B

Appendix B

Example Calculation – Case Study building: Dunedin URM typology 2

Structural Calculation Set

Example calculations for a case study building in Dunedin, a single storey unreinforced masonry, commercial office building

Steps 1 -12:

Calculation

Input parameters

Building height	$H = 3\,m$	
Importance Level	IL2	
Lateral Load Resisting System	Unreinforced masonry walls	
Period of vibration	$T_1 = 0.4\,s$	Using EAG, Clause B
Structural ductility	$\mu = 1.25$	
Soil class as per NZS1170.5	C	NZS 1170.5 Cl 3.1.3
Shear wave velocity	$V_{s30} = 400\,m/s$	This study looked at a range of Vs30 including most common NZ's site class IV with Vs30 of 275 m/s.
Effective Period SDOF	$T_{\text{eff}} = 2\pi\sqrt{\frac{m_{\text{eff}}}{g.k_{\text{eff}}}}$	*[EAG, C2.13]*

1. Structural Demand

Spectral shape factor

Class C shallow soil

The values for the MRS and NITH methods are given by:

$$C_h(0) = 1.33$$

For $0 < T < 0.1$

$$C_h(T) = 1.33 + 1.60\,(T/0.1)$$

For $0.1 < T < 0.3$

$$C_h(T) = 2.93$$

For $0.3 \le T \le 1.5$

$$C_h(T) = 2.0\,(0.5/T)^{0.75}$$

For $1.5 < T \le 3$

$$C_h(T) = 1.32/T$$

For $3 < T$

$$C_h(T) = 3.96/T^2$$

Spectral shape factor	$C_h(T) = 2.36$	NZS1170.5, Table 3.1
Spectral shape factor at a period of vibration of zero	$C_h(0) = 1.33$	NZS1170.5, Table 3.1
Hazard factor	$Z = 0.13$	NZS 1170.5 C3.1.4
Return period factor	$R = 1.0$	NZS 1170.5 Tab 3.5
Calculated return period factor hazard factor product	$ZR_{calculated} = 0.13$	*[NZS1170.5, Tab 3.7]*
Maximum hazard return period product	$ZR_{max} = 0.7$	
Hazard return period product	$ZR = min(ZR_{calculated}, ZR_{max})$ $ZR = min(0.13, 0.7)$ $ZR = 0.13$	*[NZS1170.5, Eq 3.1.(1)]*
Maximum near fault factor	$N_{max}(T) = 1.0$	*[NZS1170.5, Tab 3.7]* Unity for periods less than 1.5 s
Near fault factor	$N(T, D) = 1.0$	*[NZS1170.5, Eq 3.1(4)]* Equivalent to maximum near fault factor for Wellington CBD.
Elastic site hazard spectrum	$C(T) = C_h(T) \cdot ZR \cdot N(T, D)$ $C(T) = 2.36 \cdot 0.13 \cdot 1.0$ $C(T) = 0.31\ g$	*[NZS1170.5, Eq.3.1(1)]*
Ductility factor	$k_\mu = (\mu - 1) \cdot \frac{T_1}{0.7} + 1$ $k_\mu = (1.25 - 1) \cdot \frac{0.4}{0.7} + 1$ $k_\mu = 1.14$ $k_\mu = 1.0$	*[NZS1170.5, Cl 5.2.2.1]* *[EAG 2017, C3.3]* The ductility factor shall be set to 1.0 for ADRS spectra.
Structural performance factor	$S_p = max(0.7, 1.3 - 0.3 \cdot \mu)$ $S_p = max(0.7, 1.3 - 0.3 \cdot 1.25)$ $S_p = 0.925$	*[NZS1170.5, Cl 4.4.2]*
Horizontal design action coefficient	$C_d(T) = max\left(0.03 \cdot \mathrm{R_u}, \left(\frac{\mathrm{Z}}{20} + 0.02\right) \cdot \mathrm{R_u}, \mathrm{C(T)} \cdot \mathrm{S_p}/\mathrm{k_\mu}\right)$ $C_d(T) = max\left(0.03 \cdot 1.0, \left(\frac{0.13}{20} + 0.02\right) \cdot 1.0, 0.31 \cdot 0.925/1.0\right)$ $C_d(T) = 0.284\ g$	*[NZS 1170.5 Cl 5.2]*

Spectral acceleration capacity

$S_a = C_d(T)$
$S_a = 0.284\ g$

[EAG, C3.5]

Spectral displacement capacity

$$S_d = 9.81 \cdot \frac{T^2}{4 \cdot \pi^2} \cdot S_a$$
$$S_d = 9.81 \cdot \frac{0.4^2}{4 \cdot \pi^2} \cdot 0.284$$
$$S_d = 0.0131\ m$$

[NZS1170.5]

Hysteretic damping

$\xi_{hy} = 2\%$

[EAG, Tab C2D1]
The hysteretic damping for the structure is based on Table C2D.1 of the EQ Assess Guidelines and snipped below.

Inherent damping

$\xi_0 = 5\%$

EAG Section C2D.3.2

System damping

$\xi_{sys} = \xi_0 + \xi_{sys}$
$\xi_{sys} = 5\% + 2\%$
$\xi_{sys} = 7\%$

Spectral damping reduction factor

$$k_\xi = \left(\frac{7}{2 + \xi_{sys}}\right)^{0.5}$$
$$k_\xi = \left(\frac{7}{2 + 7}\right)^{0.5}$$
$$k_\xi = 0.88$$

In special cases of rocking URM buildings, Table C2D.1does not apply. It is not known whether rocking will govern for the URM structures in this study, so it is assumed that they will exhibit some hysteretic damping in line with Table C2D.1 which will lead to a smaller assumed structural backbone in this study.

Inelastic spectral acceleration

$S_{a,inelastic} = S_a \cdot k_\xi$
$S_{a,inelastic} = 0.284 \cdot 0.88$
$S_{a,inelastic} = 0.251$

Inelastic spectral displacement

$$S_{d,inelastic} = \frac{9.81 \cdot T^2 \cdot S_{a,inelastic}}{4 \cdot \pi^2}$$
$$S_{a,inelastic} = \frac{9.81 \cdot 0.4^2 \cdot 0.251}{4 \cdot \pi^2}$$
$$S_{a,inelastic} = 0.0100\ m$$

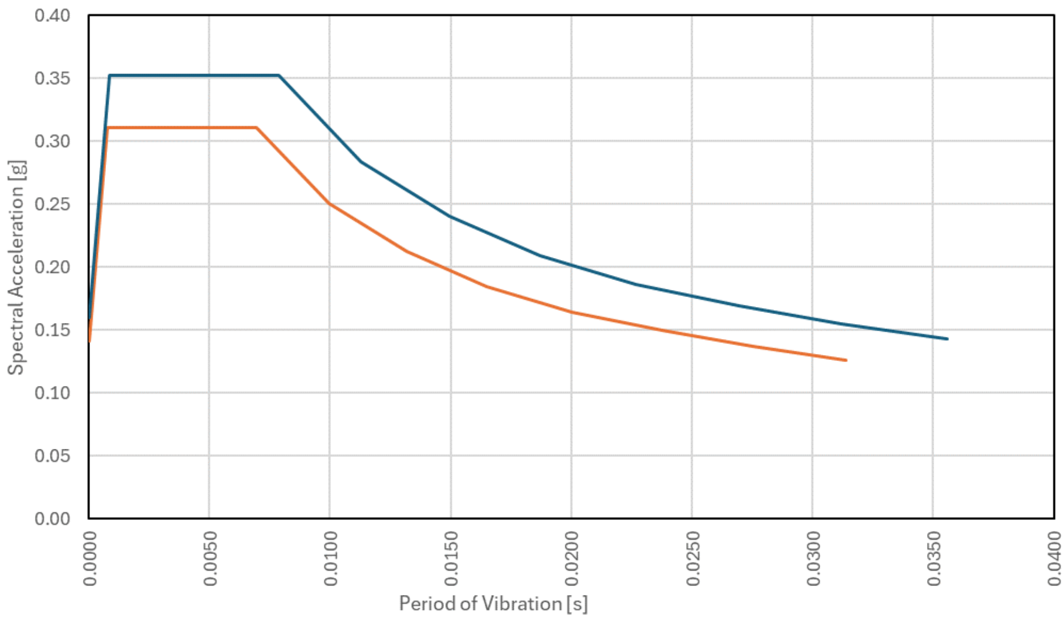
Repeating this process for different period yields the inelastic NZS1170.5:2004 demand curve.

Table *: Demand curve parameters

T	C_h	C	C_d	S_d for C_d	$S_{a,inelastic}$	$S_{d,inelastic}$
0	1.33	0.17	0.16	0.0000	0.14	0.0000
0.1	2.93	0.38	0.35	0.0009	0.31	0.0008
0.2	2.93	0.38	0.35	0.0035	0.31	0.0031

0.3	2.93	0.38	0.35	0.0079	0.31	0.0069
0.4	2.36	0.31	0.28	0.0113	0.25*	0.0100*
0.5	2	0.26	0.24	0.0149	0.21	0.0132
0.6	1.74	0.23	0.21	0.0187	0.18	0.0165
0.7	1.55	0.20	0.19	0.0227	0.16	0.0200
0.8	1.41	0.18	0.17	0.0270	0.15	0.0238
0.9	1.29	0.17	0.16	0.0312	0.14	0.0275
1	1.19	0.15	0.14	0.0356	0.13	0.0314

*Values match the hand calculation



2. Structural Equivalent Capacity

In this step, a backbone that equates to the buildings governing score is sought. What is known initially is that the building is on the earthquake-prone register, therefore this governing element must have scored approximately 20%NBS (plus or minus 10%). We also know that if we had the backbone of the structure and plotted it on an ADRS, it would score around 20%NBS.

From this information, and knowing key characteristics of the building (e.g. its stiffness and ductility), we can work backwards from the ADRS curve to generate an approximate backbone for the element of the structure that governs the %NBS score.

Site elastic spectrum at period of zero

$$C(0) = C_h(0) \cdot ZR_{final} \cdot N(T, D)$$
$$C(0) = 1.33 \cdot 0.13 \cdot 1.0$$
$$C(0) = 0.173$$

[NZS1170.5, Eq.3.1(1)]

Horizontal design action coefficient

$$C_d(0) = max\left(0.03 \cdot R, \left(\frac{Z}{20} + 0.02\right) \cdot R, C(0) \cdot S_p/k_\mu\right)$$
$$C_d(0) = max\left(0.03 \cdot 1.0, \left(\frac{0.13}{20} + 0.02\right) \cdot 1.0, 1.33 \cdot 0.925/1.0\right)$$
$$C_d(0) = 0.16$$

Ratio between PGA to spectral acceleration

$$R_{PGA/SA} = \frac{C_d}{C_d(0)}$$
$$R_{PGA/SA} = \frac{0.284}{0.16}$$
$$R_{PGA/SA} = 0.563$$

Ultimate spectral displacement

$$S_{du,inelastic} = S_{d,inelastic} \cdot \mu$$
$$S_{du,inelastic} = 0.0100 \cdot 0.125$$
$$S_{du,inelastic} = 0.0125$$

Secant period of the structure

$$T_s = \sqrt{\frac{4 \cdot \pi^2 \cdot S_{du}}{9.81 \cdot S_{a,inelastic}}}$$
$$T_s = \sqrt{\frac{4 \cdot \pi^2 \cdot 0.0125}{9.81 \cdot 0.251}}$$
$$T_s = 0.45\ s$$

The intersection of the secant period line and the inelastic demand spectrum represents the ultimate displacement of a building rated 100%NBS.

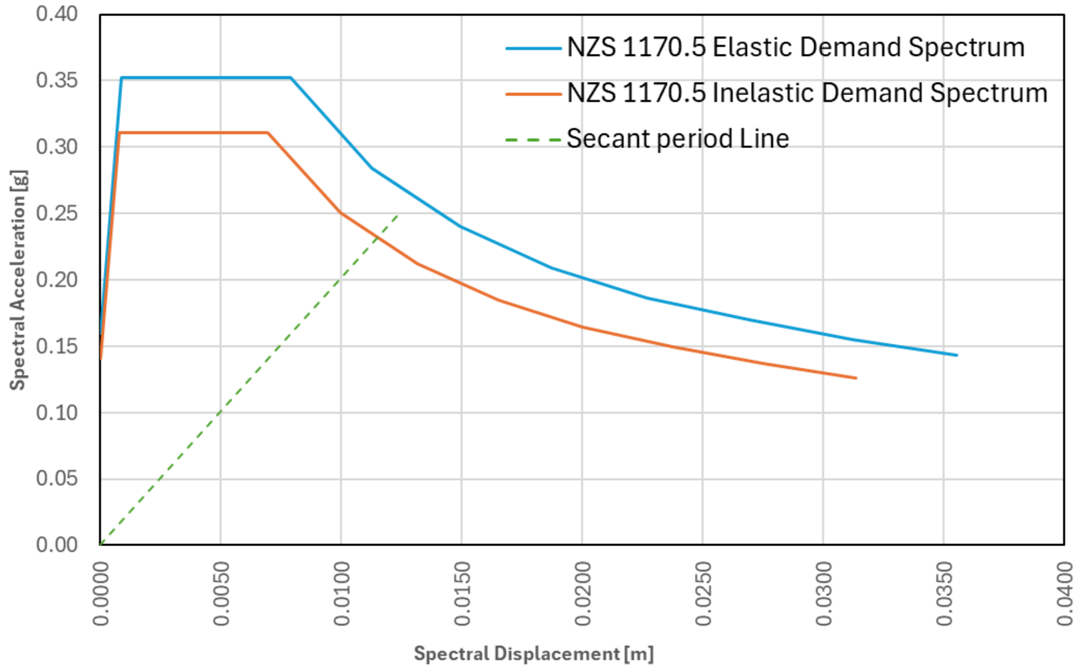


Figure: Inelastic demand curve against fictious backbone of equal stiffness and ductility to chosen structure.

Spectral acceleration of 100%NBS structure

$$S_{a,100} = 0.232$$

By interpolation

Spectral displacement of 100%NBS structure

$$S_{du,100} = 9.81 \cdot S_{a,100} \cdot \frac{T_s^2}{4\pi^2}$$
$$S_{du,100} = 9.81 \cdot 0.232 \cdot \frac{0.4^2}{4\pi^2}$$
$$S_{du,100} = 0.0115\ m$$

To establish the equivalent backbone of the earthquake-prone structure, the 100%NBS backbone is scaled down to the given %NBS.

Spectral acceleration at NBS

$$S_{a,nbs} = \%NBS \cdot S_{a,100}$$
$$S_{d,nbs} = 20\% \cdot 0.232$$
$$S_{d,nbs} = 0.046\ g$$

Spectral displacement at NBS

$$S_{du,nbs} = \%NBS \cdot S_{d,100}$$
$$S_{du,nbs} = 20\% \cdot 0.0115$$
$$S_{du,nbs} = 0.0023\ m$$

Yield spectral displacement at NBS

$$S_{dy,nbs} = \frac{S_{du}}{\mu}$$
$$S_{dy,nbs} = \frac{0.0023}{1.25}$$
$$S_{dy,nbs} = 0.0018\ m$$

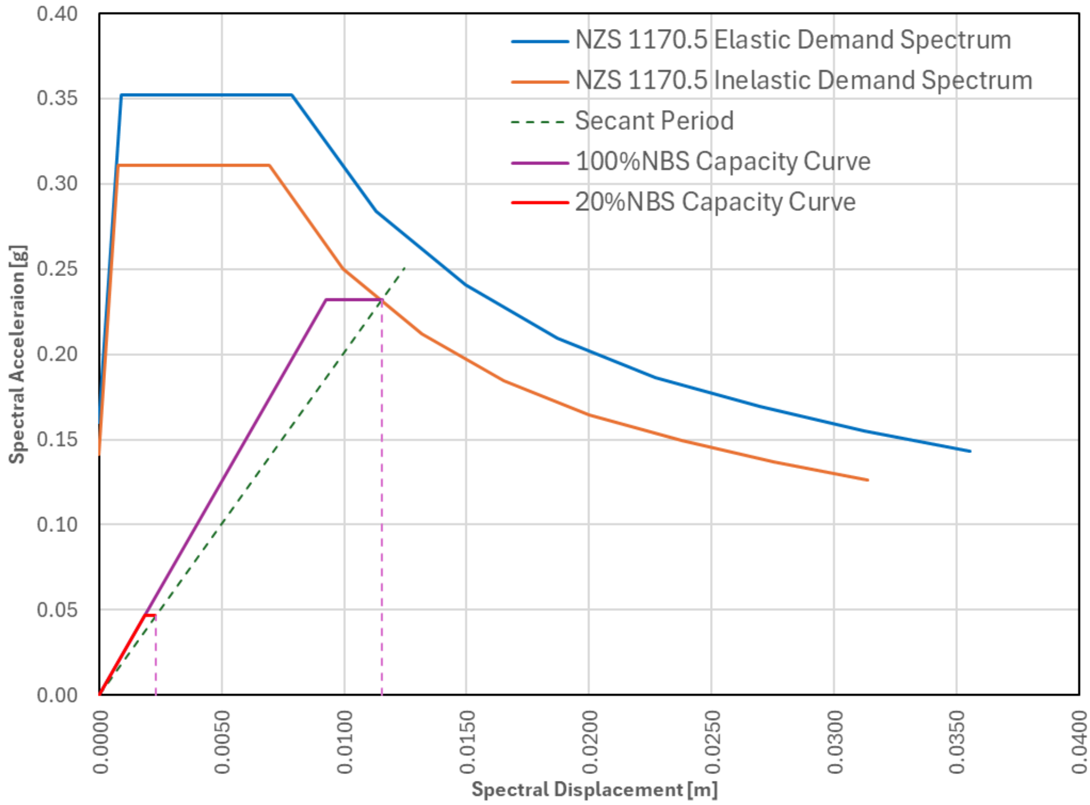


Figure: Inelastic demand curve (orange) against backbone of equal stiffness and ductility for case study building

As a back check, the %NBS can be yielded by the ratio of the ultimate displacement for the 100%NBS curve and the final %NBS curve.

%NBS of the structure

$$\%NBS = \frac{S_{d,nbs}}{S_{d,100}}$$
$$\%NBS = \frac{0.0023}{0.0115}$$
$$\%NBS = 20\%$$

Plot the point ($\Delta_{prob,20\%}$, $Sa\_{20\%}$) over the inelastic ADRS curve. Determine the Duls demand by extending a line radiating out from the origin of this point through the point ($\Delta prob\_{20\%}$, $Sa\_{20\%}$) to intersect with the ADRS curve. The %NBS earthquake score for the SDOF is the ratio of Δ_{ULS} and $\Delta prob\_{20\%}$

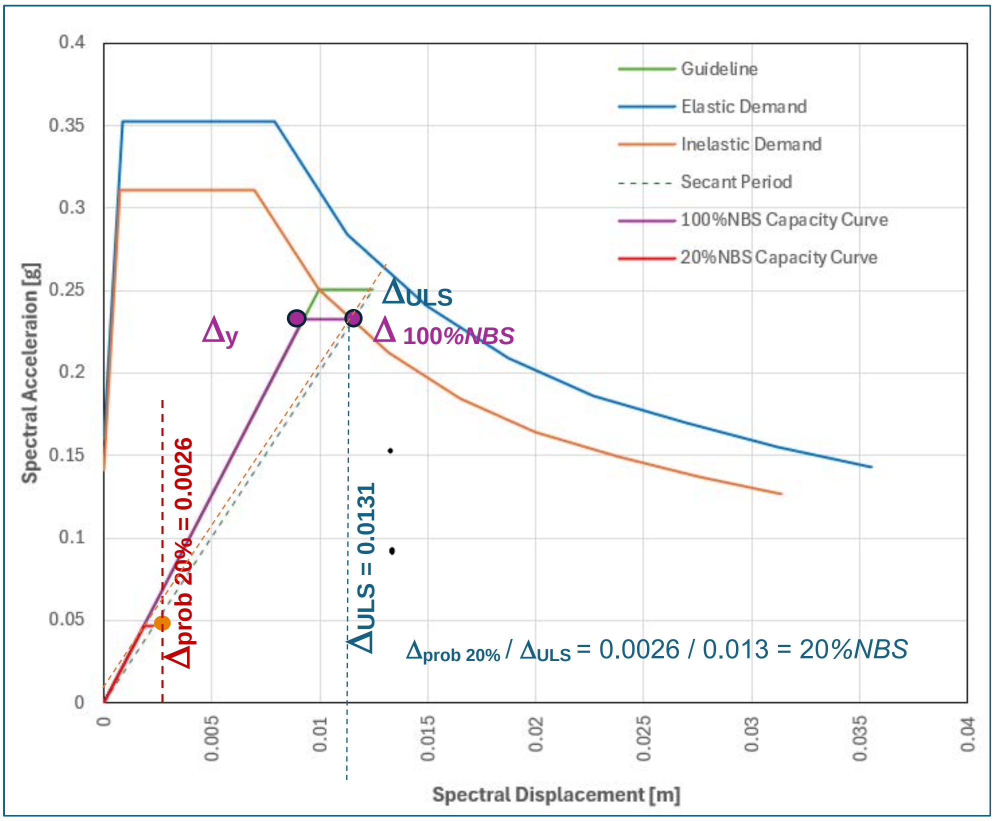


Figure: 20%NBS (no upgrade) backbone curve

3. Adjustment of Backbone for Inherent Capacity

As described in supporting documents, the backbone generated for the structure is increased by an inherent capacity factor of 2.0.

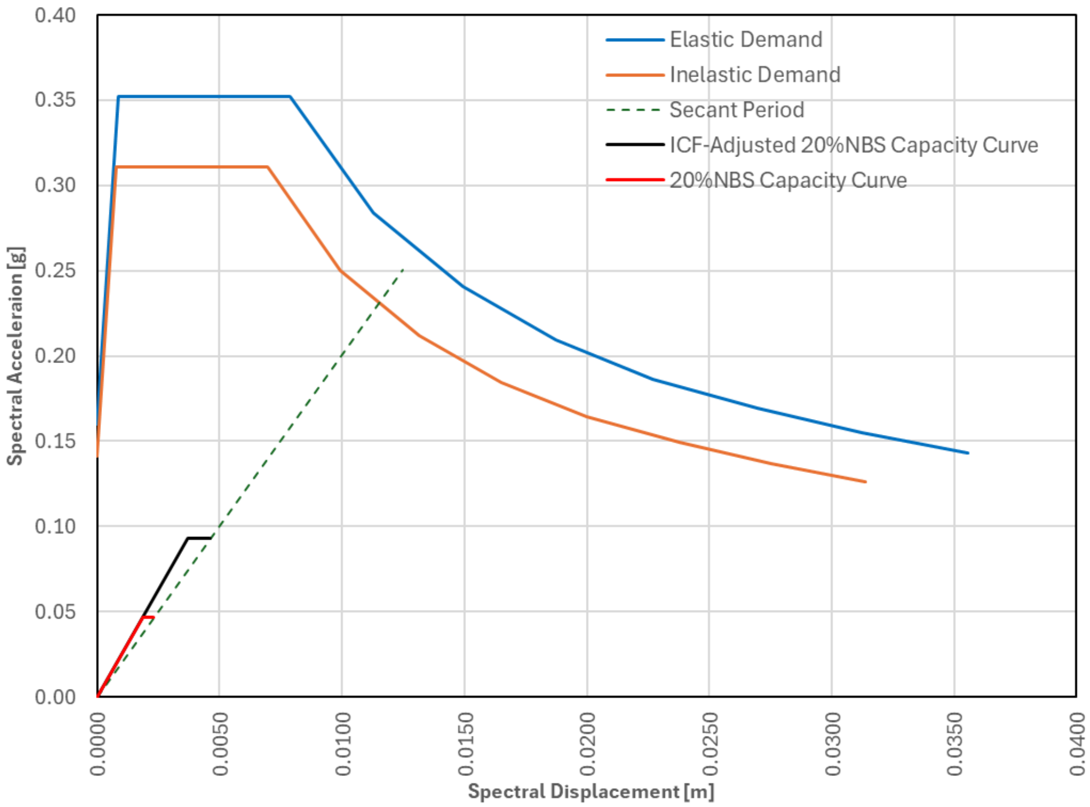


Figure: Increase in structural capacity backbone by the chosen inherent capacity factor.

Ultimate spectral displacement including inherent capacity factor

$$S_{du,ICF} = ICF \cdot S_{du,nbs}$$

$$S_{du,ICF} = 2.0 \cdot 0.0023$$
$$S_{du,ICF} = 0.0046\ m$$

Yield spectral displacement including inherent capacity factor

$$S_{dy,ICF} = ICF \cdot S_{dy,nbs}$$

$$S_{dy,ICF} = 2.0 \cdot 0.0018$$
$$S_{dy,ICF} = 0.0037\ m$$

Spectral acceleration

$$S_{a,ICF} = ICF \cdot S_{a,nbs}$$
$$S_{a,ICF} = 2.0 \cdot 0.046$$
$$S_{a,ICF} = 0.093\ g$$

4. Displacement Limits associated with Damage States

HAZUS relates defined damage states for different structural typologies and code levels to specific displacement limits.

