

**Christchurch Earthquake
CBD Building Performance Technical Investigation**

**Report on the Structural Performance
of the
Hotel Grand Chancellor
in the
Earthquake of 22 February 2011**

Prepared By:
Dunning Thornton Consultants Ltd

For:
The Department of Building & Housing

Final: 26 September 2011



Presentation to Royal Commission 17 Jan2012

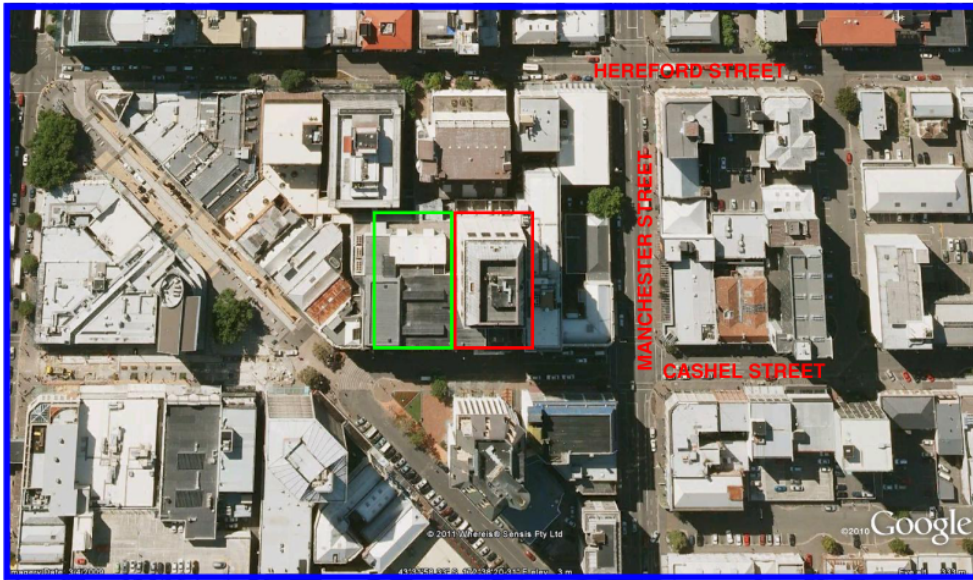




Description Of Building & Structure
Nature of Failure
Structural Actions
Wall D5-6
Seismicity
Stairs
Other Damage
Questions Answered
Recommendations
Issues Arising from Review

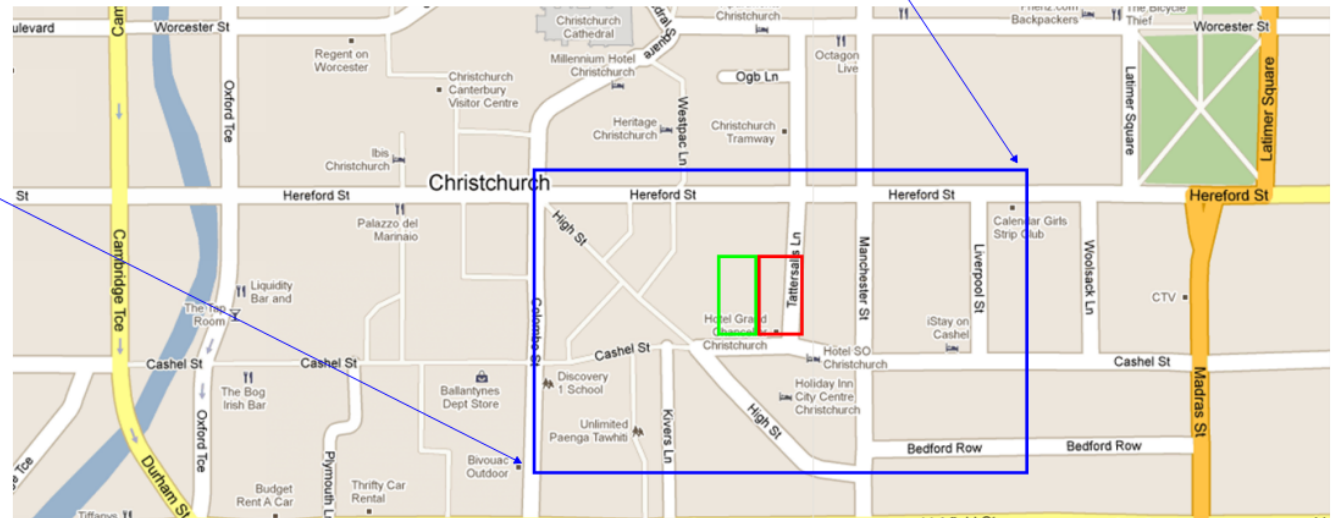
Hotel Grand Chancellor: Pre-September Earthquake

(source: C Lund & Son Ltd website)

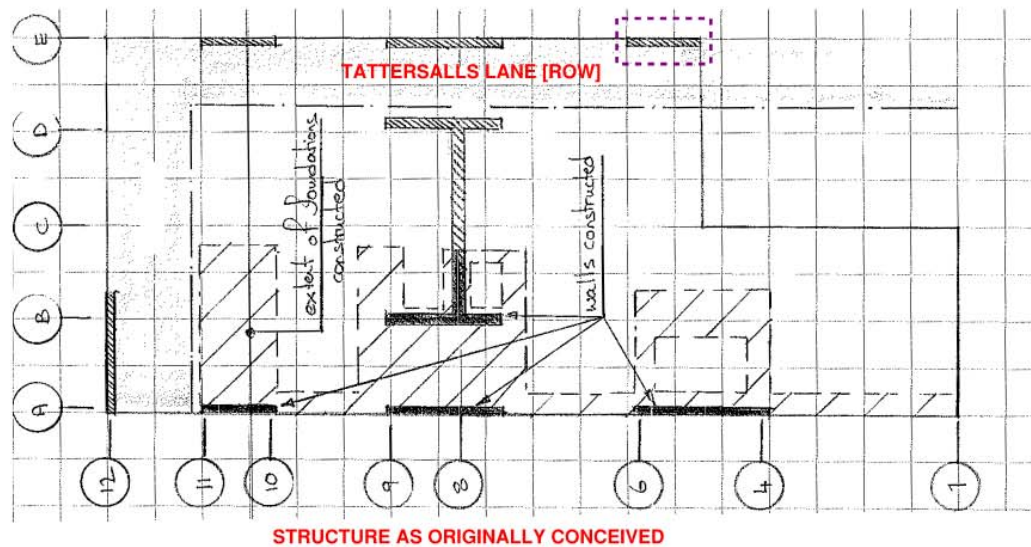
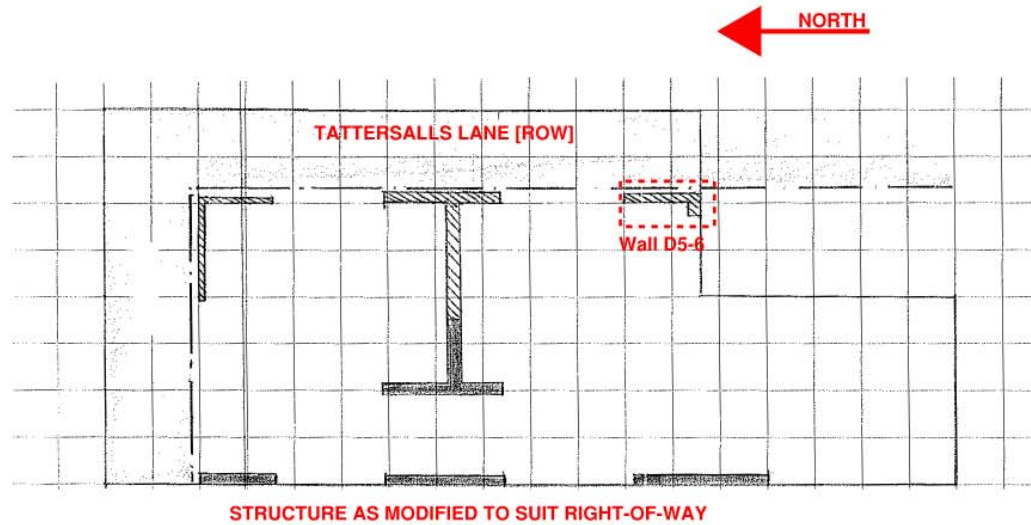
Fig.1

