Project ~~F4.3~~ 17137 – July update
Seismic loss assessment to motivate high performance building solutions

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Key Objectives

1. Demonstrate how loss assessment could be an effective means of quantifying the benefits of innovative construction technologies

2. Test and develop options for simplified loss-assessment appropriate for preliminary design phase

3. Identify and develop loss functions for non-structural elements for NZ usage

4. Identify functions from literature suitable for NZ construction, and develop fragility functions for components unique to NZ.

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Objective 1 – Loss assessment of case study buildings

- **Stage 1: Develop case study building layouts**
  - Drawings available on QuakeCoRE wiki
  - Design loading document in draft

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Stage 2: Fragility Functions

×/✓ indicates the progress of sourcing/developing fragility and consequence functions for case study layout

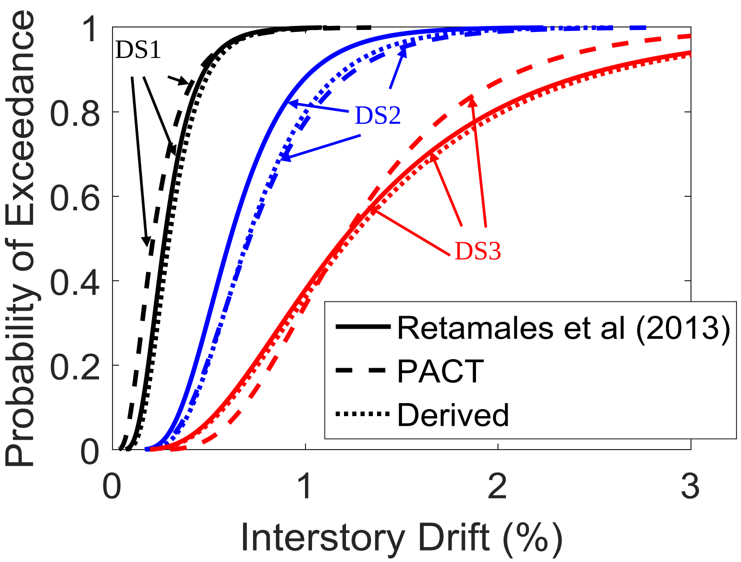
Building component	Fragility	Consequence
Structural beam/column/walls	✓	×
Floor slabs	×	×
Stairs	✓	×
Façade	✓	✓
Partitions	✓	✓
Ceiling	✓	✓
Heavy Plant	×	×
Sprinklers	✓	×
Elevators	✓	✓

Stage 2: Fragility Functions

1) Experimental data approach

Example: Partitions

Source	ID	Test Type	DS1	DS2	DS3
Davis et al. (2011)	4	In Plane – Quasi Static	0.62	0.62	1.16
	5	In Plane – Quasi Static	0.20	0.40	2.32
	6	In Plane – Quasi Static	0.40	0.62	2.66
	7	In Plane – Quasi Static	0.20	0.62	1.00
	8	In Plane – Quasi Static	0.40	1.99*	1.00
	9	In Plane – Quasi Static	0.20	0.40	0.62
	10	In Plane – Quasi Static	0.20	1.00	0.81
Petrone et al. (2015)	1	In Plane – Quasi Static	0.34	0.87	2.78
	4	In Plane – Quasi Static	0.32	1.16	1.61
Tasligedik (2014)	N/A	In Plane – Quasi Static	0.30	0.75	N/A
Restrepo and Lang (2011)	1	Two Directions – Quasi Static	0.28	0.61	0.77
	2	Two Directions – Quasi Static	0.28	0.82	0.82

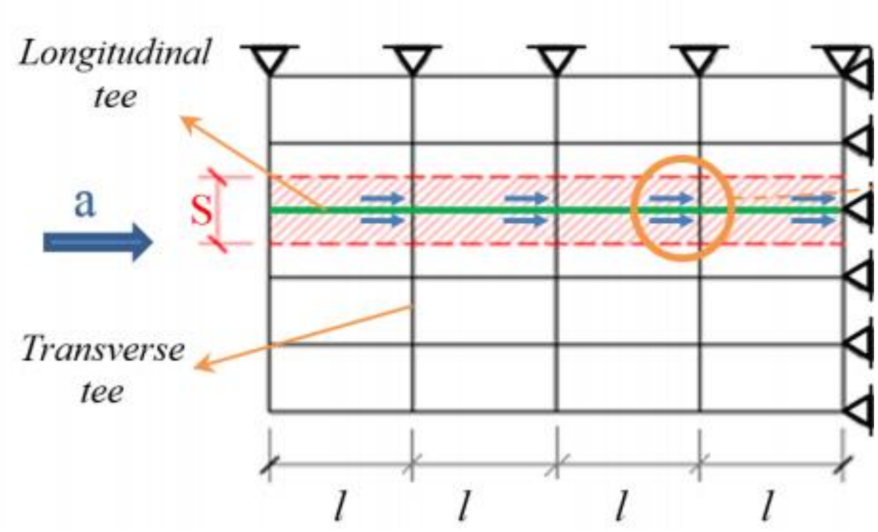


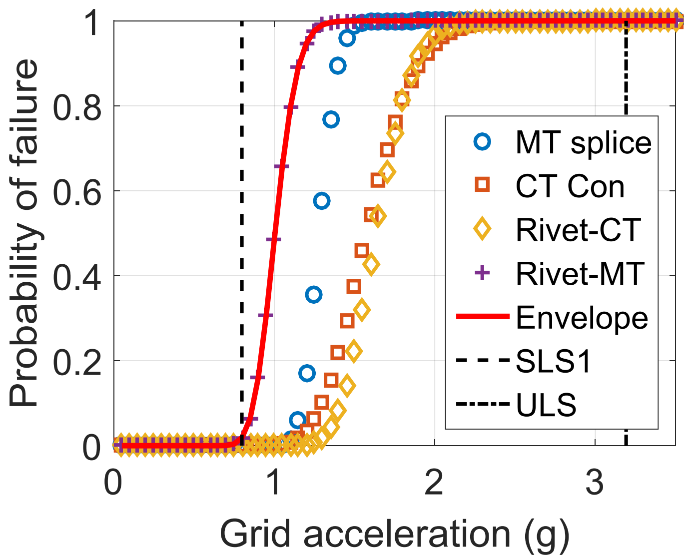
Stage 2: Fragility Functions

2) Mechanics approach using component tests

Example: Ceilings (Dhakal et al., 2016)

Fragility functions for individual ceiling components (e.g. rivets, tees) developed at UC. Used a mechanics approach to calculate demand on components and hence failure probability.