Building Properties			Inter-Story Drift at Threshold of Damage State				Spectral Displacement (Inches)							
Type	Height (Inches)						Slight		Moderate		Extensive		Complete	
	Roof	Modal	Slight	Moderate	Extensive	Complete	Median	Beta	Median	Beta	Median	Beta	Median	Beta
S4M	720	540	0.0021	0.0034	0.0086	0.0233	1.15	0.81	1.85	0.79	4.62	0.94	12.60	1.00
S4H	1,872	1,123	0.0016	0.0026	0.0064	0.0175	1.80	0.73	2.88	0.76	7.21	0.90	19.66	0.96
S5L	288	216	0.0024	0.0048	0.0120	0.0280	0.52	1.20	1.04	1.11	2.59	1.08	6.05	0.95
S5M	720	540	0.0016	0.0032	0.0080	0.0187	0.86	0.85	1.73	0.83	4.32	0.94	10.08	0.99
S5H	1,872	1,123	0.0012	0.0024	0.0060	0.0140	1.35	0.72	2.70	0.75	6.74	0.92	15.72	0.96
C1L	240	180	0.0040	0.0064	0.0160	0.0400	0.72	0.98	1.15	0.94	2.88	0.90	7.20	0.96
C1M	600	450	0.0027	0.0043	0.0107	0.0267	1.20	0.73	1.92	0.77	4.80	0.84	12.00	0.98
C1H	1,440	864	0.0020	0.0032	0.0080	0.0200	1.73	0.71	2.76	0.80	6.91	0.94	17.28	1.01
C2L	240	180	0.0032	0.0061	0.0158	0.0400	0.58	1.12	1.10	1.08	2.84	1.06	7.20	0.93
C2M	600	450	0.0021	0.0041	0.0105	0.0267	0.96	0.86	1.83	0.83	4.74	0.80	12.00	0.98
C2H	1,440	864	0.0016	0.0031	0.0079	0.0200	1.38	0.73	2.64	0.75	6.82	0.92	17.28	0.97
C3L	240	180	0.0024	0.0048	0.0120	0.0280	0.43	1.19	0.86	1.15	2.16	1.16	5.04	0.92
C3M	600	450	0.0016	0.0032	0.0080	0.0187	0.72	0.90	1.44	0.86	3.60	0.90	8.40	0.96
C3H	1,440	864	0.0012	0.0024	0.0060	0.0140	1.04	0.73	2.07	0.74	5.18	0.90	12.10	0.95
PC1	180	135	0.0032	0.0051	0.0128	0.0350	0.43	1.14	0.69	1.14	1.73	1.17	4.73	0.99
PC2L	240	180	0.0032	0.0051	0.0128	0.0350	0.58	1.14	0.92	1.10	2.31	1.10	6.30	0.93
PC2M	600	450	0.0021	0.0034	0.0086	0.0233	0.96	0.87	1.54	0.83	3.85	0.92	10.50	1.00
PC2H	1,440	864	0.0016	0.0026	0.0064	0.0175	1.38	0.74	2.21	0.76	5.55	0.91	15.12	0.96
RM1L	240	180	0.0032	0.0051	0.0128	0.0350	0.58	1.20	0.92	1.17	2.31	1.17	6.30	0.94
RM1M	600	450	0.0021	0.0034	0.0086	0.0233	0.96	0.92	1.54	0.89	3.85	0.88	10.50	0.96
RM2L	240	180	0.0032	0.0051	0.0128	0.0350	0.58	1.14	0.92	1.10	2.31	1.15	6.30	0.92
RM2M	600	450	0.0021	0.0034	0.0086	0.0233	0.96	0.90	1.54	0.87	3.85	0.86	10.50	0.96
RM2H	1,440	864	0.0016	0.0026	0.0064	0.0175	1.38	0.75	2.21	0.75	5.55	0.85	15.12	0.94
URML	180	135	0.0024	0.0048	0.0120	0.0280	0.32	1.15	0.65	1.19	1.62	1.20	3.78	1.18
URMM	420	315	0.0016	0.0032	0.0080	0.0187	0.50	1.0	1.01	0.97	2.52	0.90	5.88	0.88
MH	120	120	0.0032	0.0064	0.0192	0.0560	0.38	1.12	0.77	1.10	2.30	0.95	6.72	0.97

Figure: Selection of displacement limits from HAZUS Table 5-22 for the appropriate building typology.

Spectral displacement at DS1

$$S_{d,DS1} = 0.0254 \cdot 0.32$$
$$S_{d,DS1} = 0.0081\ m$$

Spectral displacement at DS2

$$S_{d,DS2} = 0.0254 \cdot 0.65$$
$$S_{d,DS2} = 0.0165\ m$$

Spectral displacement at DS3

$$S_{d,DS3} = 0.0254 \cdot 1.62$$
$$S_{d,DS3} = 0.0411\ m$$

Spectral displacement at DS3

$$S_{d,DS4} = 0.0254 \cdot 3.78$$
$$S_{d,DS4} = 0.0960\ m$$

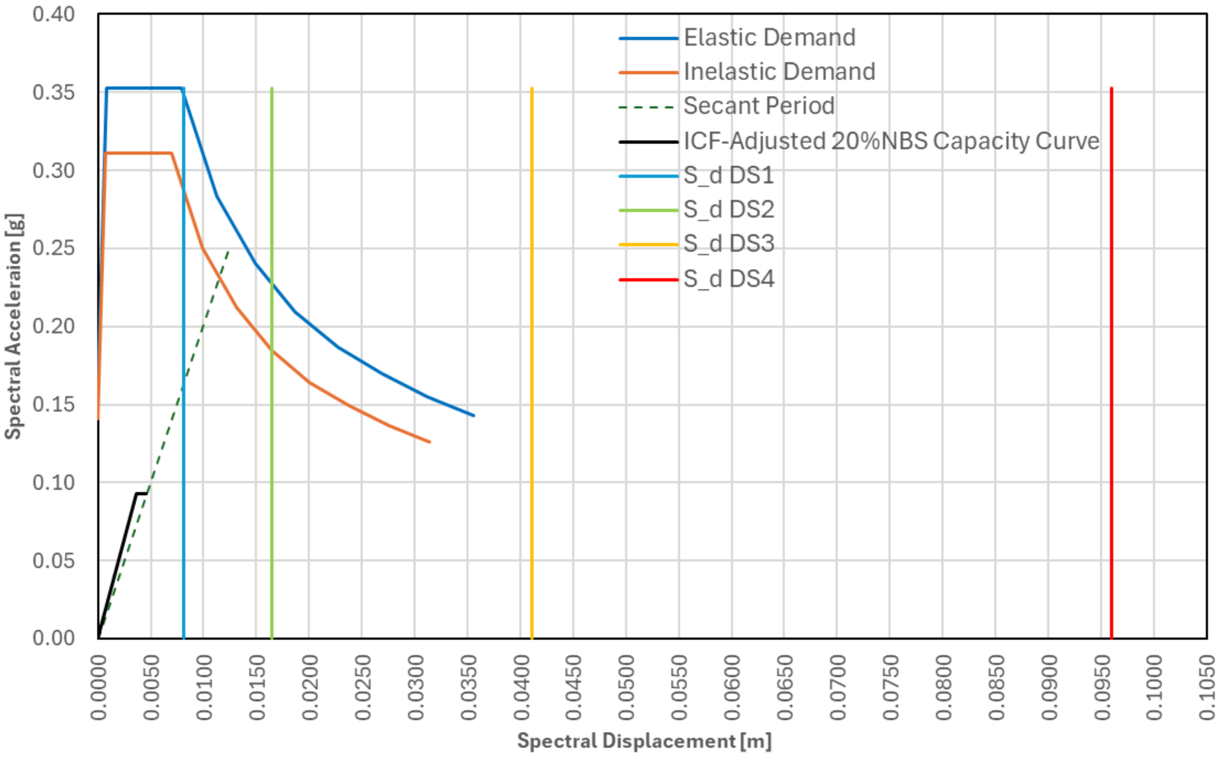


Figure: Comparison of structural backbone to HAZUS damage state spectral displacements.

5. Structural Damage State Spectral Acceleration Intensity

In this stage, the comparisons between spectral displacement limits and spectral acceleration are made for the structure. The higher damage state spectral displacement thresholds are often well above the ultimate spectral displacement of the structure. In these cases, an 'effective' ductility can be assumed. In reality, the structure will be reducing in capacity as significant damage occurs.

There are a number of complex relationships formulated between the structural pushover backbone and the true capacity as determined from an incremental dynamic analysis. We will retain the simple relationships of equal displacement and equal energy to estimate the structure's spectral acceleration capacity.

For damage state DS1, the equivalent elastic spectral acceleration is calculated below.

Slope of the elastic curve

$$K_{elastic} = \frac{S_a}{S_{dy}}$$

$$K_{elastic} = \frac{0.093}{0.0037}$$

$$K_{elastic} = 25.2$$

Effective ductility to reach damage state

$$\mu_{eff} = \frac{S_{d,DS1}}{S_{dy}}$$

$$\mu_{eff} = \frac{0.0081}{0.0037}$$

$$\mu_{eff} = 2.2$$

Area beneath the inelastic backbone beyond the yield point.

$$A_{plastic} = \left(S_{d,DS1} - S_{dy}\right) \cdot S_a$$

$$A_{plastic} = (0.0081 - 0.0037) \cdot 0.093$$

$$A_{plastic} = 4.12 \times 10^{-6}$$

Area beneath the elastic backbone

$$A_{elastic} = S_a \cdot \frac{S_{dy}}{2}$$
$$A_{elastic} = 0.0093 \cdot \frac{0.0037}{2}$$
$$A_{elastic} = 1.72 \times 10^{-6}$$

Total area beneath backbone

$$A_{backbone} = A_{plastic} + A_{elastic}$$
$$A_{backbone} = 4.12 \times 10^{-6} + 1.72 \times 10^{-6}$$
$$A_{backbone} = 5.84 \times 10^{-6}$$

The area of the backbone equals the area of the equivalent elastic curve
Rearranging for spectral displacement

$$A_{backbone} = S_{d,equiv} \cdot \frac{S_{a,equiv}}{2}$$
$$S_{d,equiv} = 2 \cdot \frac{A_{backbone}}{S_{a,equiv}}$$

The slope of the curve is the elastic slope
Rearranging for spectral displacement

$$S_{a,equiv} = K_{elastic} \cdot S_{d,equiv}$$
$$S_{d,equiv} = \frac{S_{a,equiv}}{K_{elastic}}$$

Combining the two equations

$$2 \cdot \frac{A_{backbone}}{S_{a,equiv}} = \frac{S_{a,equiv}}{K_{elastic}}$$

Rearranging for spectral acceleration yields the equivalent elastic spectral acceleration

$$S_{a,equiv} = \sqrt{2 \cdot A_{backbone} \cdot K_{elastic}}$$

$$S_{a,equiv} = \sqrt{2 \cdot 5.84 \times 10^{-6} \cdot 25.2}$$
$$S_{a,equiv} = 0.0171\ g$$

Repeating the process for each damage state gives the following values.

Damage State	Equivalent Elastic Spectral Acceleration [g]
DS1	0.171
DS2	0.262
DS3	0.429
DS4	0.663

These can be visualized as shown in the figures below (figure values are approximate only).

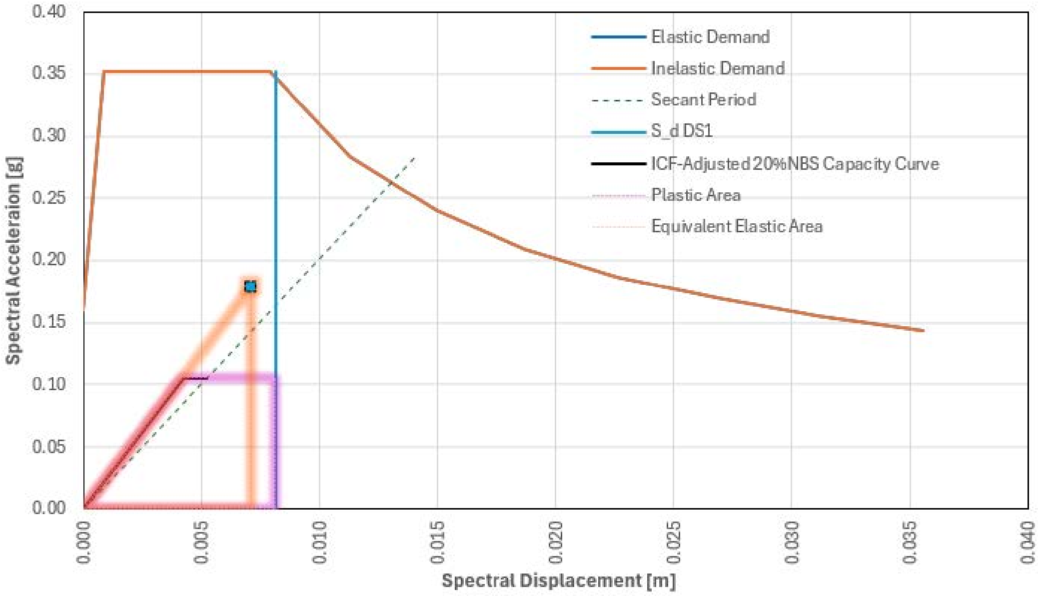


Figure: Graphical representation of equal energy method to determine DS1 equivalent spectral acceleration intensity.

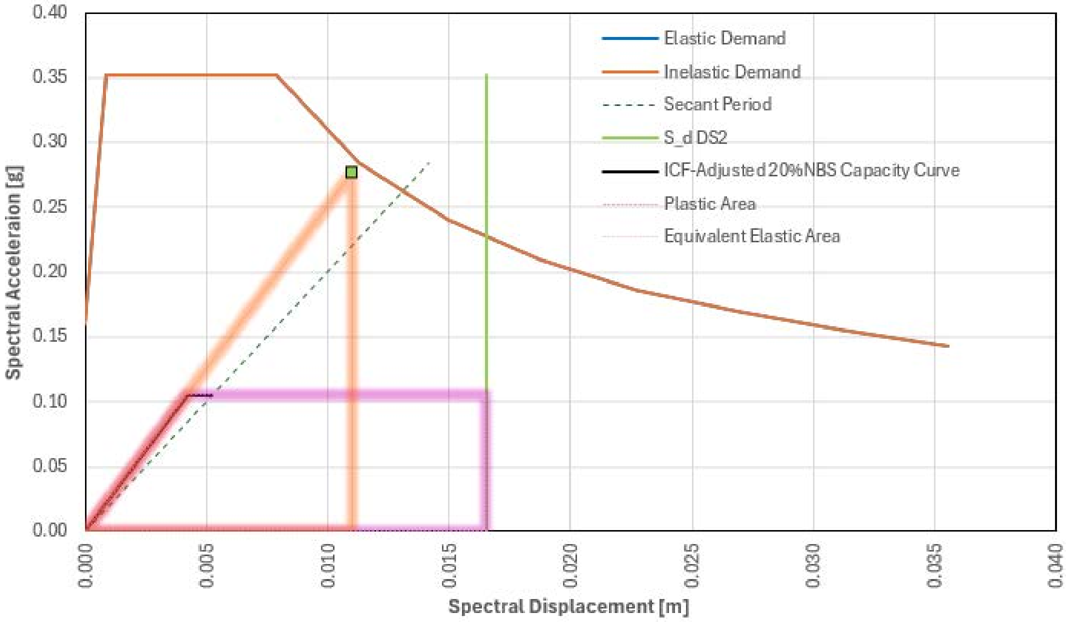


Figure: Graphical representation of equal energy method to determine DS2 equivalent spectral acceleration intensity.

Figure: Graphical representation of equal energy method to determine DS2 equivalent spectral acceleration intensity.

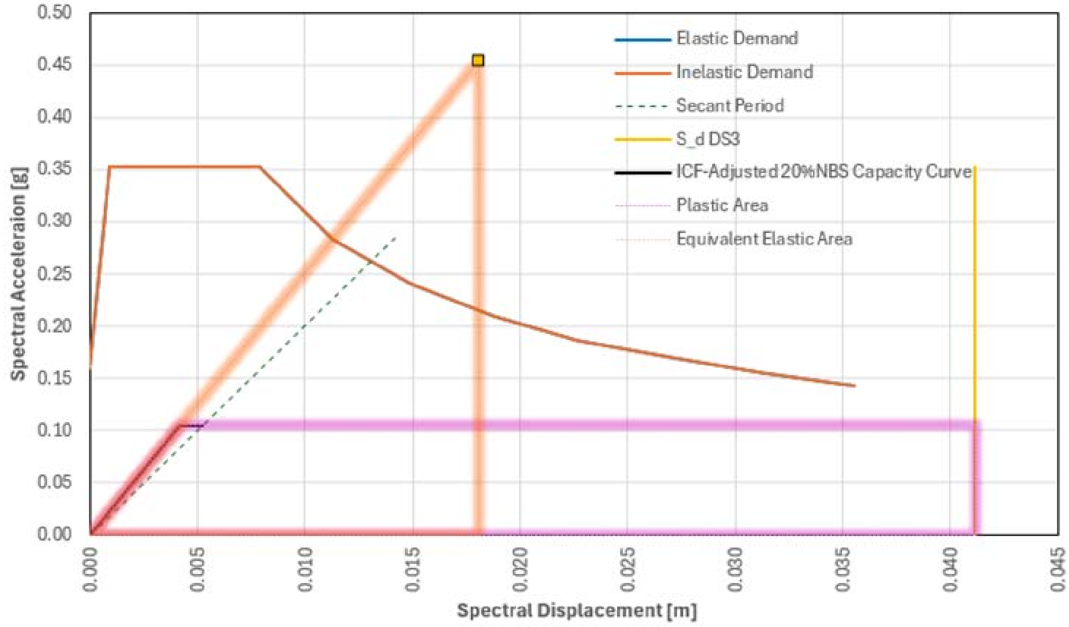


Figure: Graphical representation of equal energy method to determine DS3 equivalent spectral acceleration intensity.

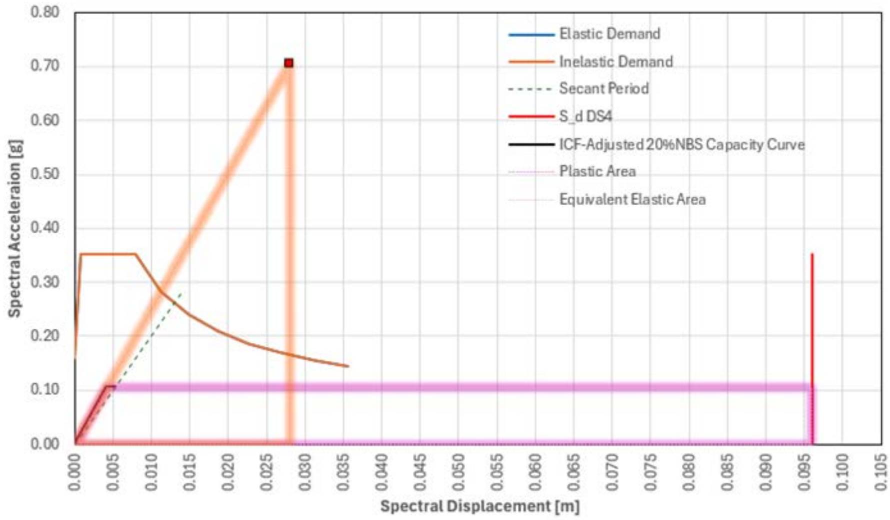


Figure: Graphical representation of equal energy method to determine DS4 equivalent spectral acceleration intensity.

6. Fragility Curves

For this example of one building, the median spectral acceleration for each fragility curve is equal to the equivalent elastic spectral acceleration capacity of this single building. For the actual calculation, all of the values of spectral acceleration for buildings in a specific city and of a specific typology would be averaged to determine the median collapse fragility spectral acceleration values.

For dispersion, the value of 0.64 shown in HAZUS is taken as the dispersion of the fragility curves.

Table: Exemplar fragility curve based on structural calculations for one building (actual calculation would be based on whole subset of the earthquake-prone building register).

Damage State	Median	Dispersion (beta)
DS1	0.171	0.64
DS2	0.262	0.64
DS3	0.429	0.64
DS4	0.663	0.64

7. Normalization of Structural Period

In order to make a comparison between a range of buildings of different periods of vibration, some method of normalization is required. Other observed methods such as Hulsey et al. (2024) have been to use a ratio of SA for the damage state against an SA capacity as per the code. Here, we have chosen to use a normalized SA at a benchmark period as this is easier to compare back to the hazard presented on the GNS Webtool for the hazard. Normalize the individual $S_a(T_1)$ intensity associated with each damage state for the individual structure to a consistent benchmark $S_a(T_{benchmark})$.

Benchmark period	$T = 0.4\ s$
Spectral shape factor of benchmark period	$C_h(T_{benchmark}) = 2.36$
Spectral shape factor of structural period	$C_h(T_1) = 2.36$
Ratio of benchmark to structural period spectral accelerations	$R_{normal} = 1.0$

In this case, because only one building is used.

8. Iteratively improve structural backbones to achieve 34% and 67%

To account for strengthening, the structural backbones are adjusted in accordance with the expected result of the retrofits to that structure. This may improve force or ductility capacity of the structure by some factor. This process is iterated until the targeted %NBS is reached. Then, the same process of converting backbones to equivalent spectral acceleration values at $T_{benchmark}$ is completed.

The below calculation shows the process undertaken to determine the backbone for a 67% strengthened structure.

Strengthening level $\%NBS_{str} = 67\%$

Relative degree to which strengthening includes the increase of force capacity. $F_F = 1.0$

Relative degree to which strengthening includes the increase of displacement capacity. $F_\mu = 1.0$

Maximum ductility that the structure can have after strengthening $\mu_{max} = 1.25$

In other words, the structure's ductility cannot be improved beyond nominally ductile.

Based on these value's increase force by some increment and ductility by some other increment and observe the changes to the structural capacity curve and inelastic structural demand curve.

No improvements in ductility are possible as the structure is already nominally ductile. Therefore, only the force increment could be improved. After successive iterations, the force increment leading to a 67% backbone was found to be

Force increment used to yield a 67% backbone. $inc_F = 4.5$

Ductility increment used to yield a 67% backbone. $inc_\mu = 1.0$

New ductility after incrementation

$$\mu_{new} = inc_\mu \cdot \mu$$
$$\mu_{new} = 1.0 \cdot 1.25$$

New ultimate spectral displacement after incrementation

$$S_{du,new} = \mu_{new} \cdot S_{du}$$

$$S_{du,new} = 1.25 \cdot 0.0037$$
$$S_{du,new} = 0.0046\ m$$

New spectral acceleration after incrementation

$$S_{a,new} = inc_F \cdot S_a$$

This value is only used for intersection with the demand curve, it is not the backbone capacity

$$S_{a,new} = 4.5 \cdot 0.093$$
$$S_{a,new} = 0.418\ g$$

New hysteretic damping as a result of ductility $\xi_{hy,new} = 2\%$ *EAG Table C2D.1*

New system damping as a result of ductility $\xi_{sys,new} = 7\%$

New spectral damping reduction factor $k_\xi = 0.88$

New elastic period of vibration

$$T_{1,new} = \sqrt{4\pi^2 \cdot \frac{S_{dy,new}}{9.81 \cdot S_{a,new}}}$$

$$T_{1,new} = \sqrt{4\pi^2 \cdot \frac{0.0037}{9.81 \cdot 0.418}}$$

$$T_{1,new} = 0.189\ s$$

New secant period of vibration

$$T_{s,new} = \sqrt{4\pi^2 \cdot \frac{S_{du,bew}}{9.81 \cdot S_{a,new}}}$$

$$T_{s,new} = \sqrt{4\pi^2 \cdot \frac{0.0046}{9.81 \cdot 0.418}}$$

$$T_{s,new} = 0.211\ s$$

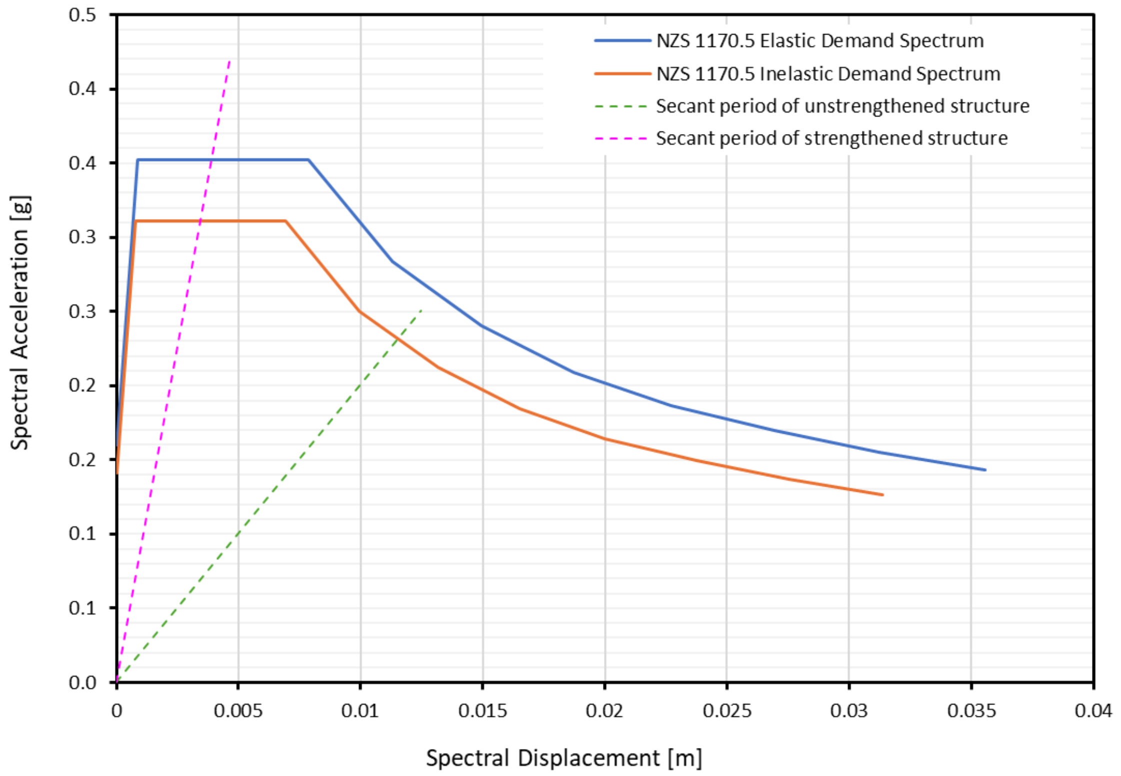


Figure: Change in secant period as a result of strengthening by improving force capacity.

