A MULTI-DISCIPLINARY APPROACH TO PROTECTION OF INFRASTRUCTURE FROM SEISMIC ACTIONS

QUEENSLAND UNIVERSITY OF TECHNOLOGY

BRISBANE, AUSTRALIA

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[1] SCHOOL OF URBAN DEVELOPMENT AND CIVIL ENGINEERING

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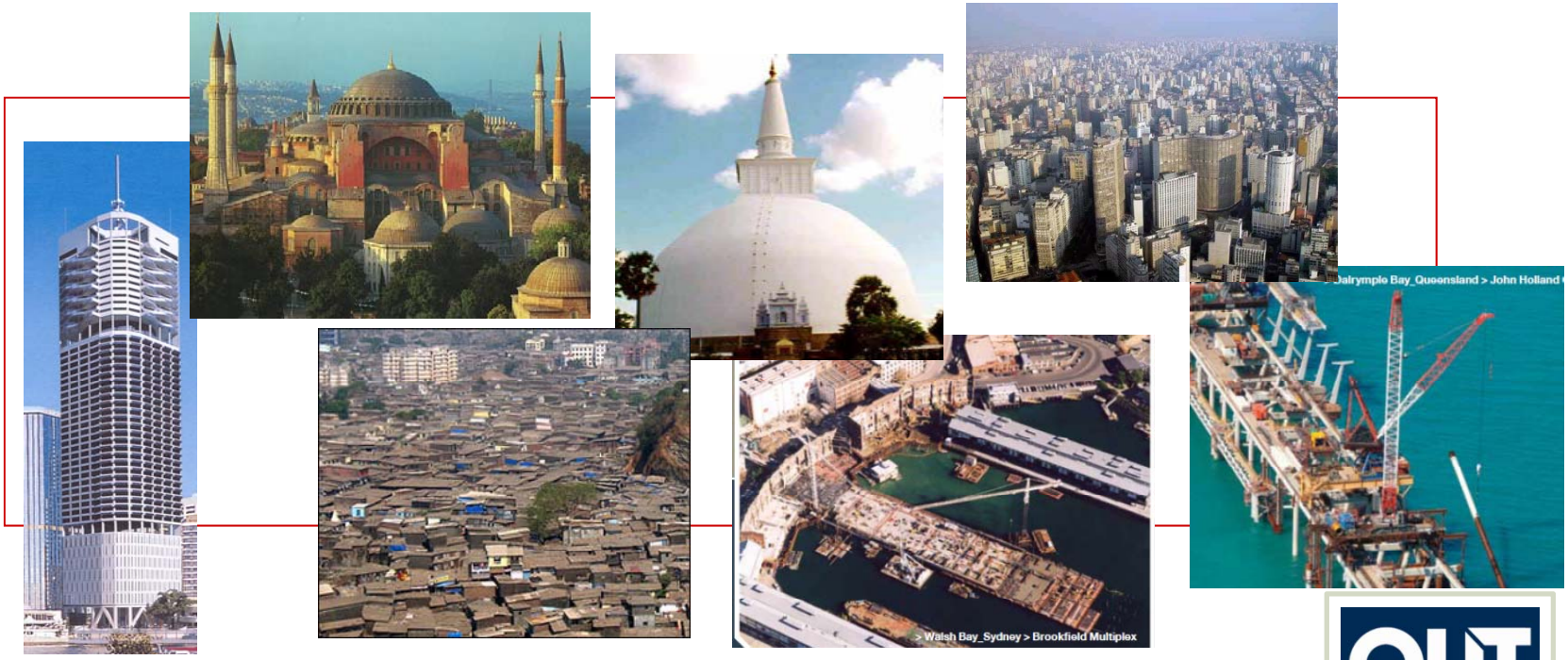

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ROLE OF RESEARCH INFRASTRUCTURES IN SEISMIC REHABILITATION

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BACKGROUND TO OUR PRESENTATION –LESSONS FROM CHRISTCHURCH, NEW ZEALAND ERTHQUAKES 2010 TO 2012






- 4 SEPTEMBER 2010, 4:35AM, MOMENT MAGNITUDE 7.1, 8 –15 SECONDS.
- 26 DECEMBER 2010, 10:30AM, MOMENT MAGNITUDE 4.7, 1-1.7 SECONDS.
- 22 FEBRUARY 2011, 12.51PM, MOMENT MAGNITUDE 6.2, 8- 10 SECONDS.
- 13 JUNE 2011, 14.20PM, MOMENT MAGNITUDE 6.0, 6-7.5 SECONDS.
- 7000 EARTHQUAKES AND AFTERSHOCKS HAVE BEEN REPORTED SINCE THE SEPTEMBER 2010 EARTHQUAKE
- SEVERAL EARTHQUAKES RANGING FROM 3.2 TO 6.0 MOMENT MAGNITUDE REPORTED IN DECEMBER 2011 AND JANUARY 2012.
- SEISMOLOGIST PREDICTION THAT AFTERSHOCKS COULD CONTINUE UP TO 30 YEARS.

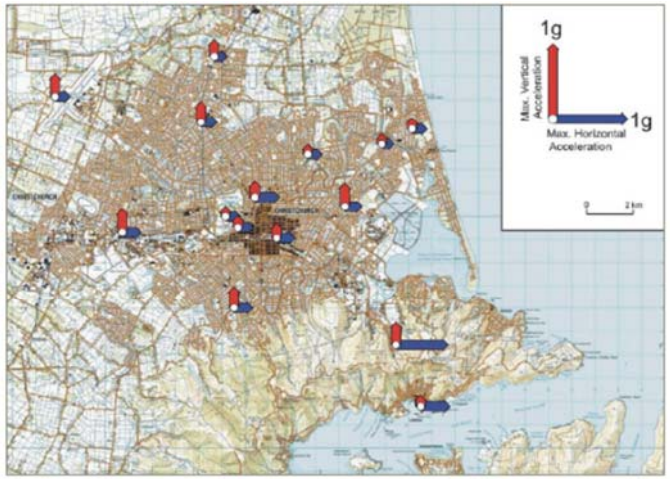

Figure 1: Maximum horizontal and vertical PGAs recorded during the 4 September 2010 earthquake at GeoNet stations

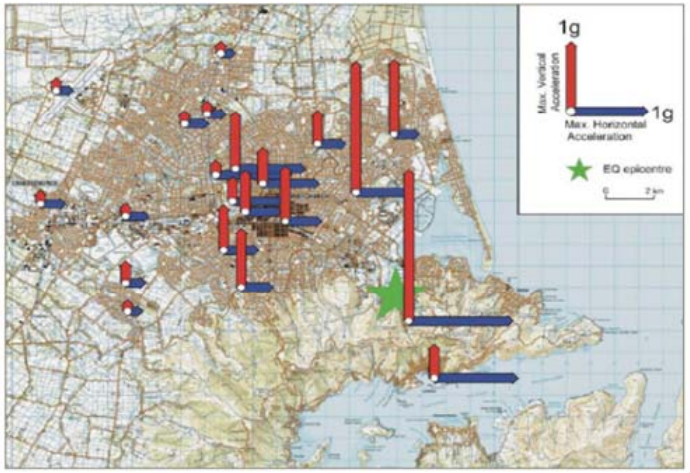

Figure 2: Maximum horizontal and vertical PGAs recorded during the 22 February 2011 earthquake at GeoNet stations

CONSEQUENCES OF THE CONTINUING SEISMIC ACTIVITY

- DAMAGE TO BRICK AND MASONRY BUILDINGS, LIQUEFACTION AND LATERAL SPREADING, FLOODING FROM BROKEN WATER AND SEWER PIPES.
- FURTHER DAMAGE TO BUILDINGS ALREADY DAMAGED BY PREVIOUS EARTHQUAKES.
- 182 DEATHS (June 2011), CATASTROPHIC FAILURE OF PREVIOUSLY DAMAGED AND UNDAMAGED BUILDINGS, SIGNIFICANT DAMAGE TO HERITAGE AND MODERN BUILDINGS.
- IRRÉPARABLE DAMAGE TO MODERATELY DAMAGED BUILDINGS, LIQUEFACTION AND ROCKFALLS FROM CLIFFS.