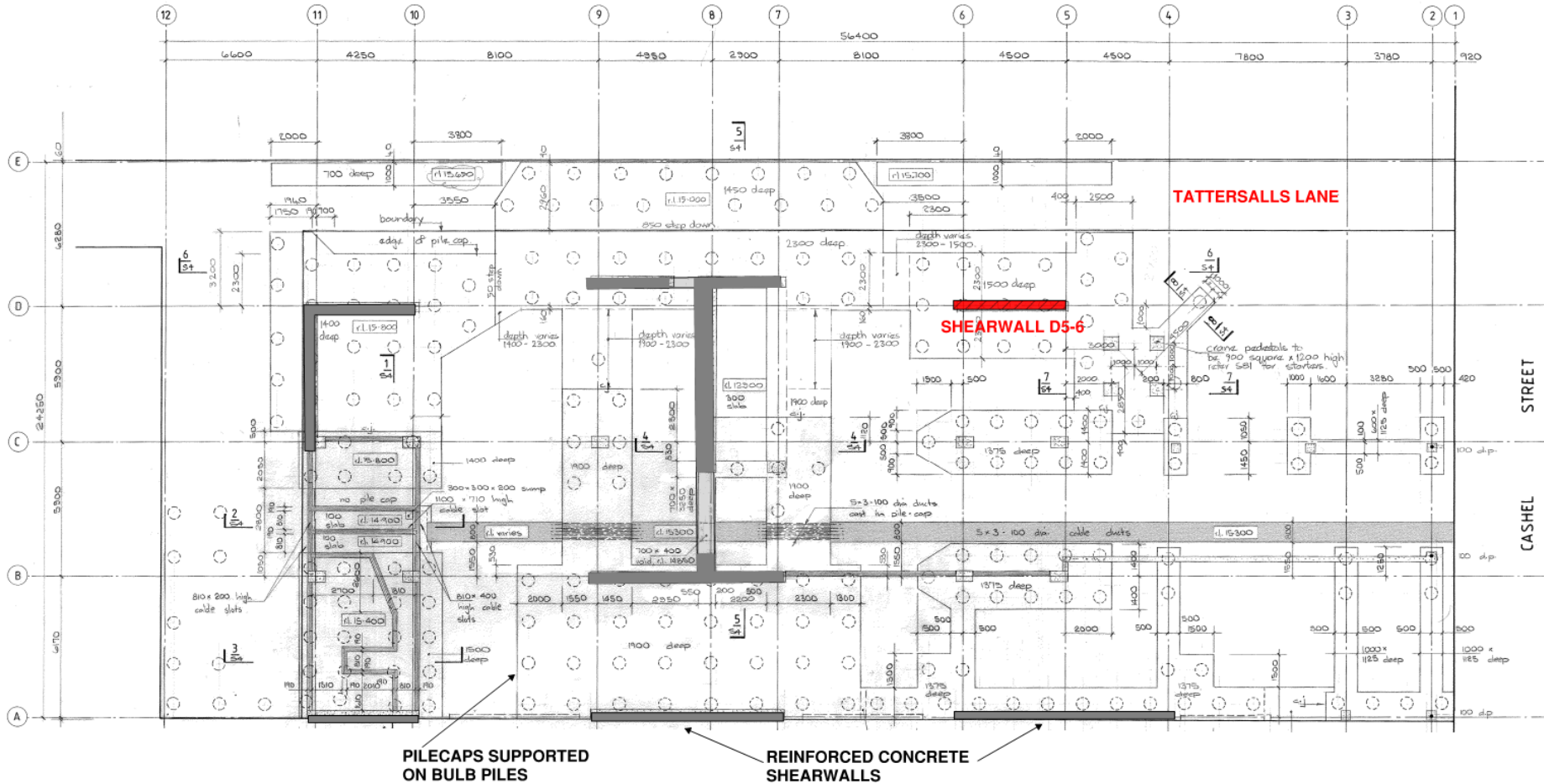


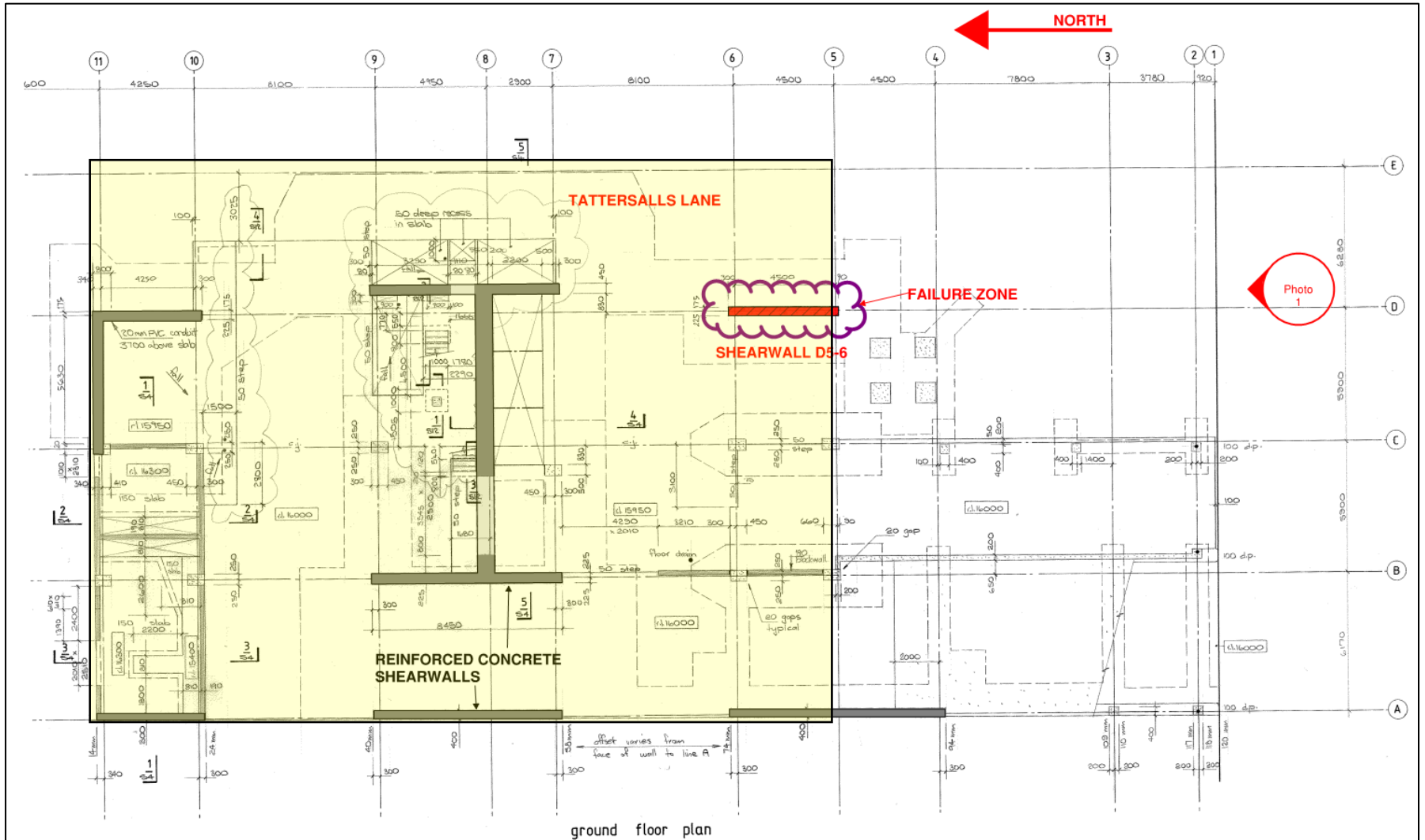
-  HOTEL GRAND CHANCELLOR
-  ADJACENT CAR PARKING BUILDING









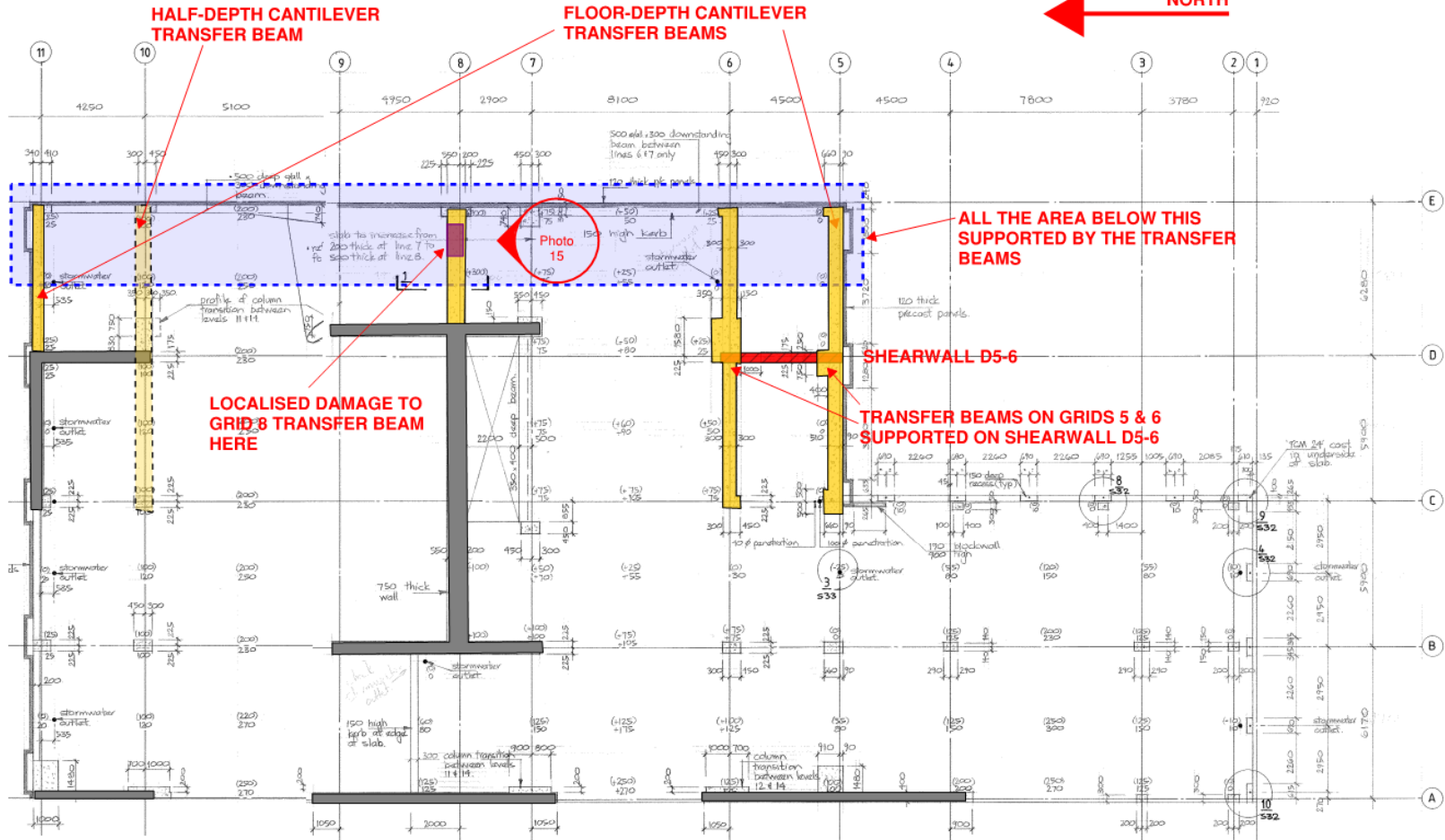


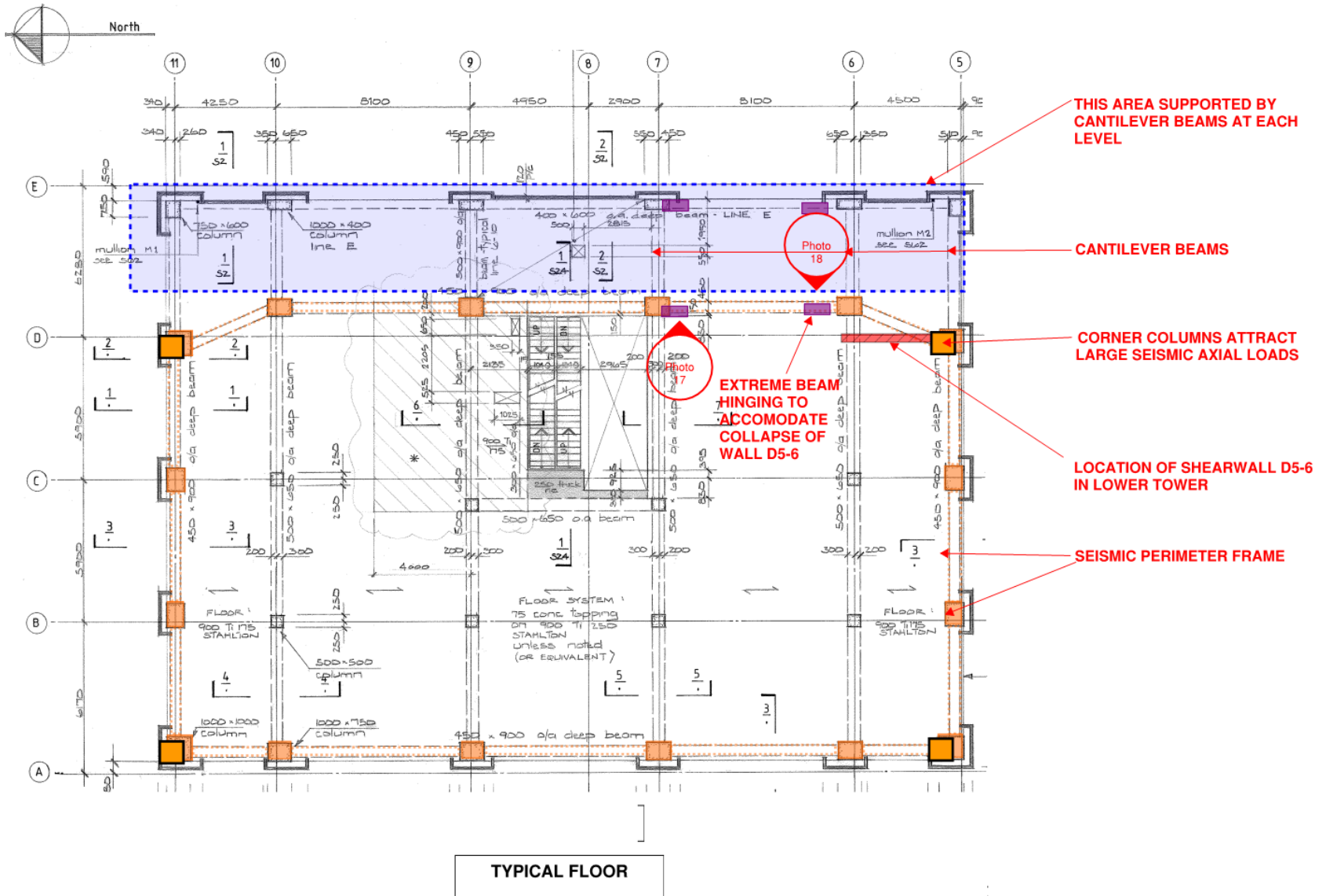
EXTRACT FROM ORIGINAL
STRUCTURAL DRAWINGS

GROUND FLOOR PLAN



Photo 13 - Folded slab at level 2

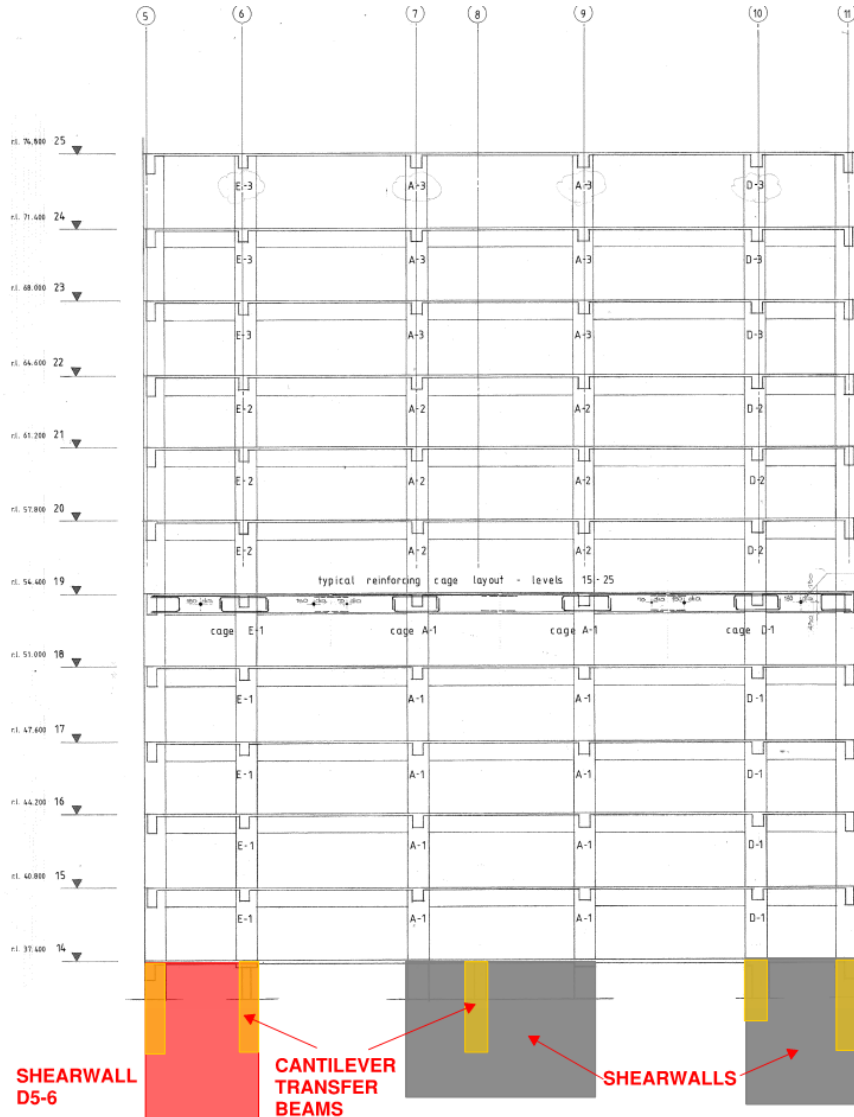




TYPICAL FLOOR

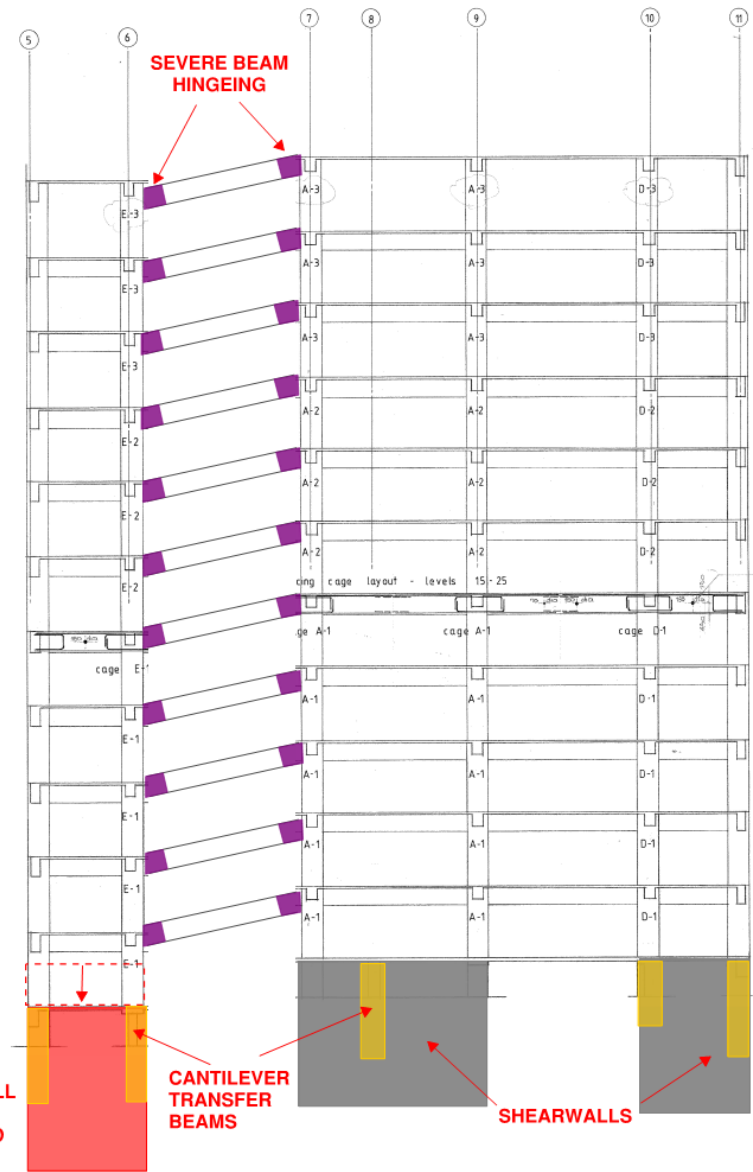
EXTRACT FROM ORIGINAL
STRUCTURAL DRAWINGS

TYPICAL UPPER TOWER PLAN



GRID D SEISMIC FRAME
PRIOR TO 22 FEBRUARY

EXTRACT FROM ORIGINAL
STRUCTURAL DRAWINGS



GRID D SEISMIC FRAME
POST 22 FEBRUARY

GRID D FRAME



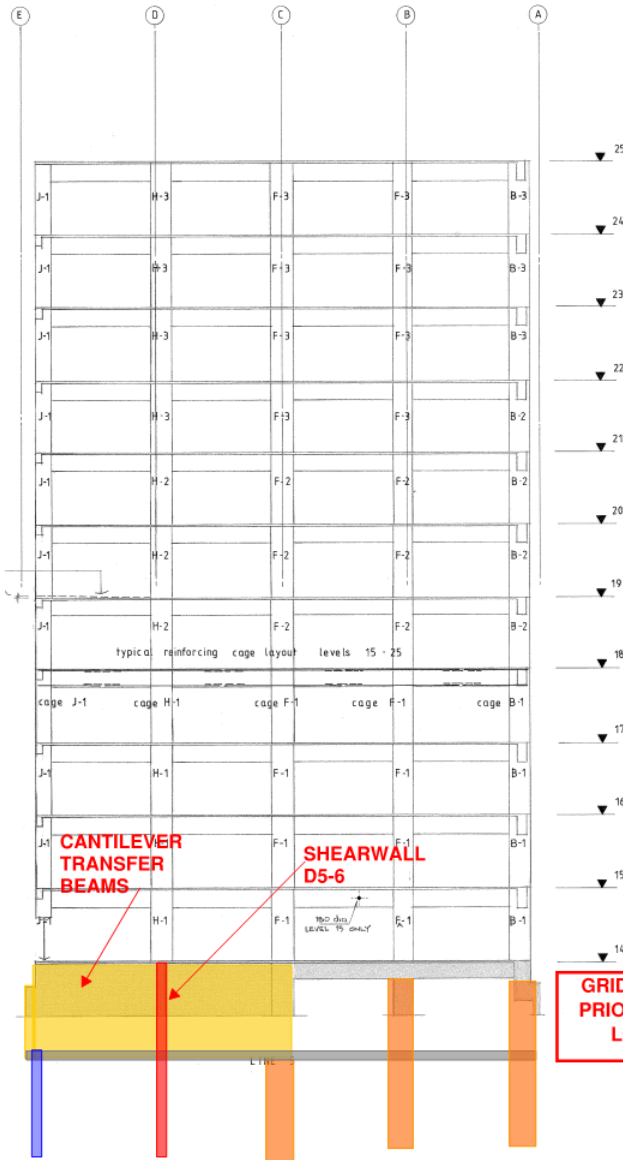
Photo 17 - Hinging in grid D tower beams