Having identified the secant period, the 100%NBS backbone can be produced.

Spectral acceleration of a 100%NBS structure $S_{a,100} = 0.311\ g$ *By intersection of secant period with inelastic demand spectrum*

Spectral displacement of a 100%NBS structure

$$S_{du,100} = 9.81 \cdot S_{a,100} \cdot \frac{T_s^2}{4\pi^2}$$

$$S_{du,100} = 9.81 \cdot 0.311 \cdot \frac{0.211^2}{4\pi^2}$$

$$S_{du,100} = 0.0034\ m$$

Spectral acceleration of the strengthened 67%NBS structure

$$S_{a,nbs} = \%NBS \cdot S_{a,100}$$

$$S_{a,nbs} = 67\% \cdot 0.311$$

$$S_{a,nbs} = 0.209\ g$$

Spectral displacement of the strengthened 67%NBS structure

$$S_{a,nbs} = \%NBS \cdot S_{du,100}$$

$$S_{du,nbs} = 67\% \cdot 0.0034$$

$$S_{a,nbs} = 0.0023\ g$$

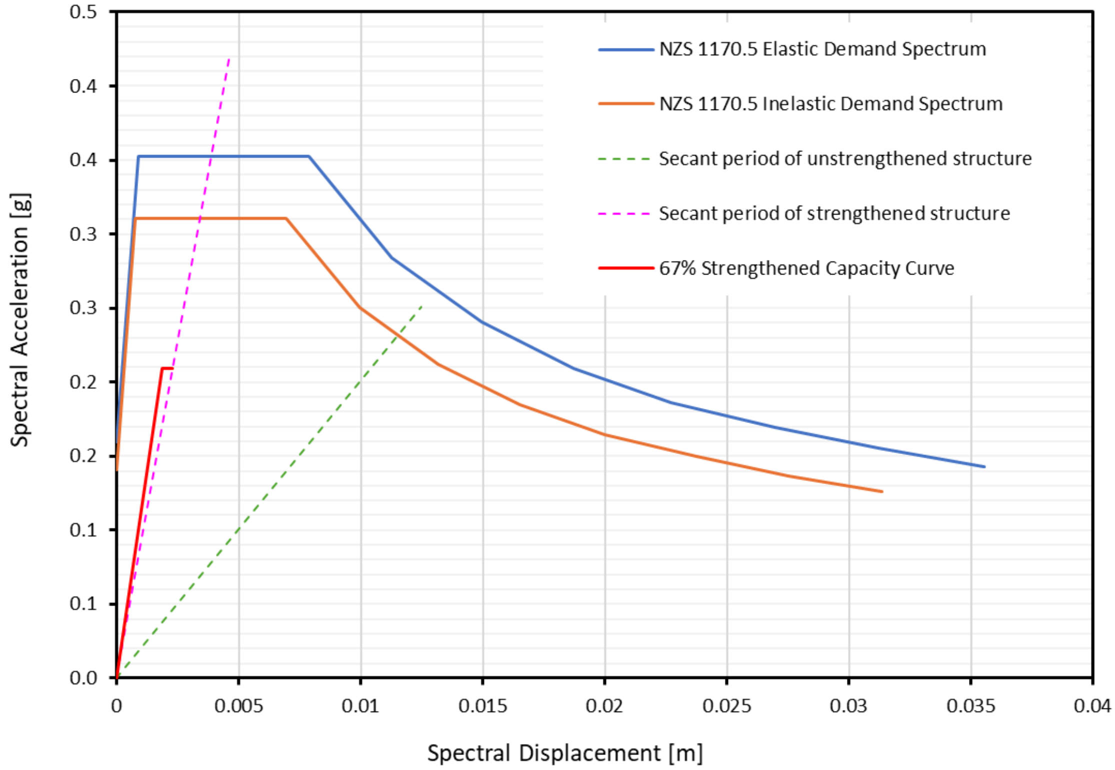


Figure: Structural capacity backbone for 67% strengthening backbone

Similar to the unstrengthened case, the steps of improving the backbone by the inherent capacity factor and establishing an equivalent elastic spectral acceleration were performed. The resulting elastic spectral accelerations are shown in the below plot.

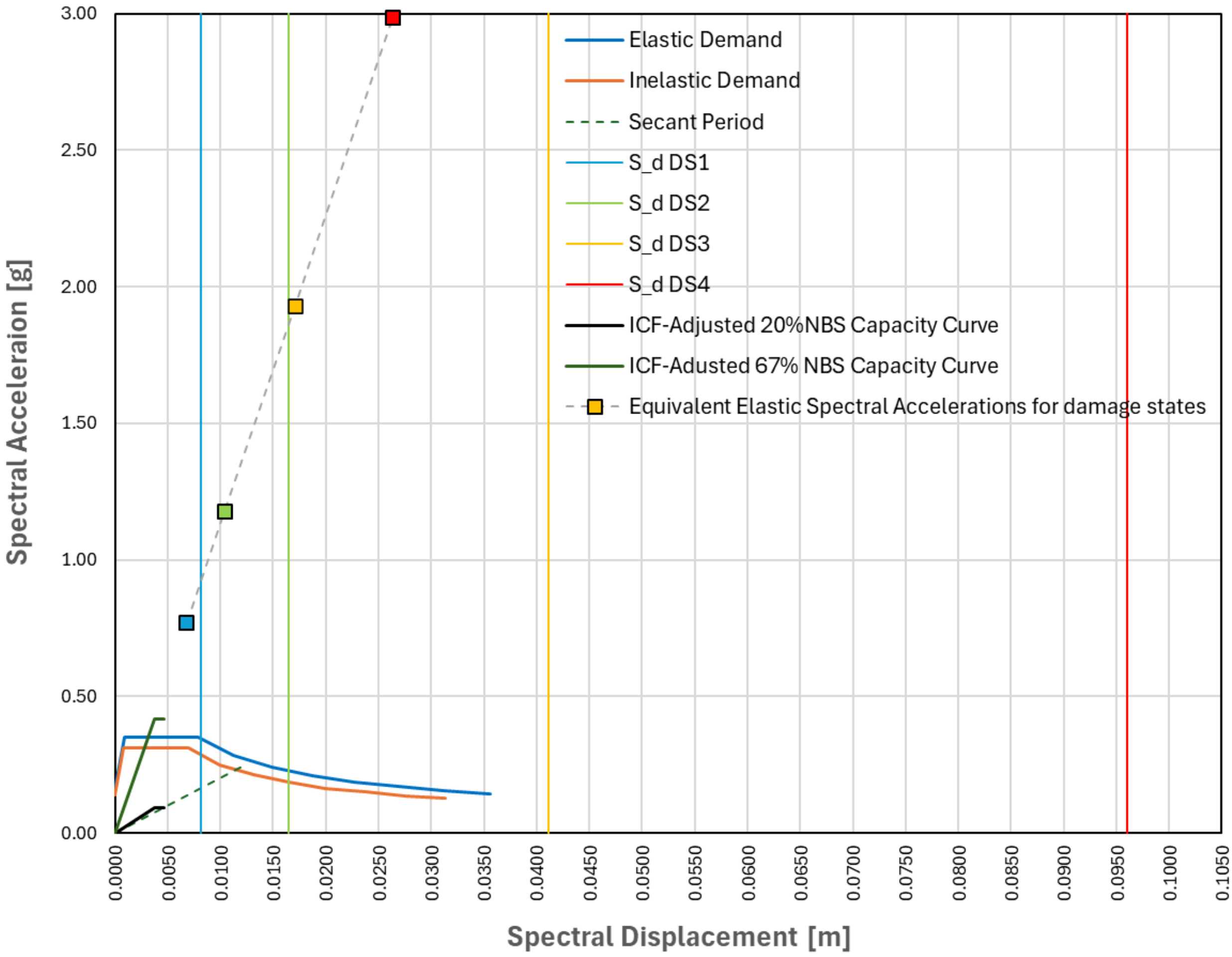


Figure: Equivalent elastic spectral accelerations for damage states

Finally, the spectral accelerations can be normalized to the benchmark period.

Benchmark period	$T = 0.4\ s$
Spectral shape factor of benchmark period	$C_h(T_{benchmark}) = 2.36$
Spectral shape factor of structural period	$C_h(T_1) = 2.93$
Ratio of benchmark to structural period spectral accelerations	$R_{normal} = 0.81$

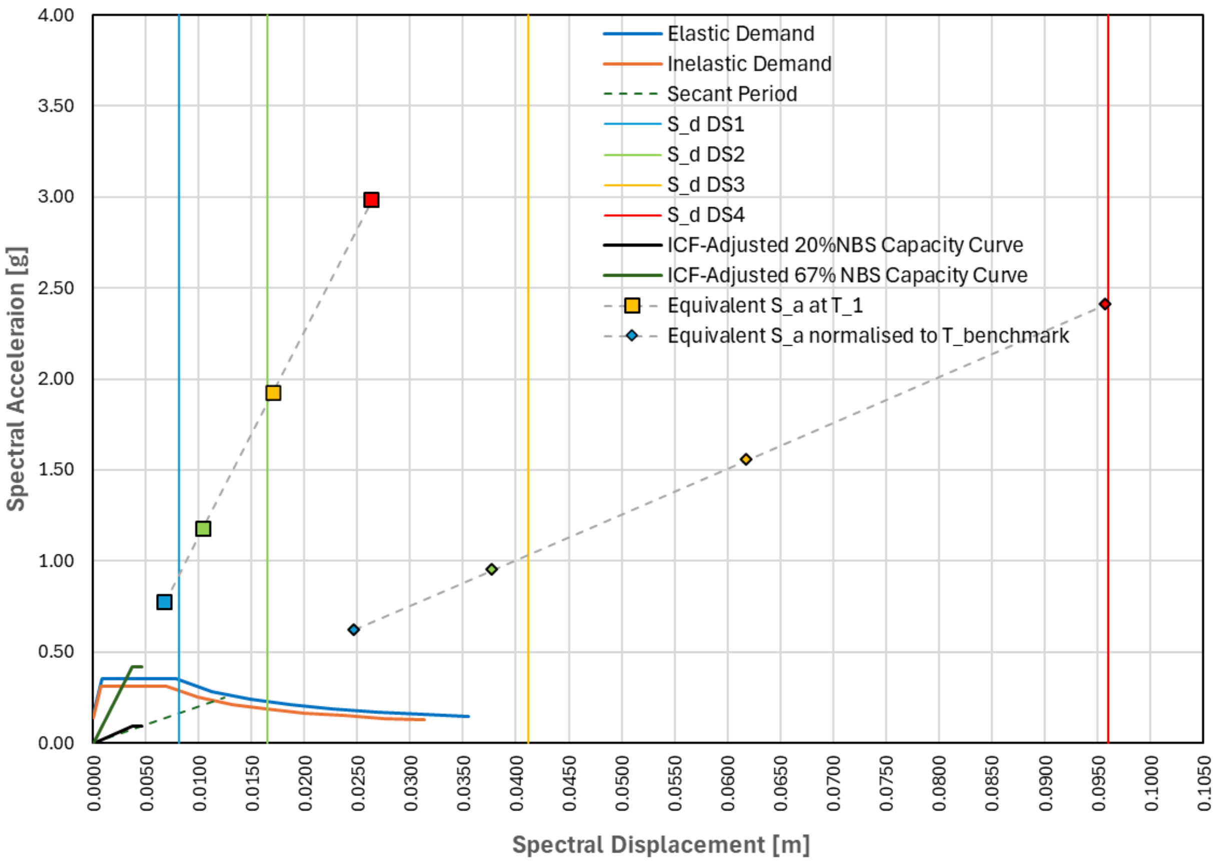


Figure: Equivalent elastic spectral accelerations for damage states normalized to the benchmark period. Diamonds represent the accelerations used as the median fragility for each damage state.

Therefore, the strengthened fragility curve is:

Damage State	Median	Dispersion (beta)
DS1	0.62	0.64
DS2	0.95	0.64
DS3	1.56	0.64
DS4	2.41	0.64

9. Identifying the new hazard intensity for given return period

Note values in the below calculation slightly misalign with the previous sections but the methodology is consistent.

RP	=	500	Return period
APE	=	0.002	Annual probability of exceedance (approximate)

Dunedin for APoE 1:2500 to 1:100 below: (short periods)

Dunedin (Vs30= 350m/s)

	PoE	0.4s	0.7s	1s	1.5s	2s
100	0.01	0.226	0.155	0.116	0.076	0.055
250	0.004	0.377	0.263	0.198	0.129	0.097
500	0.002	**0.535**	0.376	0.284	0.187	0.139
1000	0.001	0.744	0.528	0.399	0.263	0.198
2500	0.0004	1.122	0.814	0.618	0.405	0.304

T = 0.4 sec
Sa = 0.53g

10. Determine the relative likelihoods of different damage states based on earthquake scenario intensity

From previous page:

S_a	=	0.53	g

(Fragility data for unstrengthened 20%*NBS*)

Table: The probability of each damage state exceedance

DS	P [DS > ds | IM > im]
DS0	100%
DS1	80%
DS2	59%
DS3	30%
DS4	11.8%

Table: Fragility curve CDF visualised

SA(T_avg) Intensity	DS1	DS2	DS3	DS4
0.225	0.302	0.128	0.030	0.005
0.375	0.610	0.369	0.140	0.039
0.53	0.794	0.581	0.294	0.112
0.74	0.910	0.766	0.492	0.244
1.12	0.977	0.915	0.735	0.481

Based on these probabilities, the relative likelihood that a building is in a given damage state as a result of the scenario earthquake is calculated. This is the probability that the damage state is exceeded minus the probability of any higher damage states being exceeded.

Table: The relative likelihood of a given damage state

DS	P [DS > ds | IM > im]	P [DS = ds | IM > im]
DS0	100.0%	24.3%
DS1	75.7%	22.5%
DS2	53.3%	28.0%
DS3	25.3%	16.3%
DS4	9.0%	9.0%

Table: Fragility based on average of only one building in this example

DS	median	beta
DS1	0.179	0.64
DS2	0.276	0.64
DS3	0.455	0.64
DS4	0.705	0.64

Table: Probabilities at given intensities

DS	DS | IM	DS > ds | IM	
DS0	1	6%	
DS1	0.96	13%	alpha
DS2	0.85	27%	z
DS3	0.60	26%	y
DS4	0.34	28%	x

With the following formular.

DS | IM for DS0 = 1.0

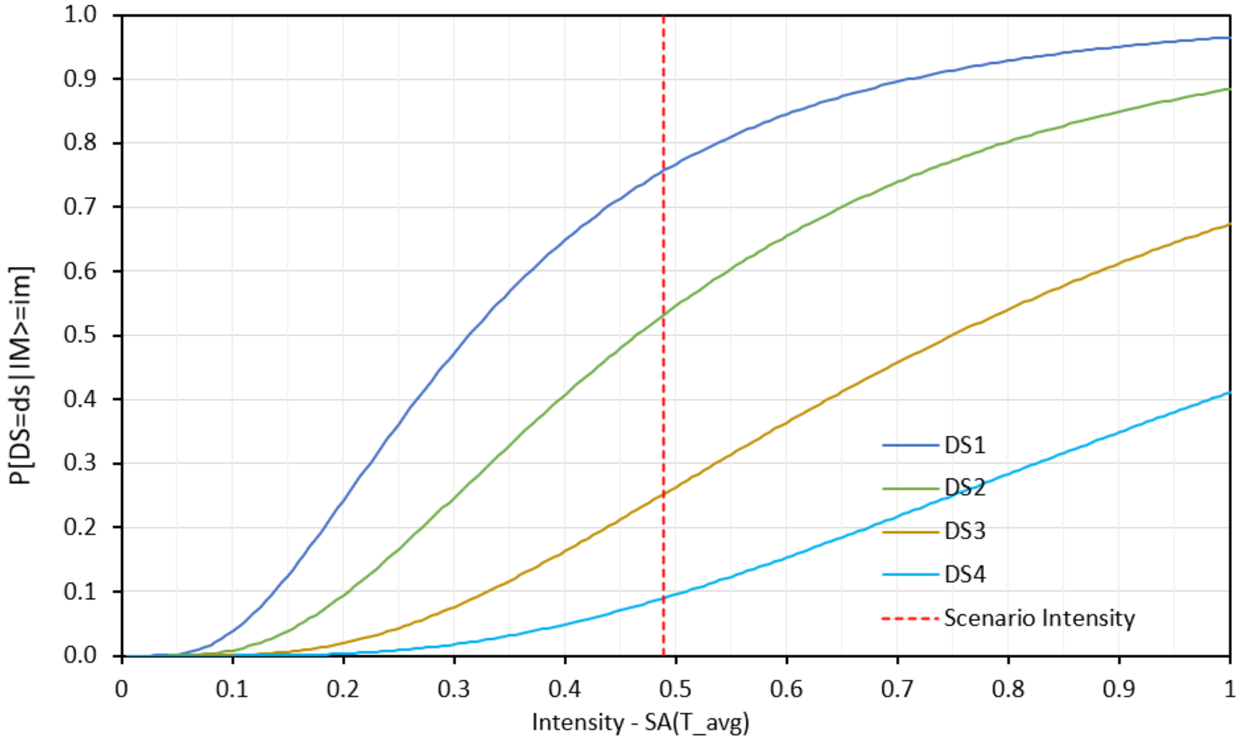
DS | IM for DS1 = NORM.DIST(LN(Sa),LN(median_DS1),Beta_DS1, TRUE,0

DS | IM for DS1 = NORM.DIST(LN(0.226),LN(0.179),(0.64) = 0.94

DS | IM for DS2 = NORM.DIST(LN(0.226),LN(0.276),(0.64) = 0.81

DS | IM for DS3 = NORM.DIST(LN(0.226),LN(0.455),(0.64) = 0.54

DS | IM for DS4 = NORM.DIST(LN(0.226),LN(0.705),(0.64) = 0.28



This can be interpreted as, for this design level earthquake scenario, there being an approximately x% chance that the earthquake-prone building totally collapses, a y% chance that the building partially collapses, a z% chance of light failure and only an alpha% chance of minor damage.

11. Loss

In the actual loss calculation, each building is assigned a ground floor area and occupancy type. The occupancy density of each building type has been provided by GNS Science *REF*. Several cases have been created to account for different times of day which impact the relative occupancy density of different building types.
For this example calculation, the following parameters have been used as a demonstration:

Occupancy type	COM13	User chosen
Ground floor area	$GFA = 300\ m^2$	User chosen
Time of day	10 am (day)	User chosen
Proportion of peak occupancy	$R_{peak} = 0.9$	Provided by GNS Science
Occupancy density	$\rho_{occ} = 1/14\ people/m^2$	Provided by GNS Science
Outside occupancy modifier	$k_{outside} = 1.1$	Provided by GNS Science

Human Consequences

For human consequences, the occupancy density at the time of the event and the ground floor area of the structure must be factored into the final loss. In this example calculation, the ground floor area is of one building only, but in the whole calculation, the total ground floor area of all buildings of the occupancy type for the given case (of location, typology, time of day, etc.) must be considered.

Here is an example of the calculation for the CS5 (in death equivalents) given that DS4 (complete collapse) occurs.

Consequence value

$$C = P[CS5|ds = DS4] \cdot R_{peak} \cdot \rho_{occ} \cdot k_{outside} \cdot GFA$$

$$C = 0.3 \cdot 0.9 \cdot \frac{1}{14} \cdot 1.1 \cdot 300$$

$$C = 6.4\ death\ equivalents$$

Human Losses

From earlier steps, the relative likelihood of damage states occurring given an event of a given severity is provided. Therefore, using CS5 as an example, the CS5 consequence for the given scenario can be determined.

Damage State	Consequence values (death equivalents given that damage state definitely occurs)	Probability of the given damage state occurring in the scenario $P[ds\ DSX]$	Expected loss in the given scenario due to given damage state
DS1	0	13%	0
DS2	0	27%	0
DS3	2.1	26%	0.6
DS4	6.4	28%	1.8

The sum of expected losses across all damage states provides the total expected loss of the scenario.

CS5 expected loss across all damage states

$$L = \sum_{DSX=DS1}^{DS4} C[ds = DSX]$$

$$C = 0 + 0 + 0.6 + 1.8$$

$$C = 2.4\ death\ equivalents$$

This process is repeated across a range of consequences.

Table: Losses for single structure example.

Consequence Type	**Damage State**	**Consequence values (death equivalents given that damage state definitely occurs) (units specific to consequence)**	Probability of the given damage state occurring in the scenario $P[ds \quad DSX]$	**Expected loss in the given scenario due to given damage state (units specific to consequence)**
CS2	DS1	0.20	13%	0.03
CS2	DS2	0.80	27%	0.22
CS2	DS3	1.40	26%	0.37
CS2	DS4	1.00	28%	0.28
CS3	DS1	0.0	13%	0.00
CS3	DS2	0.0	27%	0.01
CS3	DS3	0.8	26%	0.20
CS3	DS4	3.2	28%	0.92
CS4	DS1	0.0	13%	0.00
CS4	DS2	0.0	27%	0.00
CS4	DS3	1.1	26%	0.29
CS4	DS4	3.3	28%	0.93
CS5	DS1	0.0	13%	0.00
CS5	DS2	0.0	27%	0.00
CS5	DS3	2.1	26%	0.55
CS5	DS4	6.4	28%	1.80
CS2_USAR	DS1	0.2	13%	0.03
CS2_USAR	DS2	0.8	27%	0.22
CS2_USAR	DS3	1.4	26%	0.37
CS2_USAR	DS4	1.0	28%	0.28
CS3_USAR	DS1	0.0	13%	0.00
CS3_USAR	DS2	0.0	27%	0.01
CS3_USAR	DS3	0.8	26%	0.20
CS3_USAR	DS4	3.2	28%	0.92
CS4_USAR	DS1	0.0	13%	0.00
CS4_USAR	DS2	0.0	27%	0.00
CS4_USAR	DS3	1.1	26%	0.29
CS4_USAR	DS4	3.3	28%	0.93
CS5_USAR	DS1	0.0	13%	0.00
CS5_USAR	DS2	0.0	27%	0.00
CS5_USAR	DS3	2.1	26%	0.55
CS5_USAR	DS4	6.4	28%	1.80
DR	DS1	0.1	13%	0.01
DR	DS2	0.3	27%	0.08
DR	DS3	0.8	26%	0.21
DR	DS4	1.0	28%	0.28
Carbon repair	DS1	0.1	13%	0.01
Carbon repair	DS2	0.3	27%	0.08
Carbon repair	DS3	0.8	26%	0.21

Carbon repair	DS4	1.0	28%	0.28
BD direct	DS1	1.0	13%	0.13
BD direct	DS2	270.0	27%	73
BD direct	DS3	365.0	26%	95
BD direct	DS4	365.0	28%	103
BD indirect	DS1	1.0	13%	0.13
BD indirect	DS2	270.0	27%	73
BD indirect	DS3	365.0	26%	95
BD indirect	DS4	365.0	28%	103

Table: Aggregated losses for single structure example.

Damage State	Expected Loss
CS2	0.9
CS3	1.1
CS4	1.2
CS5	2.4
CS2_USAR	0.9
CS3_USAR	1.1
CS4_USAR	1.2
CS5_USAR	2.4
DR	0.6
Carbon repair	0.6
BD direct	270
BD indirect	270

12. Costed Loss

Given the costs for the individual case, and the losses established in the previous sections, the costs of each consequence can be calculated.