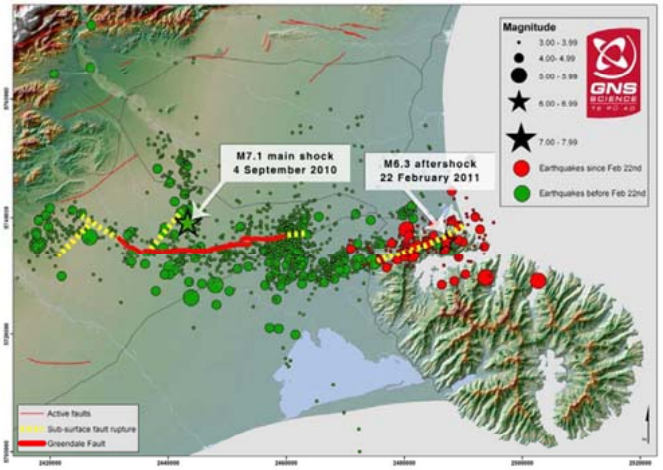

Figure 4.1: Fault rupture length and aftershock sequence for the 4 September 2010 and 22 February 2011 events. (Source: GNS)

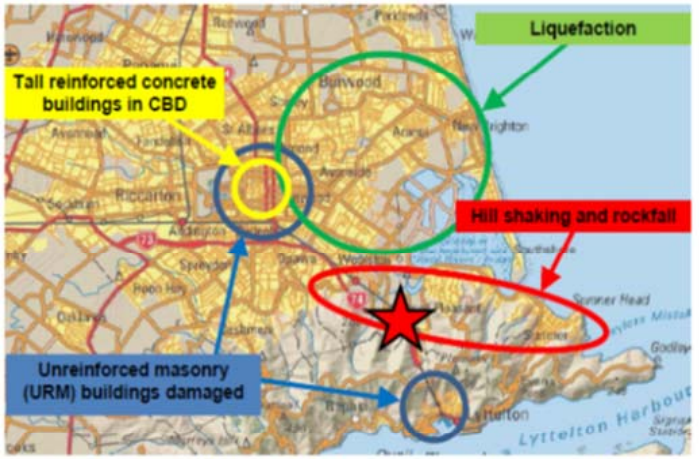

Figure 4.3: Overview of the impact of the 22 February 2011 Christchurch aftershock on the built environment.

A MULTI-DISCIPLINARY APPROACH TO PROTECTION OF INFRASTRUCTURE FROM SEISMIC ACTIONS

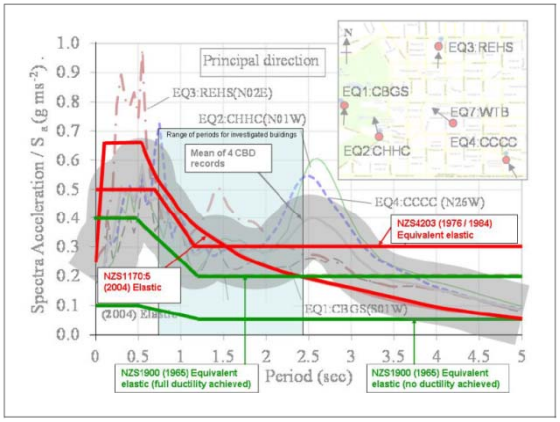

Figure 4.5 (a) Design versus demand – 4 September 2010

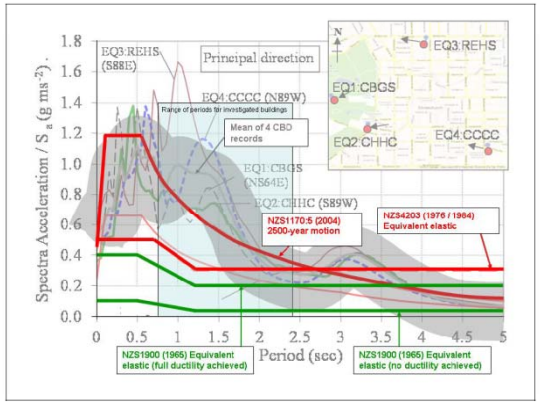

Figure 4.5 (b) Design versus demand – 22 February 2011

STRENGTH DEMAND EXCEEDS CODE COMPLIANT DESIGN CAPACITY

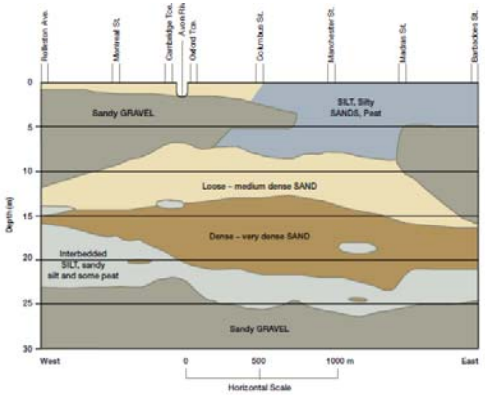

Figure 4: Subsurface cross section of Christchurch CBD along Hereford Street (reproduced and modified from Elder and McCahon, 1990)

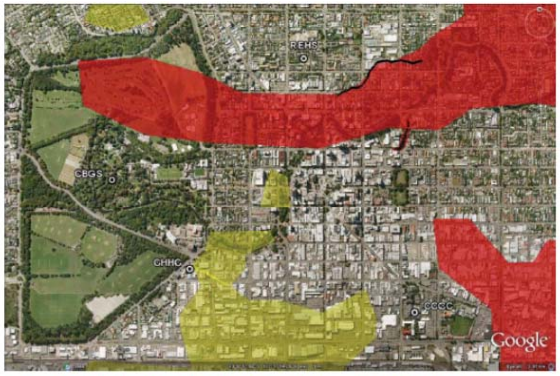

Figure 5: Preliminary liquefaction map indicating areas within the CBD affected by liquefaction in the 22 February earthquake. Legend: red = moderate to severe liquefaction; green = low to moderate liquefaction