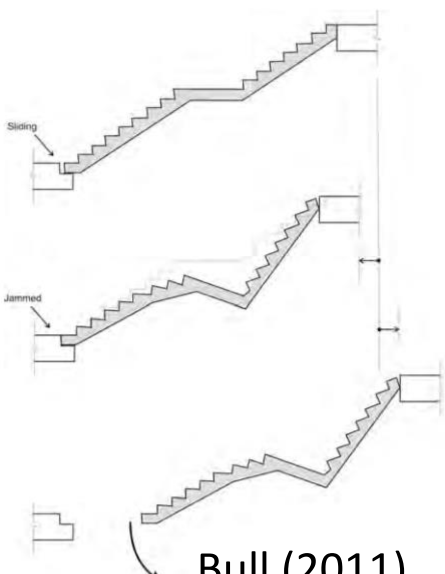


Stage 2: Fragility Functions

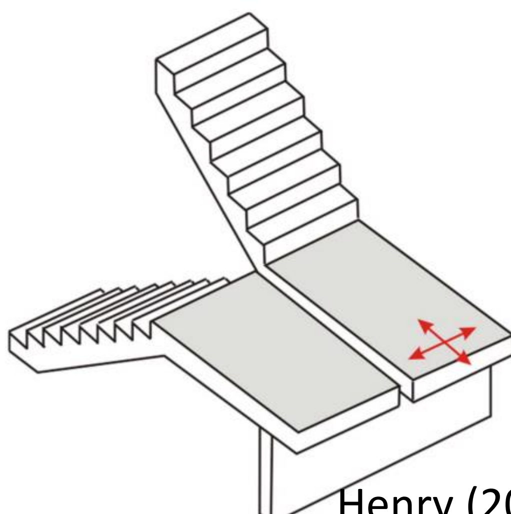
3) Engineering judgement/mechanics

Example: Stairs

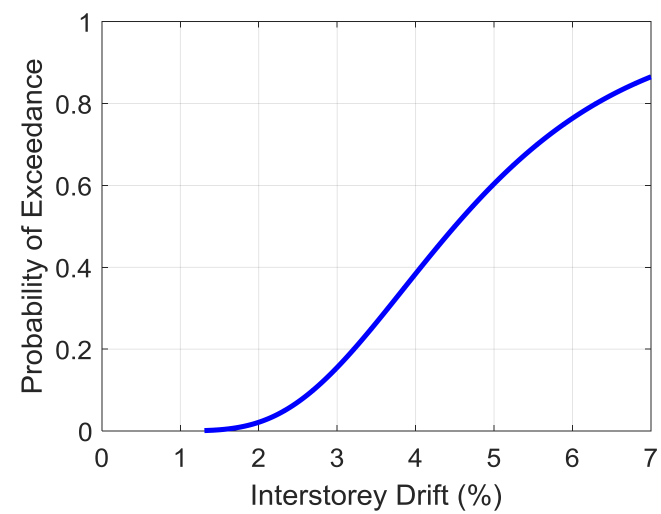
- Simmons (2000) tested precast straight stairs
- Switchback stairs mostly used in new construction
- Assumed stairs will not be damaged if free to slide, and only "failure" would be loss-of-support (width specified in design)



Bull (2011)



Henry (2015)

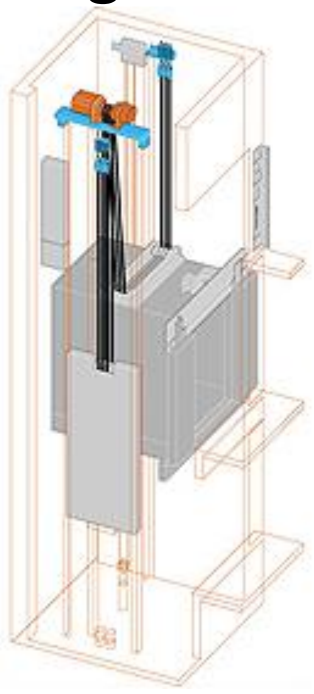


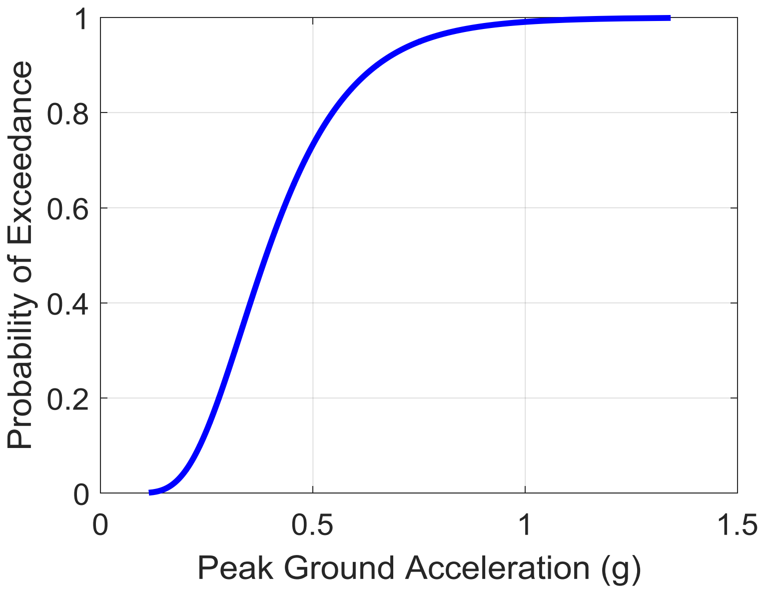
Stage 2: Fragility Functions

4) Directly from literature

Example: Traction elevators (Porter, 2016)