To complete the example with CS5, the costed loss is:

Costed loss

$$CL = L * Cost$$

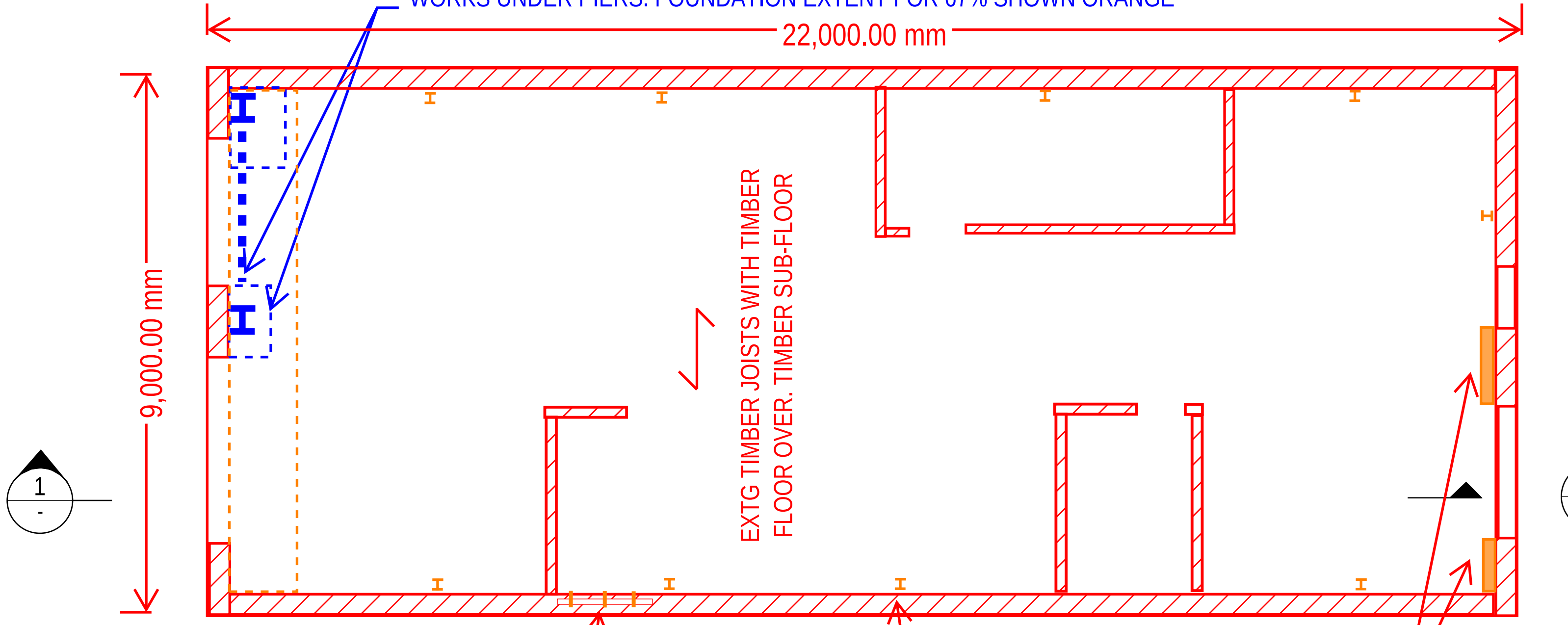
$$CL = 2.4 * \$17.5M$$

$$CL = \$41.3M$$

D

Appendix D

Seismic Retrofit Concepts For Reference Buildings



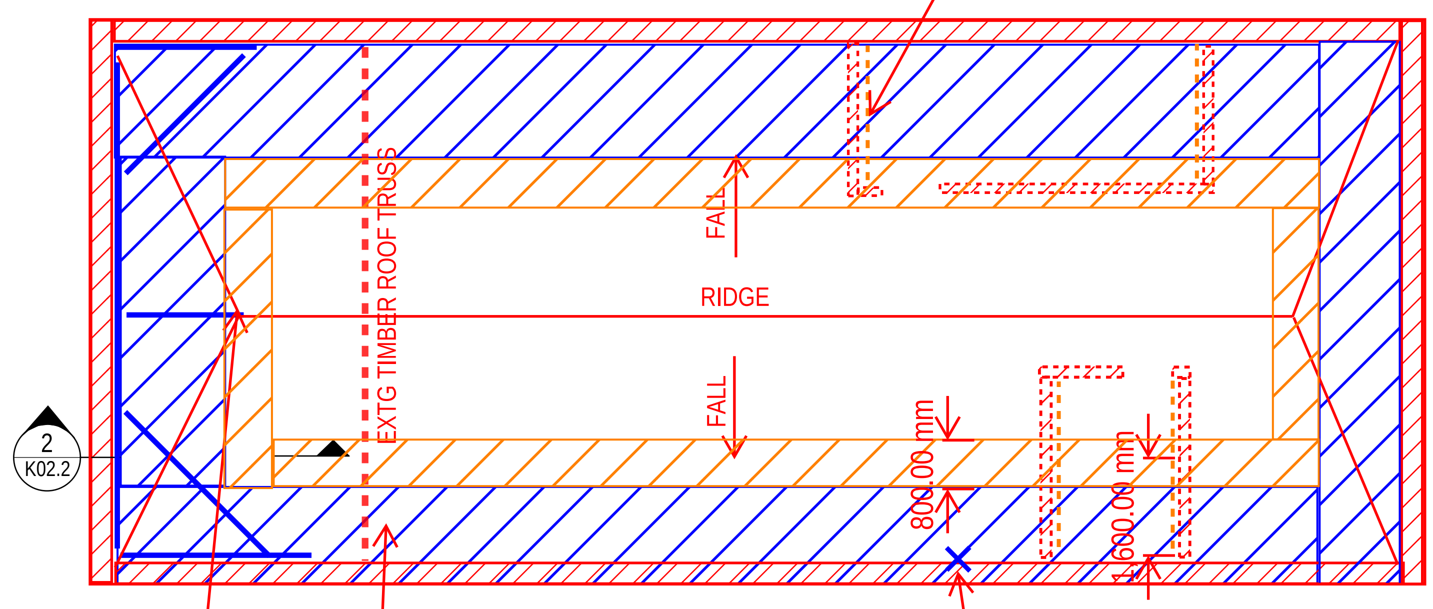
1 GROUND FLOOR NEW STEEL BRACED BAY WITH STEEL POSTS. FOUNDATION WORKS UNDER PIERS. FOUNDATION EXTENT FOR 67% SHOWN ORANGE

5 TO ACCOUNT FOR VARIATION BETWEEN CAVITY AND SOLID WALL URM CONSTRUCTION. ALLOW FOR PYTHON CAVITY TIE ANCHORS TO 50% OF THE WALLS ON LVL1. 250mm LONG AT 900mm CRS EACH WAY

9 150mm THK RC OVERLAY TO PIERS ADJACENT TO DOOR OPENINGS

6 67% ONLY. 150UC VERTICAL STRONG BACKS AT 3.9m CRS GROUND TO LVL 1. 2-M16 CHEMICAL ANCHORS AT 800mm CRS UP HEIGHT OF POST. ALLOW FOR WORKS TO TIE POSTS INTO EXTG ROOF AND FLOOR TIMBER

PLAN - GROUND FLOOR LEVEL



8 67% ONLY. STEEL PFC WALER BEAM TO TOP OF INTERNAL WALLS THAT ARE PARALLEL TO ROOF TRUSSES

PLAN - ROOF

2 ROOF TOP PARAPET RESTRAINT AND 4m ALONG SIDE WALLS. REFER DETAIL SK02.2

4 NEW 19mm PLY LINING TO UNDERSIDE OF TRUSS FOR 2000mm WIDTH ADJACENT TO LONGITUDINAL WALLS. ALLOW BLOCKING AND M16-600mm CRS EPOXY ANCHORS. TYPICAL TO PERIMETER. ADDITIONAL EXTENT FOR 67%NBS SHOWN IN ORANGE

3 INSTALL NEW STEEL BRACKETS FROM ROOF TRUSS TO MASONRY WALL AT APPROX 1600mm CRS. 2-M16 EPOXY ANCHORS TO WALL AND 2-M16 BOLTED THROUGH TRUSS BOTTOM CHORD. TYPICAL TO BOTH SIDE WALLS

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2 ROOF TOP PARAPET RESTRAINT. REFER DETAIL SK02.2

7 67% ONLY. ALLOW FOR UPGRADE OF CANOPY HANGER CONNECTIONS AND NEW PLYWOOD UNDERLAY WITH TIMBER RIBBON PLATE BOLTED TO URM

1 SECTION
- SCALE

EXAMPLE PHOTO OF TYPICAL TYPOLOGY

NOTES:

1.0 GENERAL
1.1 REFER TO ATTACHED SCHEDULE FOR SEISMIC STRENGTHENING SCOPE FOR OTHER REGIONS, USE AND GFA
1.2 BLUE COLOURED TEXT REPRESENTS SCOPE FOR 34%NBS. ORANGE COLOURED TEXT REPRESENTS SCOPE IN ADDITION TO 34%NBS SCOPE TO GET to 67%NBS
1.3 STRUCTURAL WORKS ONLY SHOWN. CONSEQUENTIAL WORKS AS A RESULT OF INSTALLING STRUCTURAL SCOPE SHALL BE ALLOWED FOR.

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Project: COST BENEFIT ANALYSIS OF THE EARTHQUAKE PRONE BUILDINGS IN NZ

Title: SEISMIC RETROFIT CONCEPT DESIGN TYPOLOGY 2 - URM 34 and 67%NBS - CHRISTCHURCH

Discipline: STRUCTURAL

Drawing No.: SE-K002.1 — Rev. A

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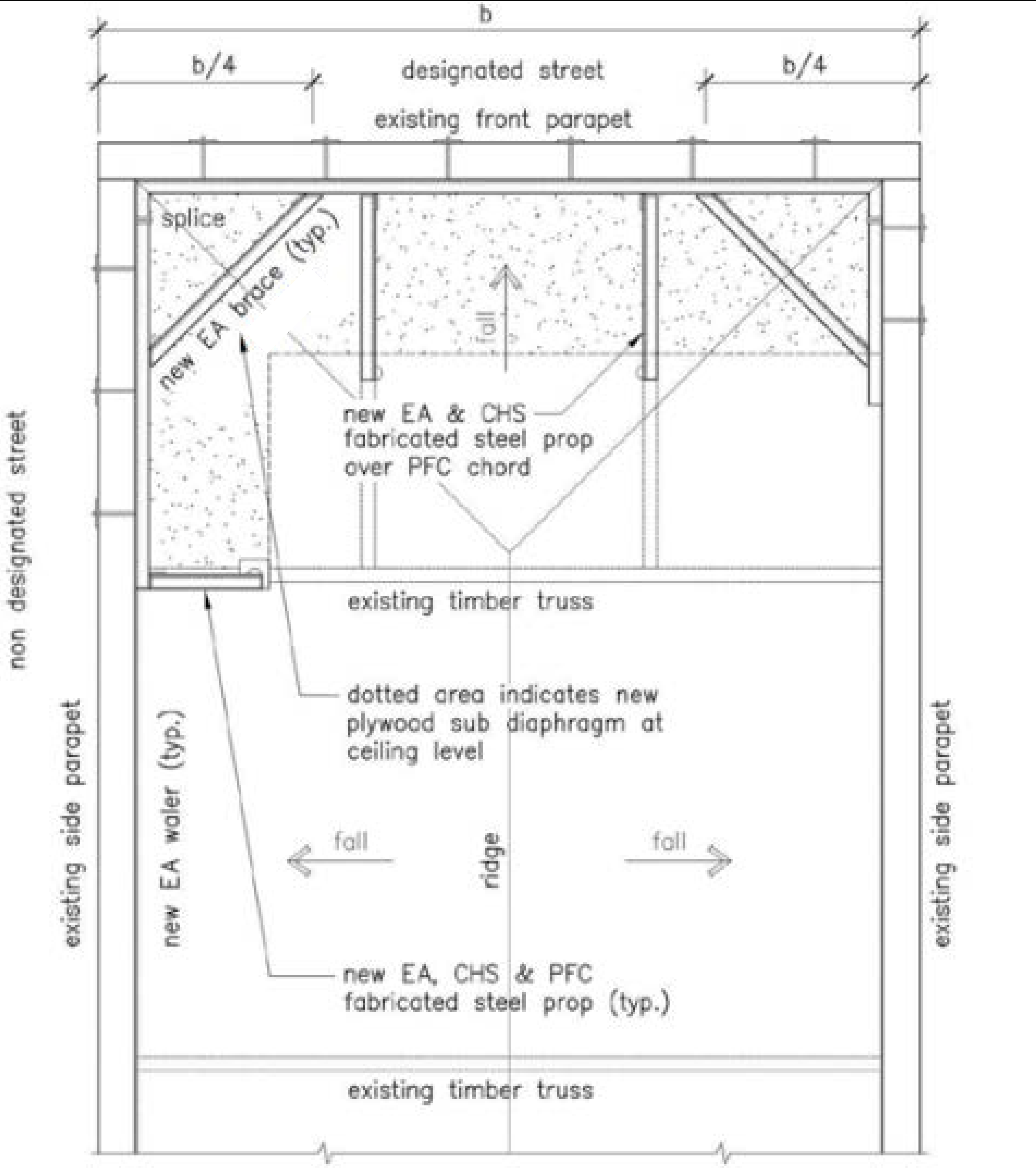
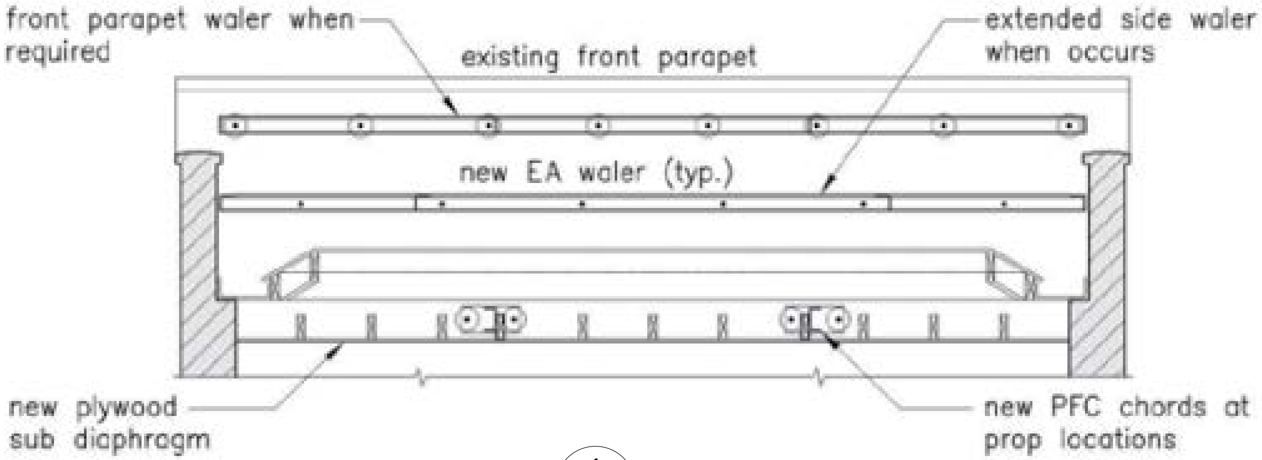


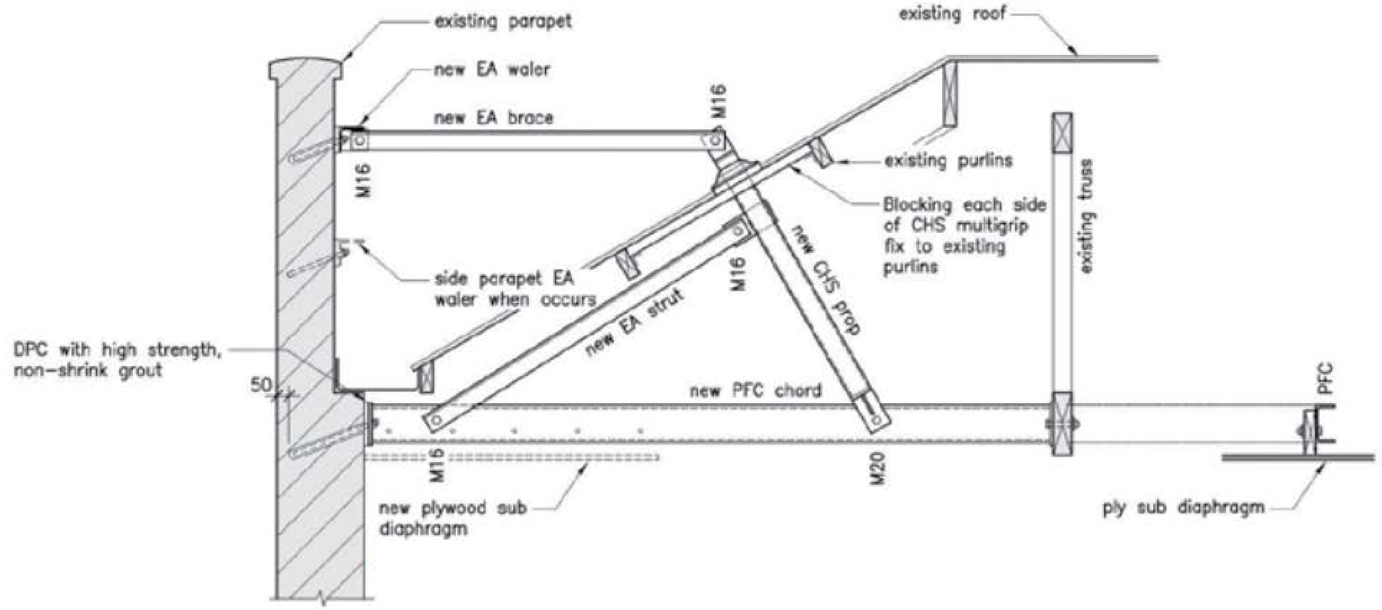
plan

3 SECTION (VIEW ROTATED 90 DEGREES)
K02.1 SCALE



rear elevation

1 SECTION
- SCALE



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BLUEBEAM

DO NOT SCALE

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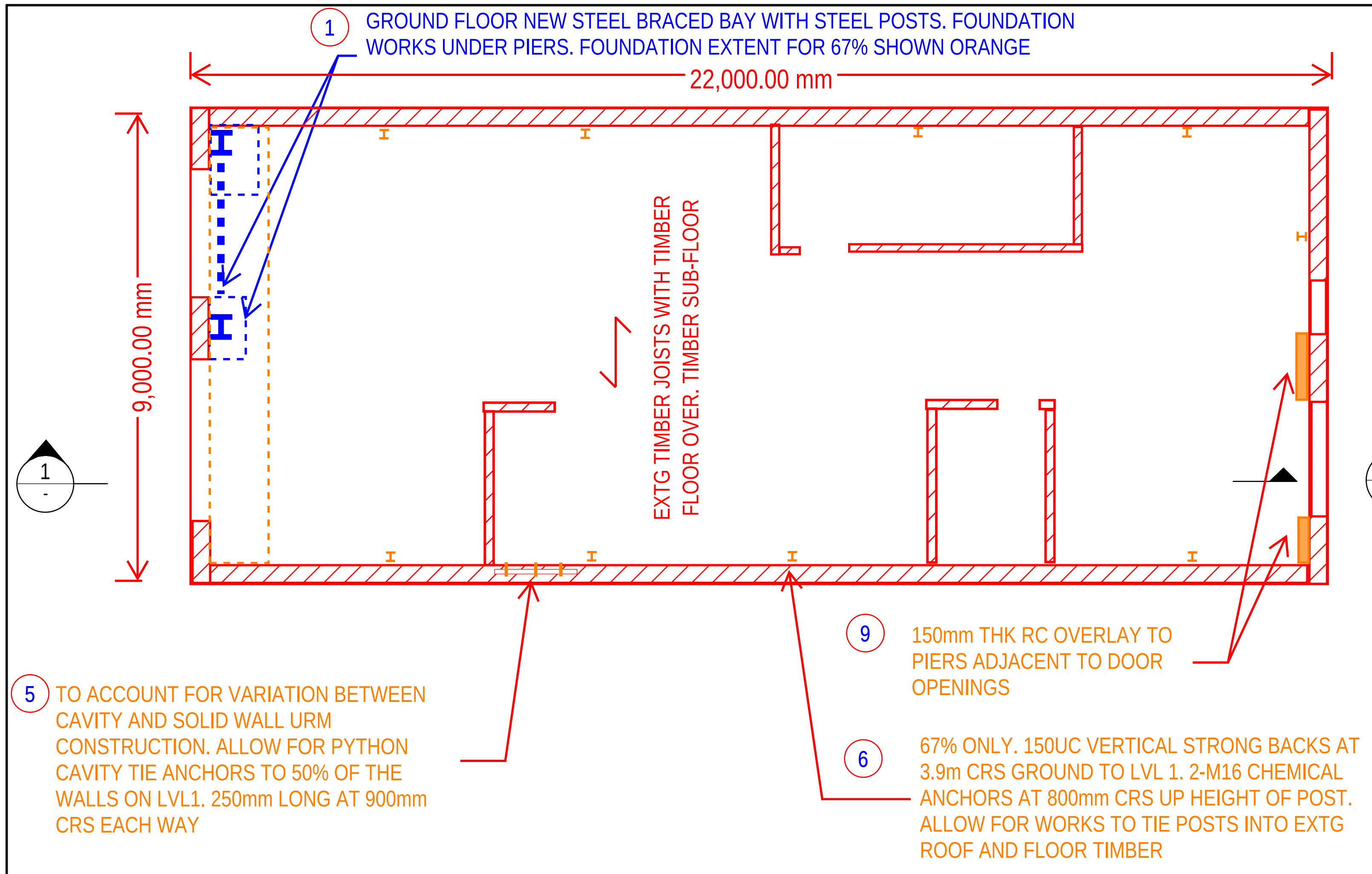
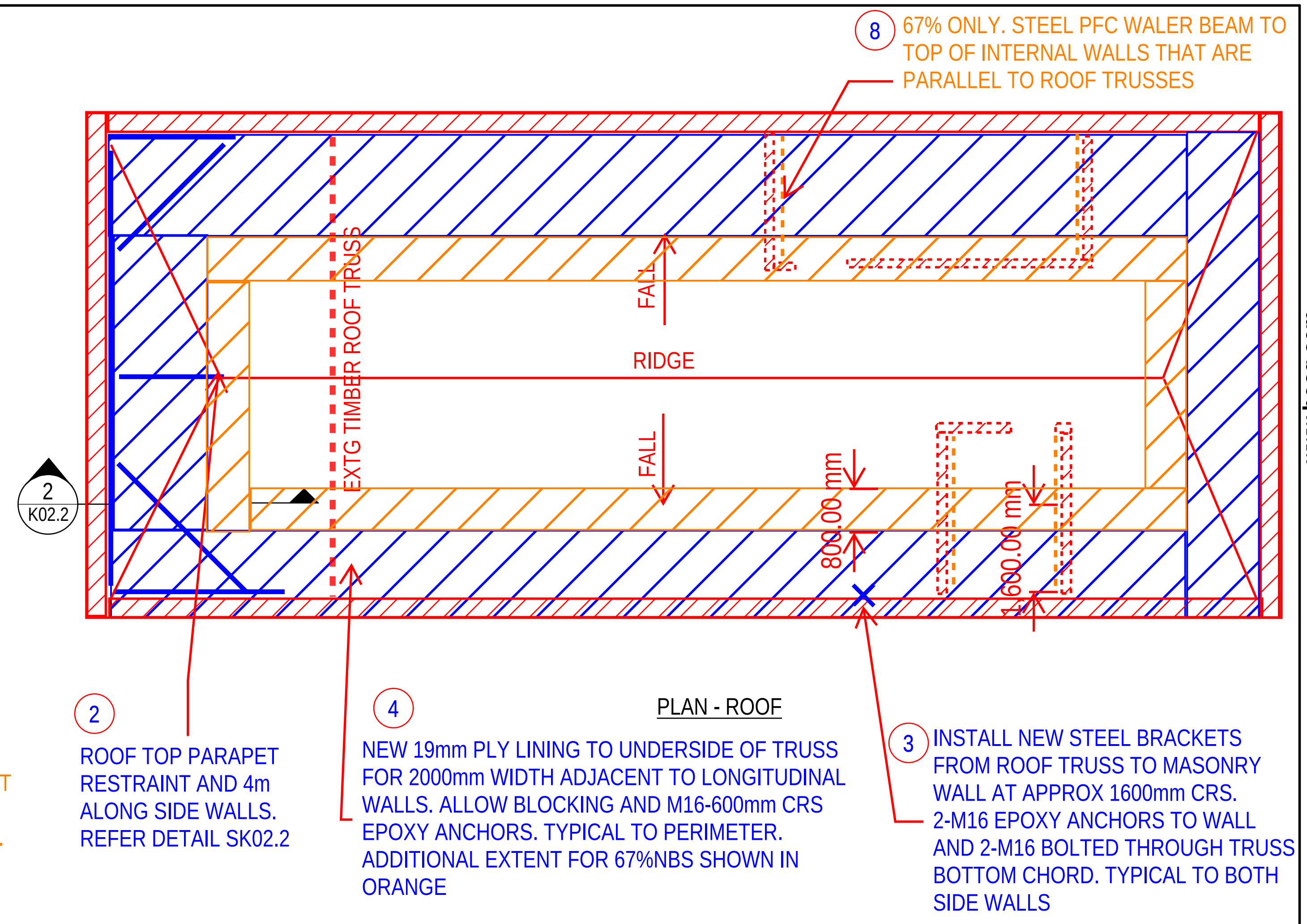
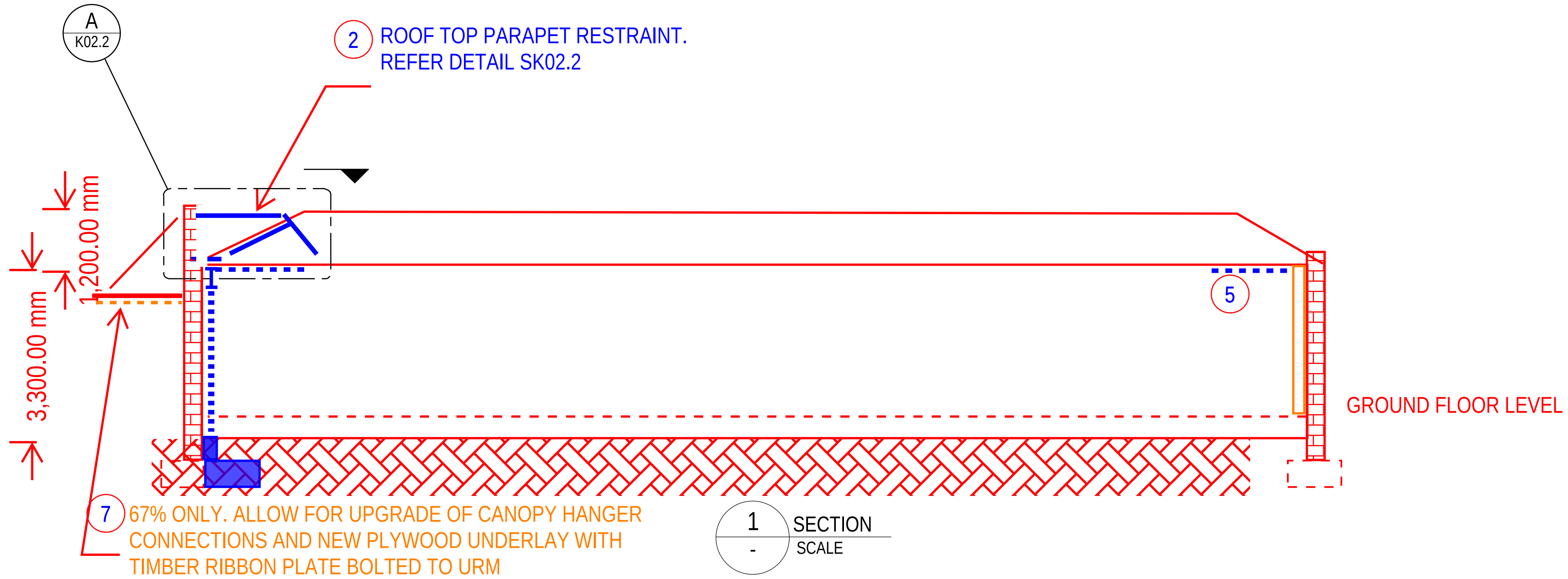