SOIL PROFILE VULNERABLE TO LIQUEFACTION AND LATERAL SPREAD

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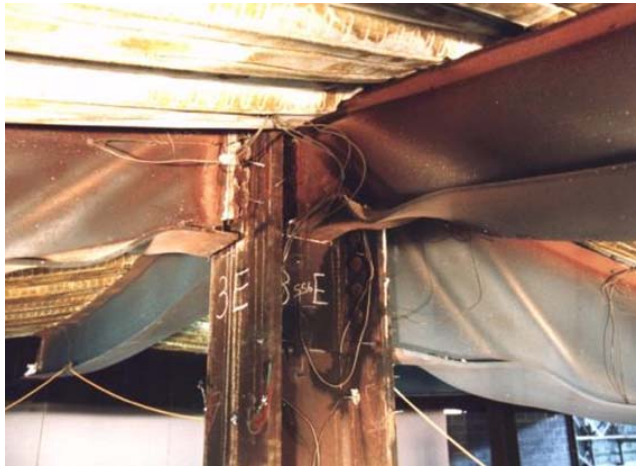
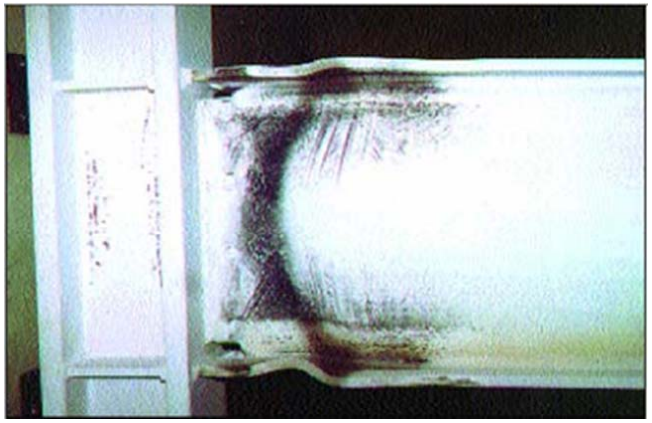
FAILURE OF SHEAR WALLS





COLUMN BEAM FRAMES VULNERABLE TO CATASTROPHIC FAILURE UNDER REPITITIVE SEISMIC EVENTS

CURRENT STRUCTURAL DESIGN PRACTICE

- SEISMIC ENERGY DISSIPATED WITH YIELDING AT PREDETERMINED LOCATIONS AND CONTROLLED DEFORMATION.
- NON-CATASTROPHIC DAMAGE TO STRUCTURE AND POTENTIAL DAMAGE TO NON STRUCTURAL COMPONENTS.

ALTERNATIVE STRUCTURAL DESIGN PRACTICE

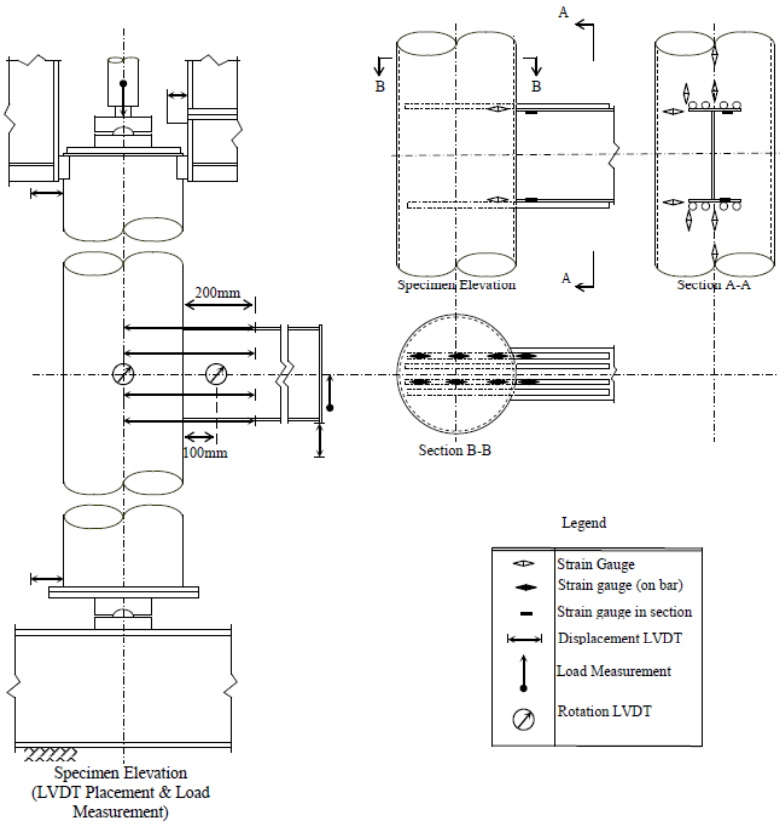
- REPLACEABLE MECHANICAL COMPONENTS IN PLACE OF YIELDING MATERIALS.
- PASSIVE AND ACTIVE SYSTEMS THAT MODIFY RESPONSE TO SEISMIC EFFECTS.
- CONTROL SYSTEMS THAT ENHANCE PERFORMANCE AND RELIABILITY.
- DESIGN FOR INERTIAL AND KINEMATIC EFFECTS IN FOUNDATION SYSTEMS.

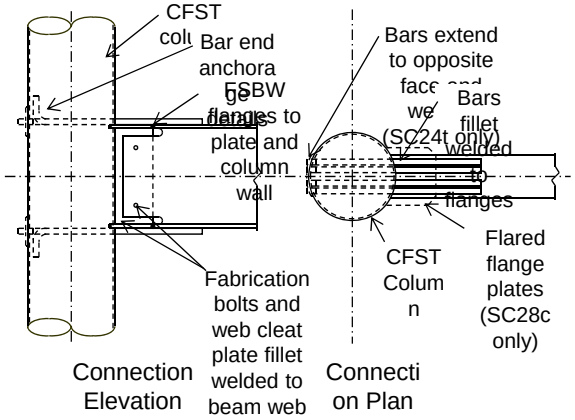
THE MULTIDISCIPLINARY APPROACH

- NON LINEAR TIME HISTORY ANALYSIS FOR STRUCTURAL SYSTEM.
- MECHANICALLY ENGINEERED COMPONENTS FOR TRANSLATION AND ROTATION.
- PASSIVE AND ACTIVE DAMPING SYSTEMS FOR RESPONSE CONTROL.
- MICRO-ELECTRO-MECHANICAL SENSOR AND RELIABILITY MONITORING SYSTEMS FOR PERFORMANCE ENHANCEMENT OF COMPONENTS.
- ASSESSMENT AND CONTROL OF GROUND STRUCTURE INTERACTION AND FOUNDATION PERFORMANCE DUE TO KINEMATIC EFFECTS.