Photo 18 - Hinging in grid D tower beams

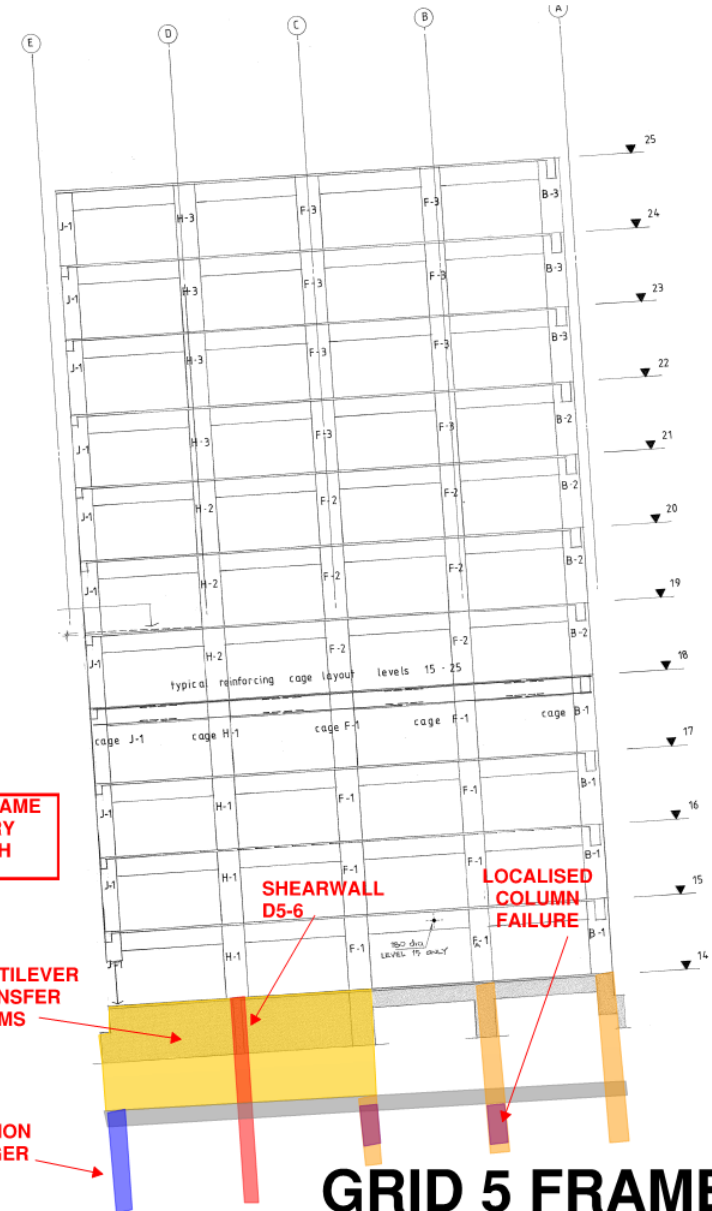


Photo 19 - Hinging in grid D tower beams



**GRID 5 SEISMIC FRAME
PRIOR TO 22 FEBRUARY
LOOKING SOUTH**

**EXTRACT FROM ORIGINAL
STRUCTURAL DRAWINGS**



**GRID 5 SEISMIC FRAME
POST FEBRUARY
LOOKING SOUTH**

GRID 5 FRAME



Photo 1 - Southern Elevation - During Construction



Cantilever
Transfer beam
on Grid 5

Separation between upper
and lower frames on grid E

Shearwall D5-6

Photo 2 - Southern Elevation - During Construction



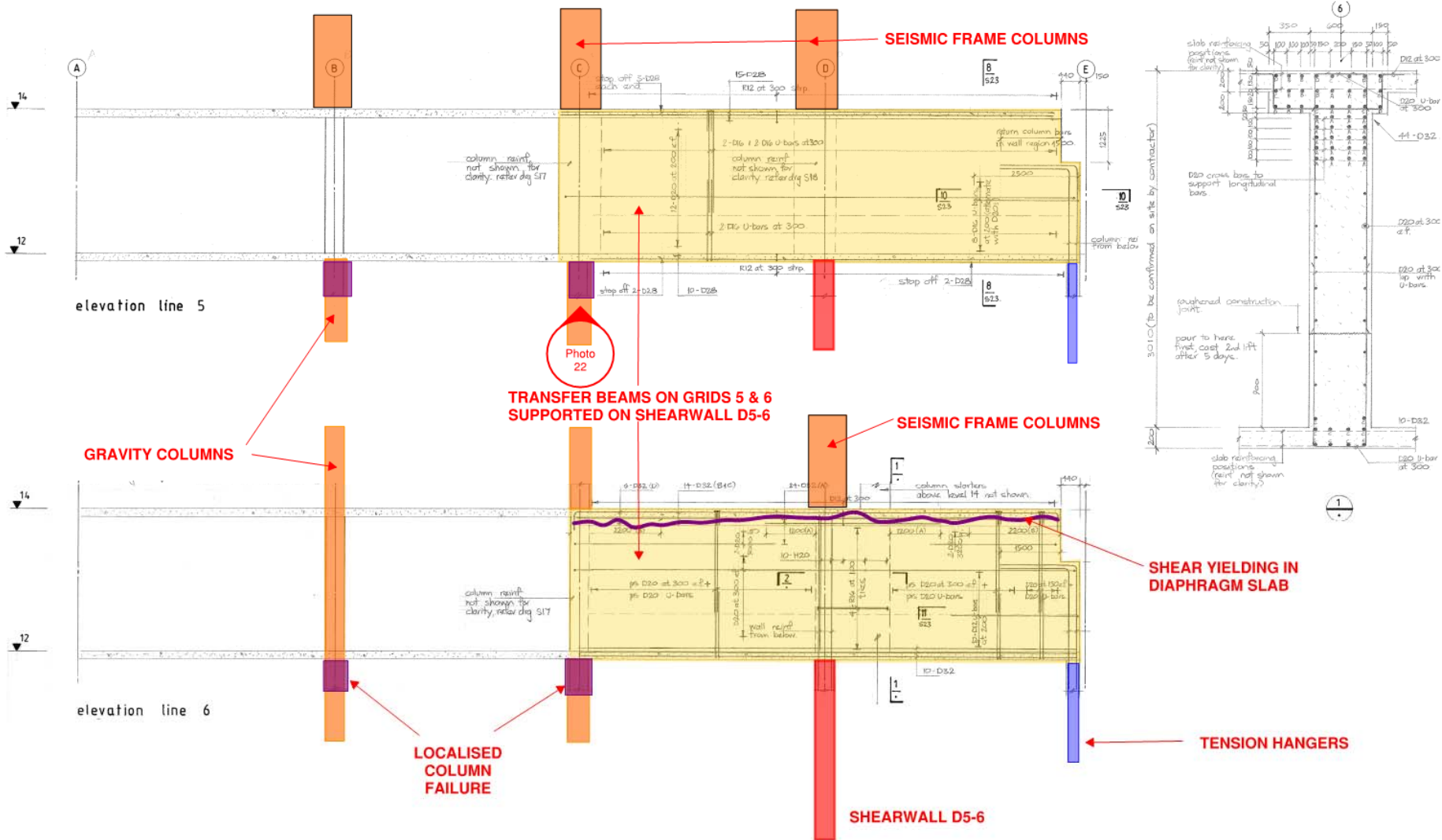
Photo 3 - Southern Elevation - Post February