PLAN - GROUND FLOOR LEVEL



PLAN - ROOF



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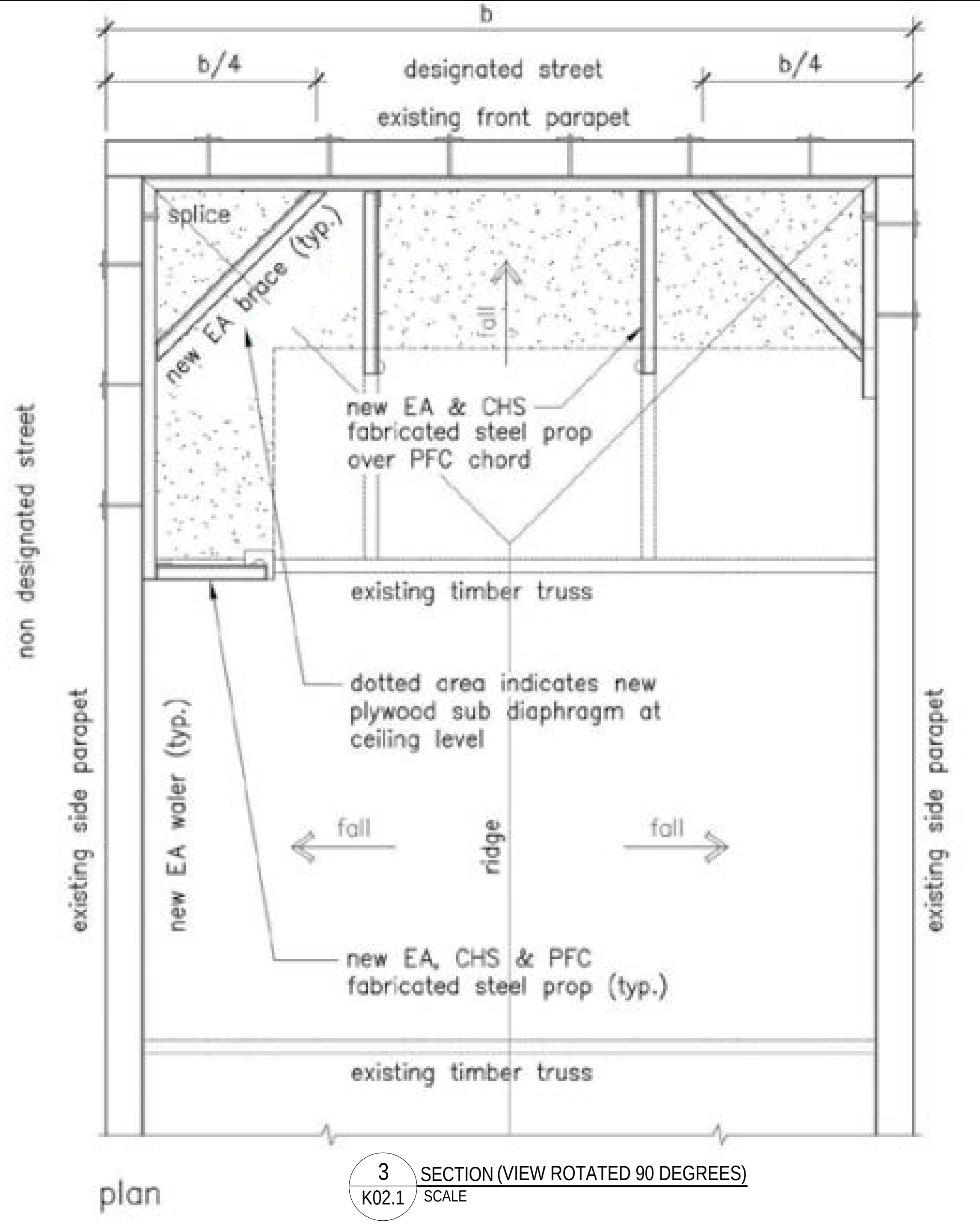
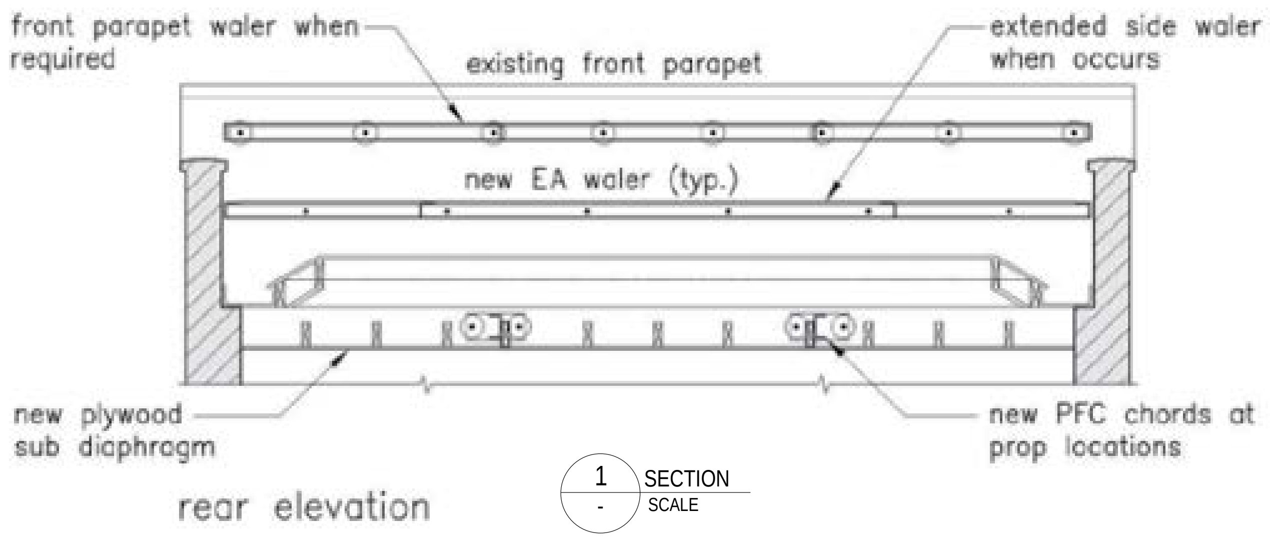
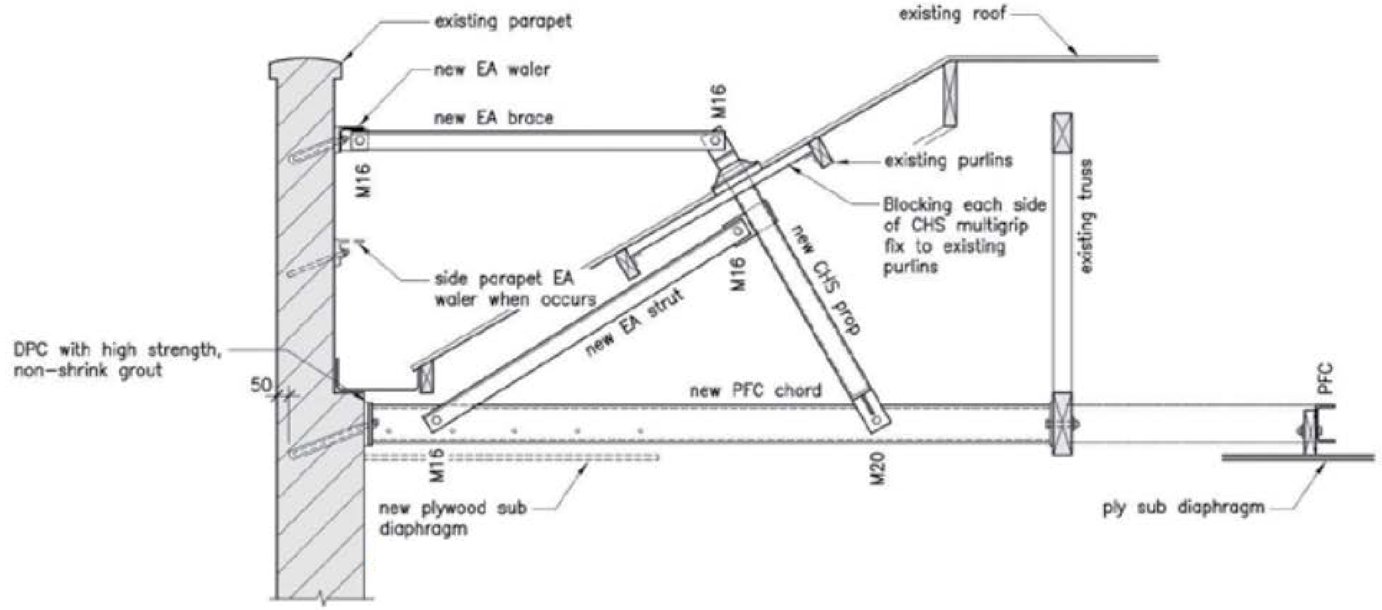


3 SECTION (VIEW ROTATED 90 DEGREES)
K02.1 SCALE



1 SECTION
- SCALE



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Drawing No. SE-K002.2 Rev. A

BLUEBEAM

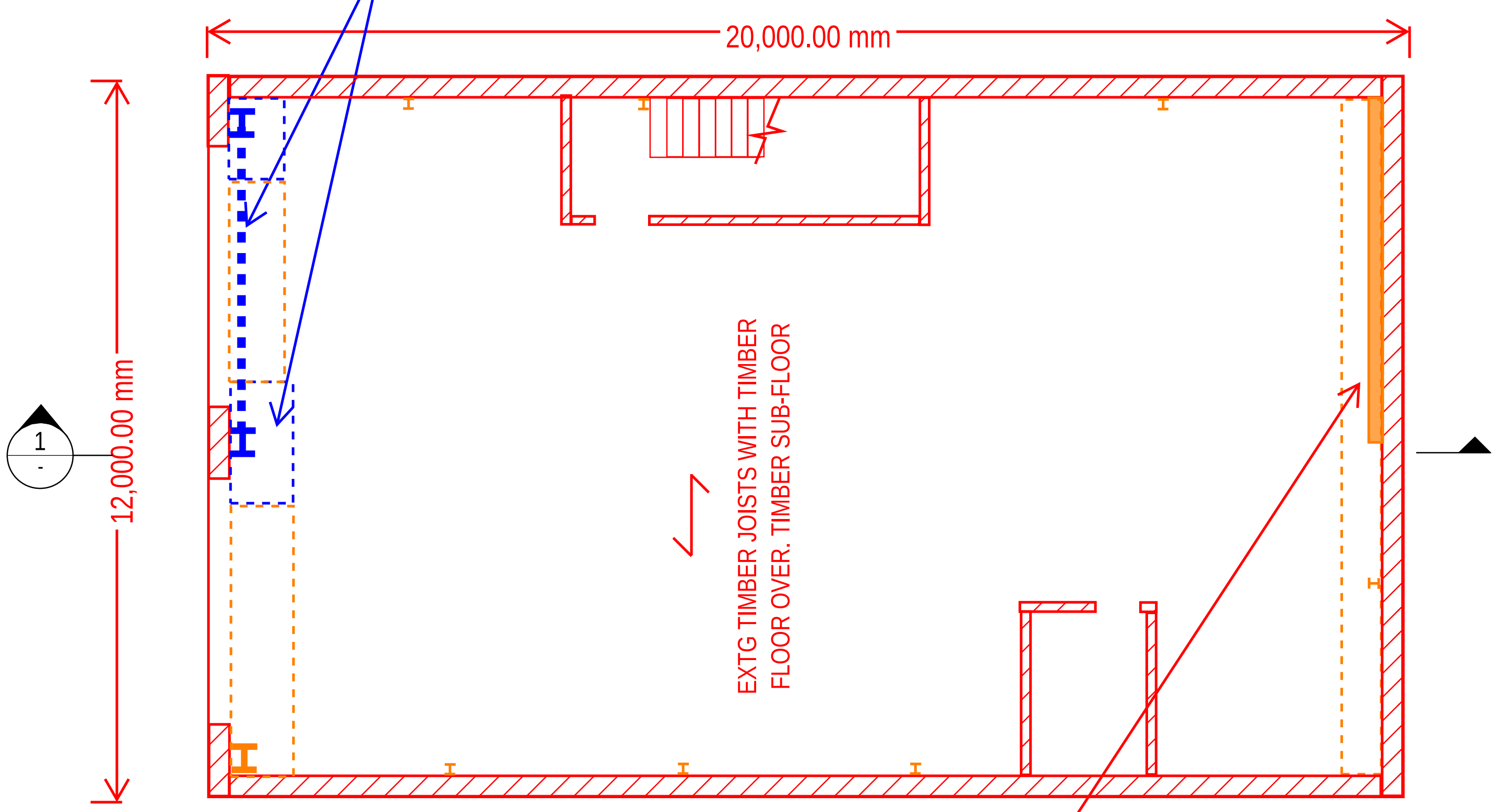
DO NOT SCALE

IF IN DOUBT ASK.

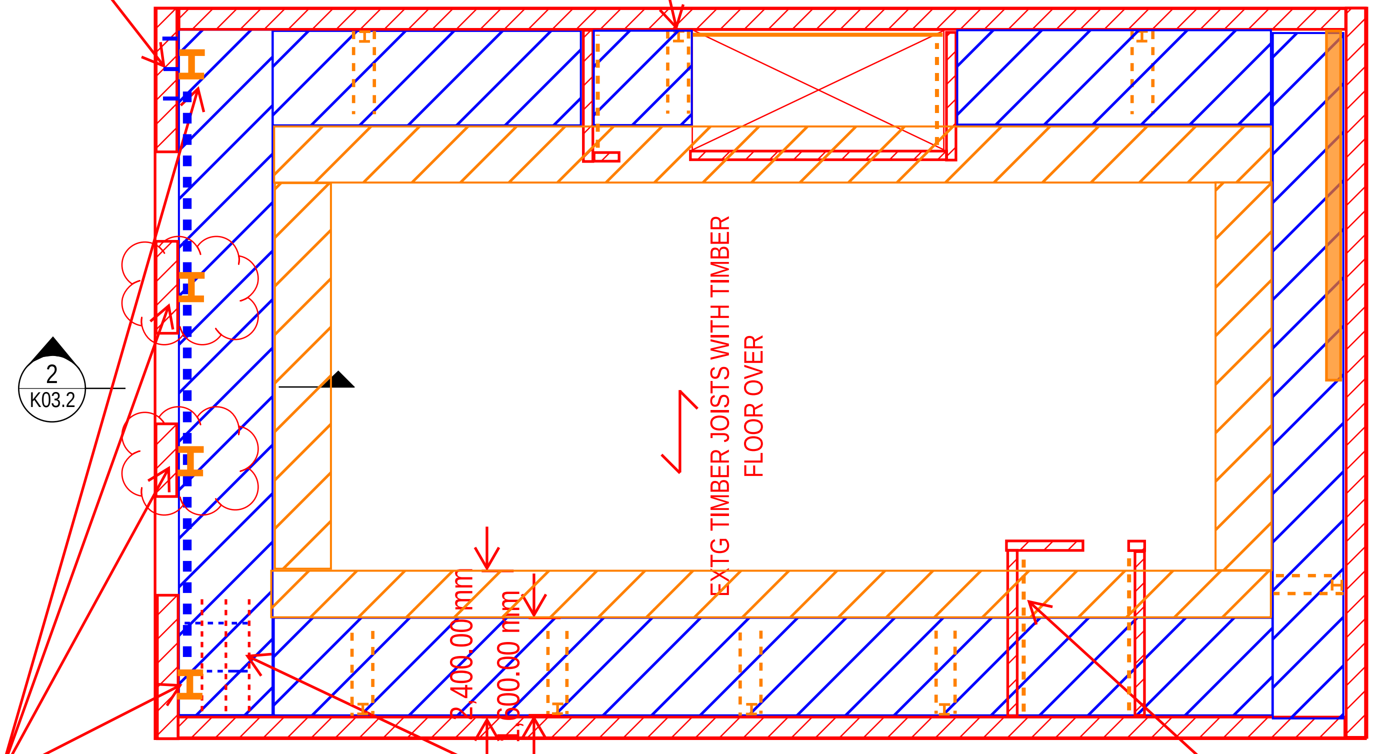
4 GROUND FLOOR NEW TENSION/COMPRESSION STEEL CROSS BRACED BAY WITH STEEL POSTS. FOUNDATION WORKS UNDER PIERS. STEEL DRAG PLATE AT LEVEL 1.

3 TO ACCOUNT FOR VARIATION BETWEEN CAVITY AND SOLID WALL URM CONSTRUCTION. ALLOW FOR PYTHON CAVITY TIE ANCHORS TO 50% OF THE WALLS ON LVL1. 350mm LONG AT 600mm CRS EACH WAY

5 67% ONLY. 150UC VERTICAL STRONG BACKS. 2-M16 CHEMICAL ANCHORS AT 800mm CRS UP HEIGHT OF POST. ALLOW FOR WORKS TO TIE POSTS INTO EXTG ROOF AND FLOOR TIMBER. NEW 200PFC WALER AT STAIR LOCATION BOLTED TO URM AND CONNECTED TO ADJ STRONG BACK AND WALL.



PLAN - GROUND FLOOR LEVEL



PLAN - LEVEL 1

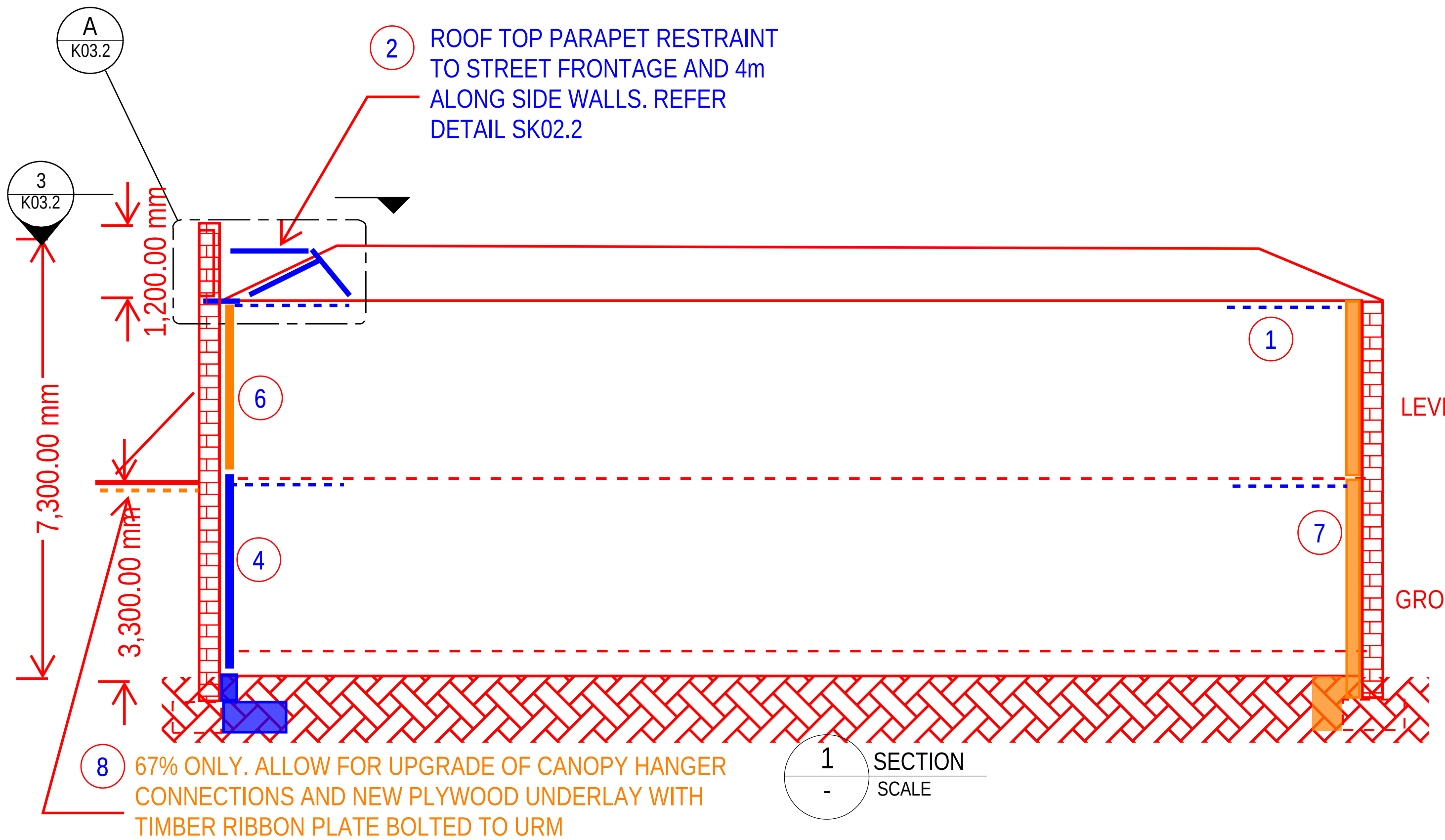
7 67% ONLY. 150mm THK RC WALL FROM GROUND TO UNDERSIDE OF ROOF. DOWELL INTO EXTG URM WALL. NEW FOUNDATION

6 67% ONLY. STEEL PORTAL FRAME FROM LEVEL 1 TO ROOF. DRILL AND EPOXY DOWELLS INTO ADJACENT BRICK ALL AROUND

1 REMOVE EXTG FLOORING AND INSTALL NEW PLYWOOD. NEW SOLID BLOCKING BETWEEN JOISTS AND M16 CHEMICAL ANCHORS INTO FACADE. SIMILAR TO UNDERSIDE OF ROOF LEVEL. ADDITIONAL DIAPRAGM EXTENT FOR 67% SHOWN IN ORANGE HATCH

9 67% ONLY. STEEL PFC WALER BEAM TO TOP OF INTERNAL WALLS THAT ARE PARALLEL TO FLOOR JOISTS AND ROOF TRUSSES

2 ROOF TOP PARAPET RESTRAINT TO STREET FRONTAGE AND 4m ALONG SIDE WALLS. REFER DETAIL SK02.2



8 67% ONLY. ALLOW FOR UPGRADE OF CANOPY HANGER CONNECTIONS AND NEW PLYWOOD UNDERLAY WITH TIMBER RIBBON PLATE BOLTED TO URM

1 SECTION
- SCALE

EXAMPLE PHOTO OF TYPICAL TYPOLOGY

NOTES:

1.0 GENERAL
1.1 REFER TO ATTACHED SCHEDULE FOR SEISMIC STRENGTHENING SCOPE FOR OTHER REGIONS, USE AND GFA
1.2 BLUE COLOURED TEXT REPRESENTS SCOPE FOR 34%NBS. ORANGE COLOURED TEXT REPRESENTS SCOPE IN ADDITION TO 34%NBS SCOPE TO GET to 67%NBS
1.3 STRUCTURAL WORKS ONLY SHOWN. CONSEQUENTIAL WORKS AS A RESULT OF INSTALLING STRUCTURAL SCOPE SHALL BE ALLOWED FOR

2.0 TIMBER
2.1 ALL WORKS TO COMPLY WITH RELEVATN CLAUSES OF THE NZBC AND THE NEW ZEALAND BUILDING ACT
2.2 ALL TIMBER CONSTRUCTION TO COMPLY WITH NZS 3604
2.3 ALL BRACING WORKS TO COMPLY WITH NZS 3604 and GIB EZYBRACE SPECIFICATIONS

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No.	Revision	By	Chk	Appd	Date
B	CONCEPT DESIGN				30.05.25
A	WIP - TO PEER REVIEWER				30.04.25

Drawing Originator: Beca

Original Scale (A1) | Reduced Scale (A3) | Design | Drawn | Dsg Verifier | Dwg Check
* Refer to Revision 1 for Original Signature