STRUCTURAL STEEL CONNECTIONS TO CONCRETE FILLED STEEL TUBES

BEUTEL, THAMBIRATNAM AND PERERA





TEST SPECIMEN, TEST FRAME AND DATA ACQUISITION

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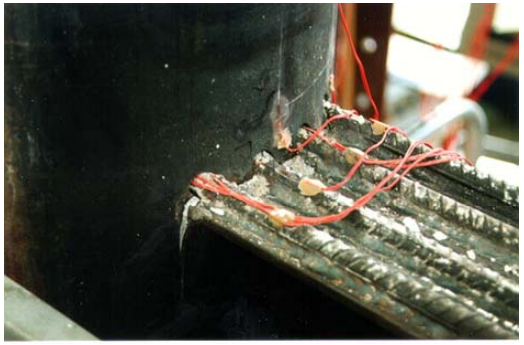
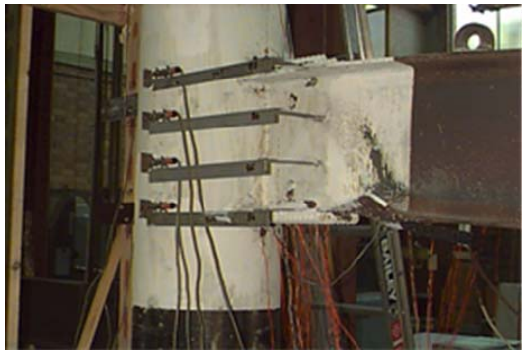
BAR FAILURE



STEEL TUBE FAILURE

YIELDING OF STEEL BEAMS



CONCRETE ANCHORAGE FAILURE

YIELD AND FAILURE MODES INVESTIGATED

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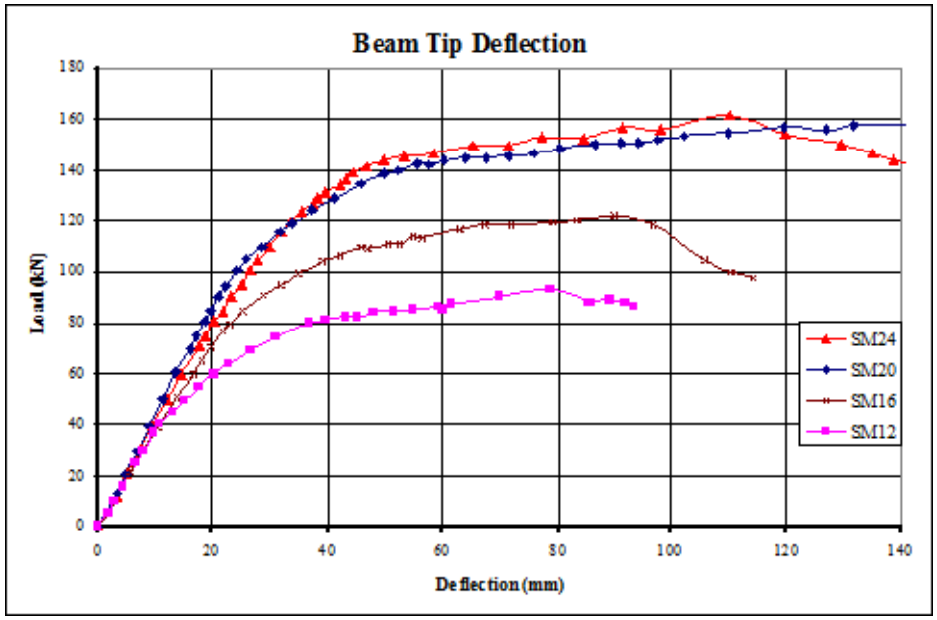
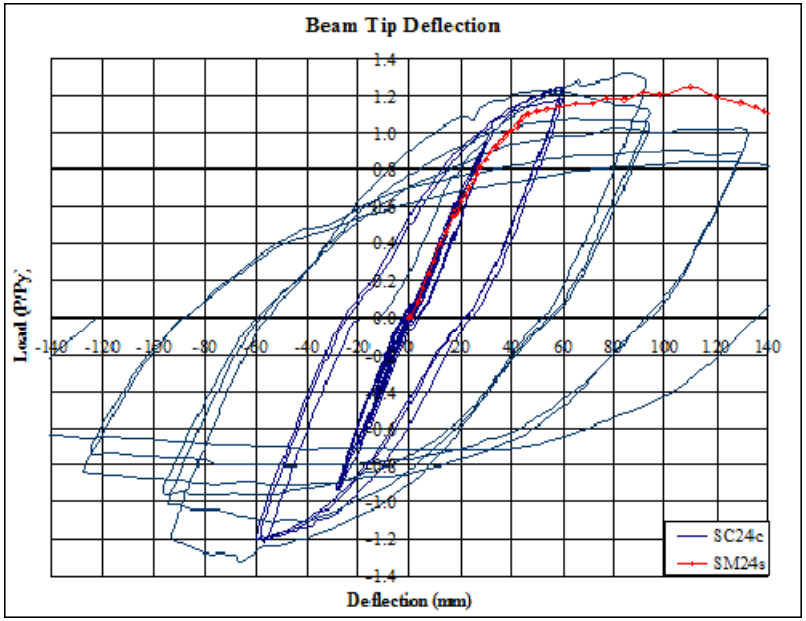