- Based on observations from Loma Prieta and Northridge events





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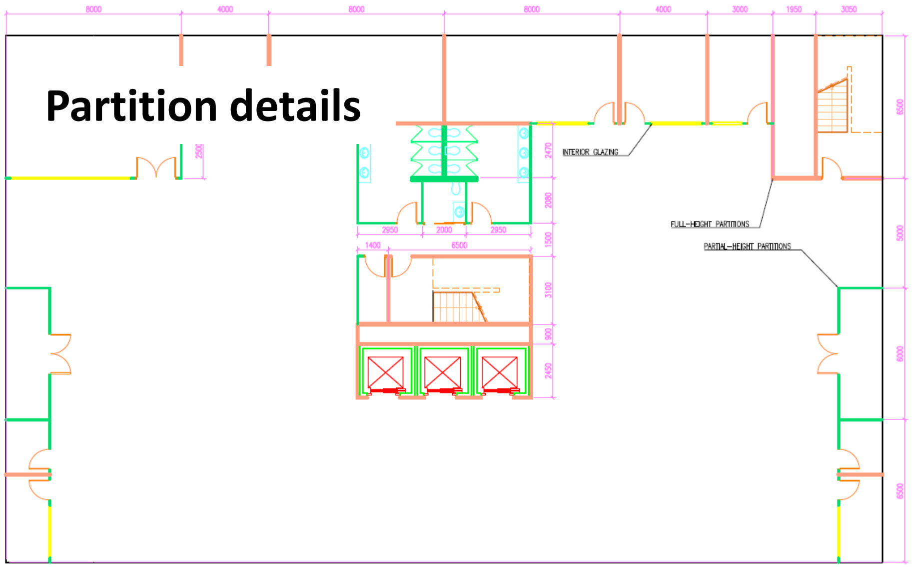
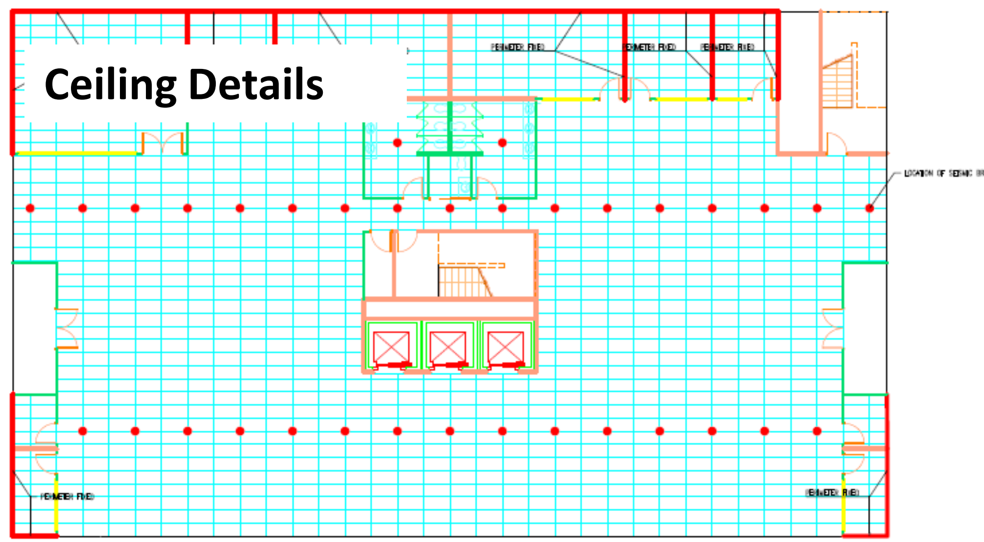
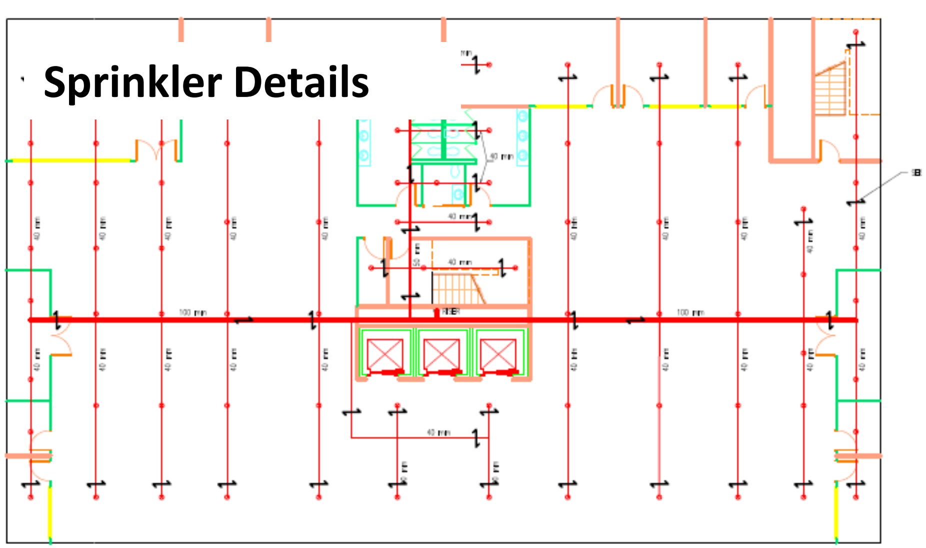
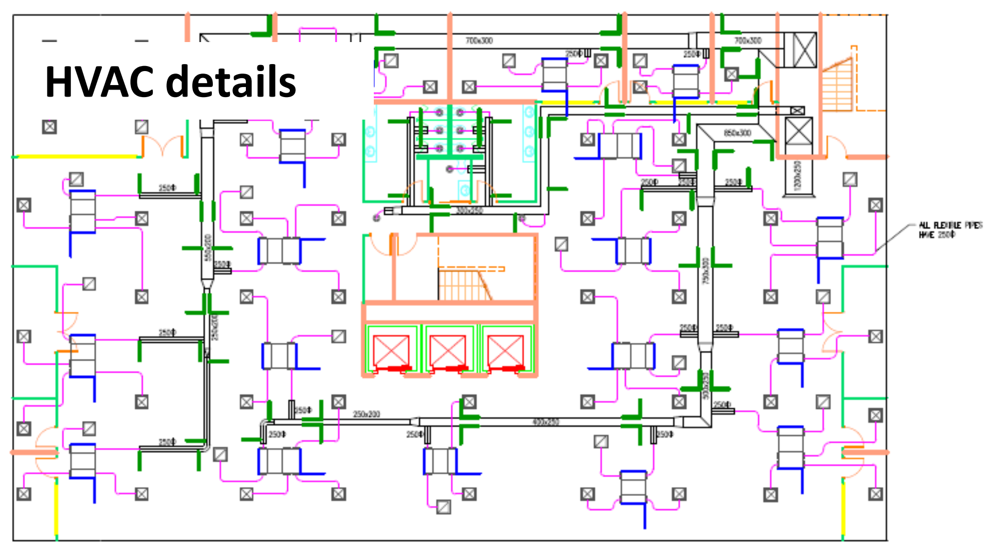
Building Layout









Stage 3: Building design

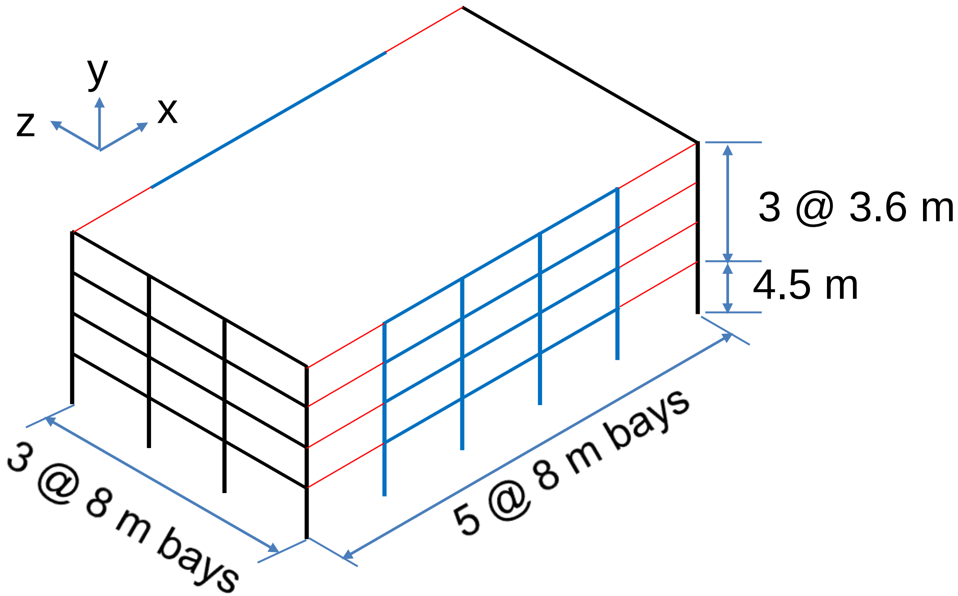
Case study buildings planned or being designed