Client: MINISTRY OF BUSINESS, INNOVATION & EMPLOYMENT — HĪKINA WHAKATUTUKI

Project: COST BENEFIT ANALYSIS OF THE EARTHQUAKE PRONE BUILDINGS IN NZ

Title: SEISMIC RETROFIT CONCEPT DESIGN TYPOLOGY 3 - URM 34 and 67%NBS - CHRISTCHURCH

Discipline: STRUCTURAL

Drawing No. SE-K003.1 Rev. B

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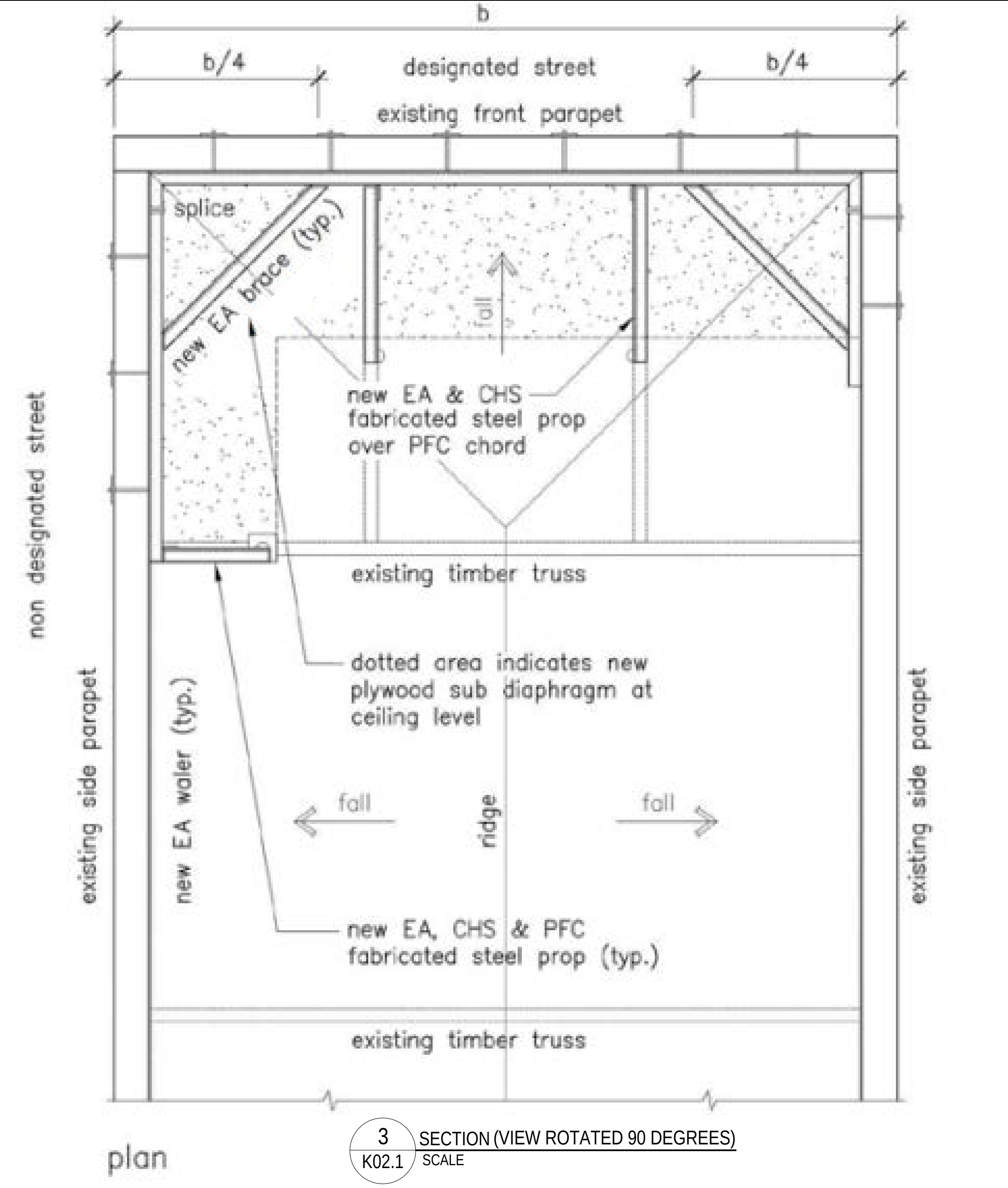
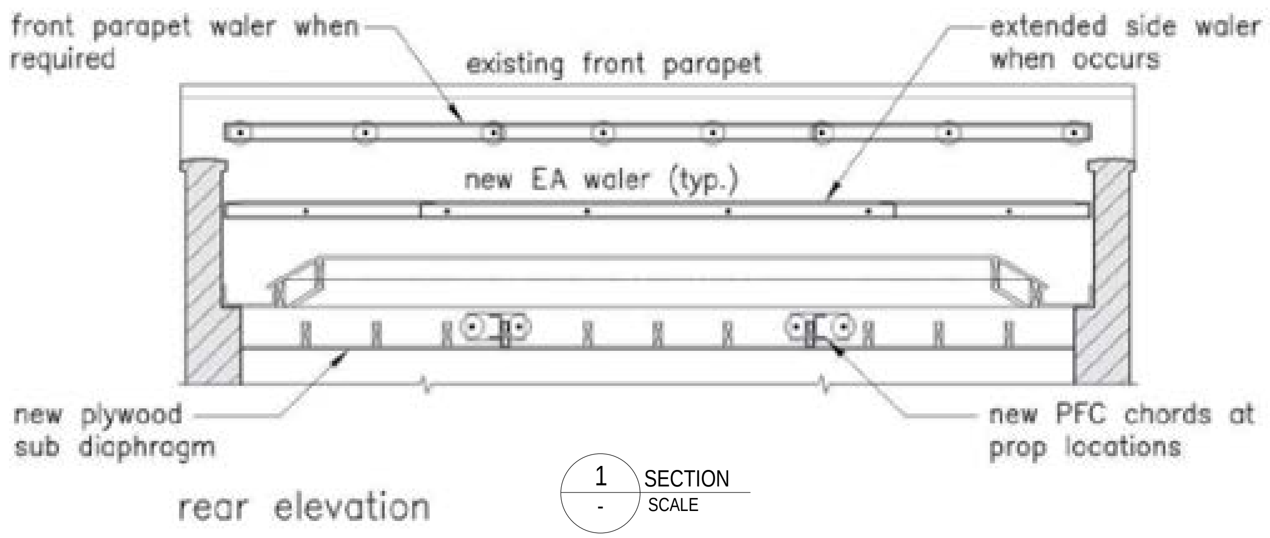
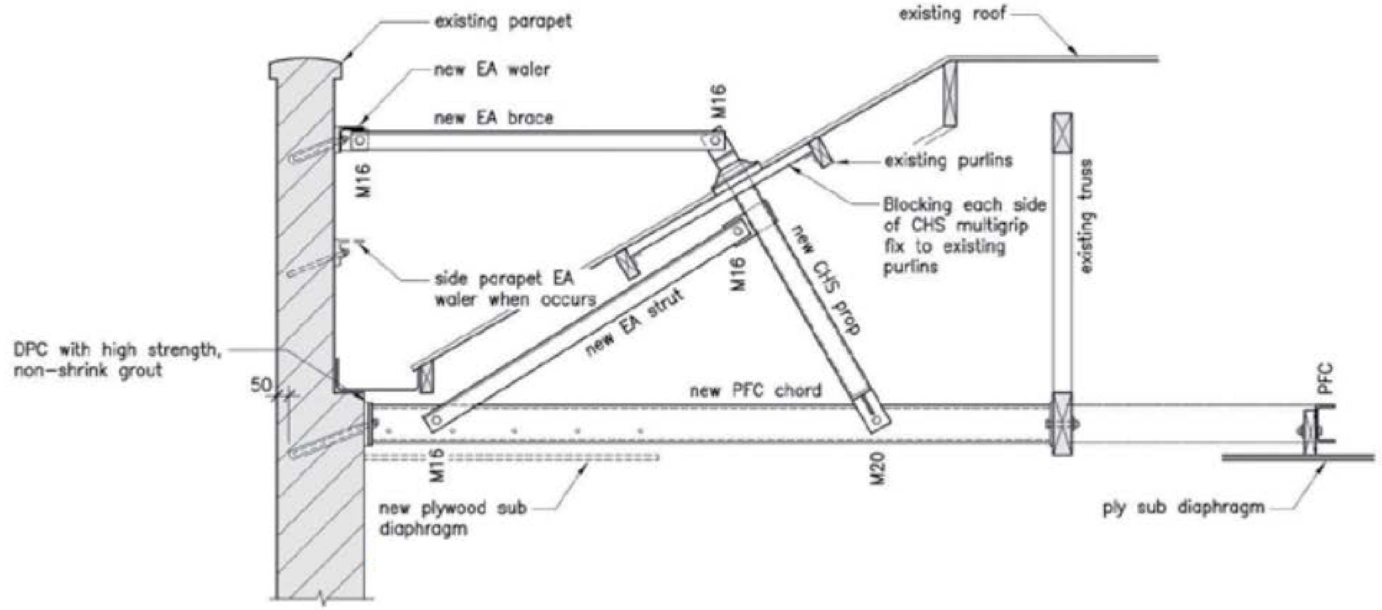


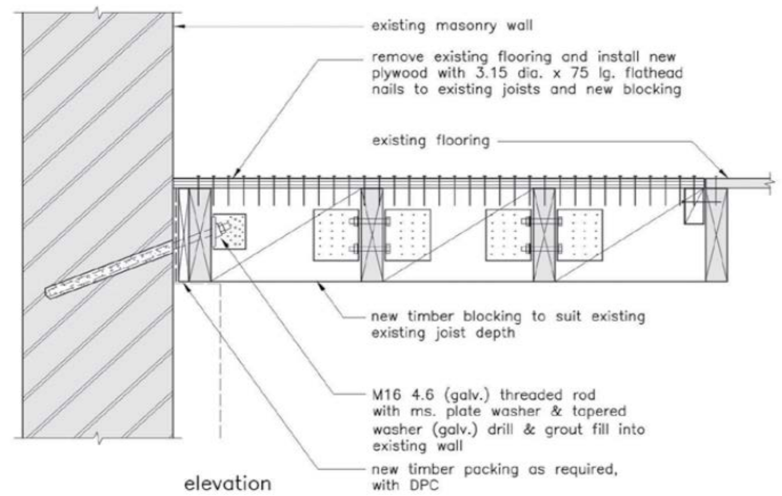
3 SECTION (VIEW ROTATED 90 DEGREES)
K02.1 SCALE



1 SECTION
- SCALE



A DETAIL
SK-02.1 SCALE



2 SECTION
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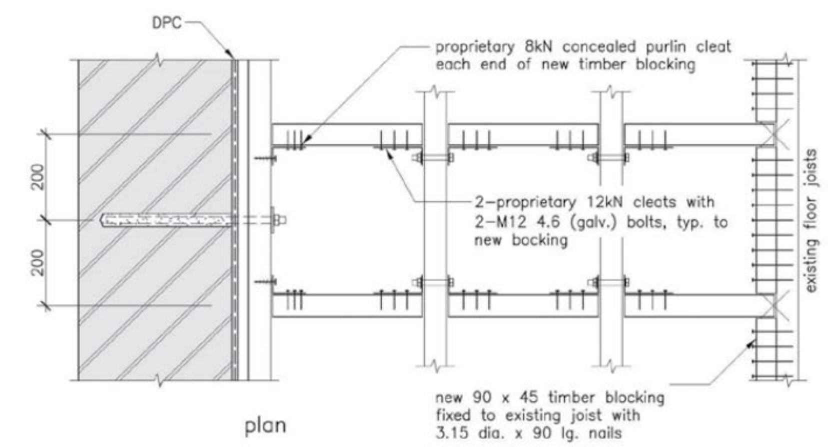

3 SECTION
- SCALE

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No.	Revision	By	Chk	Appd	Date
B	CONCEPT DESIGN	AJ	GH	JS	30.04.25

Drawing Originator: Beca

Original Scale (A1) | Design | Drawn
Reduced Scale (A3) | Dsg Verifier | Dwg Check
* Refer to Revision 1 for Original Signature

Client: MINISTRY OF BUSINESS, INNOVATION & EMPLOYMENT
HĪKINA WHAKATUTUKI

Project: COST BENEFIT ANALYSIS OF THE EARTHQUAKE PRONE BUILDINGS IN NZ

Title: SEISMIC RETROFIT CONCEPT DESIGN
TYPOLOGY 3
34%NBS - CHRISTCHURCH

Discipline: STRUCTURAL

Drawing No.: SE-K003.2

Rev.: B

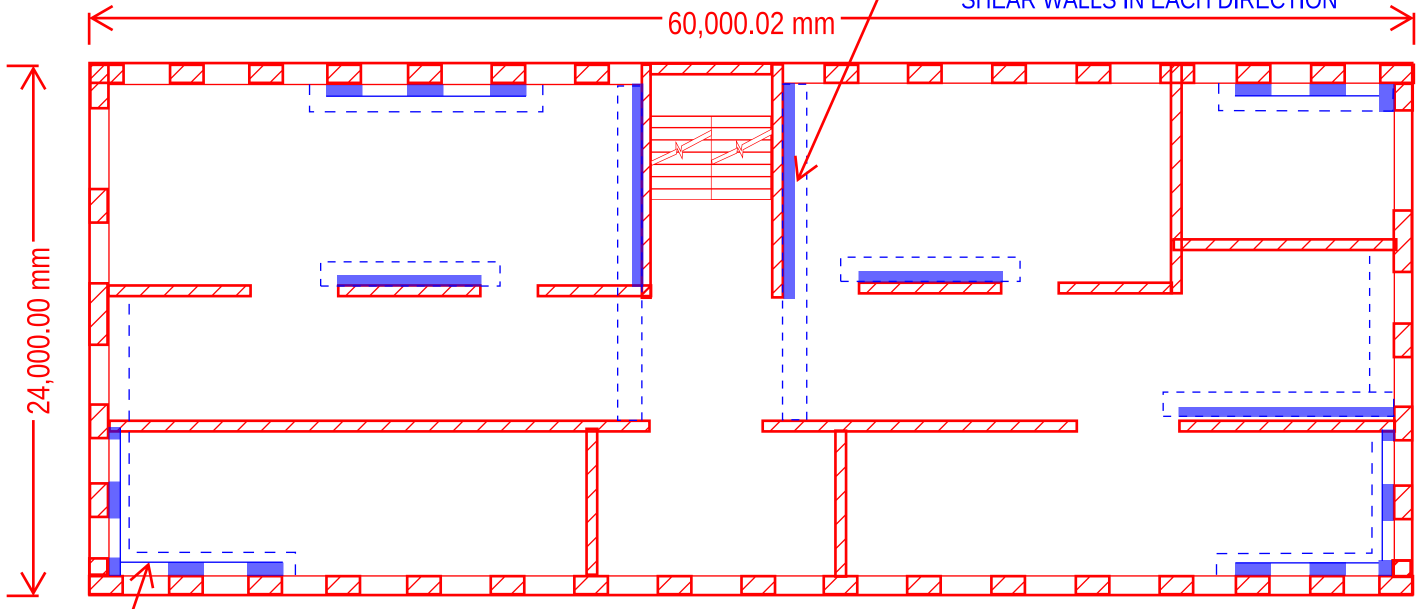
BLUEBEAM

DO NOT SCALE

IF IN DOUBT ASK.

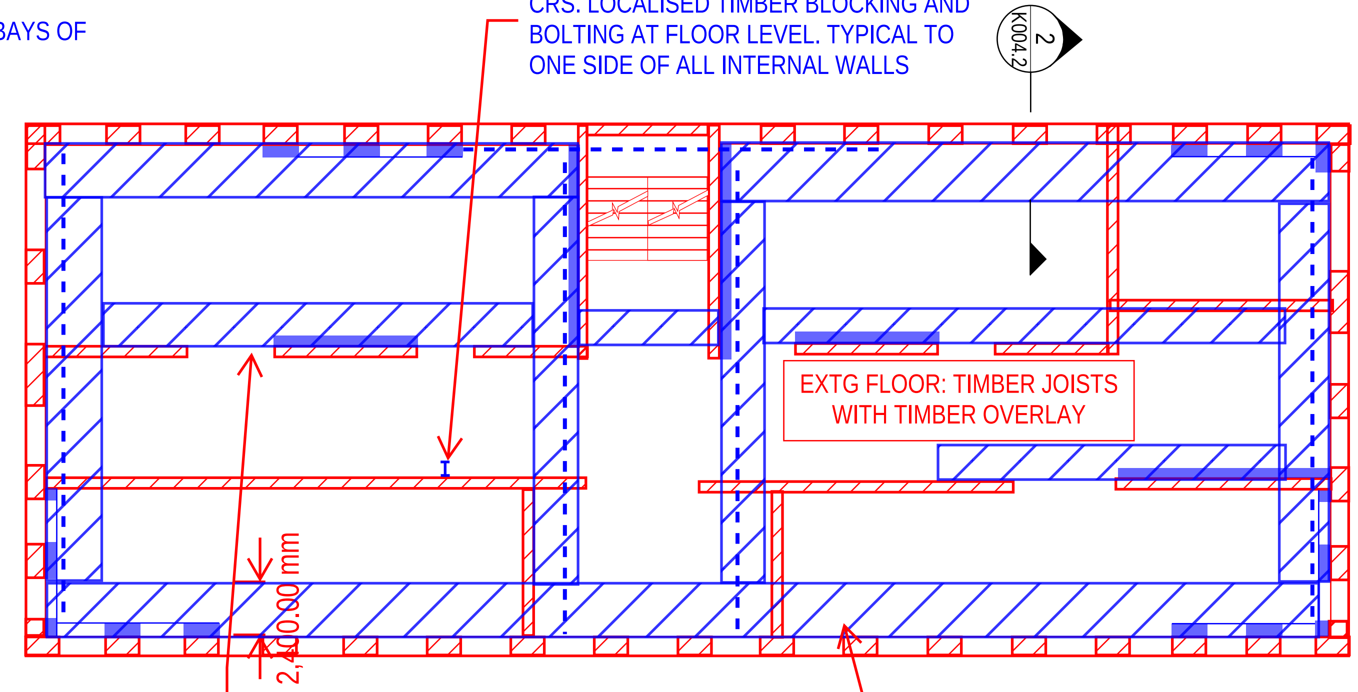
2 150mm THK RC WALLS DOWELLED INTO EXISTING URM. NEW RC FOUNDATIONS DOWELLED INTO EXISTING FOUNDATIONS.
FOR FIELDING AND WELLINGTON ALLOW FOR TWO MORE BAYS OF SHEAR WALLS IN EACH DIRECTION

7 NEW STEEL 200UB STRONG BACKS AT 4m CRS. LOCALISED TIMBER BLOCKING AND BOLTING AT FLOOR LEVEL. TYPICAL TO ONE SIDE OF ALL INTERNAL WALLS



1 150mm THK RC OVERLAY PIERS AND BEAMS (OVER WINDOWS) DOWELLED INTO EXISTING URM. NEW RC FOUNDATIONS DOWELLED INTO EXISTING FOUNDATIONS.
FOR FIELDING AND WELLINGTON ALLOW FOR 50% MORE BAYS OF OVERLAYS IN EACH DIRECTION

PLAN - GROUND FLOOR LEVEL

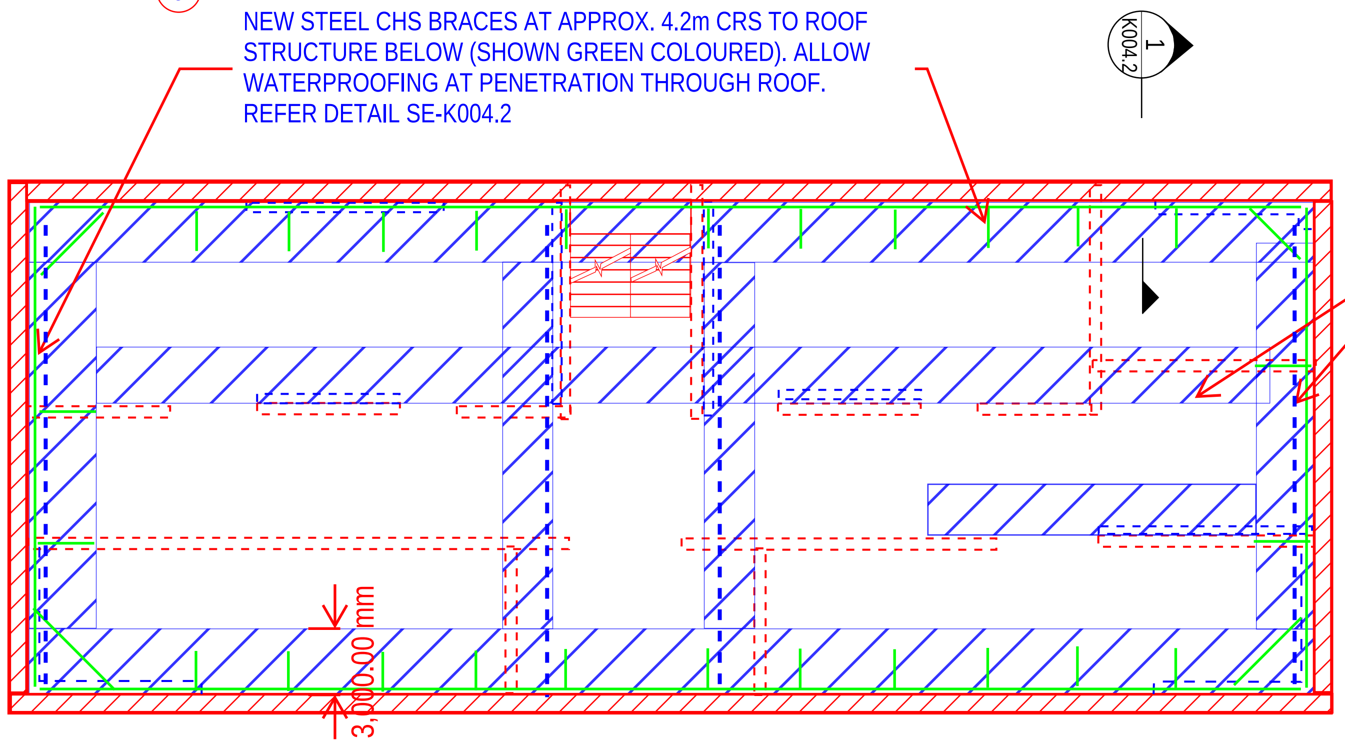


3 NEW SECTION OF 19mm PLY HEAVILY NAILED TO EXTG JOISTS BELOW. NEW SOLID TIMBER BLOCKING WITH METAL NAIL STRAPS ACROSS INTERSECTIONS. NEW TIMBER RIBBON PLATES DRILL AND EPOXY INTO NEW RC WALL OVERLAY. TYPICAL TO NEW RC OVERLAY WALLS. STEEL EA DRAG MEMBERS LOCALLY UNDER FLOOR SHOWN DASHED

PLAN - LEVEL 1 and 2

4 NEW 2000mm WIDE SECTION OF 19mm PLY HEAVILY NAILED TO EXTG JOISTS BELOW. NEW SOLID TIMBER BLOCKING WITH METAL NAIL STRAPS ACROSS INTERSECTIONS. NEW RIBBON PLATES DRILL AND EPOXY INTO EXTG URM WALL. TYPICAL TO PERIMETER WALLS. STEEL EA DRAG MEMBERS LOCALLY UNDER FLOOR SHOWN DASHED

5 NEW STEEL WALER BEAM ON FLAT AT TOP OF PARAPET. NEW STEEL CHS BRACES AT APPROX. 4.2m CRS TO ROOF STRUCTURE BELOW (SHOWN GREEN COLOURED). ALLOW WATERPROOFING AT PENETRATION THROUGH ROOF. REFER DETAIL SE-K004.2



6 NEW 2000mm WIDE SECTION OF 19mm PLY HEAVILY NAILED TO UNDERSIDE OF EXTG ROOF MEMBERS (SHOWN HATCHED). NEW SOLID TIMBER BLOCKING AND NEW RIBBON PLATES DRILL AND EPOXY INTO EXTG URM WALL. STEEL EA DRAG MEMBERS LOCALLY UNDER FLOOR SHOWN DASHED

PLAN - ROOF LEVEL

EXAMPLE PHOTO OF TYPICAL TYPOLOGY

NOTES:

1.0 GENERAL
1.1 REFER TO ATTACHED SCHEDULE FOR SEISMIC STRENGTHENING SCOPE FOR OTHER REGIONS, USE AND GFA
1.2 THE SCOPE IS FOR RETROFIT TO ACHIEVE 34%NBS FOR CHRISTCHURCH U.N.O. REFER TO SE-K004.3 FOR 67%NBS SCHEME
1.2 STRUCTURAL WORKS ONLY SHOWN. CONSEQUENTIAL WORKS AS A RESULT OF INSTALLING STRUCTURAL SCOPE SHALL BE ALLOWED FOR

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No.	Revision	By	Chk	Appd	Date
A	CONCEPT DESIGN				30.05.25

Drawing Originator: Beca

Original Scale (A1) | Reduced Scale (A3) | Design | Drawn | Dsg Verifier | Dwg Check
* Refer to Revision 1 for Original Signature