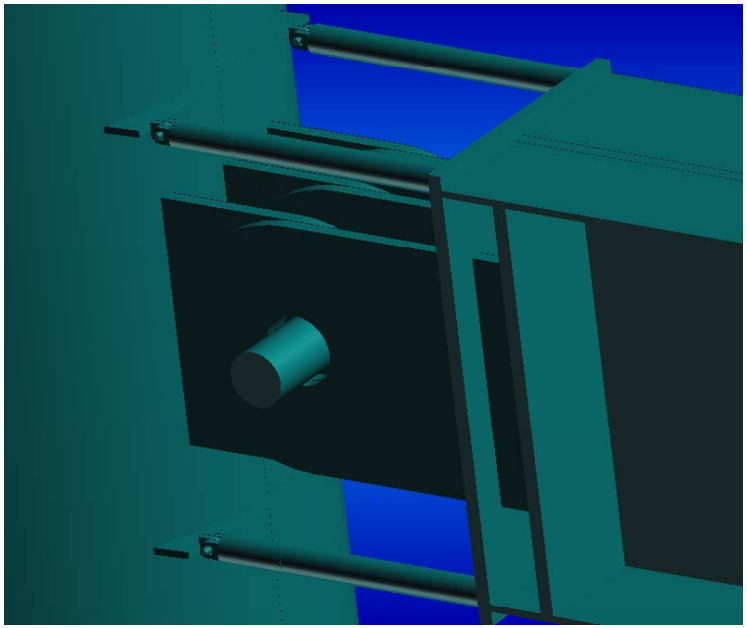
MONOTONIC LOADING

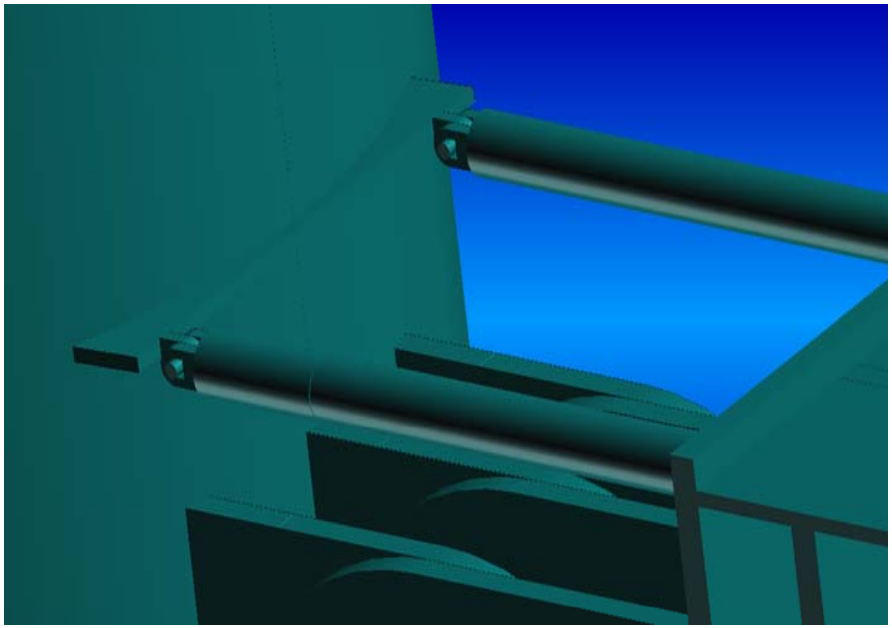


CYCLIC LOADING

RESULTS OF STABLE POST YIELD BEHAVIOUR IN BEAMS FROM EXPERIMENTAL STUDIES

SUBJECT FOR CONTINUING RESEARCH

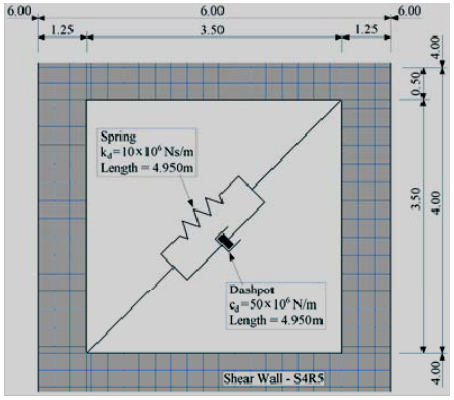


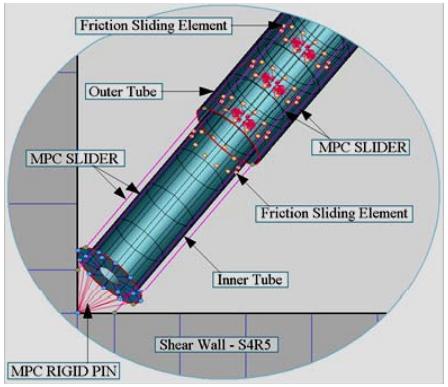


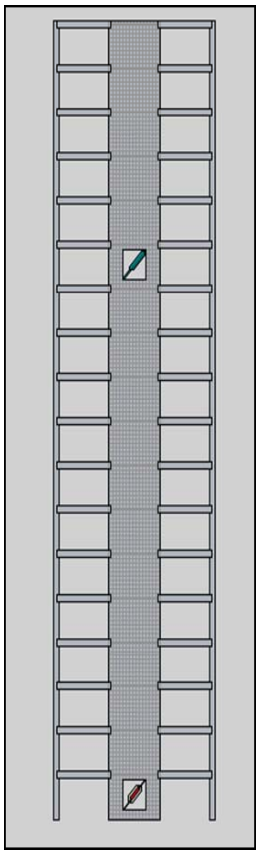
MECHANICAL CONNECTIONS WITH SHEAR PINS AND DAMPING STRUTS

SHEAR WALL SYSTEMS WITH EMBEDDED DAMPING

MARKO, THAMBIRATNAM AND PERERA

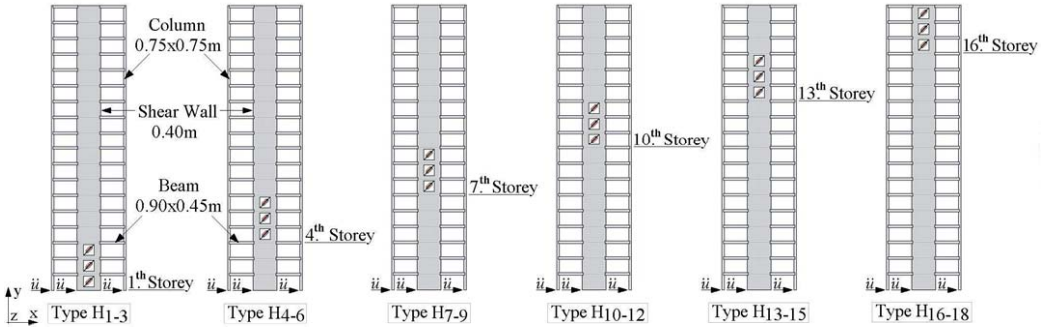