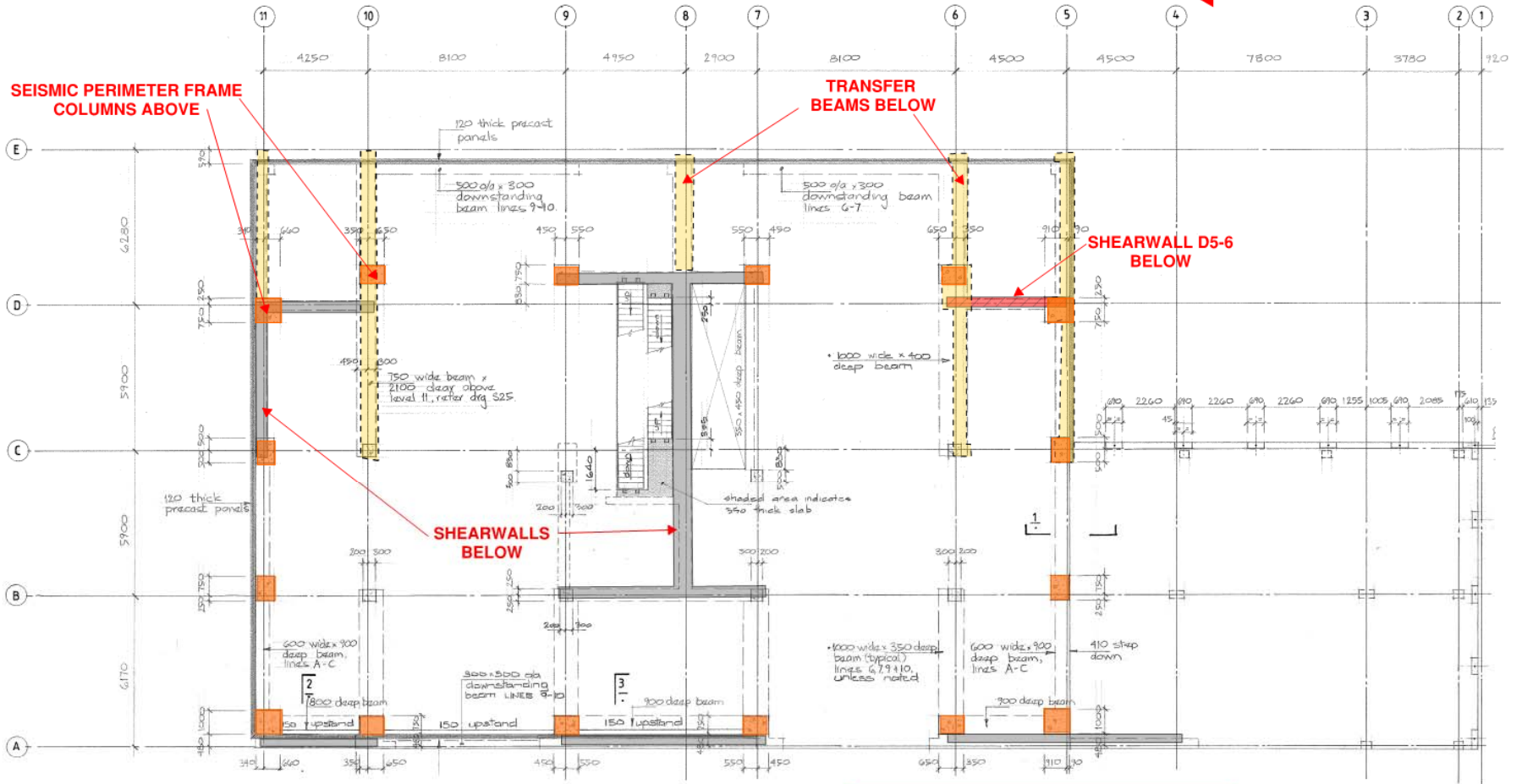


Photo 4 - Eastern
Elevation - Post
February



Photo 5 - Damage at junction
between podium and tower -
not related to pounding

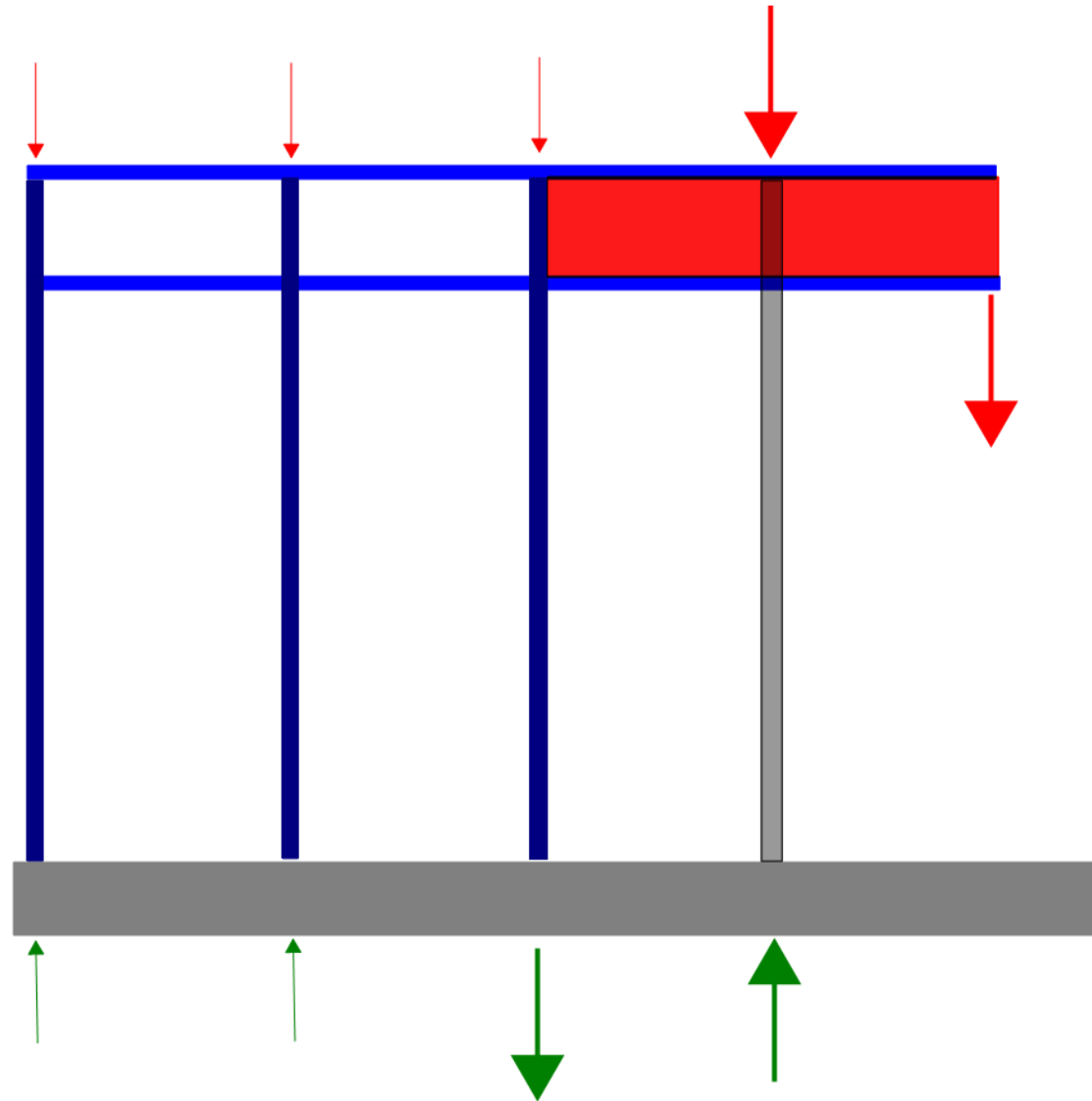




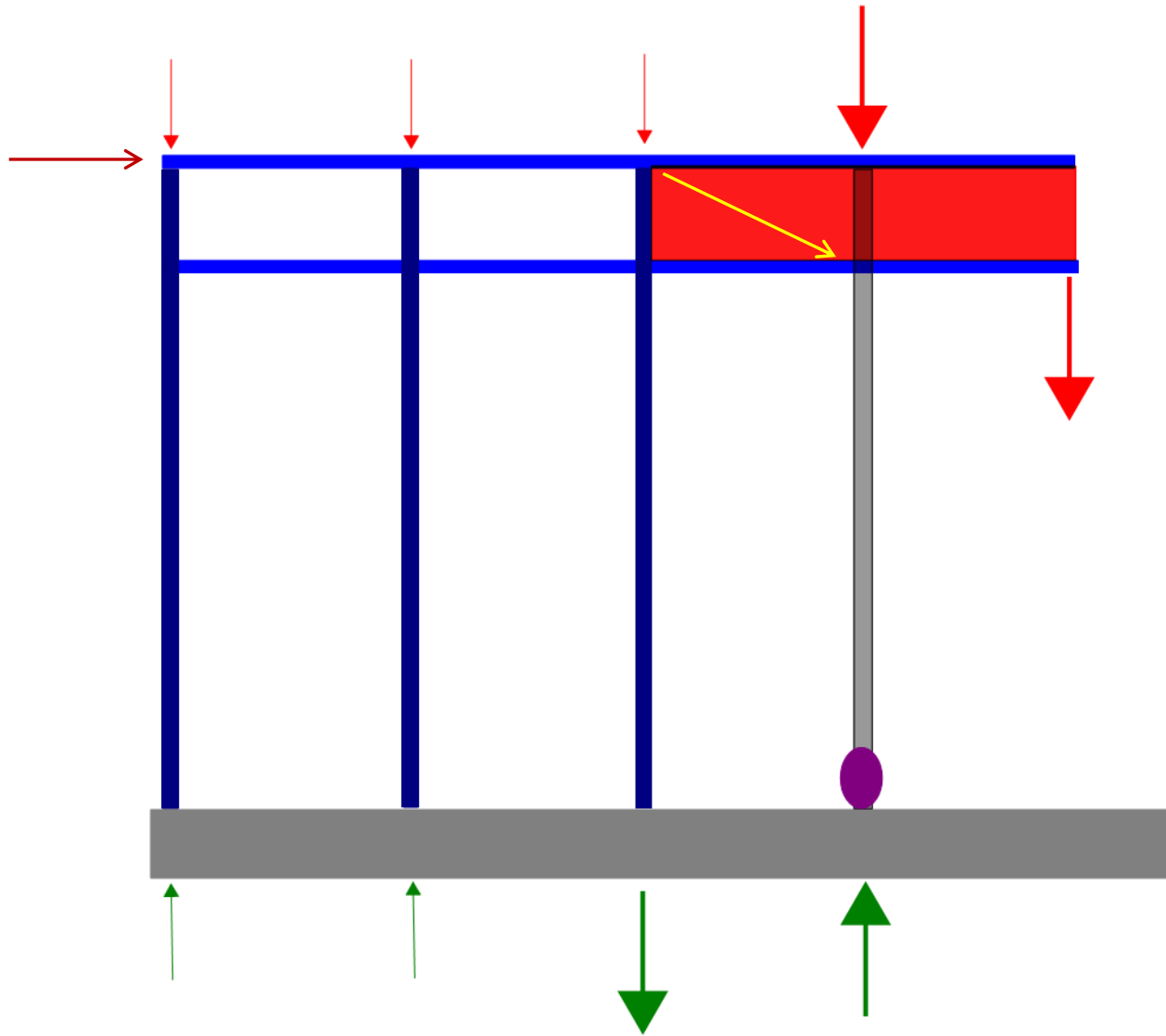
NOTE: LEVEL 14 IS THE TRANSFER FLOOR WHERE THE SEISMIC RESISTING SYSTEMS CHANGE FROM SHEARWALLS BELOW TO MOMENT RESISTING FRAMES ABOVE



Photo 14 - Hingeing in grid E beams 6-7



DAMAGE MECHANISM 1



DAMAGE MECHANISM 2



Photo 20 - Crushed columns at level 10, lines 5 & 6



Photo 21 -
Crushed
columns at level
10, lines 5 & 6



Photo 22 -
Crushed
columns at level
10, lines 5 & 6



F.1.2 Moment

In-plane code moment <i>maximum from Etabs Analysis</i>	6000kNm
Building over-strength of approximately 2 Assessed moment Range	10-15MNm
Out-of-plane moment	600kNm

F.1.3 Shear

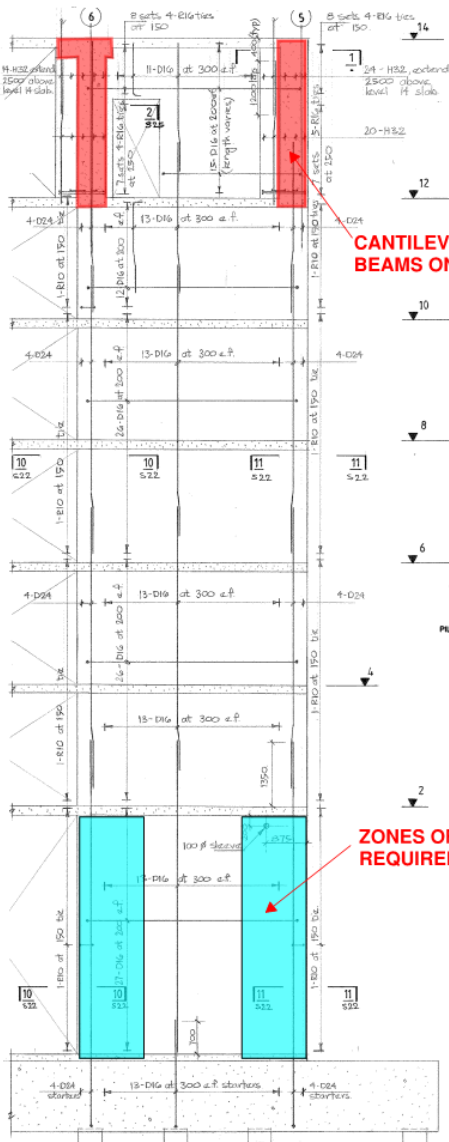
In-plane shear	800kN
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F.1.4 Combined Actions – possible maximums

Axial load	33-45MN
Seismic in-plane moment	10-15MNm
Shear	1.5-2MN

Original Design Actions

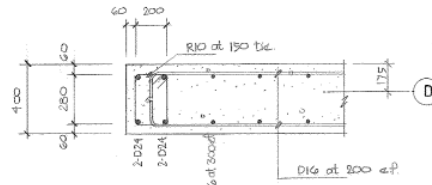
Axial Load	=	17MN
Moment	=	8MNm
Shear	=	800kN



CANTILEVER TRANSFER BEAMS ON GRIDS 5 & 6

ZONES OF CONFINEMENT AS REQUIRED BY NZS3101:1982 (& 2006)

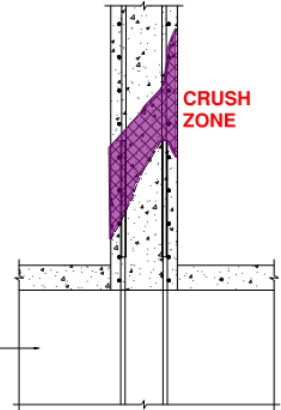
WALL D5-6 ELEVATION



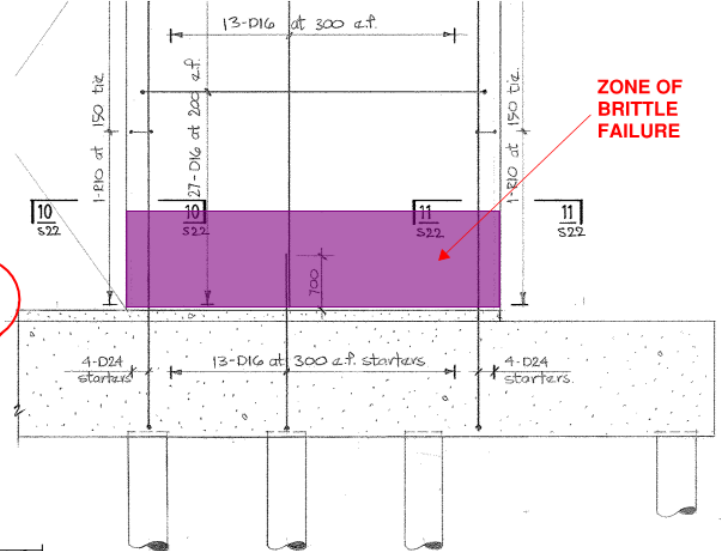
10 11 opp. hand
S18 S48



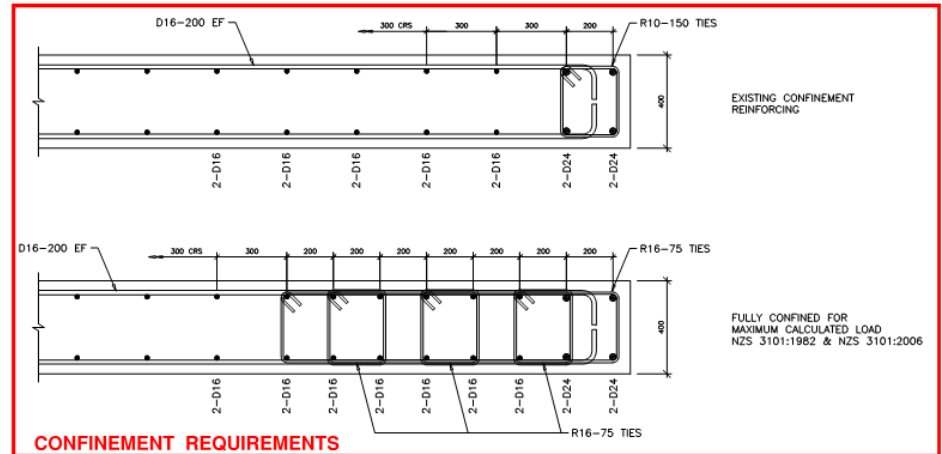
Photo 10



CROSS-SECTION SHOWING FAILURE MODE



BASE OF WALL DETAIL



CONFINEMENT REQUIREMENTS

WALL D5-6

EXTRACT FROM ORIGINAL STRUCTURAL DRAWINGS



Photo 6 - Shearwall D5-6 - Base Failure



Photo 7 - Shearwall D5-6 - Hingeing at top of ground floor



Photo 8 - Shearwall D5-6 - Hingeing at top of ground floor



Photo 9 - Shearwall D5-6 Failure - End View

Brittle, transverse failure,
absence of confinement

Lapped reinforcing



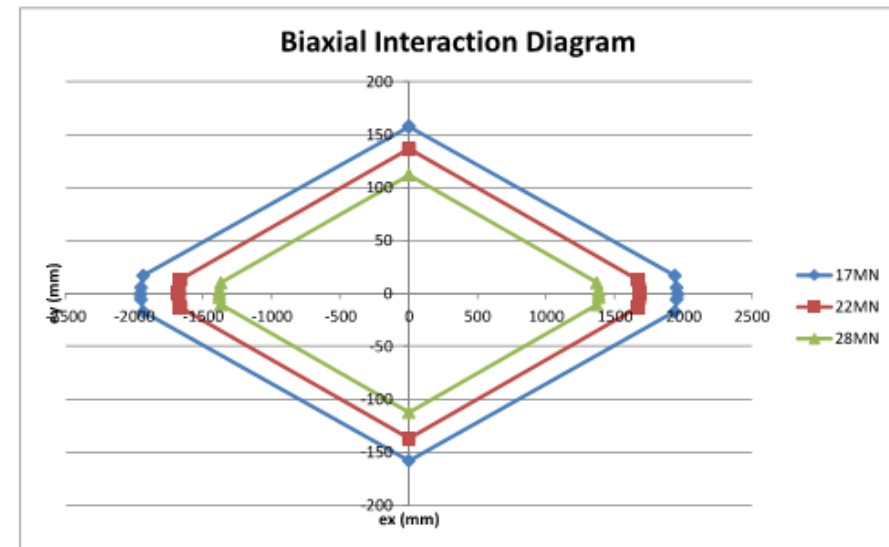
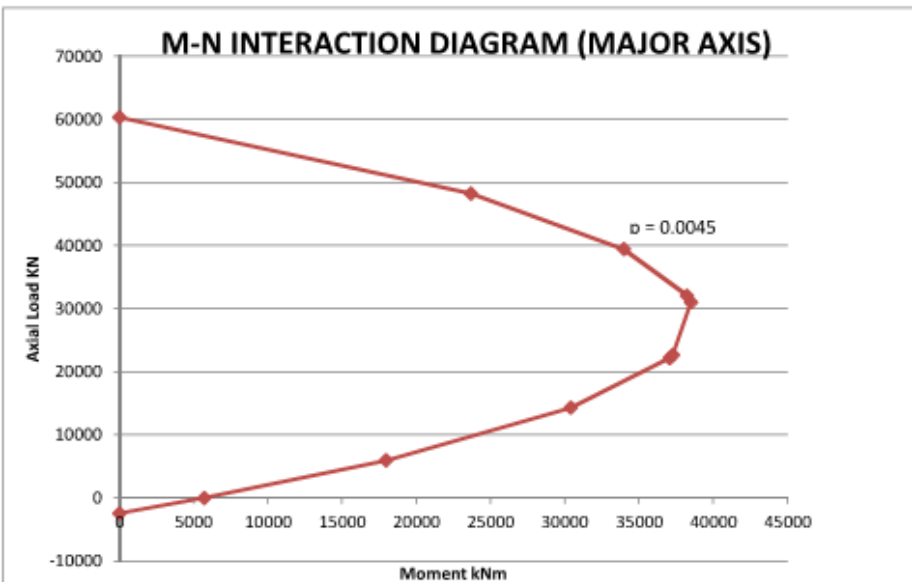
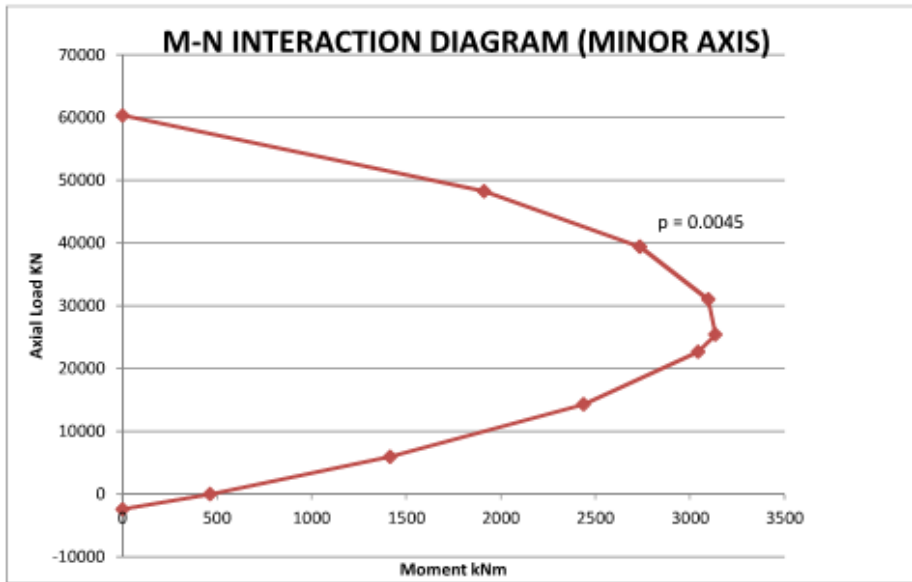
Photo 10 - Shearwall D5-6 Failure - Close-up