Client: MINISTRY OF BUSINESS, INNOVATION & EMPLOYMENT HĪKINA WHAKATUTUKI

Project: COST BENEFIT ANALYSIS OF THE EARTHQUAKE PRONE BUILDINGS IN NZ

Title: SEISMIC RETROFIT CONCEPT DESIGN TYPOLOGY 4 - URM 34%NBS - CHRISTCHURCH

Discipline: STRUCTURAL

Drawing No. SE-K004.1 Rev. A

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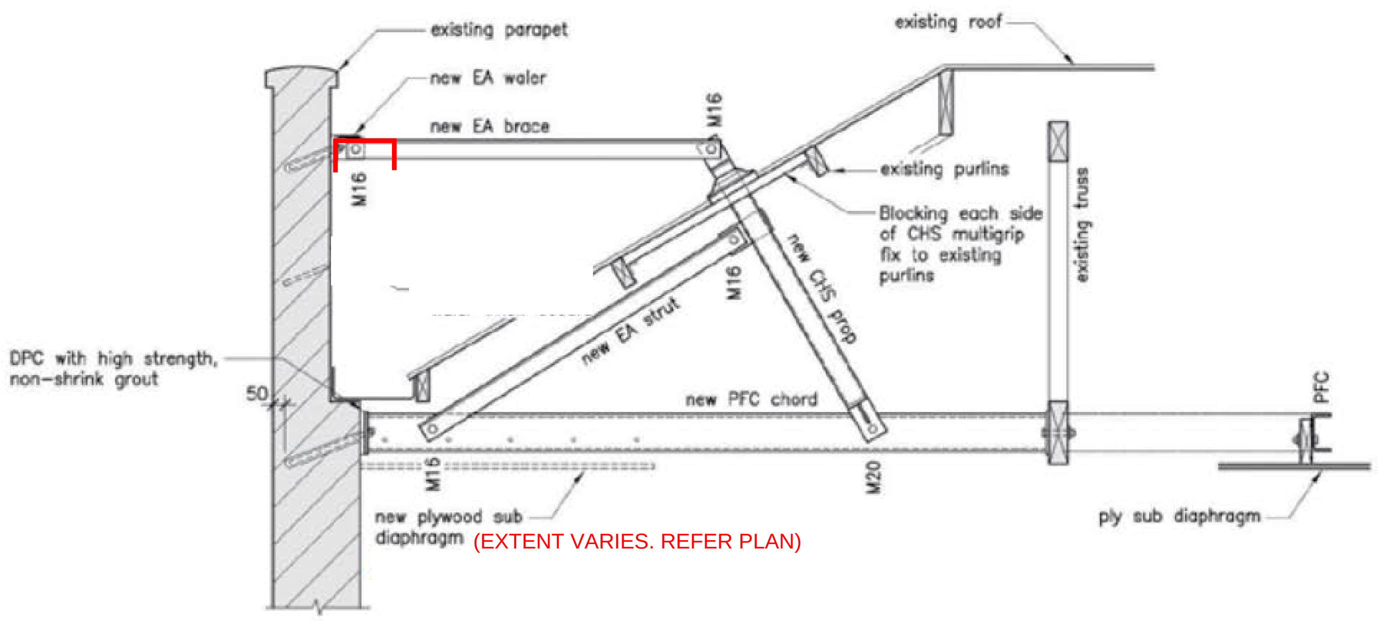
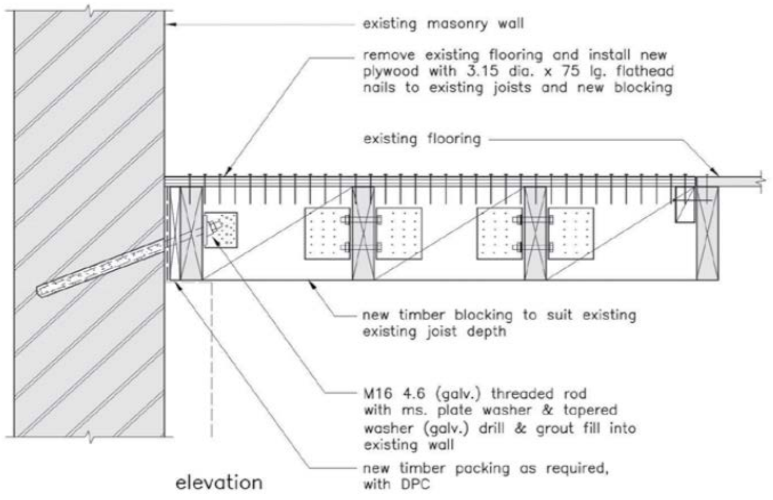
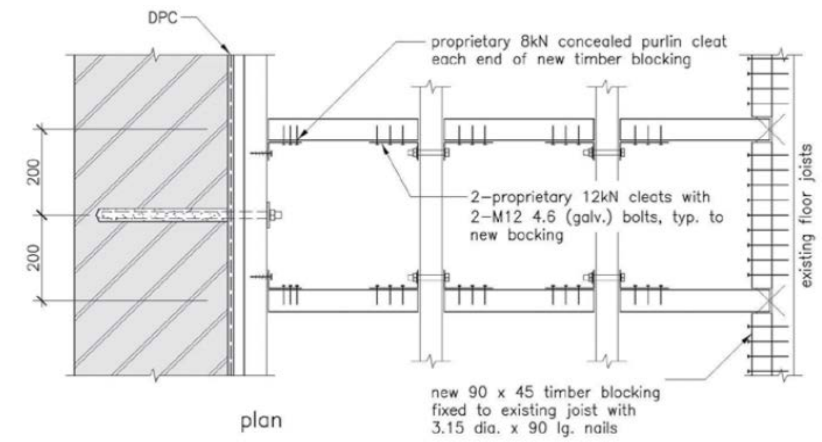
IF IN DOUBT ASK.



1 SECTION
SK-04.1 SCALE



2 SECTION
K04.1 SCALE



3 SECTION
- SCALE

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A	CONCEPT DESIGN				30.05.25

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Client: MINISTRY OF BUSINESS, INNOVATION & EMPLOYMENT HĪKINA WHAKATUTUKI

Project: COST BENEFIT ANALYSIS OF THE EARTHQUAKE PRONE BUILDINGS IN NZ

Title: SEISMIC RETROFIT CONCEPT DESIGN TYPOLOGY 4 34%*NBS* - CHRISTCHURCH

Discipline: STRUCTURAL

Drawing No. SE-K004.2 Rev. A

BLUEBEAM

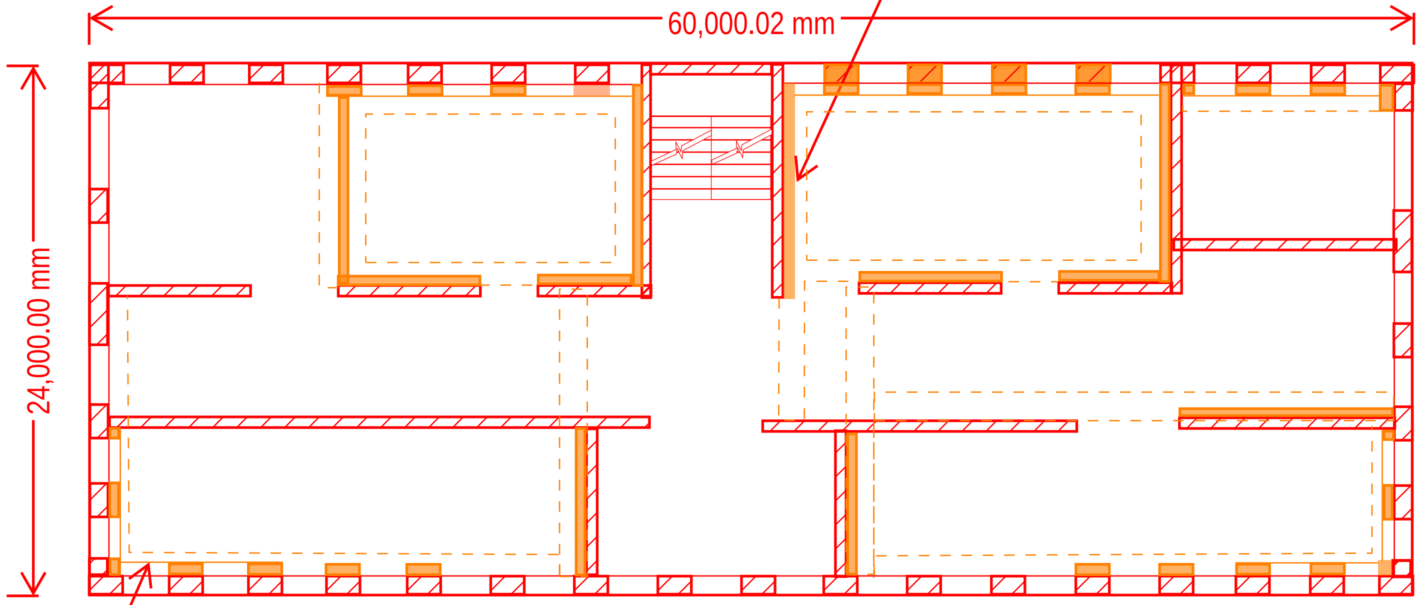
DO NOT SCALE

IF IN DOUBT ASK.

8 200mm THK RC WALLS DOWELLED INTO EXISTING URM. NEW RC FOUNDATIONS DOWELLED INTO EXISTING FOUNDATIONS

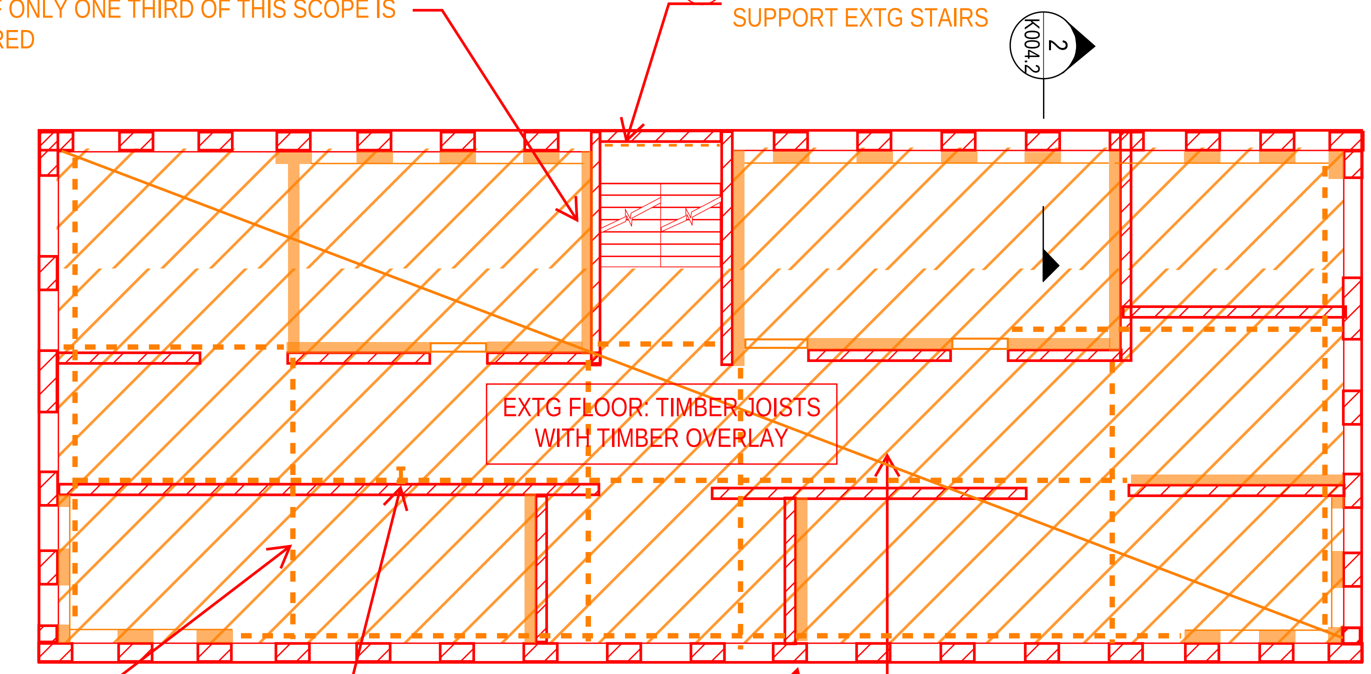
8 200mm THK RC WALLS TYP. FOR LEVEL 2-ROOF ONLY ONE THIRD OF THIS SCOPE IS REQUIRED

11 NEW STEEL BEAM AND CONNECTIONS TO SUPPORT EXTG STAIRS



7 250mm THK RC OVERLAY PIERS AND BEAMS (OVER WINDOWS) DOWELLED INTO EXISTING URM. NEW RC FOUNDATIONS DOWELLED INTO EXISTING FOUNDATIONS

PLAN - GROUND FLOOR LEVEL



PLAN - LEVEL 1 and 2

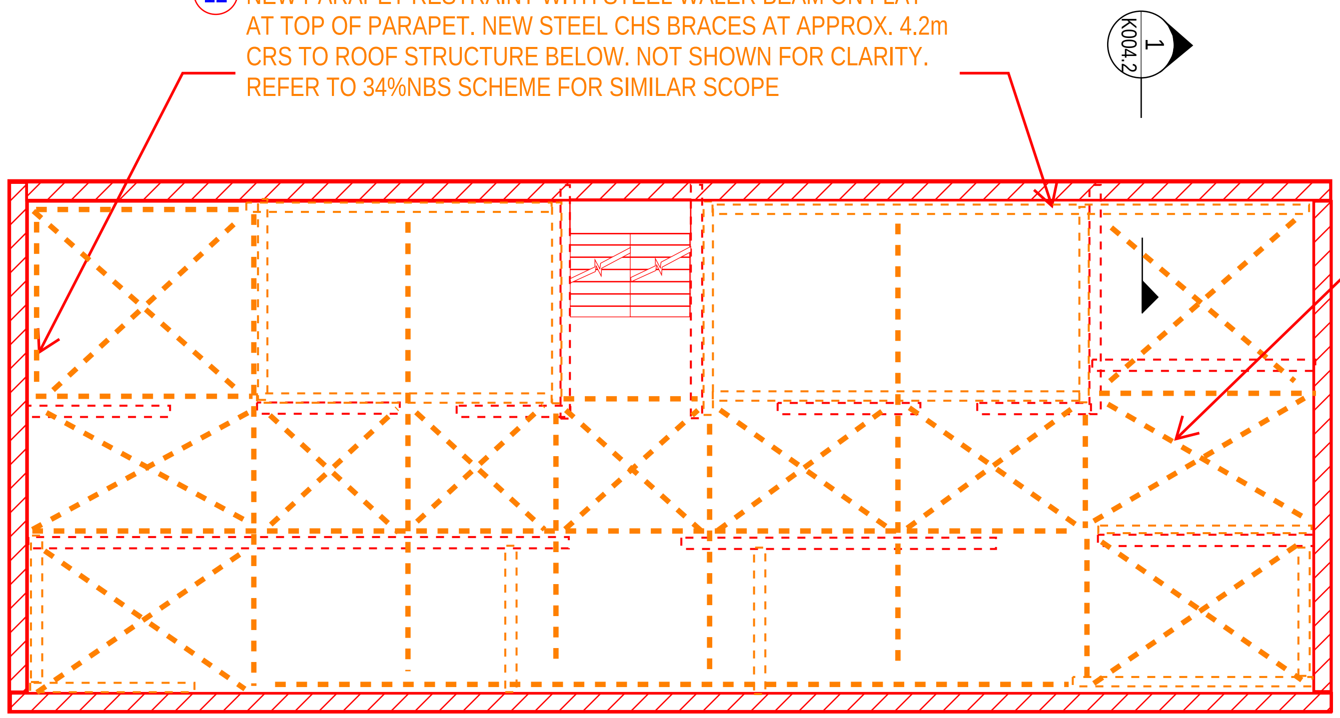
9 NEW STEEL TIES TO UNDERSIDE OF EXTG TIMBER FLOOR JOISTS. NEW SOLID TIMBER BLOCKING HEAVILY NAILED TO ADJACENT FLOOR JOISTS AND REGULAR BOLTS FROM TIE PLATES TO BLOCKING/JOISTS.

10 NEW 19mm PLY OVERLAY HEAVILY NAILED TO EXTG JOISTS BELOW. NEW SOLID TIMBER BLOCKING AND NEW RIBBON PLATES DRILL AND EPOXY INTO EXTG URM WALL. TYPICAL TO PERIMETER WALLS.

14 NEW STEEL 200UB STRONG BACKS AT 3m CRS. LOCALISED TIMBER BLOCKING AND BOLTING AT FLOOR LEVEL. TYPICAL TO ONE SIDE OF ALL INTERNAL WALLS. ONLY APPLIES TO LEVEL 2 FOR AUCKLAND AND DUNEDIN

15 TO ACCOUNT FOR VARIATION BETWEEN SOLID AND CAVITY URM WALL CONSTRUCTION, FOR 50% OF THE EXTERNAL WALL LENGTH ALLOW PYTHON CAVITY TIES AT 600mm CRS IN BOTH DIRECTIONS

12 NEW PARAPET RESTRAINT WITH STEEL WALER BEAM ON FLAT AT TOP OF PARAPET. NEW STEEL CHS BRACES AT APPROX. 4.2m CRS TO ROOF STRUCTURE BELOW. NOT SHOWN FOR CLARITY. REFER TO 34%NBS SCHEME FOR SIMILAR SCOPE



13 NEW STEEL CROSS BRACED ROOF DIAPHRAGM TO UNDERSIDE OF ROOF STRUCTURE AT CEILING LEVEL. STEEL EA CROSS BRACES WITH SHS STRUTS. PFC ON FLAT WHERE MEMBERS ARE AROUND THE PERIMETER BOLTED TO EXISTING WALLS

PLAN - ROOF LEVEL

EXAMPLE PHOTO OF TYPICAL TYPOLOGY

NOTES:

1.0 GENERAL

1.1 REFER TO ATTACHED SCHEDULE FOR SEISMIC STRENGTHENING SCOPE FOR OTHER REGIONS, USE AND GFA

1.2 THE SCOPE IS FOR RETROFIT TO ACHIEVE 67%NBS FOR CHRISTCHURCH U.N.O. REFER TO SE-K004.1 FOR 34%NBS SCHEME

1.2 STRUCTURAL WORKS ONLY SHOWN. CONSEQUENTIAL WORKS AS A RESULT OF INSTALLING STRUCTURAL SCOPE SHALL BE ALLOWED FOR

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No.	Revision	By	Chk	Appd	Date
A	CONCEPT DESIGN				30.05.25

Drawing Originator: Beca

Original Scale (A1) | Reduced Scale (A3) | Design | Drawn | Dsg Verifier | Dwg Check

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Client: MINISTRY OF BUSINESS, INNOVATION & EMPLOYMENT HĪKINA WHAKATUTUKI

Project: COST BENEFIT ANALYSIS OF THE EARTHQUAKE PRONE BUILDINGS IN NZ

Title: SEISMIC RETROFIT CONCEPT DESIGN TYPOLOGY 4 - URM 67%NBS - CHRISTCHURCH

Discipline: STRUCTURAL

Drawing No.: SE-K004.3

Rev.: A

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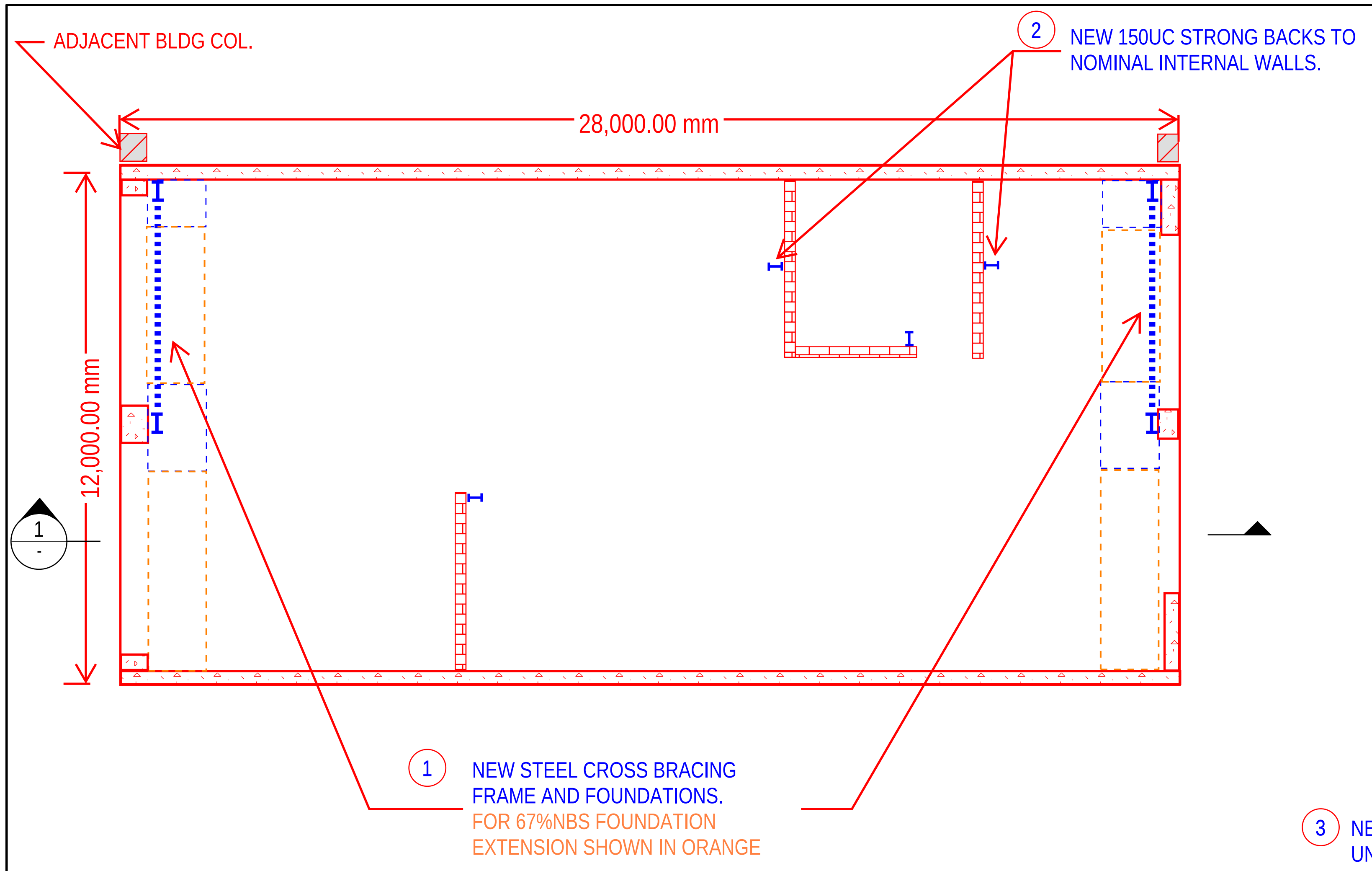