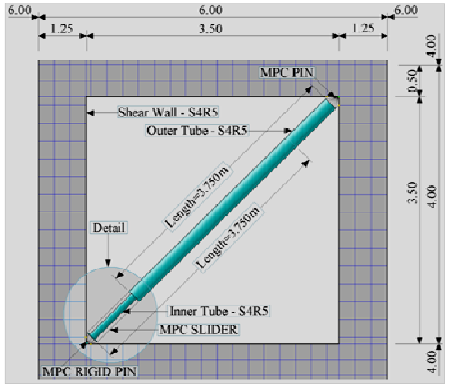


VISCO-ELASTIC DAMPER

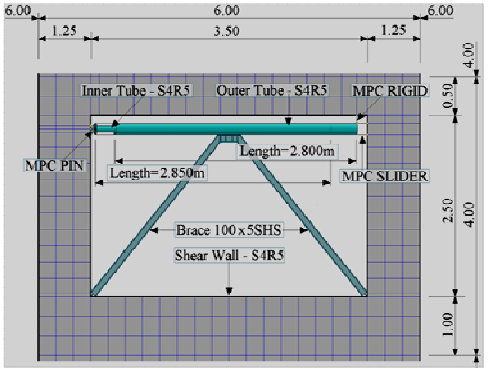
FRICTION DAMPER



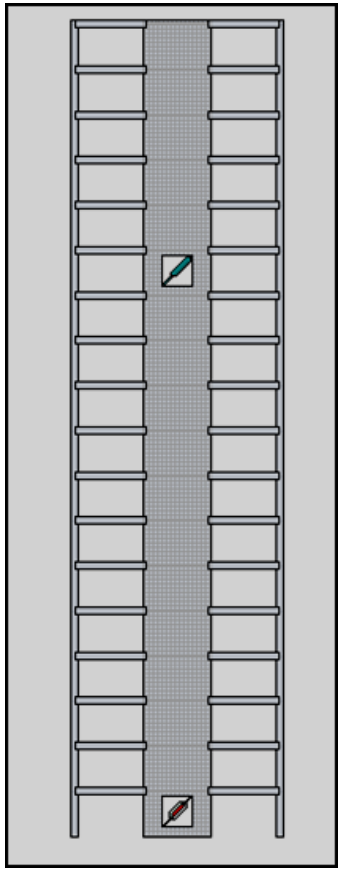
ALTERNATIVE DAMPER PLACEMENTS

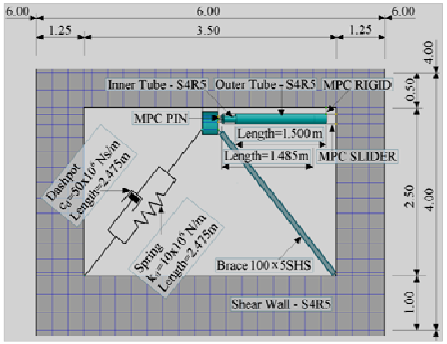


DIAGONAL BRACE

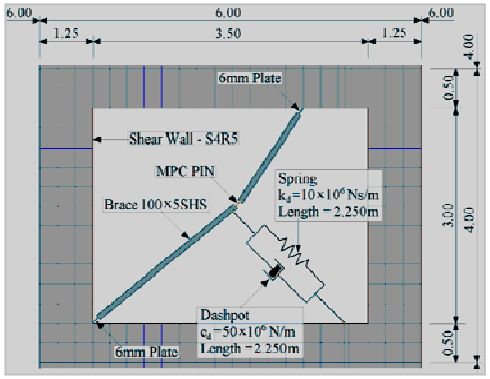


CHEVRON BRACE





HYBRID DAMPER



LOWER-TOGGLE DAMPER

DAMPER ARRANGEMENTS AND COMBINATION

Damper placed in cut-out of shear wall

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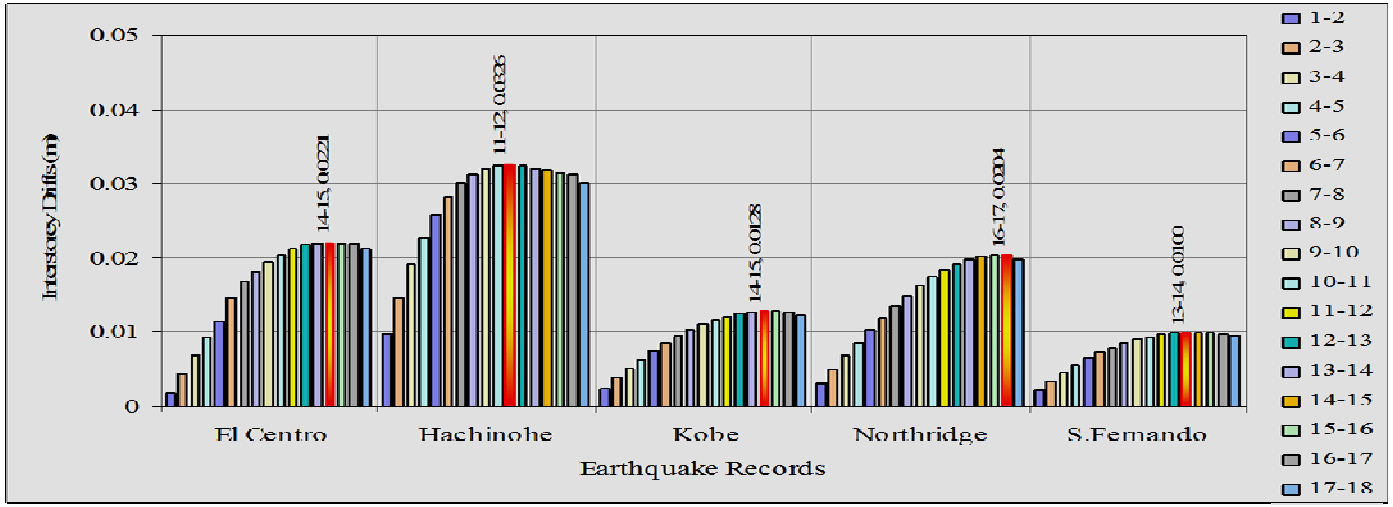
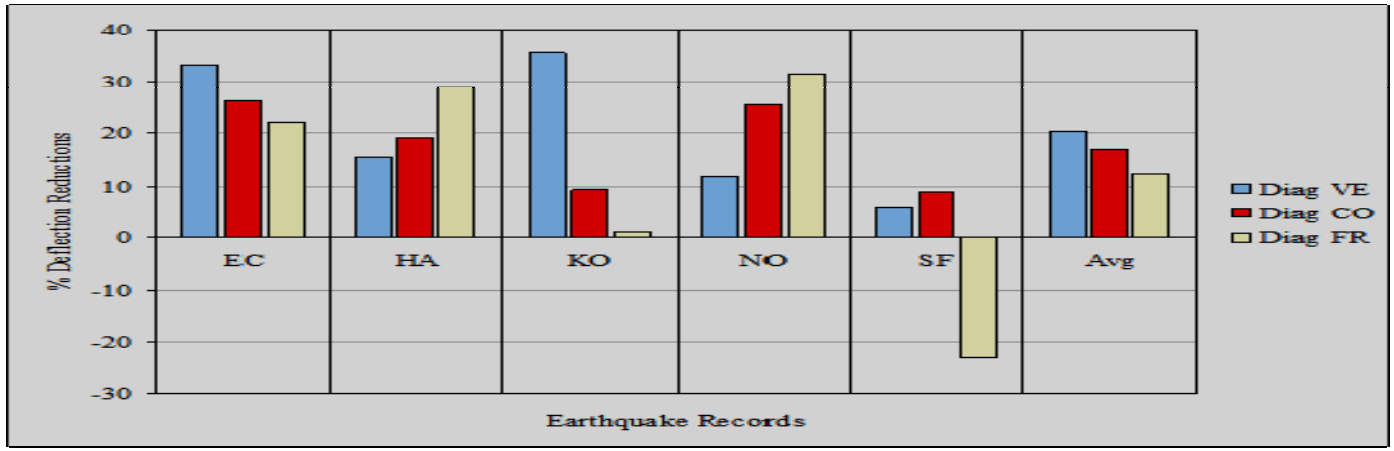


