake safety consideration are not always implemented strictly.

There should be constant monitoring during construction to ensure compliance with the approved structural drawings. At present this is the responsibility of the building inspector in the various districts. However with the increase boost in building construction it is far too much for the present staff to adequately monitor the various stages of construction.

Recommendations

Approaches to vulnerability reduction for engineered structures include the following:

- ***Absolutely no construction should take place before necessary approvals from the regulatory body.***
- ***Good site planning***
 - Analysis of probable landslides, rock-fall, liquefaction susceptibility etc.
- ***Adequate planning and analysis of structural measures to resist such forces***
 - Choice of appropriate lateral force resisting system in building
 - Detail analysis
- ***Adequate design and proper detailing of structural components***
 - Design of each and every component in detail
 - Consideration of ductility and detailing

- ***Construction with suitable materials***
 - Choices of suitable materials
 - Quality of materials

- ***Good workmanship under adequate supervision***
 - Supervision by adequate engineer
 - Good workmanship
 - Preparation of leaflets, posters and handbook

- ***Licensed Contractors***
 - Must have a license in order to practice construction

- ***Raising awareness***
 - The public, home and building owners should be aware about the consequences of an earthquake, necessary actions for mitigation and also the affordability of the technology.

Training (local and international) for personnels in the regulatory approval agencies and increasing capability of local institutions

http://www.adpc.net/CASITA/Course%20Modules/Earthquake%20vulnerability%20reduction%20for%20cities/EVRC0401B_Structural_vulnerability_reduction.pdf

Implementation Strategy for Achieving Seismic Safety

Three strategies should be taken together to achieve seismic safety of buildings

1. ***New Construction: Stop Increasing Risk***, all new construction should be earthquake resistant so that there is no increase in risk.
2. ***Existing Buildings: Decrease Unacceptable Risk***, existing structures should be either retrofitted or reconstructed to withstand reasonable shaking.
3. ***Accept Inevitable Earthquake: Prepare for Consequences***, awareness level should be increased at all levels from policy makers to community to individuals

http://www.adpc.net/CASITA/Course%20Modules/Earthquake%20vulnerability%20reduction%20for%20cities/EVRC0401B_Structural_vulnerability_reduction.pdf

CLOSING REMARKS

From the regulatory agency side, there is limited resources and manpower. The overall construction industry should be more regulated and not necessarily by government. It can

also be regulated by civic responsibility i.e. owners and the relevant stakeholders taking responsibility to ensure safety and adherence to seismic specifications.

The introduction of registered contractors, builders and technicians is necessary. These persons should possess a license in order to work in the construction industry and should be required to undergo annual training in prescribed areas to keep their license. Unless these stringent measures are put in place, it is unlikely that there will be any significant improvement in earthquake resistant design of buildings in the foreseeable future.

In conclusion, I do hope that the recommendations provided will assist with mitigating the **impacts on Vulnerability of Trinidad and Tobago's building infrastructure**. I would like to thank my fellow colleagues at the Ministry of Works and Transport for their assistance with today's presentation and to today's Committee for providing both the Ministry and I with the opportunity to share this information with you. Hopefully, some practical solutions will be arrived at. I thank you.

	Target Building Performance Levels			
	Collapse Prevention Level (5-E)	Life Safety Level (3-C)	Immediate Occupancy Level (1-B)	Operational Level (1-A)
Overall Damage	Severe	Moderate	Light	Very Light
General	Little residual stiffness and strength, but load-bearing columns and walls function. Large permanent drifts. Some exits blocked. Infills and unbraced parapets failed or at incipient failure. Building is near collapse.	Some residual strength and stiffness left in all stories. Gravity-load-bearing elements function. No out-of-plane failure of walls or tipping of parapets. Some permanent drift. Damage to partitions. Building may be beyond economical repair.	No permanent drift. Structure substantially retains original strength and stiffness. Minor cracking of facades, partitions, and ceilings as well as structural elements. Elevators can be restarted. Fire protection operable.	No permanent drift. Structure substantially retains original strength and stiffness. Minor cracking of facades, partitions, and ceilings as well as structural elements. All systems important to normal operation are functional.
Nonstructural components	Extensive damage.	Falling hazards mitigated but many architectural, mechanical, and electrical systems are damaged.	Equipment and contents are generally secure, but may not operate due to mechanical failure or lack of utilities.	Negligible damage occurs. Power and other utilities are available, possibly from standby sources.
Comparison with performance intended for buildings designed under the <i>NEHRP Provisions</i> , for the Design Earthquake	Significantly more damage and greater risk.	Somewhat more damage and slightly higher risk.	Less damage and lower risk.	Much less damage and lower risk.

The following tables indicate the damage corresponding to the TPLs for a number of vertical and horizontal structural elements respectively (excerpted from FEMA 356). Similar tables exist for the nonstructural elements