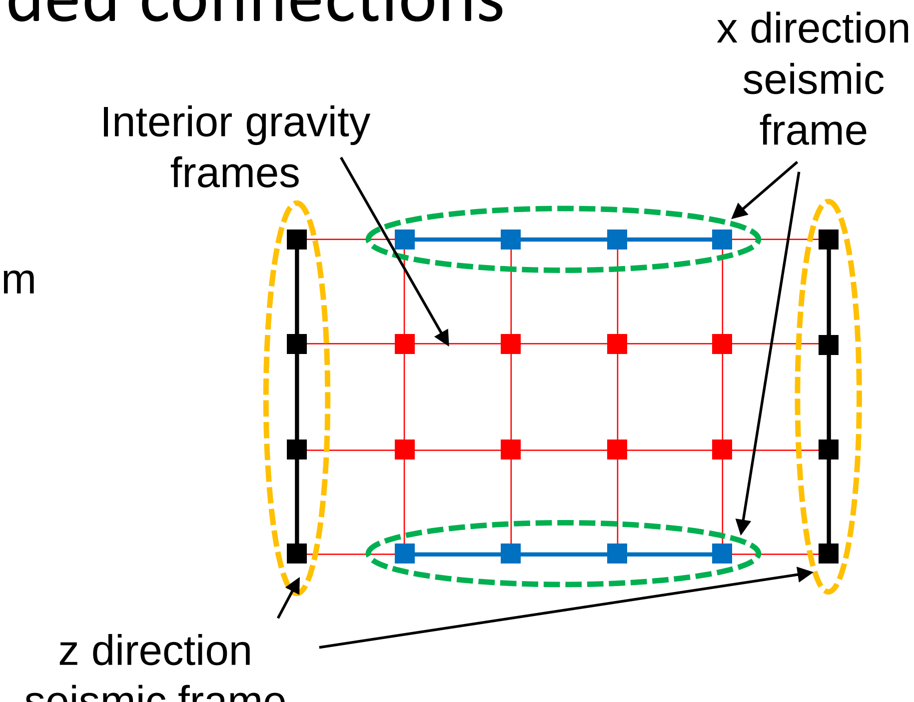
- Steel buildings:
  1. Moment resisting frame (MRF) with traditional connections
  2. MRF with friction connections
  3. MRF with viscous dampers
  4. Eccentrically braced frame
  5. Base isolated MRF

Stage 3: Building design

Building layout (currently 4-storey, but 12-storey planned in future)

- Exterior columns have fixed-base connections
- Interior columns have pinned-base connections
- Gravity beams have pin-ended connections





Stage 3: Building design

Building details:

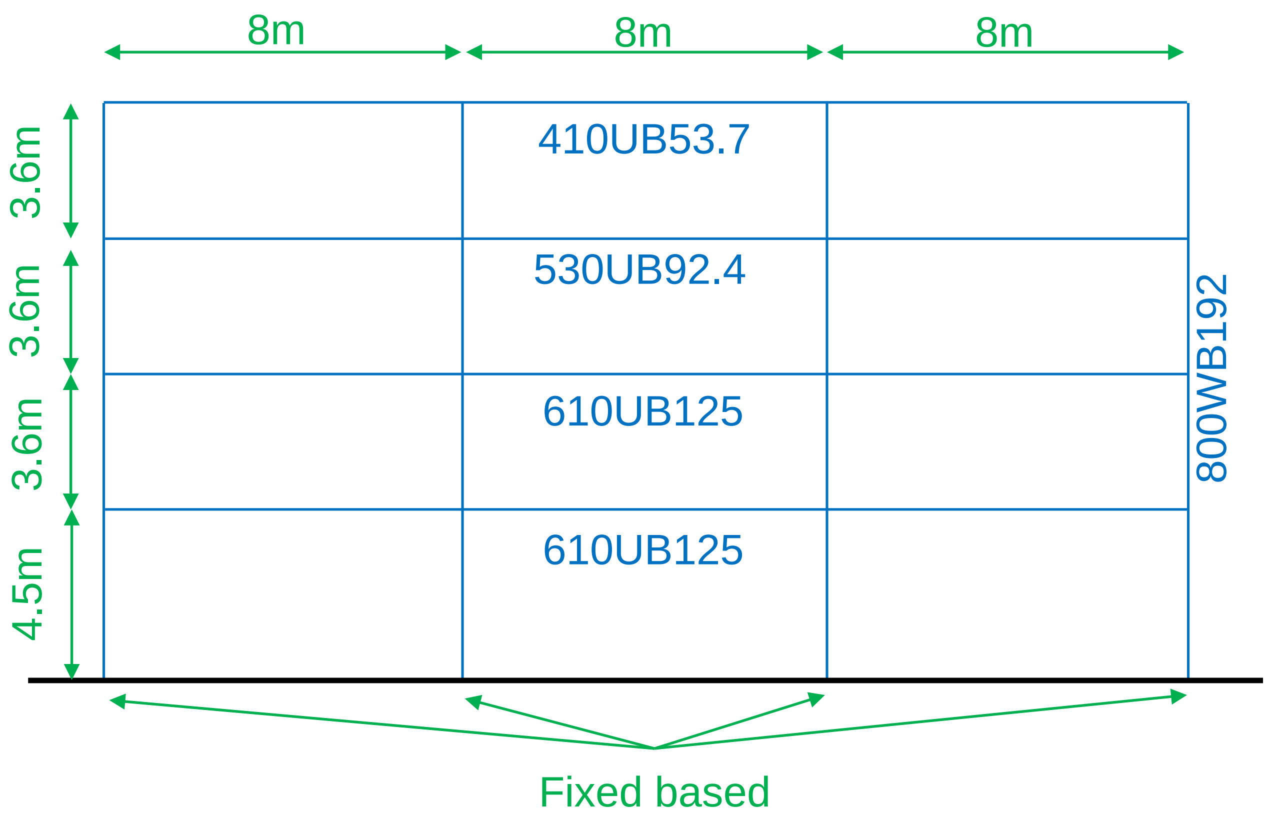
- Office usage located in Christchurch
- $\mu = 4$ at ultimate limit state seismic action
- $\mu = 1$ at serviceability limit state seismic action (some moment redistribution allowed)
- $\mu \leq 1$ for all other actions

Site details:

- Subsoil type D conditions for seismic action
- Terrain category of 4 for wind action
- Region N4 sub-alpine conditions for snow action