INTERSTORY DRIFTS

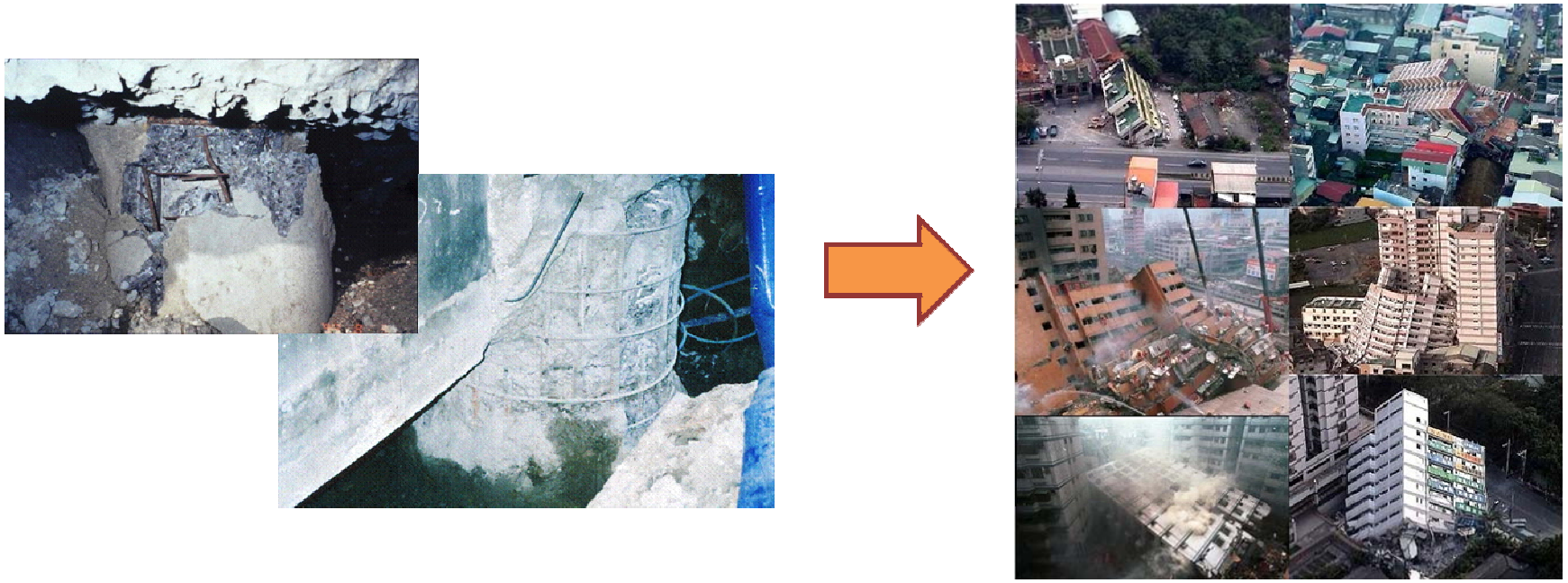


TIP DEFLECTION REDUCTION

RESULTS OF ANALYTICAL SIMULATION AND PERFORMANCE

SOIL-PILE INTERACTION IN DEEP LAYERED MARINE SEDIMENT UNDER SEISMIC EXCITATION

PEIRIS, THAMBIRATNAM AND PERERA



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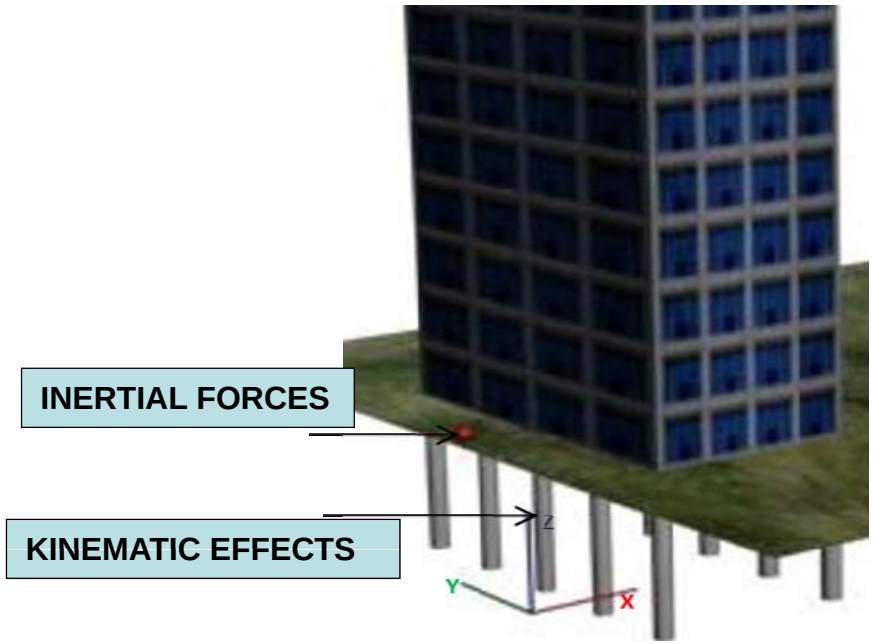

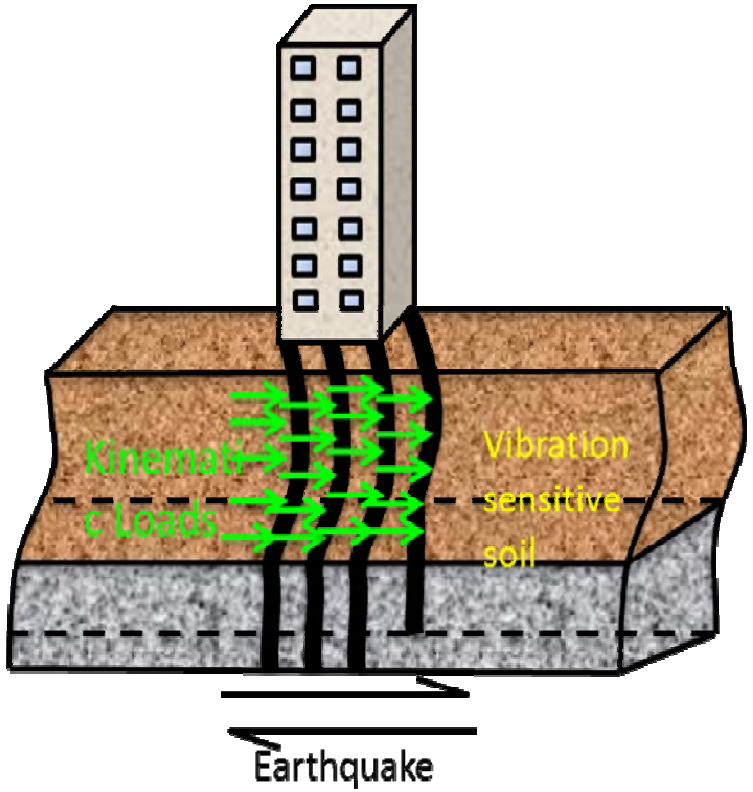

INVESTIGATION OF KINEMATIC EFFECTS ON FOUNDATIONS – LATERAL SPREADING

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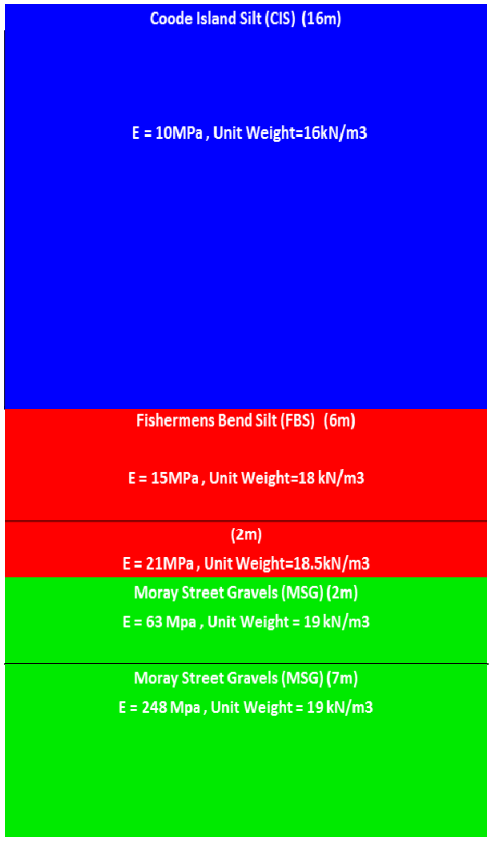
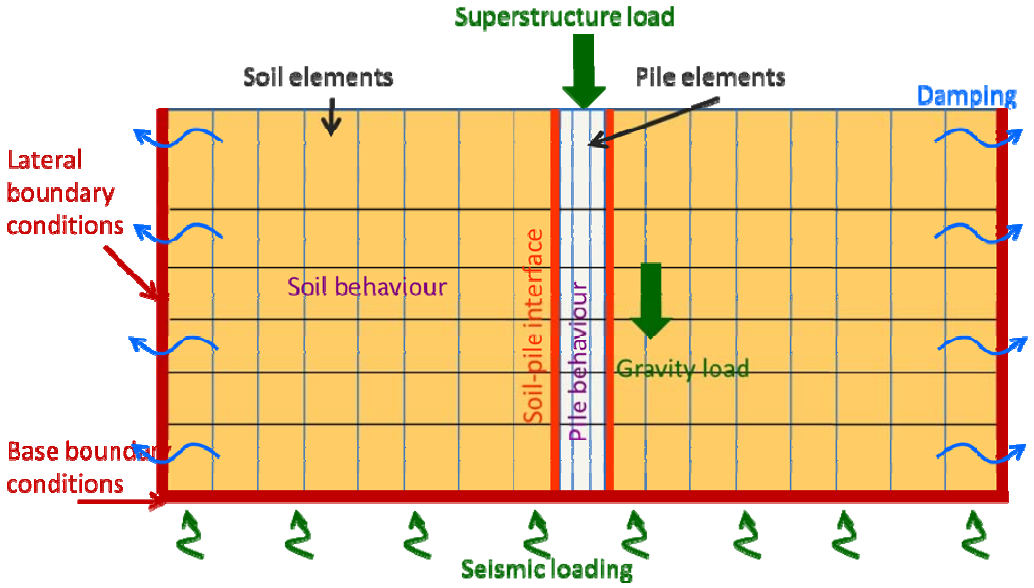