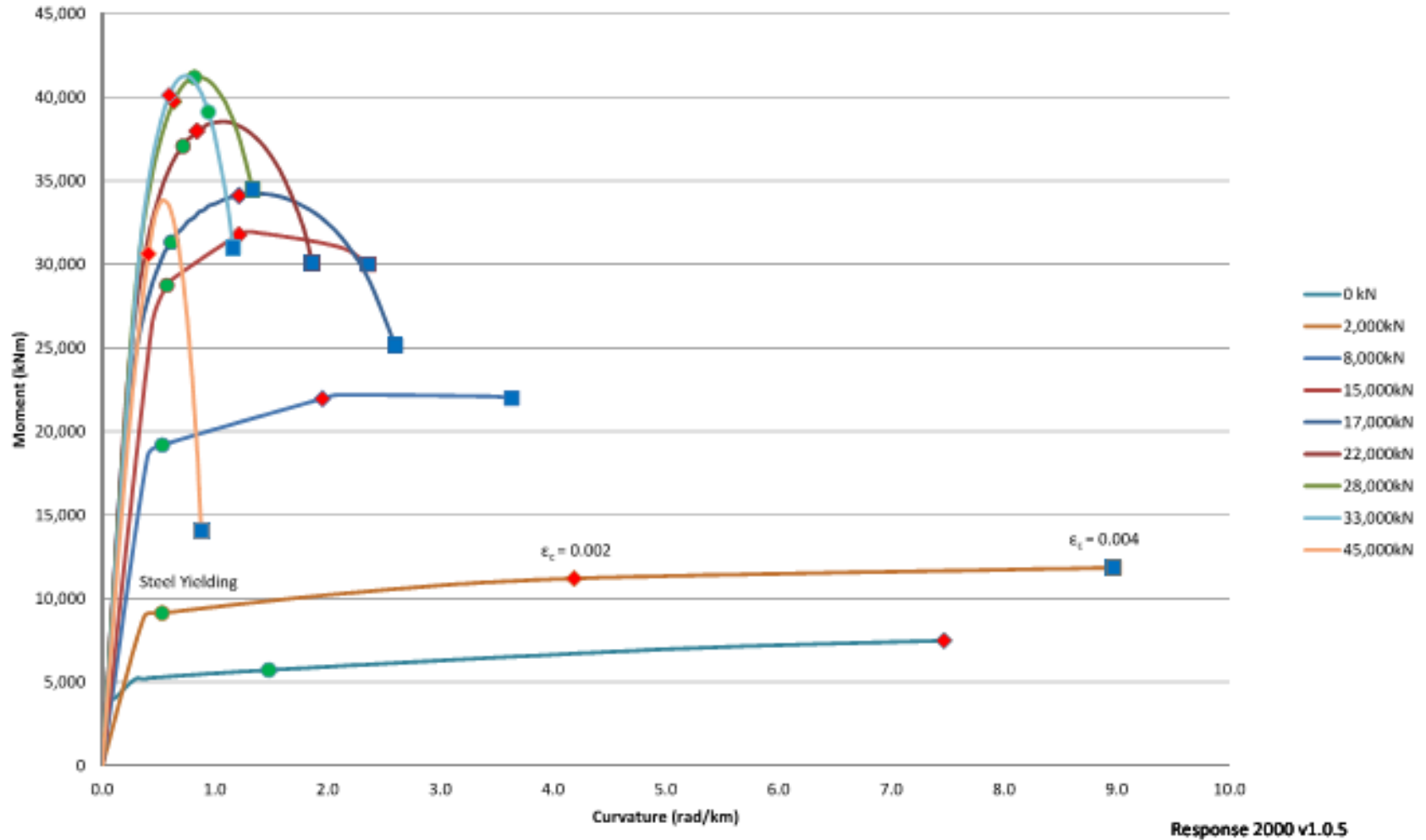
Photo 11 - Similar Shearwall Failure
Not the Hotel Grand Chancellor



Photo 12 - Similar Shearwall Failure
Not the Hotel Grand Chancellor

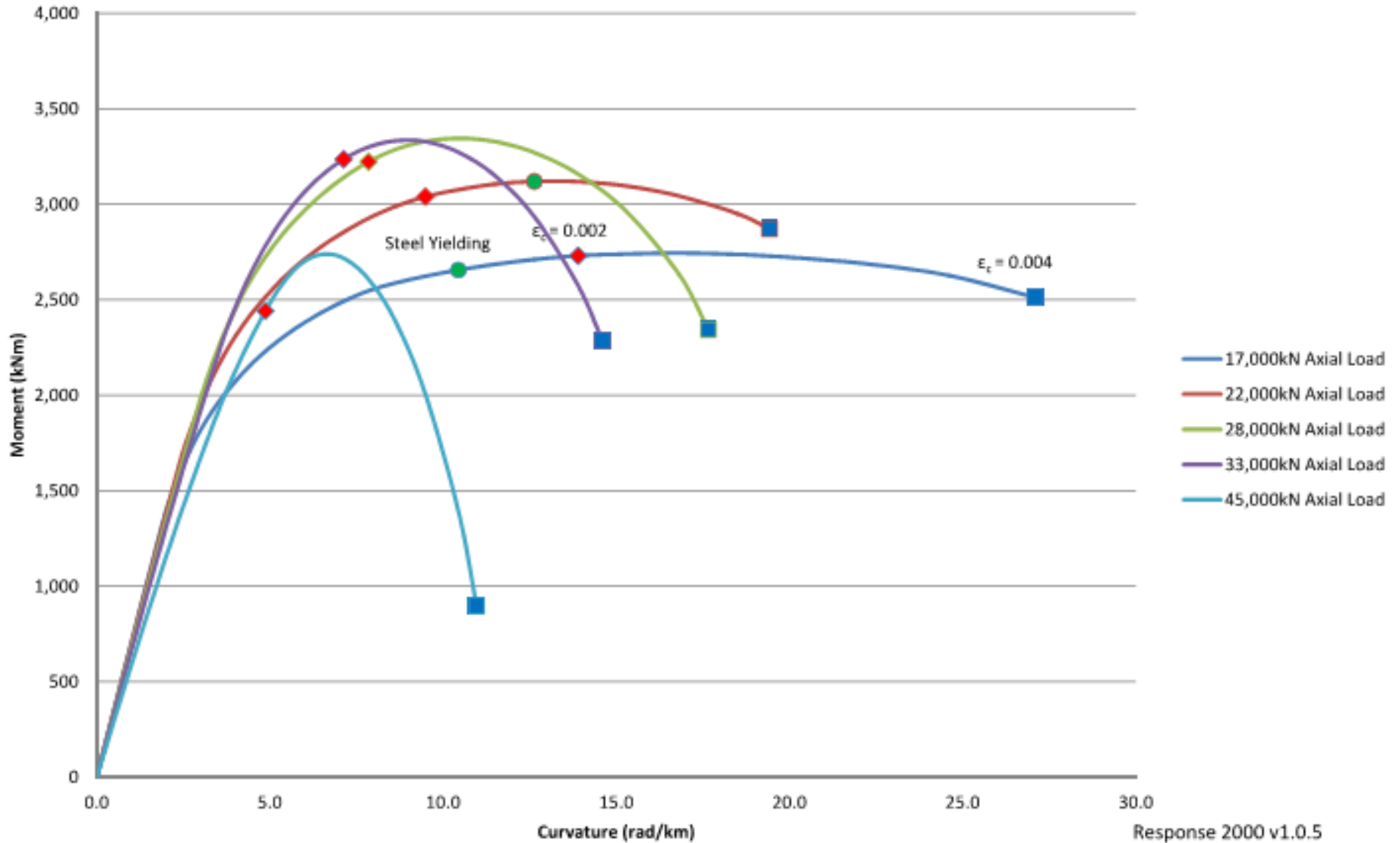


Moment Curvature - Major Axis

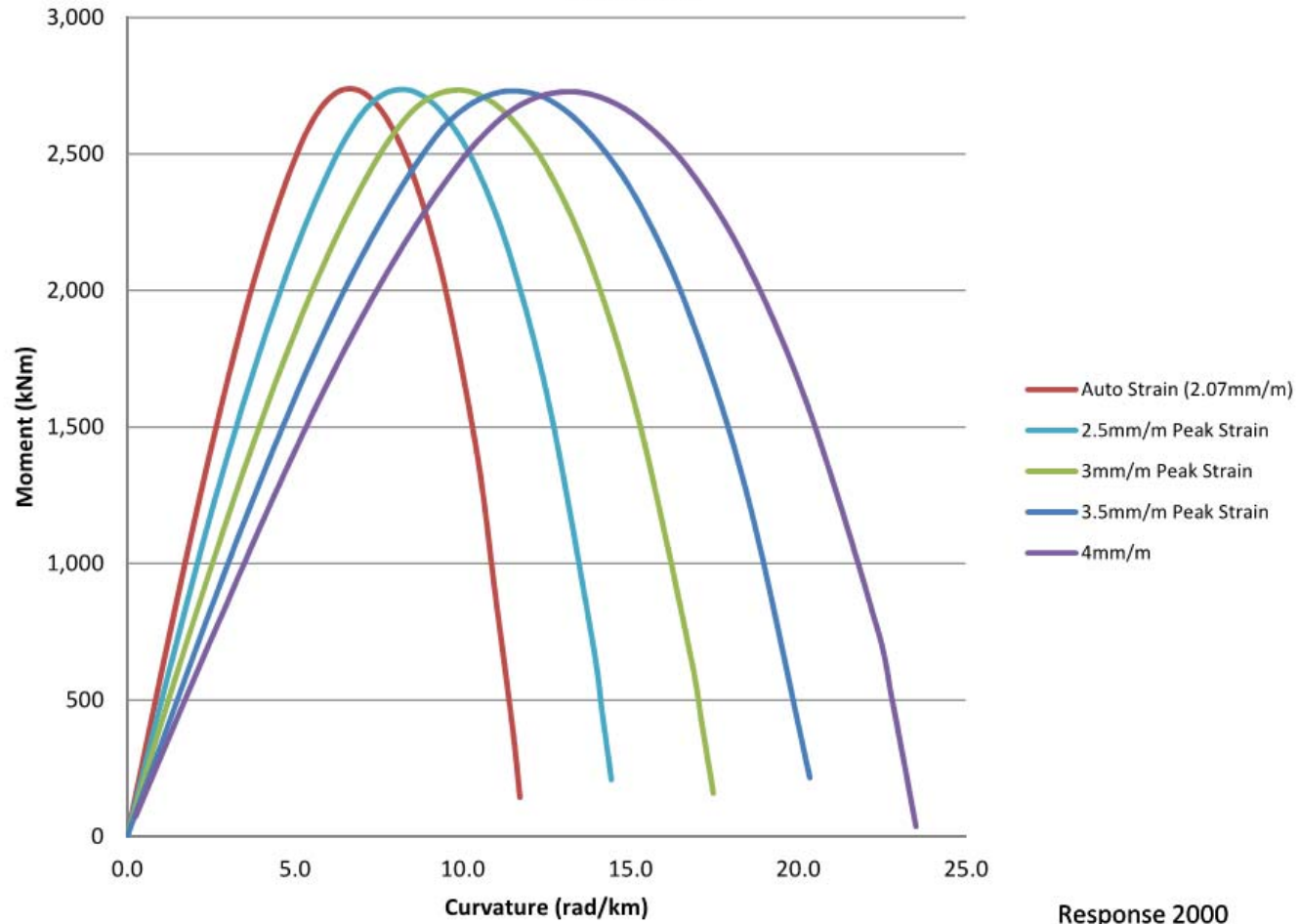


Moment Curvature - Major Axis

Moment Curvature - Minor Axis



Minor Axis Moment Curvature - Differing Peak Concrete Strains



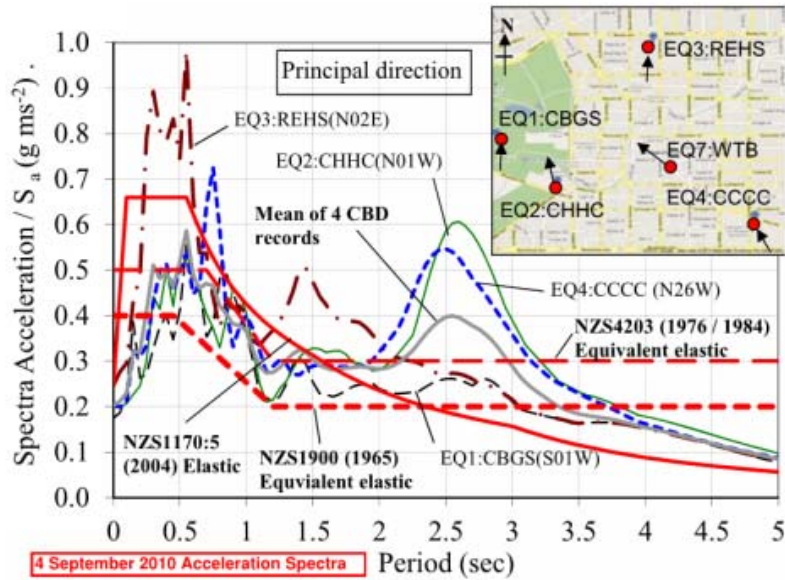


Fig. 6(a)

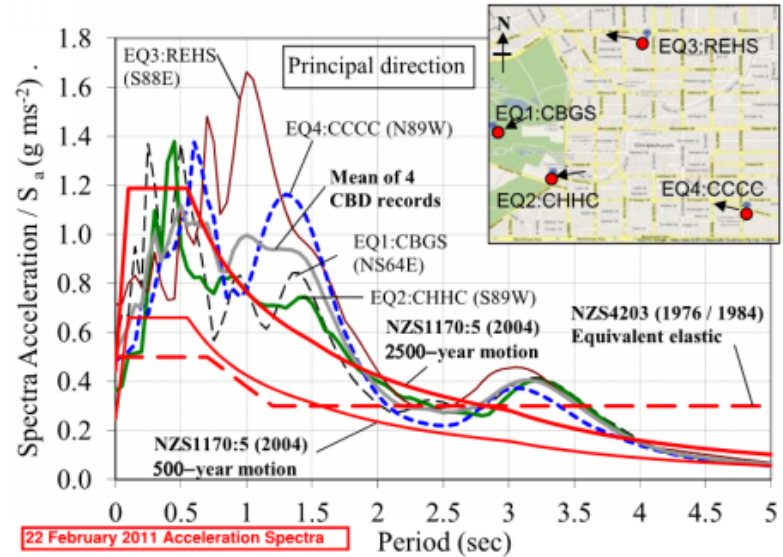


Fig. 6(c)

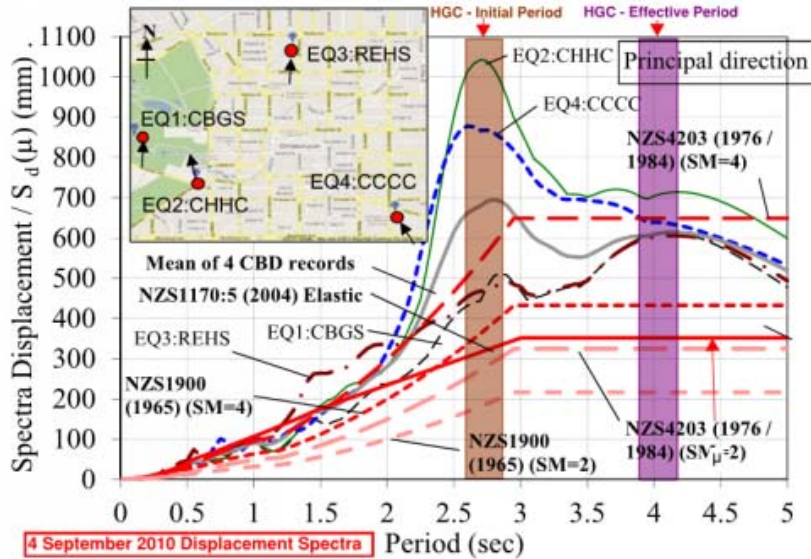


Fig. 6(b)