Stage 3: Building design

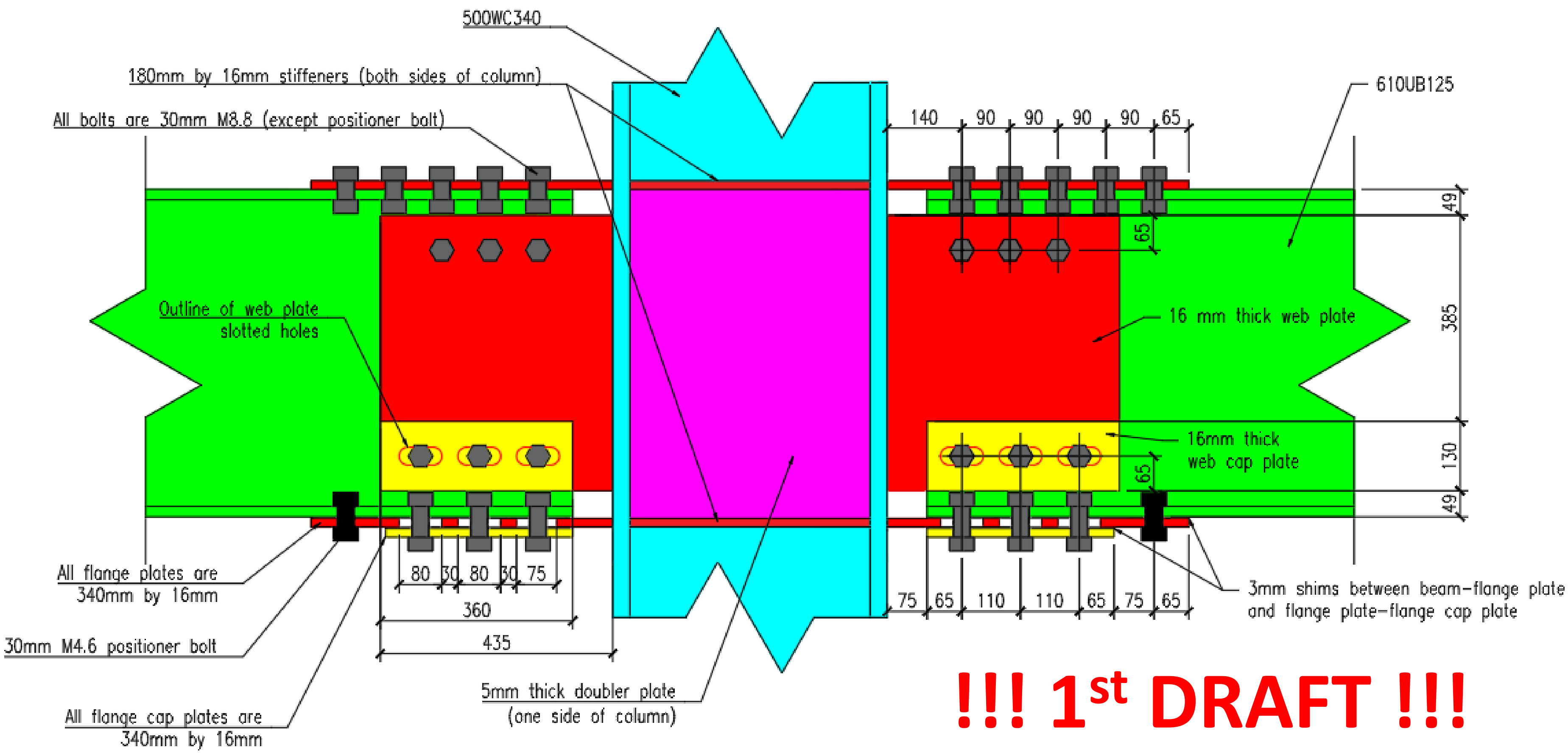
Member sizing:



Stage 3: Building design

Design of connections:

- With guidance from Gregory MacRae and Charles Clifton



!!! 1st DRAFT !!!

Stage 3: Building design

Design report in draft:

- Elastic modelling approach and assumptions
- Derivation of demands
- Detailed design of a beam-column and column-base joint
- Detailed checks of other members
- Inelastic modelling approach and assumptions for checking design using non-linear time history analyses

Beneficial as publication document for industry or for students as a reference

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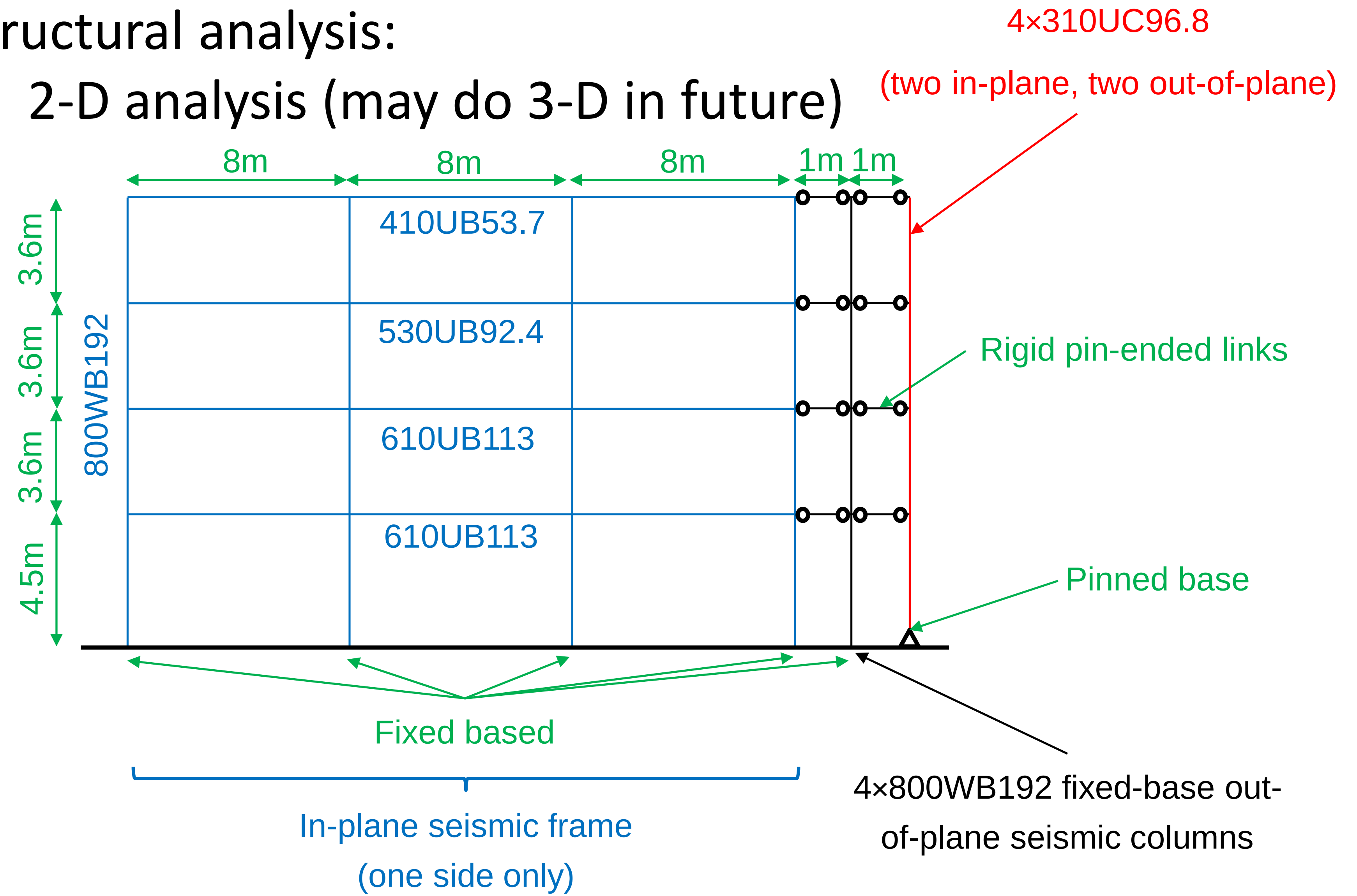
Stage 4: Loss Estimation Study

Structural analysis:

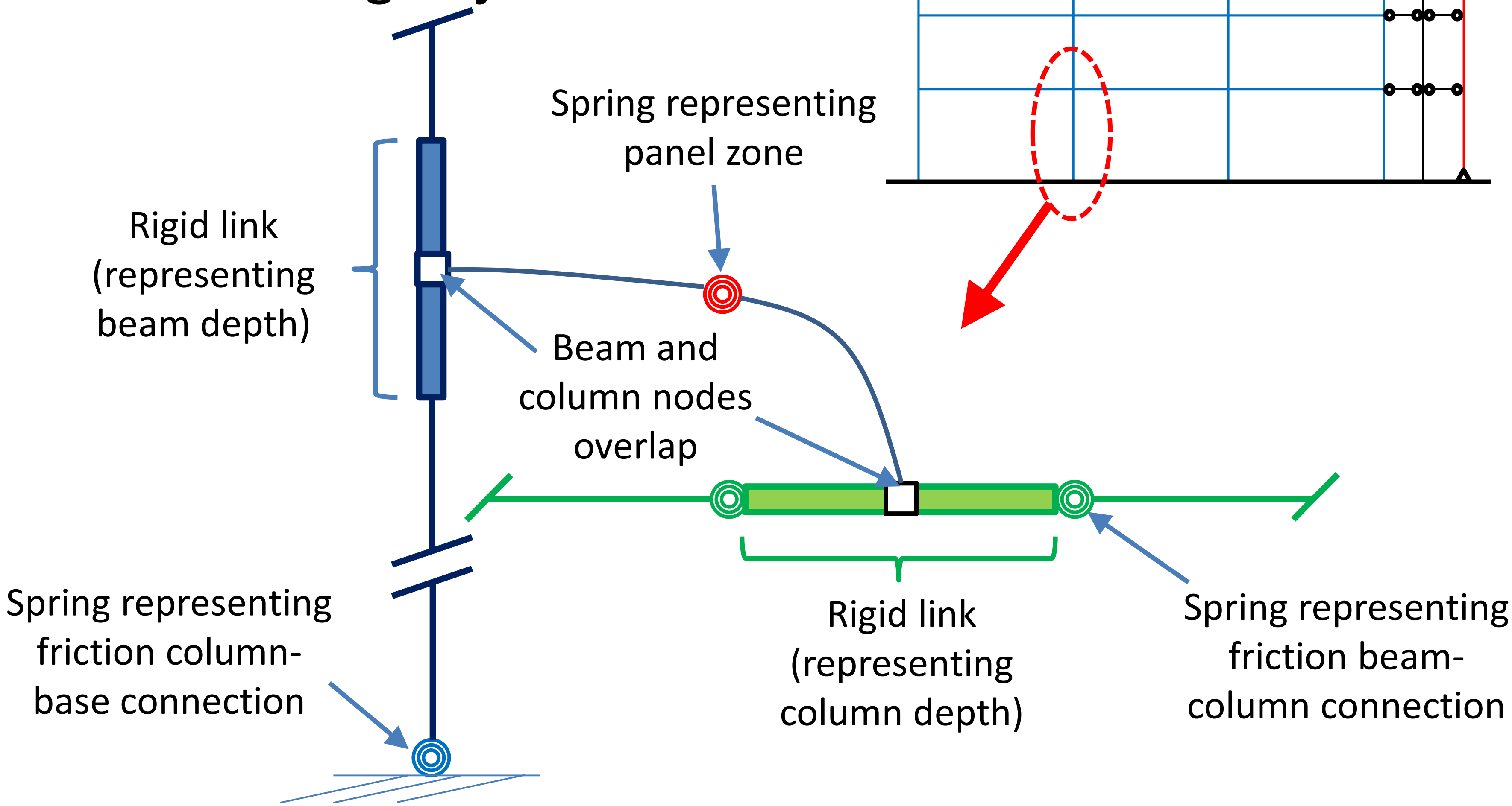
- 2-D analysis (may do 3-D in future)



Stage 4: Loss Estimation Study

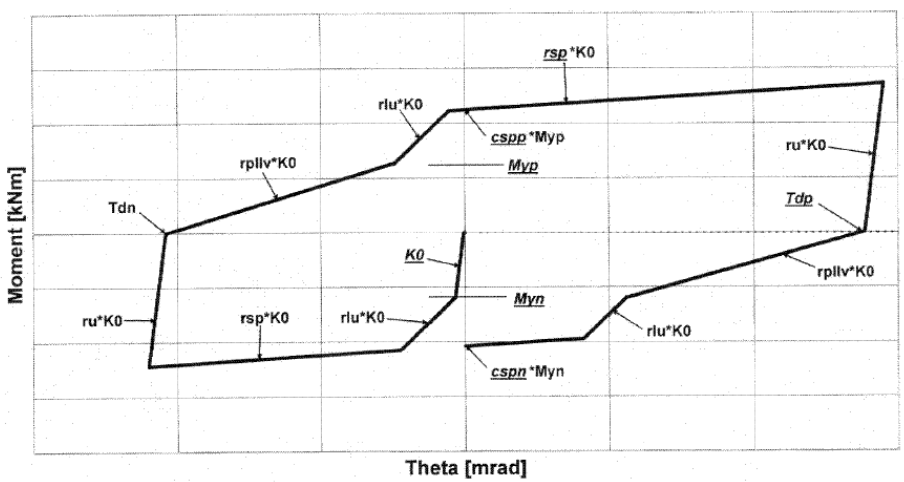
Structural analysis:

- Modelling of joints

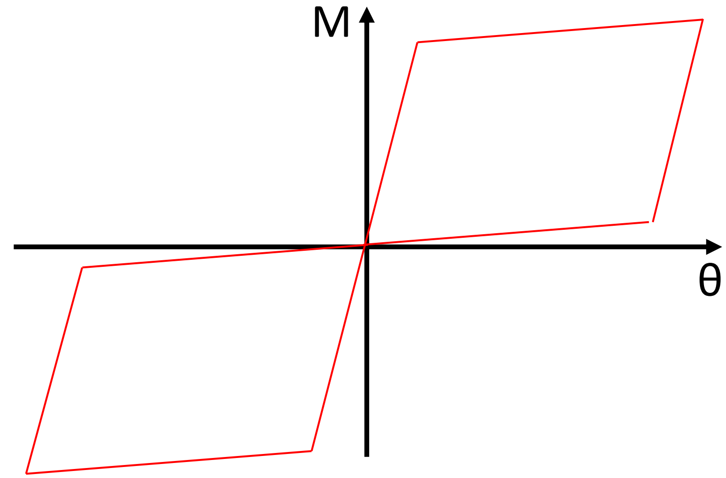


Stage 4: Loss Estimation Study

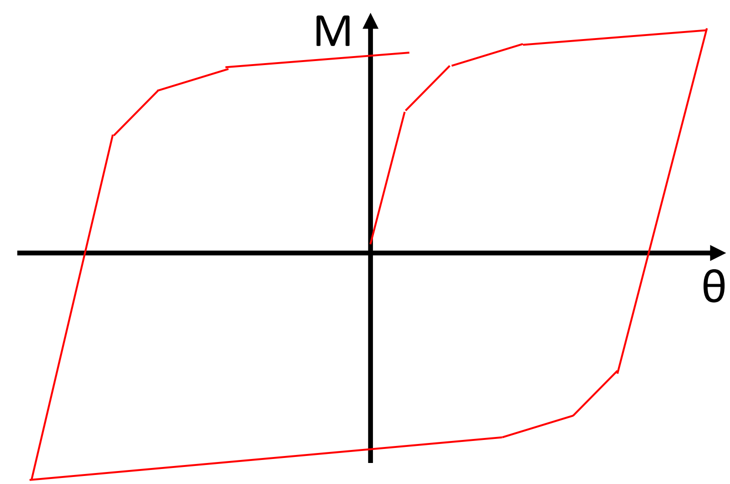
Structural analysis:



Friction beam-column connection
(from Ruaumoko2D)



Friction column-base connection
(based on tests from Borzouie (2016))



Panel zone behaviour excluding hardening effect
(from Kim and Engelhardt (2002))

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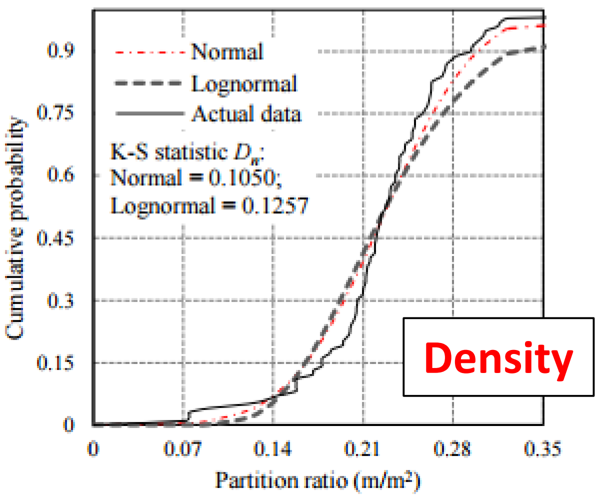
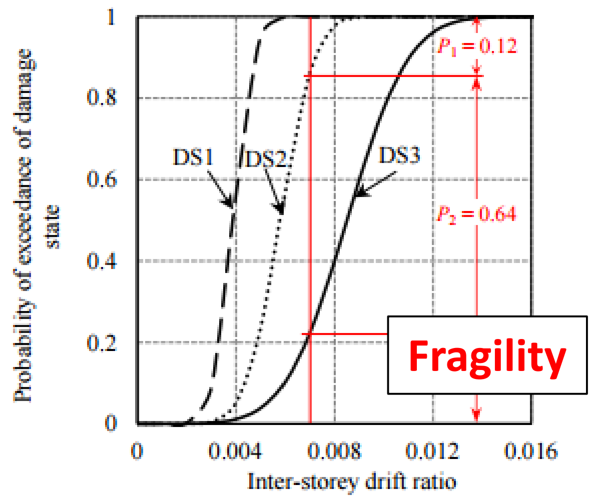
Loss Functions - Cladding

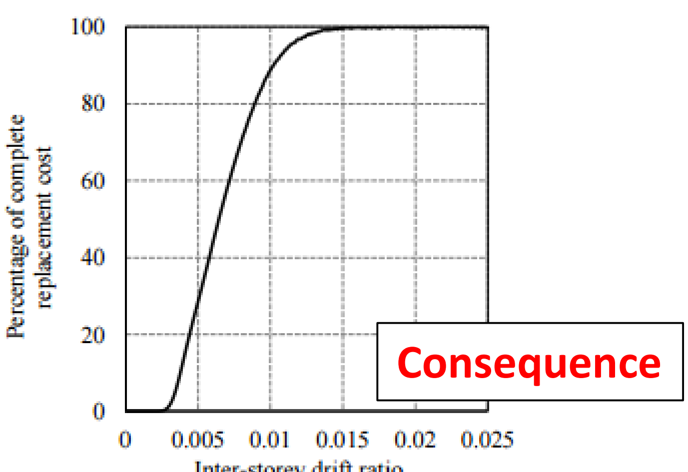
Aim:

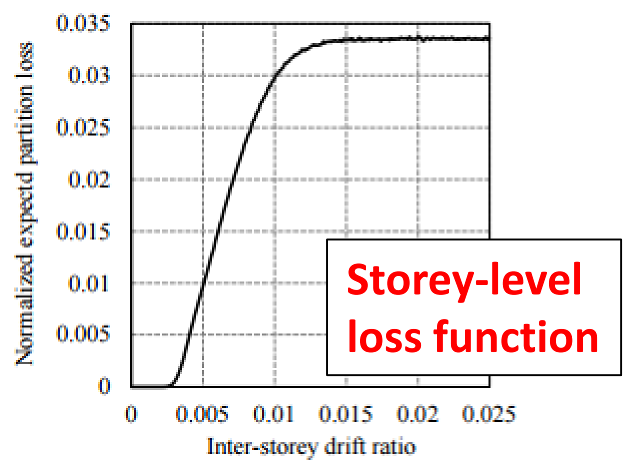
- Developing storey-level normalized loss functions for use in simplified loss estimation approaches





Example for partitions (Dhakal et al. 2016)





Loss Functions - Cladding

Building Survey

- Building usage
- Total exterior surface area
- Type of cladding
- Percentage of exterior surface area covered by given cladding type (for building front, sides, and back)