TYPICAL MOVEMENT SENSITIVE SOIL PROFILE



SOIL STRUCTURE INTERACTION MODEL

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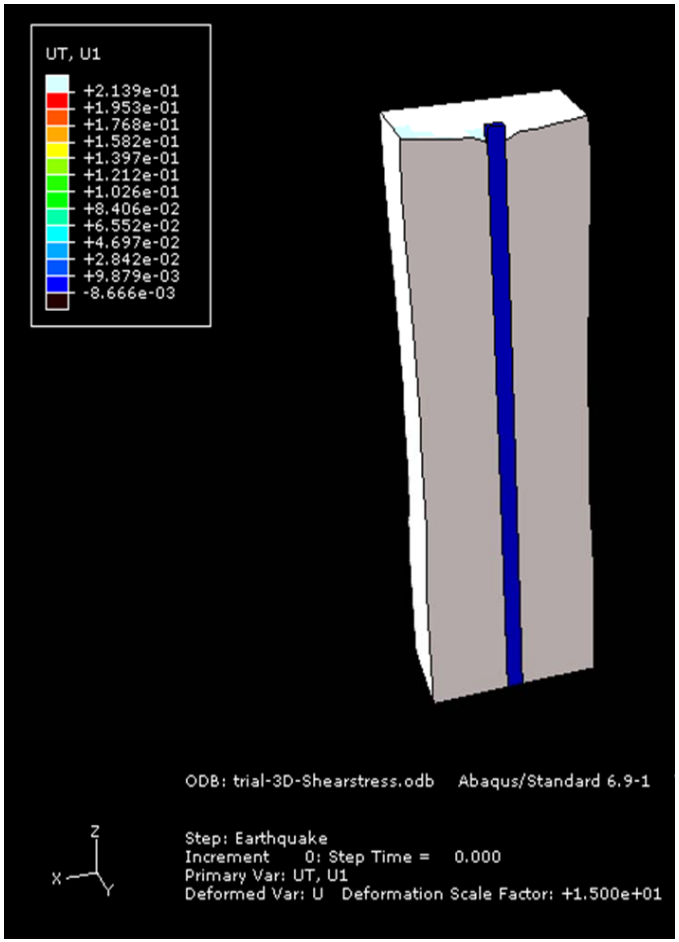
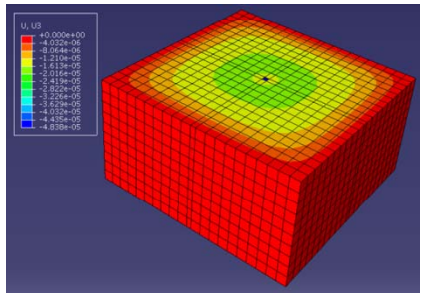
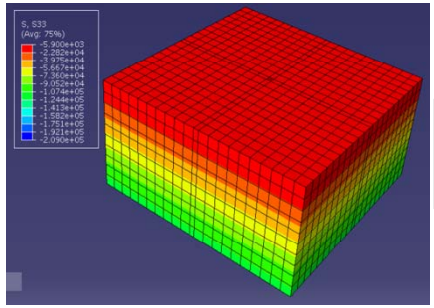
LATERAL PILE DISPLACEMENT

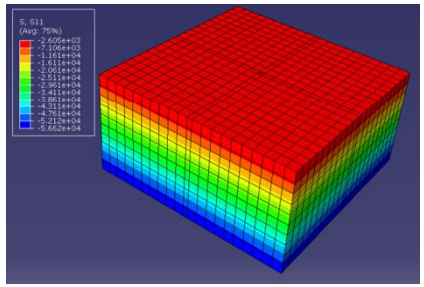




VERTICAL DISPLACEMENT



VERTICAL STRESSES



HORIZONTAL STRESSES

SOIL AND PILE INTERACTIVE ACTIONS

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ROLE OF RESEARCH INFRASTRUCTURES IN SEISMIC REHABILITATION

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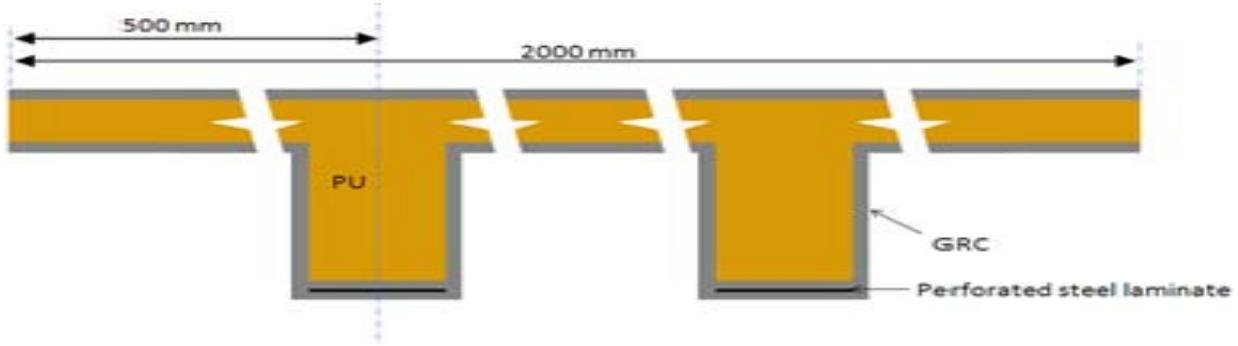
LIGHTWEIGHT BUILDING COMPONENTS -HYBRID-COMPOSITE FLOOR PLATE SYSTEM ABEYSINGHE, THAMBIRATNAM AND PERERA



- GLASS FIBRE REINFORCED CONCRETE SHELL + PERFORATED STEEL LAMINATE + POLYURETHANE CORE
- 50-70% LIGHTER THAN CONVENTIONAL FLOOR PLATE SYSTEMS
- TOTAL SELF WEIGHT REDUCTION OF STRUCTURE - MINIMUM 20%.
- 15 – 20% REDUCTION OF INERTIAL SEISMIC FORCES EOR 4 TO 20 STOREY BUILDINGS IN COMPARISON CONVENTIONAL BUILDINGS

ACKNOWLEDGEMENTS

1. INTERIM REPORT, OCTOBER 2011 – CANTAERBURY EARTHQUAKE COMMISSION

2. STAGE 1 EXPERT PANEL REPORT, NEW ZEALAND DEPARTMENT OF BUILDING AND HOUSING

3. RESEARCHERS AT THE QUEENSLAND UNIVERSITY OF TECHNOLOGY - JASON BEUTEL, JULIUS MARKO, THANUJA PEIRIS AND CHANAKA ABEYSINGHE