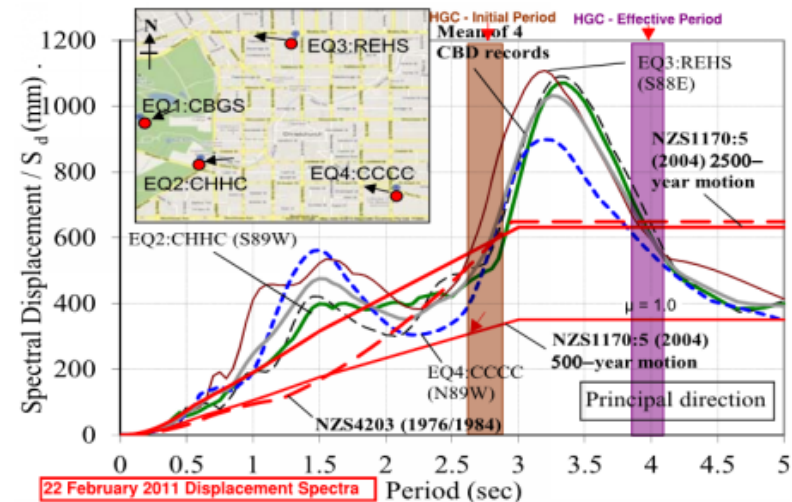
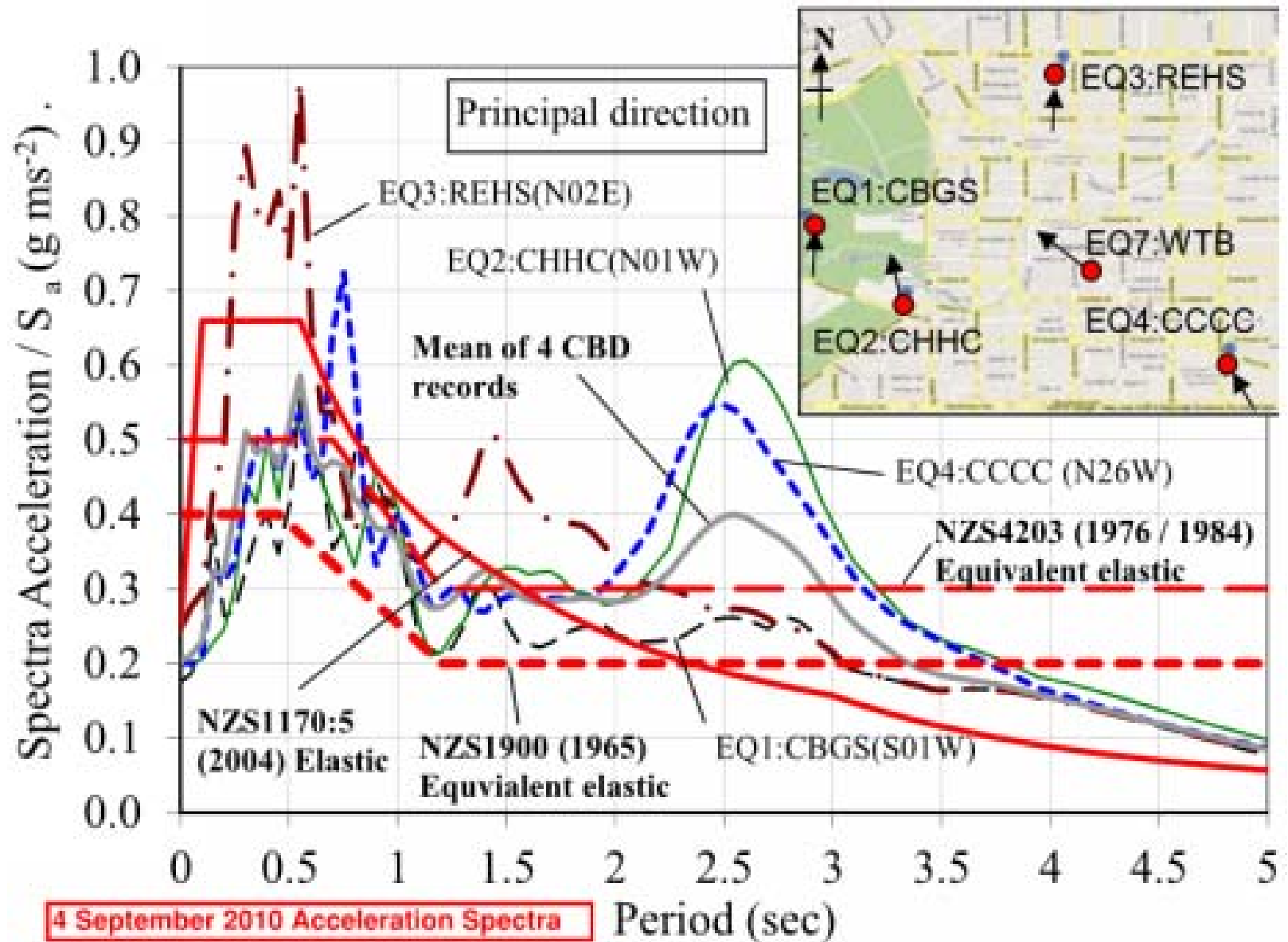


Fig. 6(d)

Spectral source
 Kam, W. Y., Pampanin, S., 2011 "General Performance of Buildings in Christchurch CBD after the 22 Feb 2011 Earthquake: a Contextual Report", Department of Civil and Natural Resources Engineering, University of Canterbury



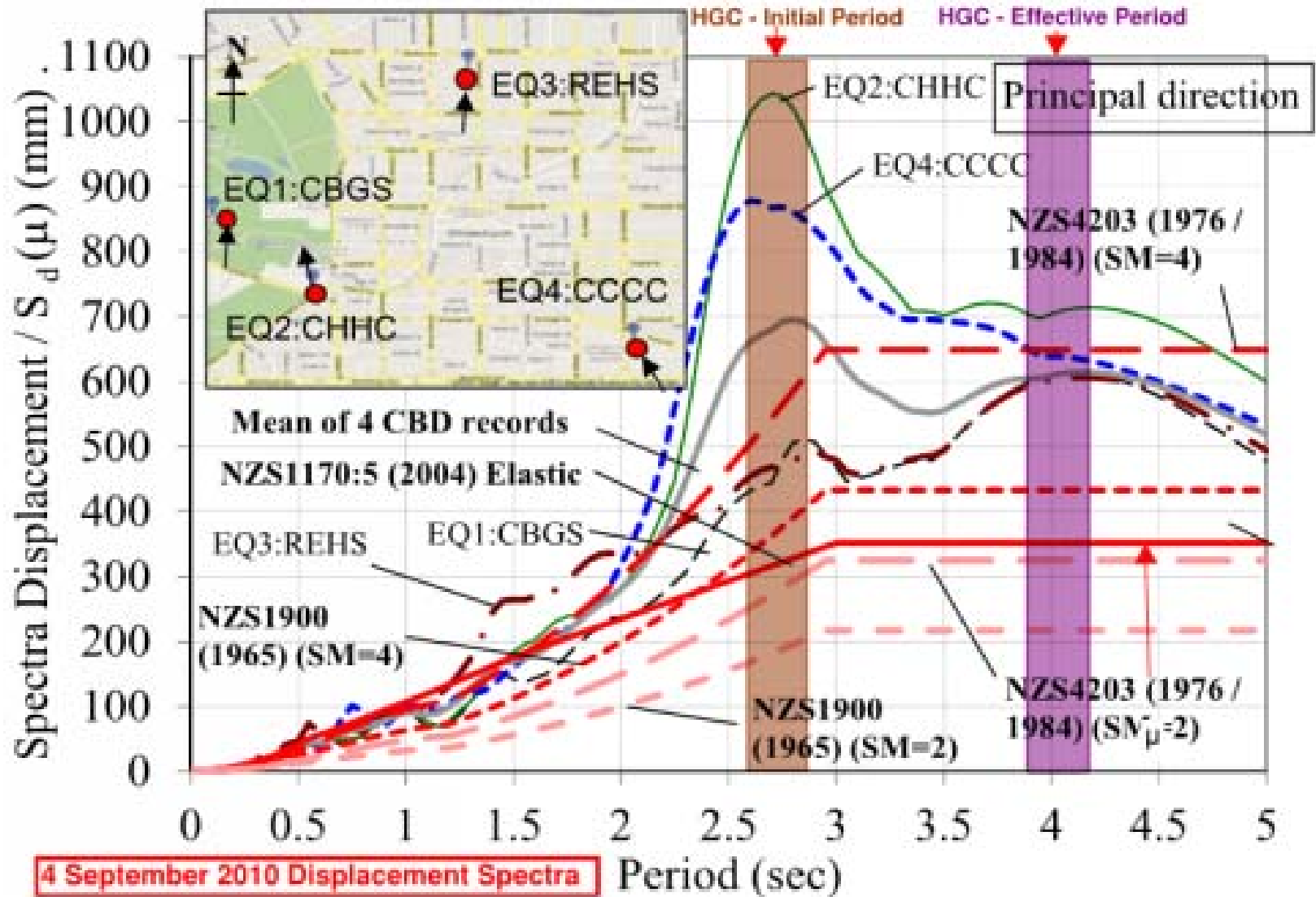


Fig. 6(b)

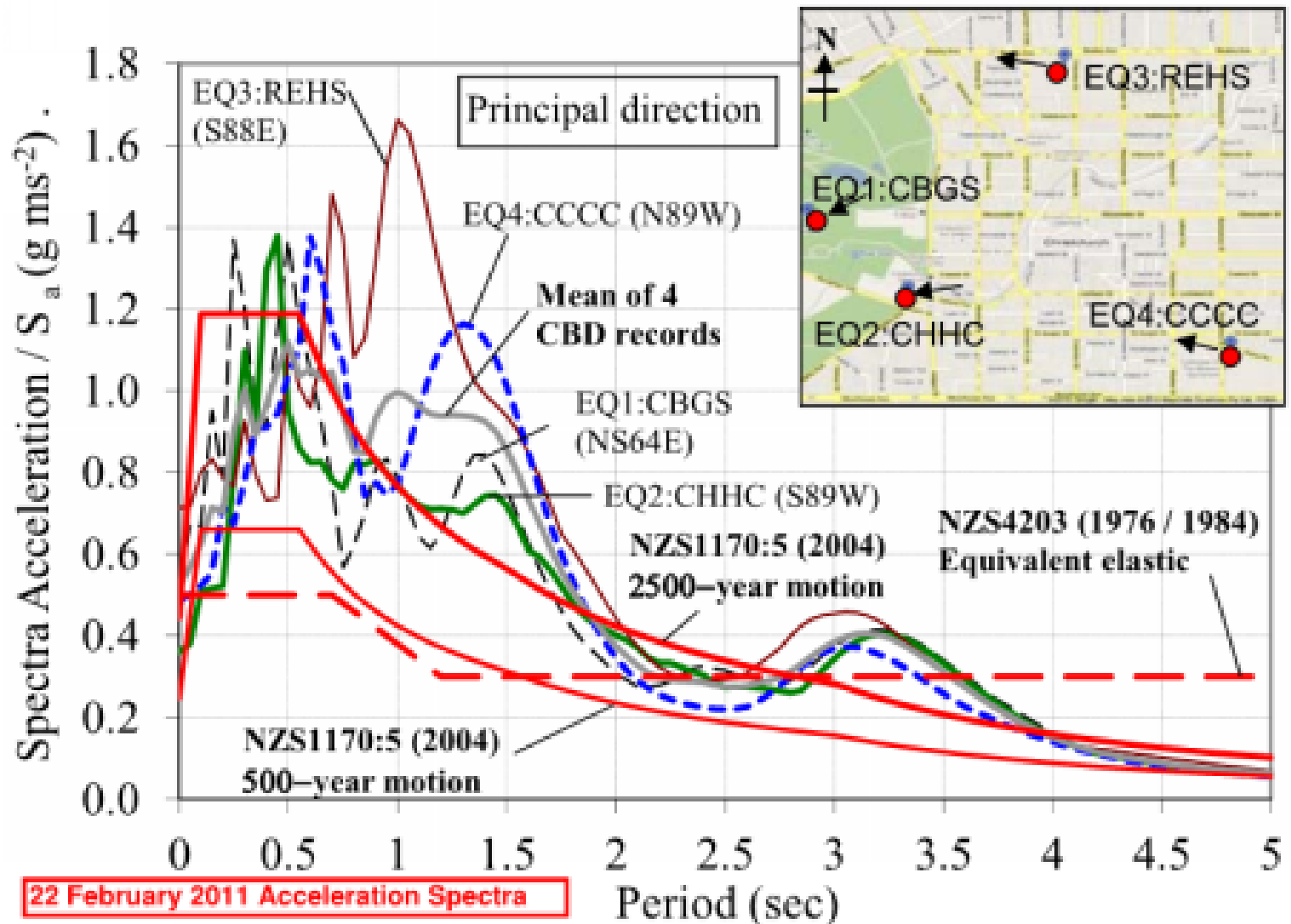


Fig.6 (c)