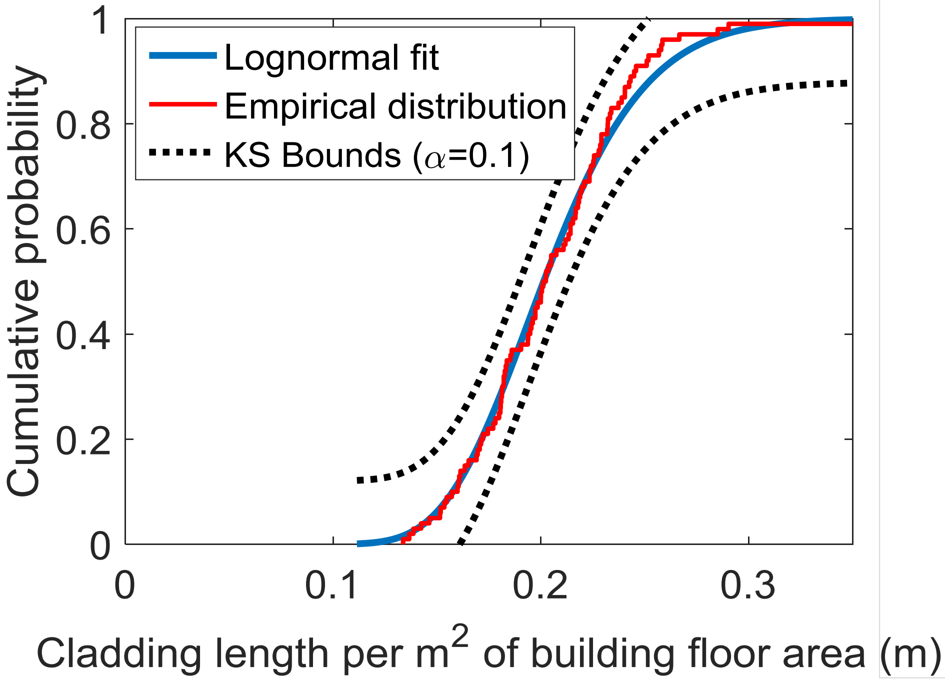
*all dimenssions in meter

Building	Area	Building ID	address	Type	Storey	Dimenssion Length	Dimenssion Width	Useage
Turners Auction		1	6 Detriut Pl	Commercial	2	45	20	Car seller
Vision College Christchurch Campus		2	48 Hazeldon Rd	Commercial	4	70	35	CarPark
Hunter Furnituer		3	221 Moonhouse Ave	Commercial	3	100	60	Warehouse
Briscoes Homefare		4	196 Salisbury Street	Commercial	3	55	40	Warehouse
Commercial Building (Selling)		5	113 Machester Street	Commercial	5	60	30	Commercial Building
Office Products Depot		6	46 Bath Street	Commercial	1	20	30	Car parts
AA Insurance		7	8 Hawdon Street	Commercial	2	30	30	Car Testing
Post Shop	750	8	54 Cashel Street	Commercial	1	30	25	Post shop
Ganellen construction(Firstfloor)	1300	9	253 Monstreal Street	Commercial	1	50	28	Commercial
Ganellen construction	1300	10	253 Monstreal Street	Commercial	2	50	28	Commercial
Under construction	400	11	245 Montreal Street	Commercial	2	20	20	Commercial
Storage House	625	12	6 Hawdon street	Commercial	1	25	25	Commercial
Miles Contineatal	1296	13	60 Tuan street	Commercial	1	36	36	Car dealer
Audis	528	14	32 Tuan Street	Commercial	1	22	24	Car dealer
Audis(Second floor)	528	15	32 Tuan Street	Commercial	1	22	24	Car dealer
Archibalds	1215	16	28 Tuan Street	Commercial	1	24	41	Commercial
Archibalds(Second floor)	1215	17	28 Tuan Street	Commercial	1	24	41	Commercial
Wilson	140	18	189 Antigua Street	Commercial	1	10	14	Commercial
Canterbury Medical Research Fondation	400	19	195 Antigua Street	Commercial	1	20	20	Reasurch
Canterbury Medical Research Fondation	400	20	195 Antigua Street	Commercial	1	20	20	Reasurch
Electrolux Sales abd Service	484	21	210 Antigua Street	Commercial	1	22	22	Service
Lifetime	320	22	192 Moorhouse Avenu	Commercial	1	20	16	Service
Lifetime	320	23	192 Moorhouse Avenu	Commercial	1	20	16	Service
ENGEO	240	24	120 Montreal street	Commercial	1	12	20	Construction
ENGEO(Second foor)	240	25	120 Montreal street	Commercial	1	12	20	Construction
Deal	600	26	118 Montreal street	Commercial	1	15	60	Construction
Deal(Other side)	300	27	118 Montreal street	Commercial	1	15	40	Construction
Active	900	28	119 Montreal Steet	Commercial	1	30	30	Seller
Active(second floor)	900	29	119 Montreal Steet	Commercial	1	15	20	

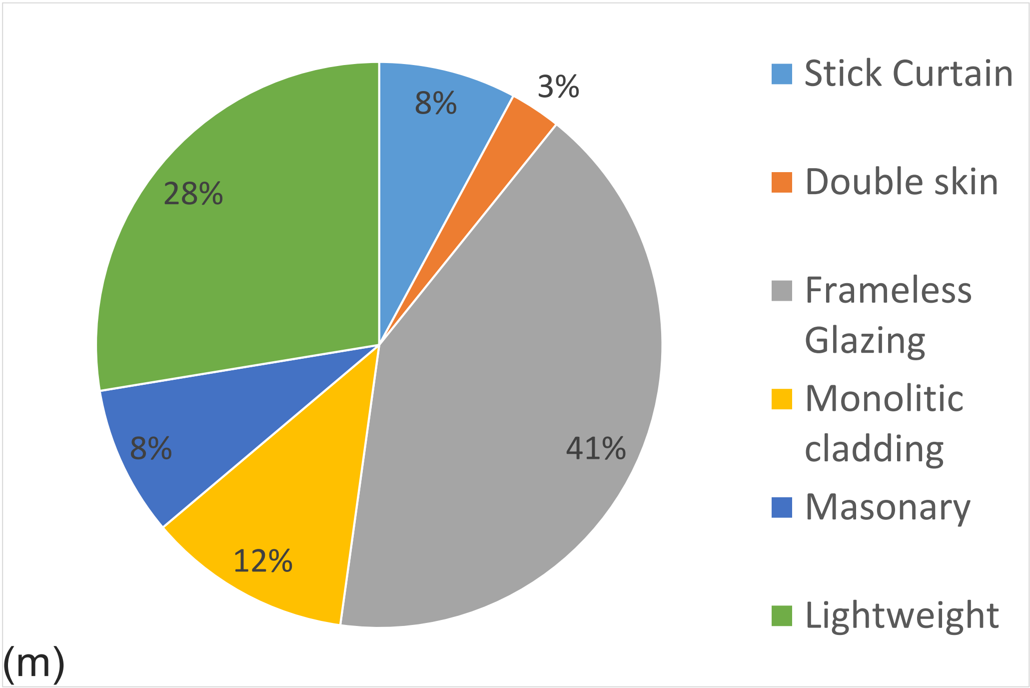
Building	Types of cladding: Curtain Wall F	Curtain Wall B	Curtain Wall S	stick curtain F	stick curtain B	stick curtain S	Double skin F	Double skin B	Double skin S	Frameless glazing F	Frameless glazing B	Frameless glazing S	monolithic cladding F	monolithic cladding B	monolithic cladding S	M F
Turners Auction										10	10	40				
Vision College Christchurch Campus												8				
Hunter Furnituer										9						
Briscoes Homefare							30	50	30	20	10					
Commercial Building (Selling)				20	30	30	4			8	8	5				
Office Products Depot										10		20	10		10	
AA Insurance							5	5			7					
Post Shop							12	12	18	8	8	7				
Ganellen construction(Firstfloor)										50	50	28				
Ganellen construction										10	10	8				
Under construction				15	15	15										
Storage House										2						
Miles Contineatal										33		20				
Audis				20			2	22	24							
Audis(Second floor)							17	22	24	5						
Archibalds										28	0	35				
Archibalds(Second floor)				24	0	40				24	0	0				
Wilson										8			0	10	14	
Canterbury Medical Research Fondation										20						
Canterbury Medical Research Fondation										20		20	3	22	1	
Electrolux Sales abd Service										20			3		1	
Lifetime							10	10	15	10	10	15				
Lifetime							10	10	15	10	10	15				
ENGEO										16	2					
ENGEO(Second foor)																
Deal										15						
Deal(Other side)																
Active										20	20					
Active(second floor)																

Loss Functions - Cladding

Sample findings for commercial buildings:



Distribution of amount of cladding used per m^2 of building floor area



Common types of cladding used

Loss Functions - Cladding

Surveying building contractors

- Common types/sizes/properties of cladding used in practice
- Methods for observing damage
- Repair strategies
- Cost of repairs

QuakeCORE annual workshop

Three posters:

- Would loss estimation help motivate the use of low-damage steel building design solutions?
- Developing generalized cladding loss functions for loss optimization seismic design
- Component damage fragility functions for New Zealand usage