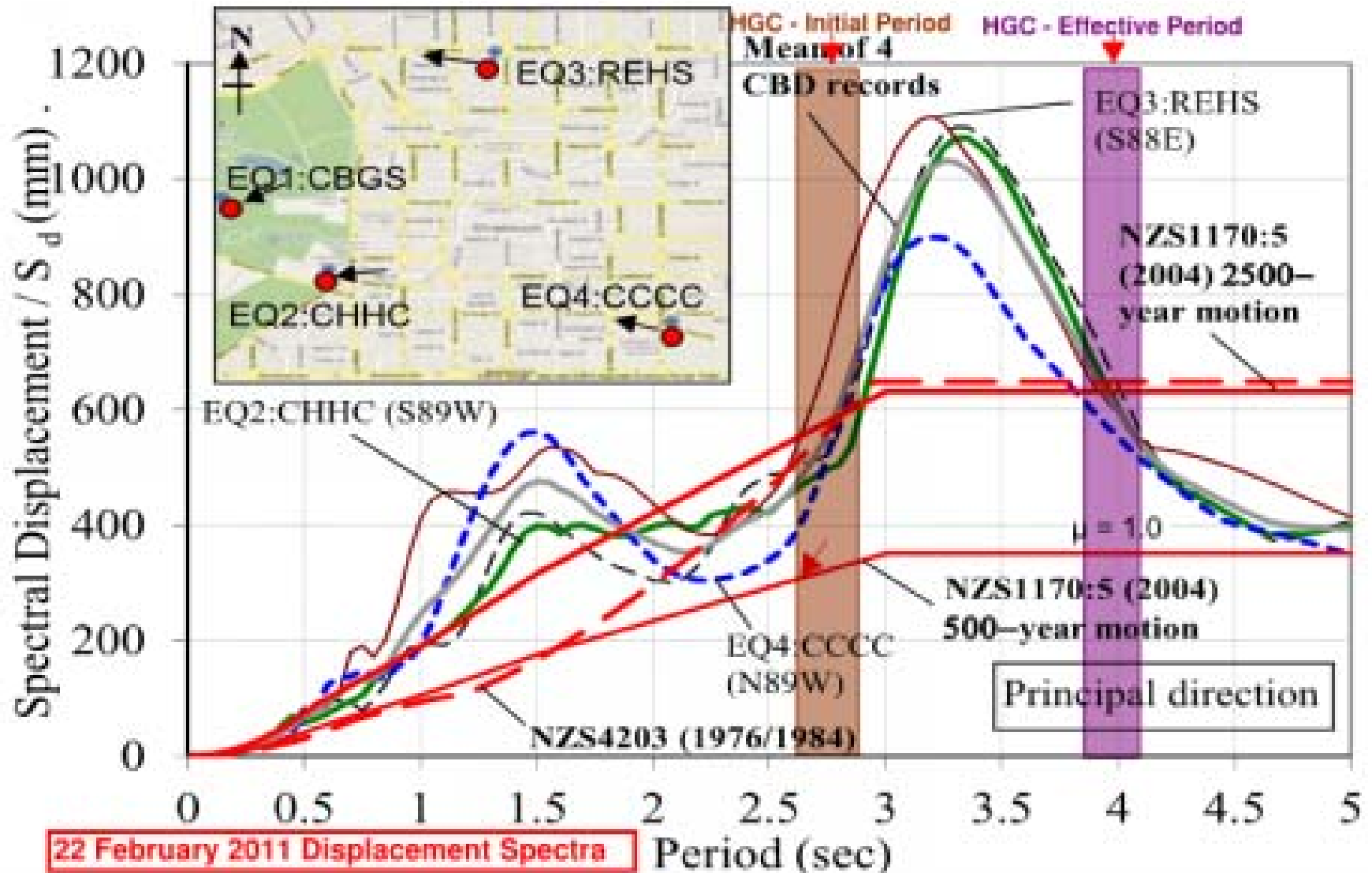
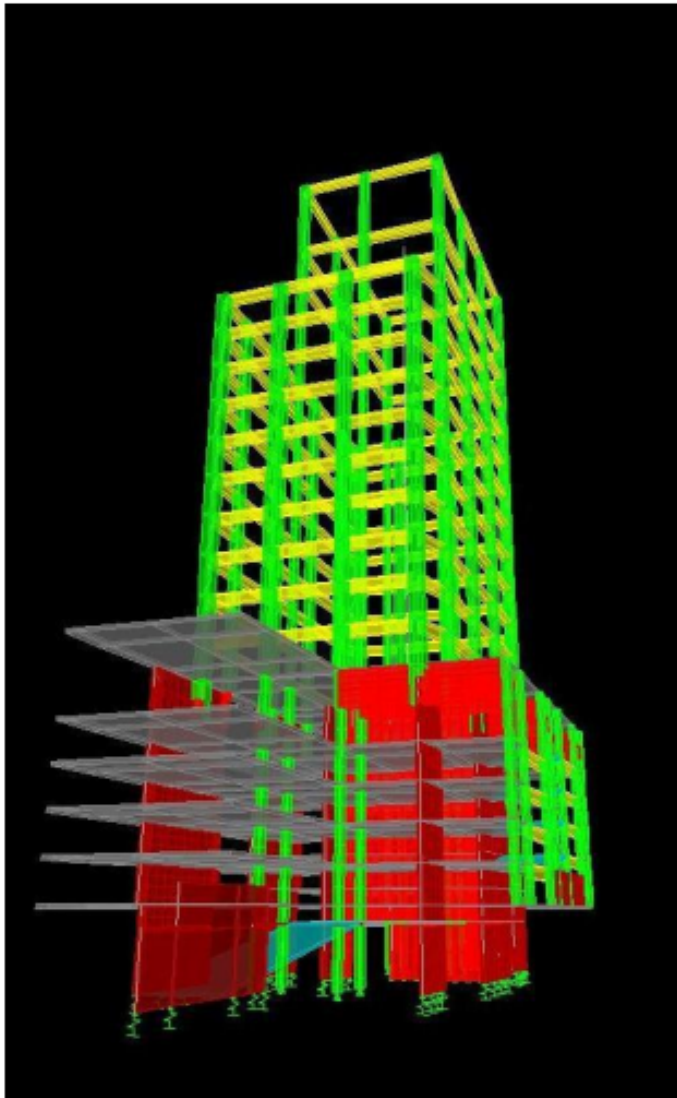
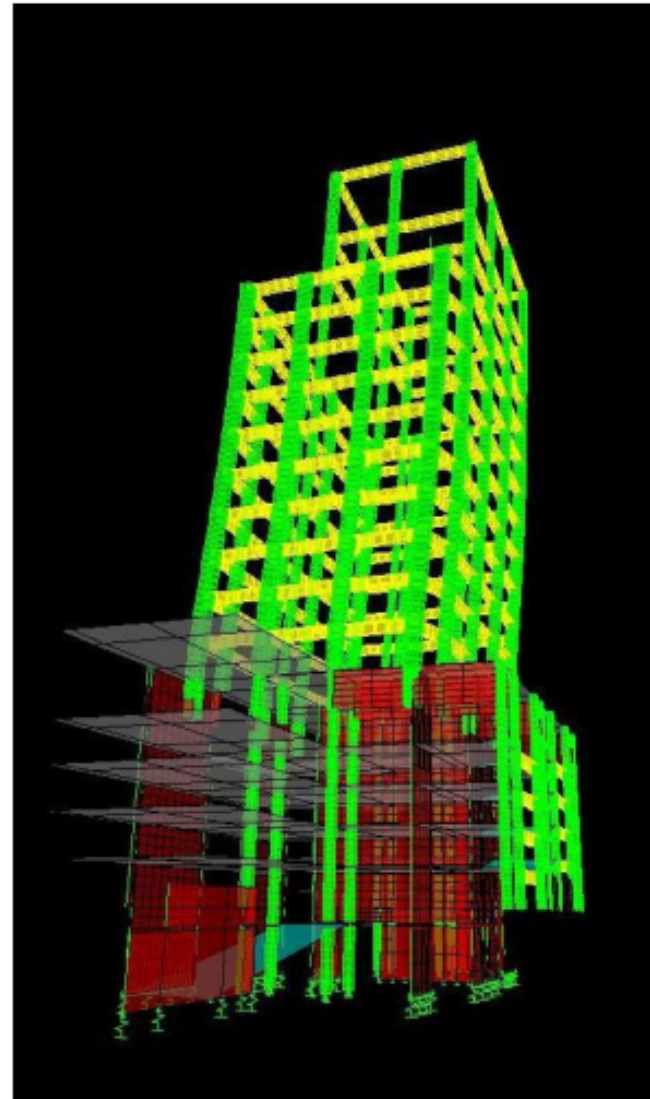


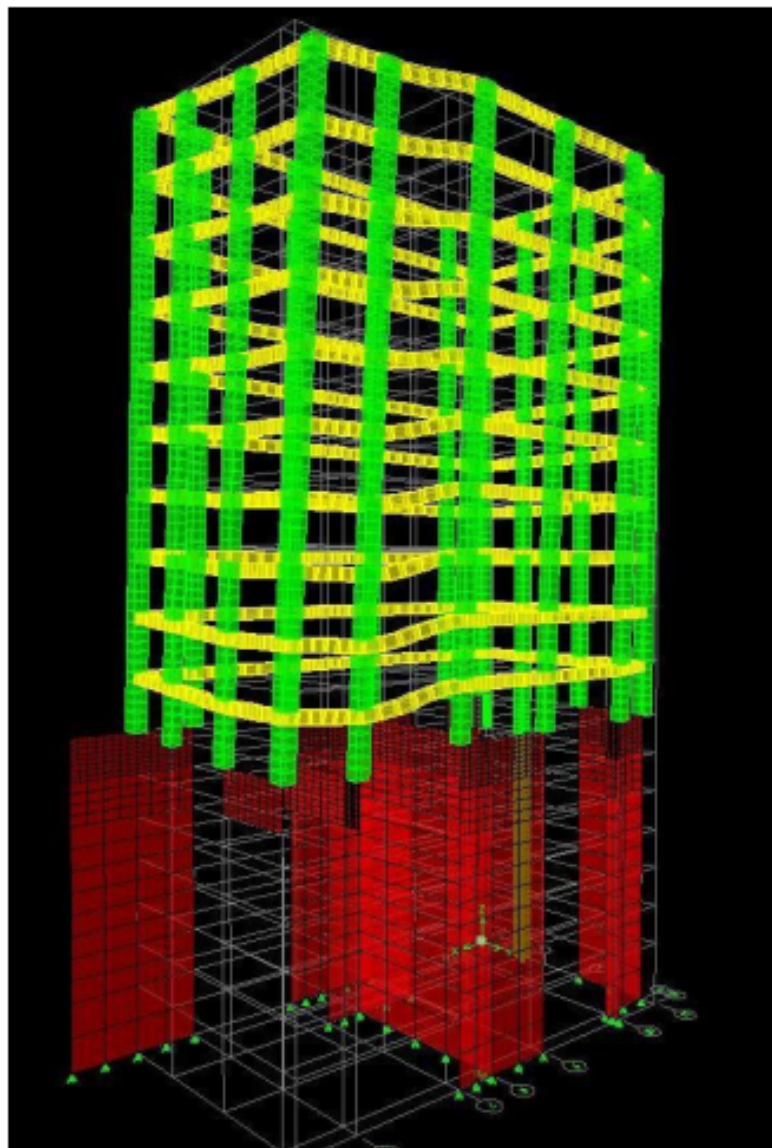
Fig. 6(d)



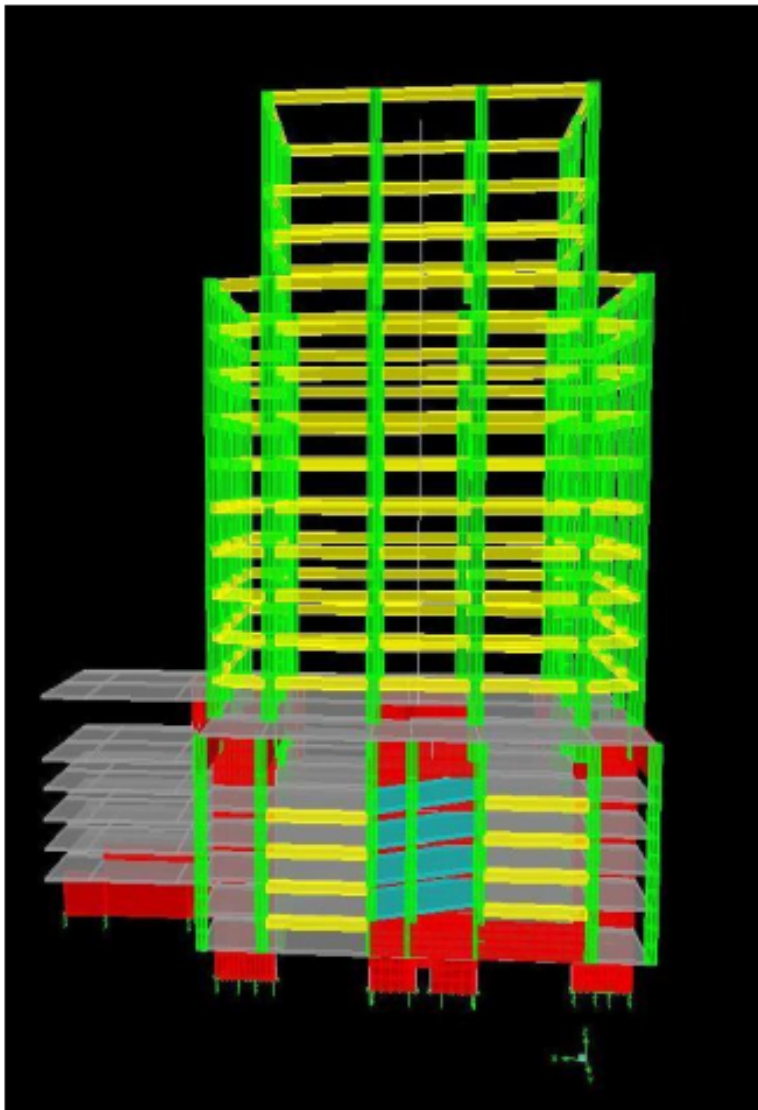
South (Front) View



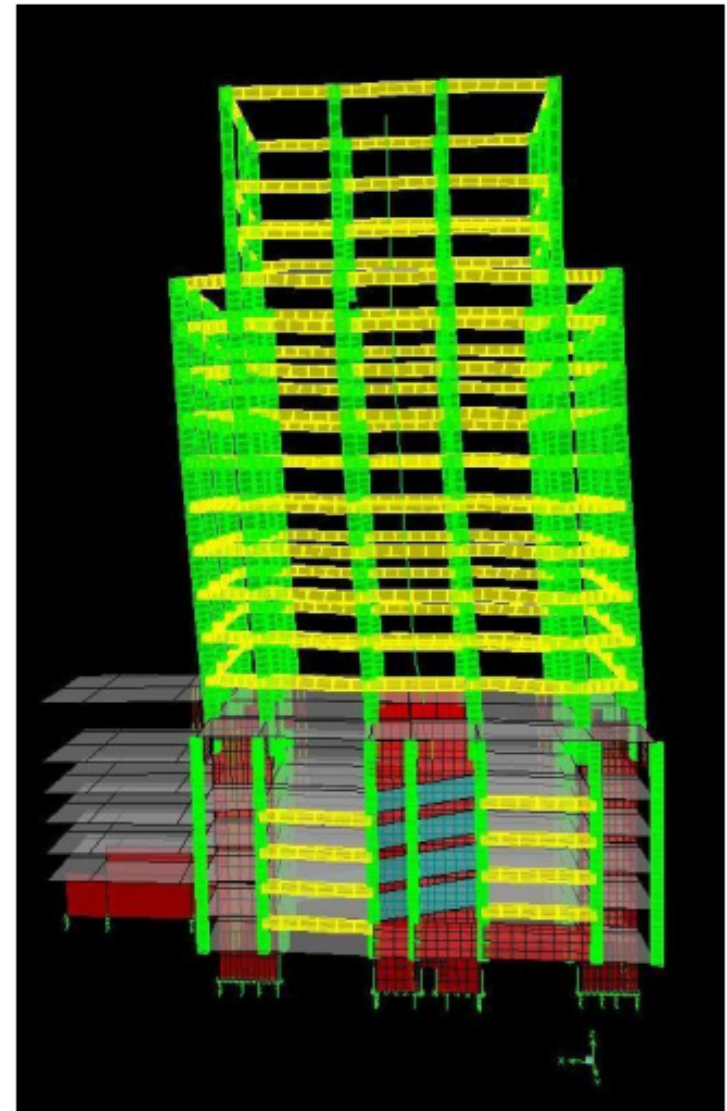
South View -Deformed



Corner Displacement



East Side View



East Side View - Deformed

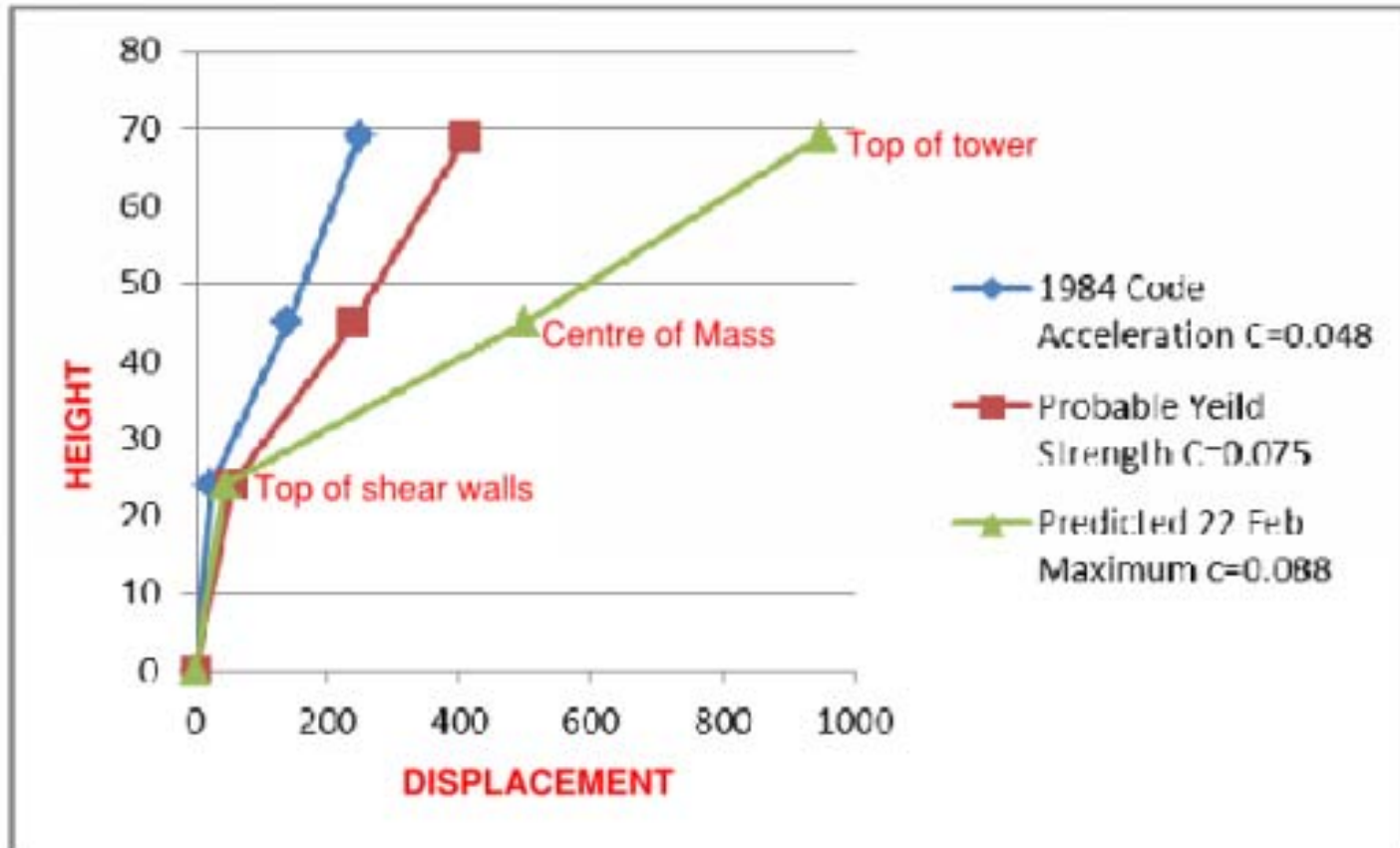
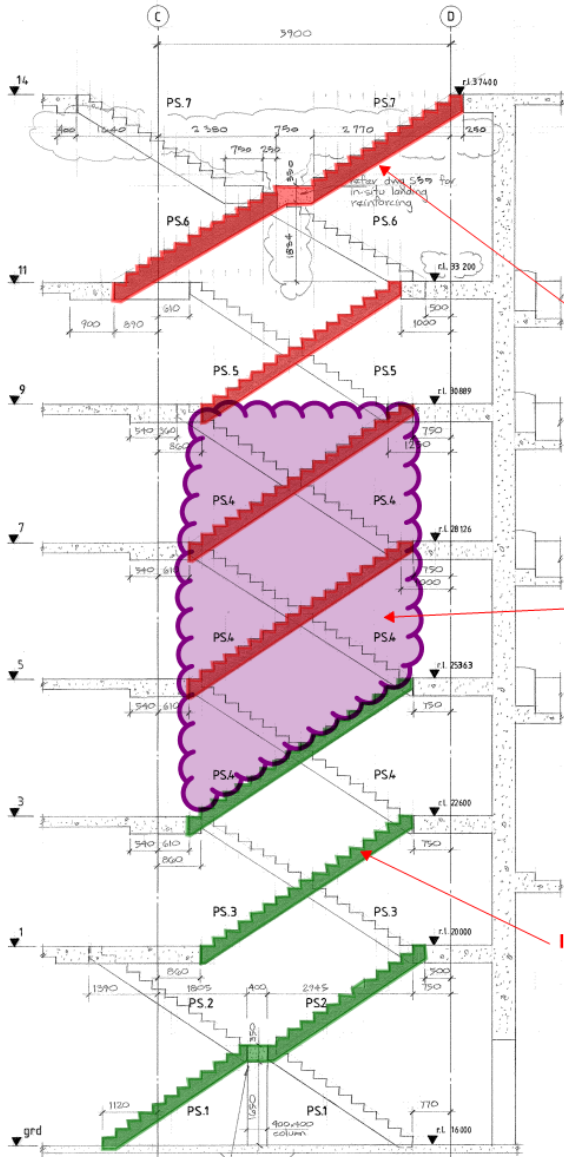


Fig.7

EXTRACT FROM ORIGINAL
STRUCTURAL DRAWINGS

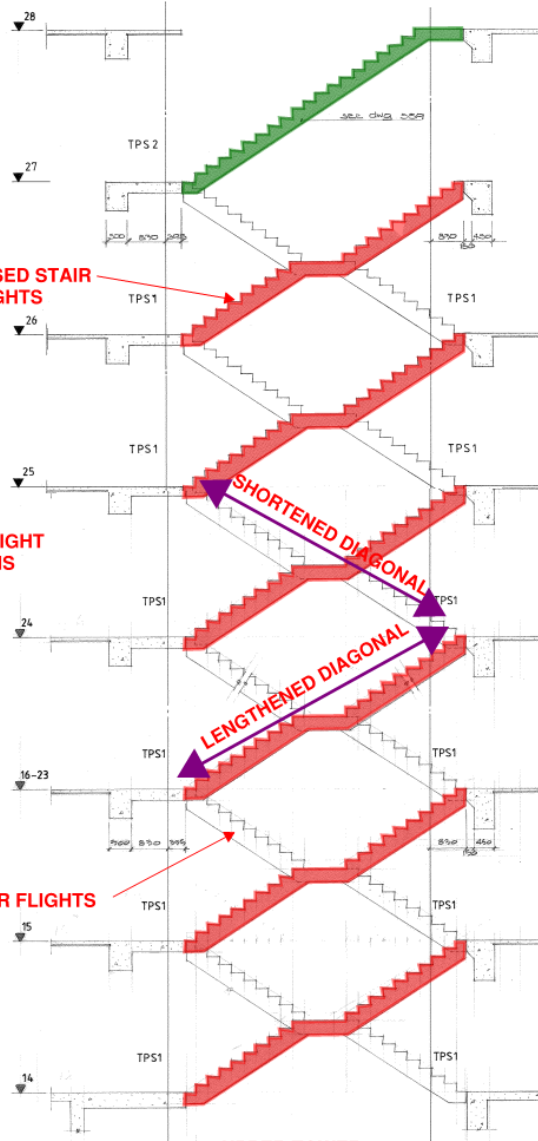


LOWER TOWER

COLLAPSED STAIR
FLIGHTS

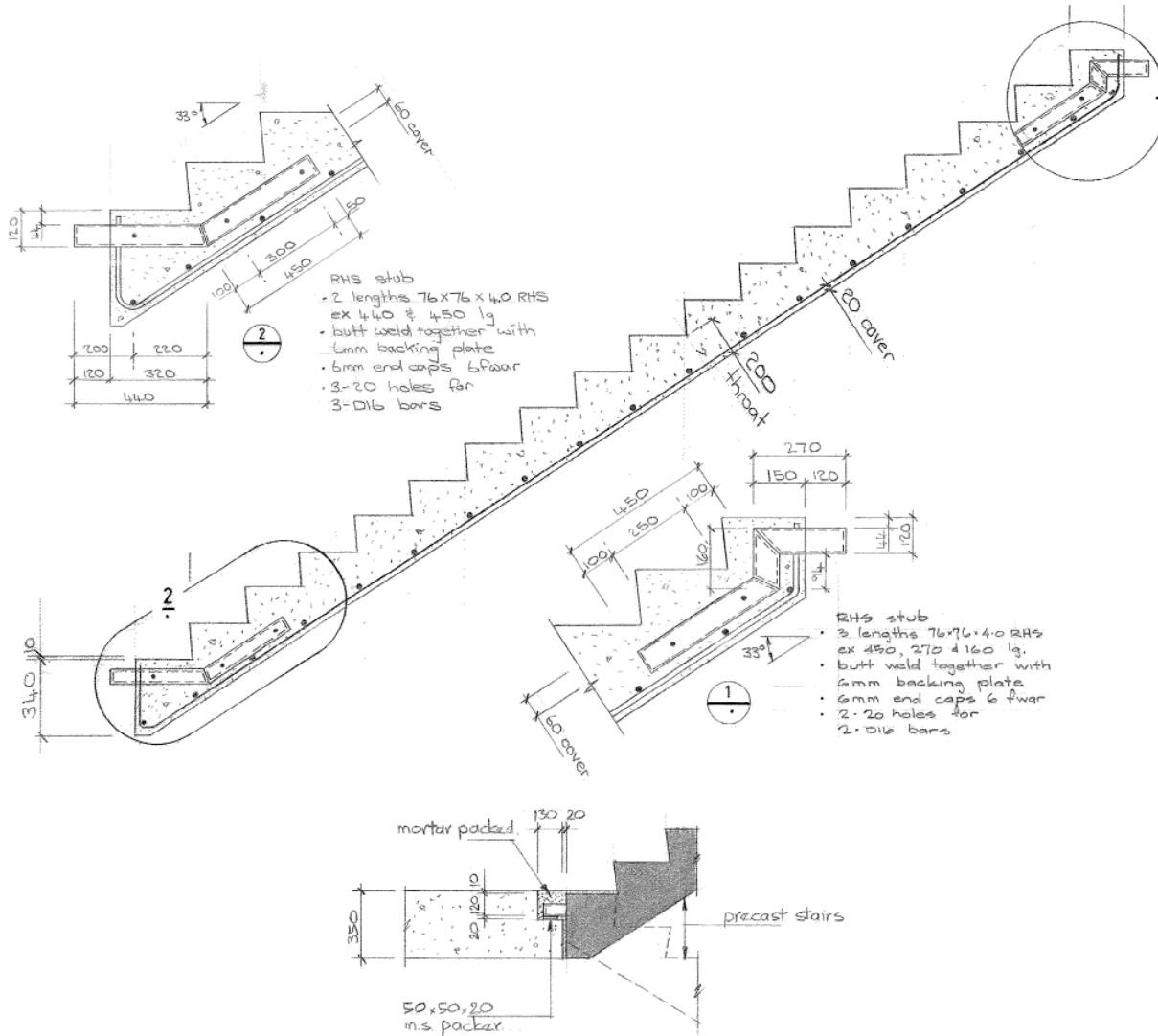
STAIR FLIGHT
DEBRIS

INTACT STAIR
FLIGHTS

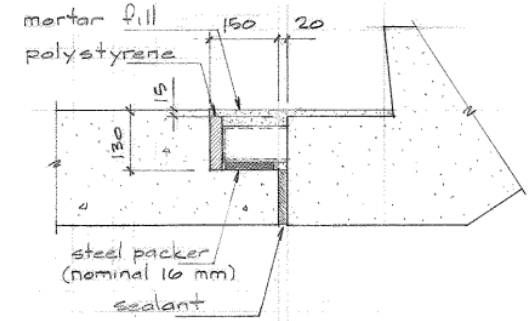


UPPER TOWER

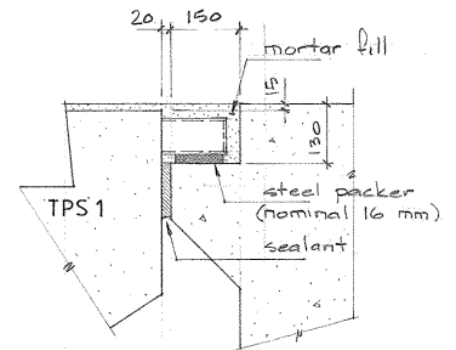
STAIR SECTIONS



typical stair fixing
at floor levels



bottom fixing TPS1
TPS2



top fixing TPS1



Photo 23 - Top of intact stair flight

Landing damage



Photo 24 -
Highest surviving
stair, supporting
debris

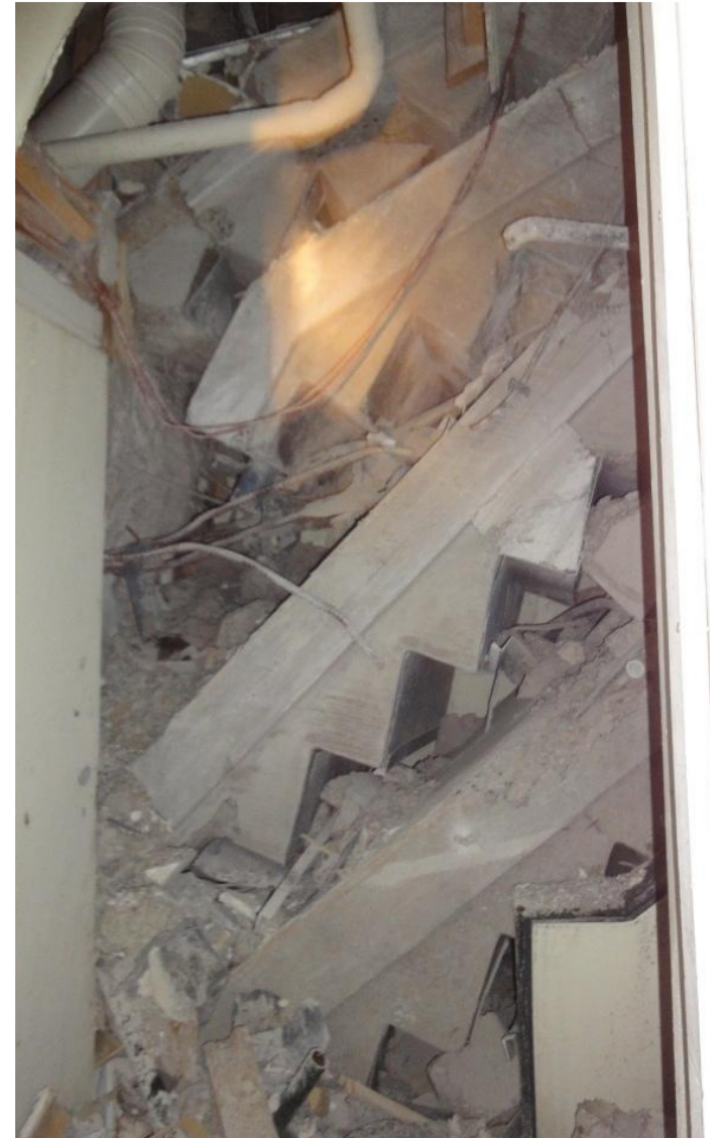
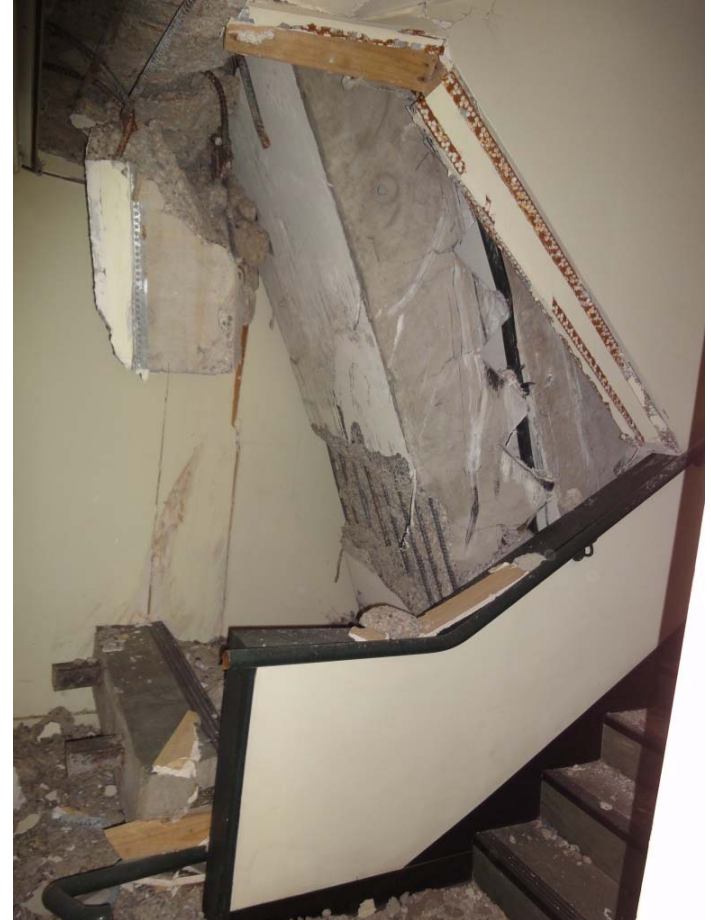


Photo 25 - Stair Debris







Questions Answered

- Response to September Event
 - Compliance with Contemporary Codes?
 - Failure in a 'Code' Event?
 - Failure in NZS1170.5 Event?
 - %NBS?
 - Stair collapse dependent on wall failure?
-
-

Recommendations

- Design Rigour for Irregularity
- Resign Rigour for Flexural Shear Walls
- Stair Separation
- Floor Depth Walls
- Design Rigour for Displacement Induced Actions
- Frames Supported on Cantilevers
- *Ratcheting*

Issues Raised In Review

- Bi-Directional Loading
- Performance of Other Walls
- Likelihood of Stair Failure
- P-Delta Effects
- Vertical Acceleration Effects
- Speed of Loading
- Ratcheting