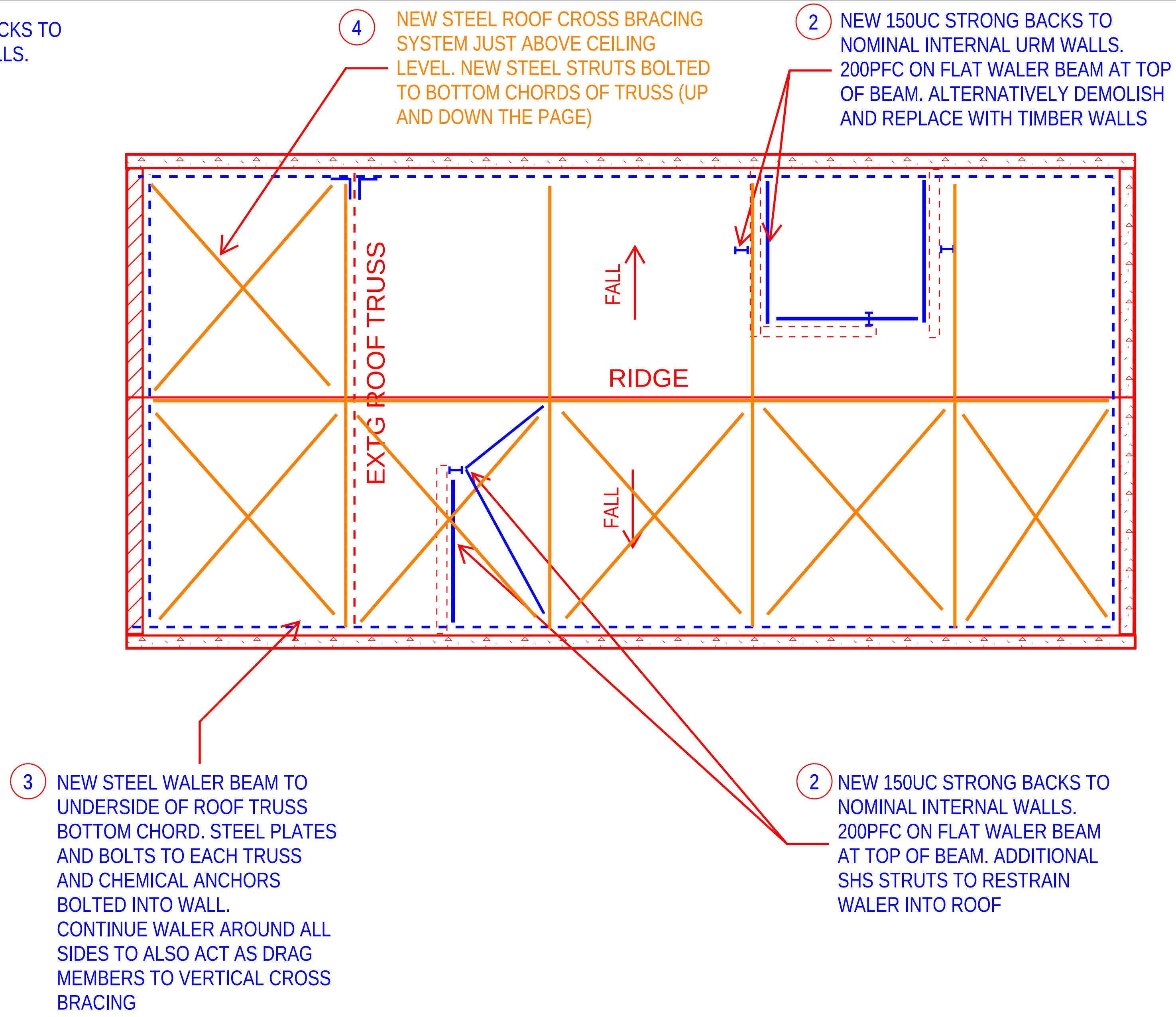

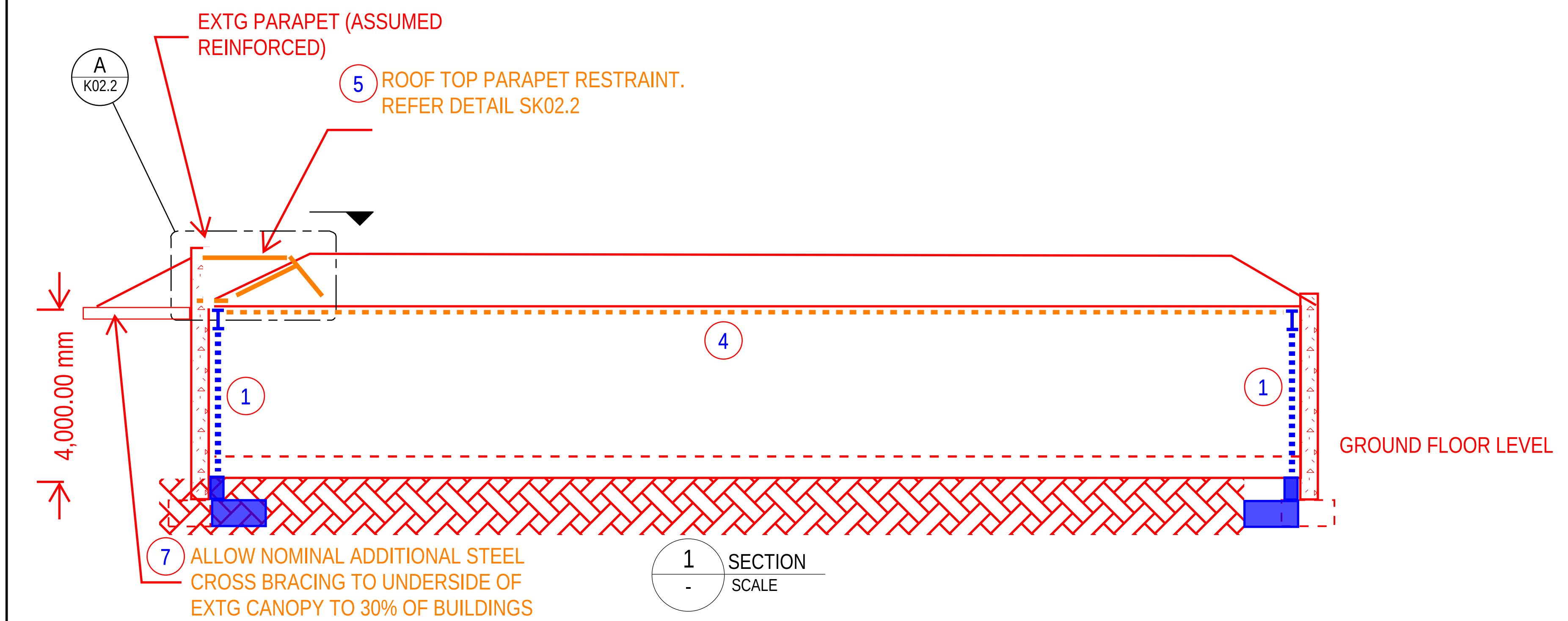

1 SECTION
- SCALE

EXAMPLE PHOTO OF TYPICAL TYPOLOGY

NOTES:

1.0 GENERAL
1.1 REFER TO ATTACHED SCHEDULE FOR SEISMIC STRENGTHENING SCOPE FOR OTHER REGIONS, USE AND GFA
1.2 BLUE COLOURED TEXT REPRESENTS SCOPE FOR 34%NBS. ORANGE COLOURED TEXT REPRESENTS SCOPE IN ADDITION TO 34%NBS SCOPE TO GET to 67%NBS
1.3 STRUCTURAL WORKS ONLY SHOWN. CONSEQUENTIAL WORKS AS A RESULT OF INSTALLING STRUCTURAL SCOPE SHALL BE ALLOWED FOR

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No.	Revision	By	Chk	Appd	Date
B	CONCEPT DESIGN				30.05.25
A	WIP - PEER REVIEW				23.05.25

Drawing Originator: Beca

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Client: MINISTRY OF BUSINESS, INNOVATION & EMPLOYMENT HĪKINA WHAKATUTUKI

Project: COST BENEFIT ANALYSIS OF THE EARTHQUAKE PRONE BUILDINGS IN NZ

Title: SEISMIC RETROFIT CONCEPT DESIGN TYPOLOGY 5 - LOW RISE SHEAR WALLS 34 and 67%*NBS* - CHRISTCHURCH

Discipline: STRUCTURAL

Drawing No. SE-K005.1 Rev. B

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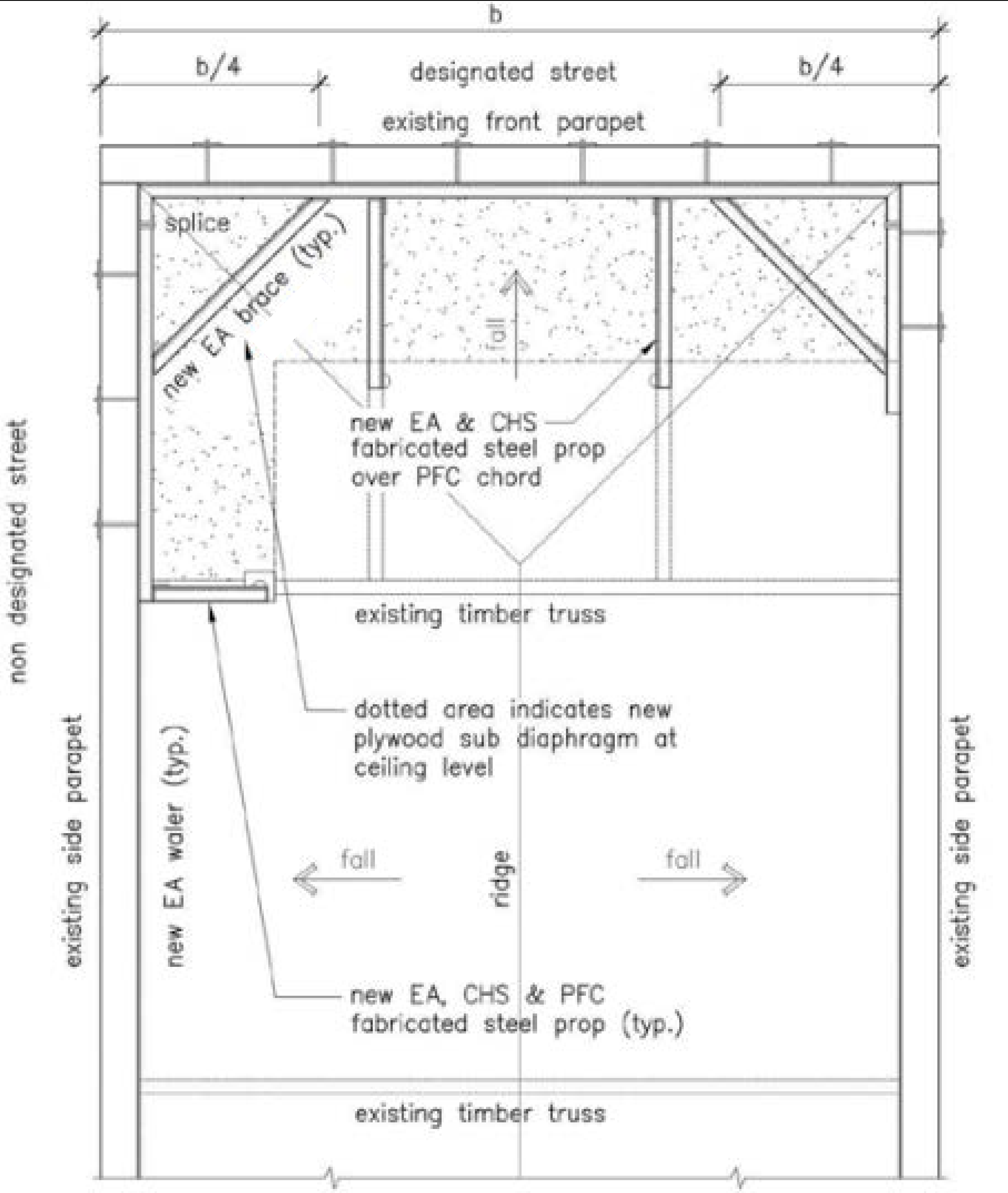
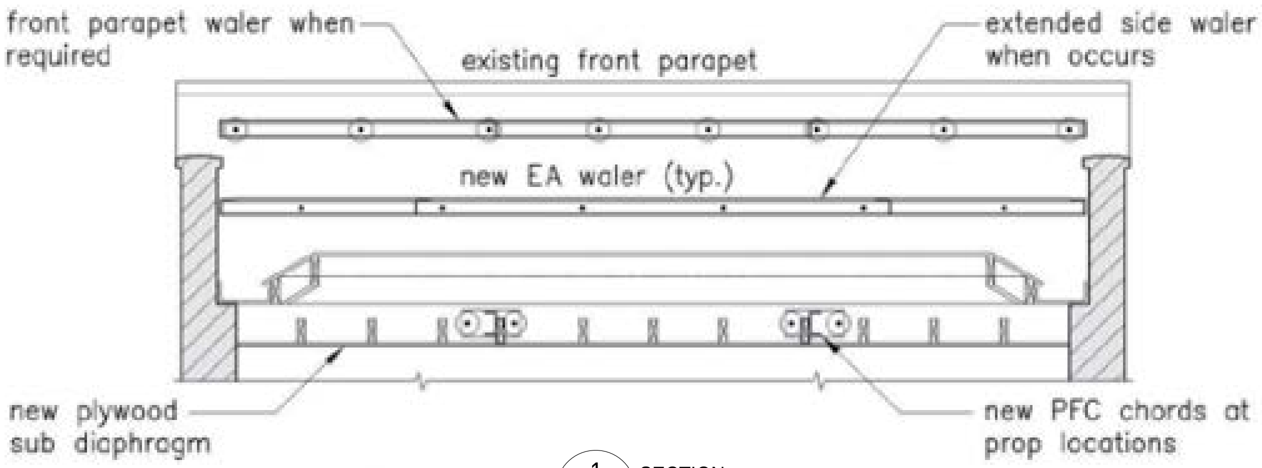


plan

3 SECTION (VIEW ROTATED 90 DEGREES)
K02.1 SCALE



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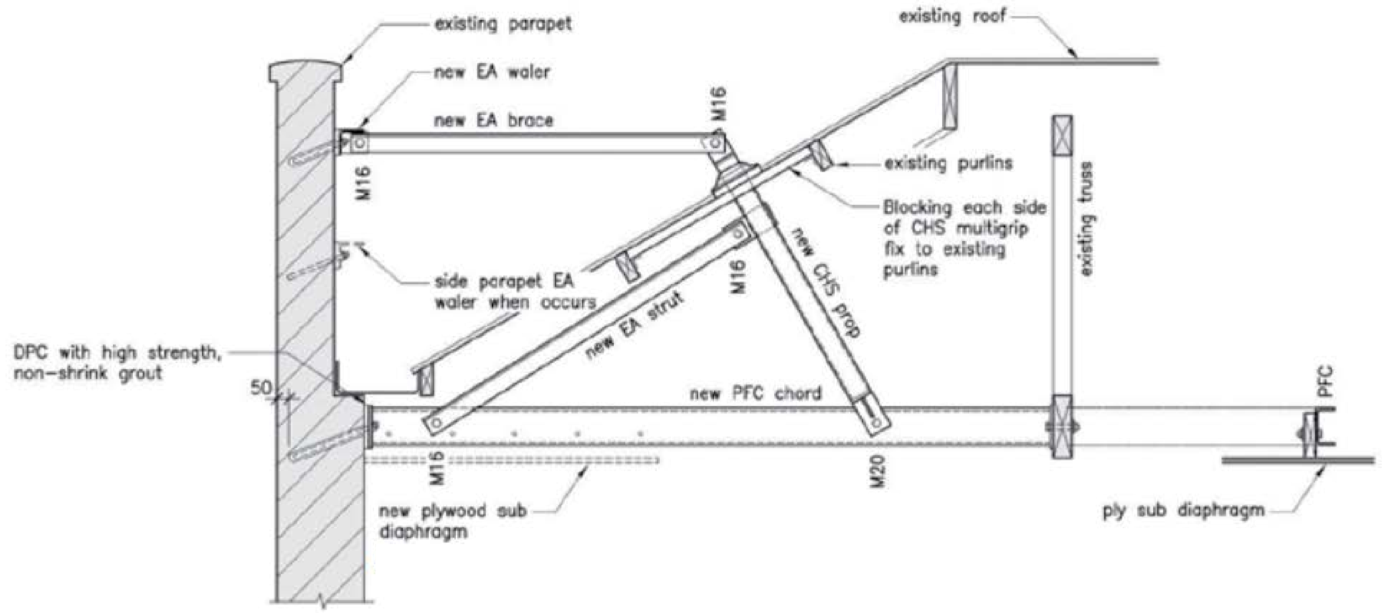
1 SECTION
- SCALE



A DETAIL
SK-02.1 SCALE

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No.	Revision	By	Chk	Appd	Date
A	CONCEPT DESIGN				30.05.25

Drawing Originator: Beca

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Client: MINISTRY OF BUSINESS, INNOVATION & EMPLOYMENT HĪKINA WHAKATUTUKI

Project: COST BENEFIT ANALYSIS OF THE EARTHQUAKE PRONE BUILDINGS IN NZ

Title: SEISMIC RETROFIT CONCEPT DESIGN TYPOLOGY 4 - LOW RISE SHEAR WALL 34 and 67%*NBS* - CHRISTCHURCH

Discipline: STRUCTURAL

Drawing No.: SE-K005.2 Rev. A

BLUEBEAM

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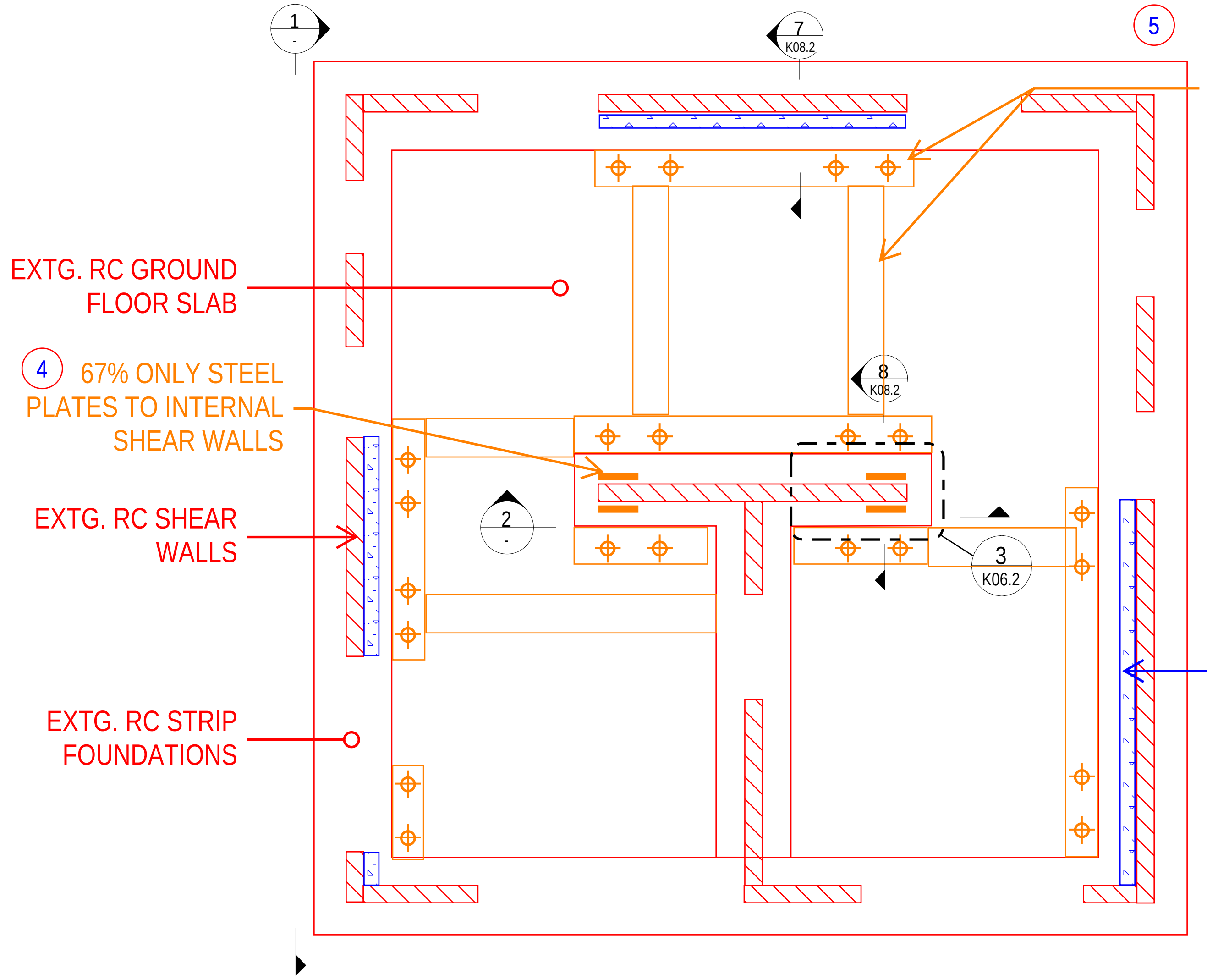
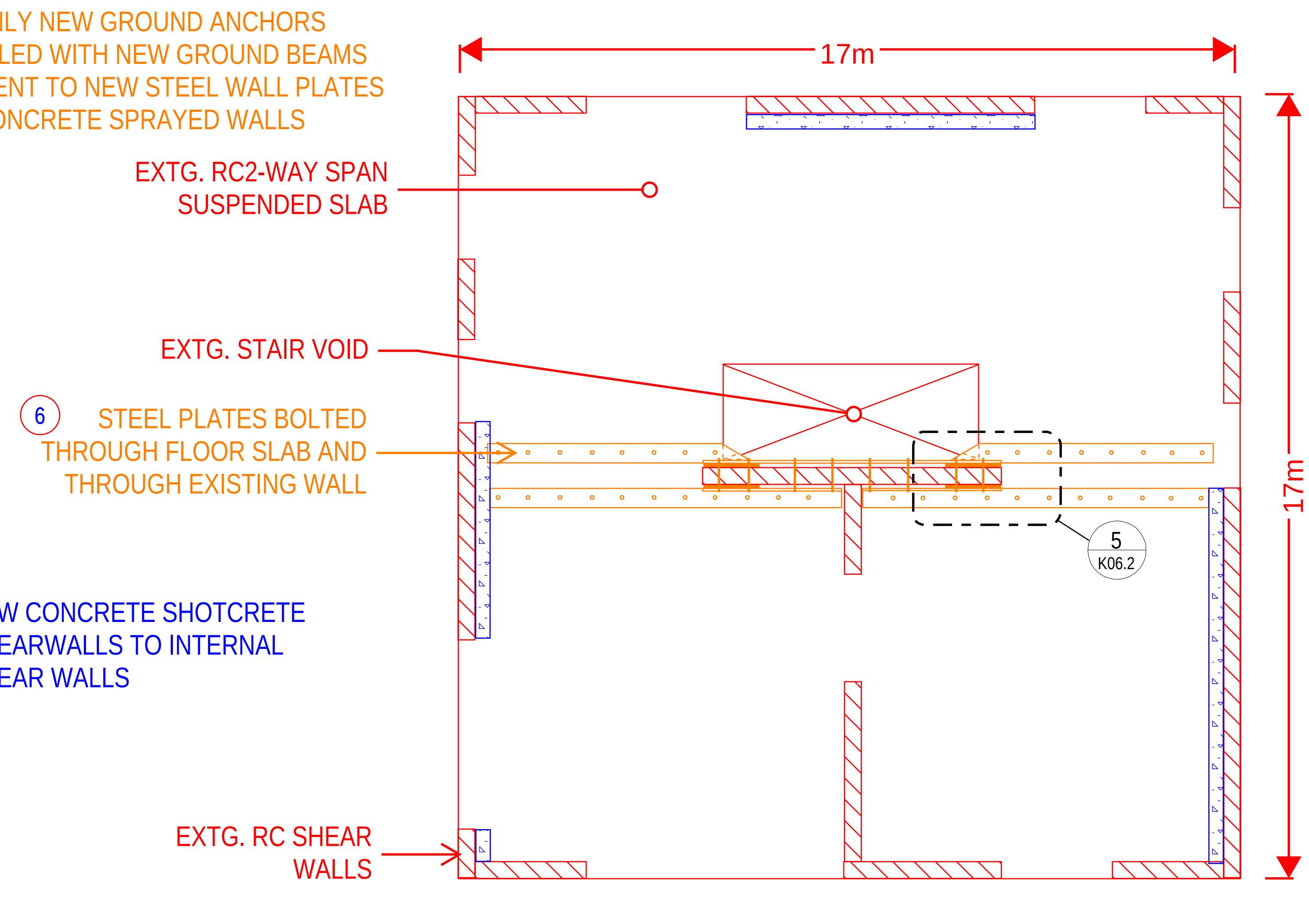


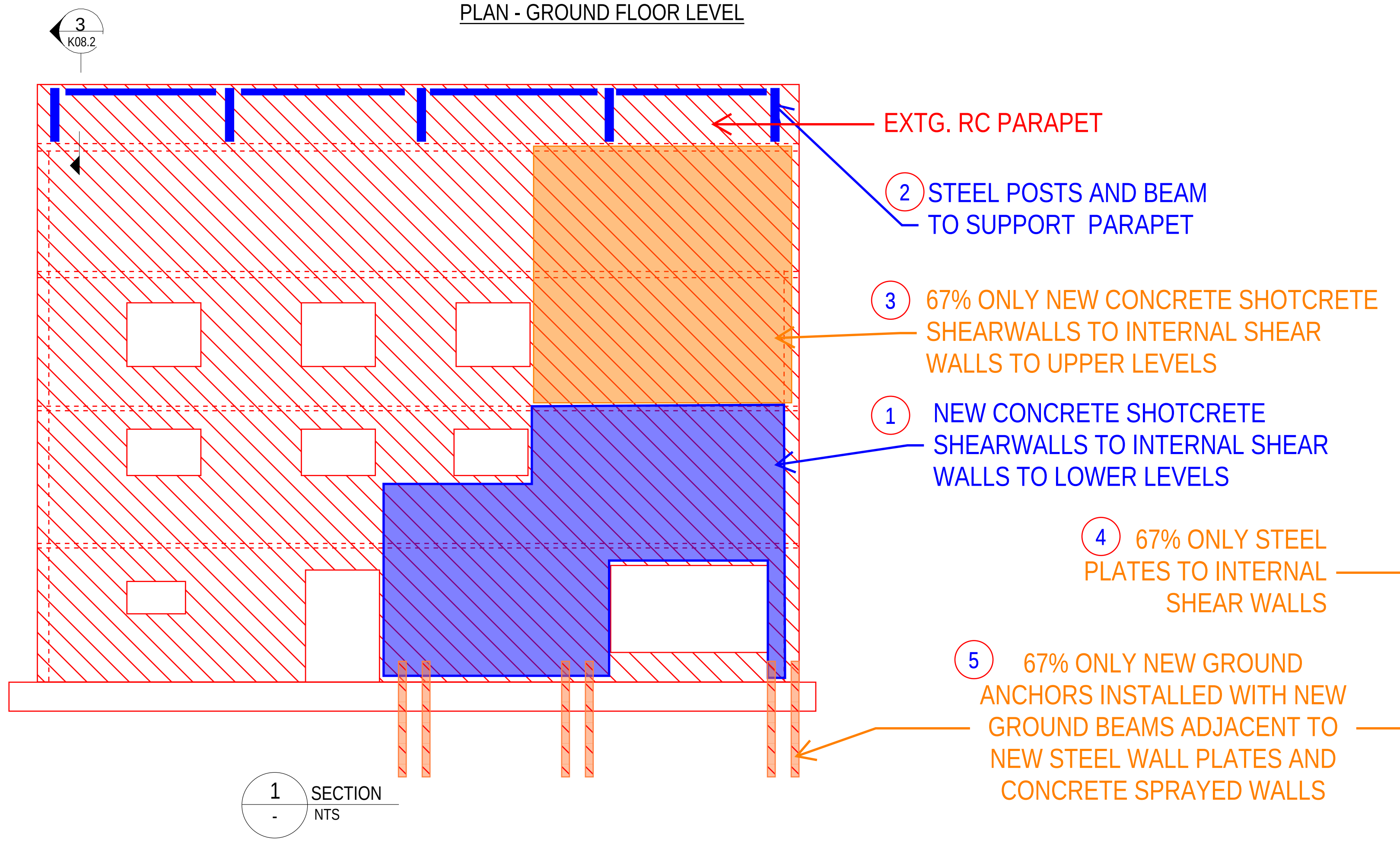
PLAN - GROUND FLOOR LEVEL



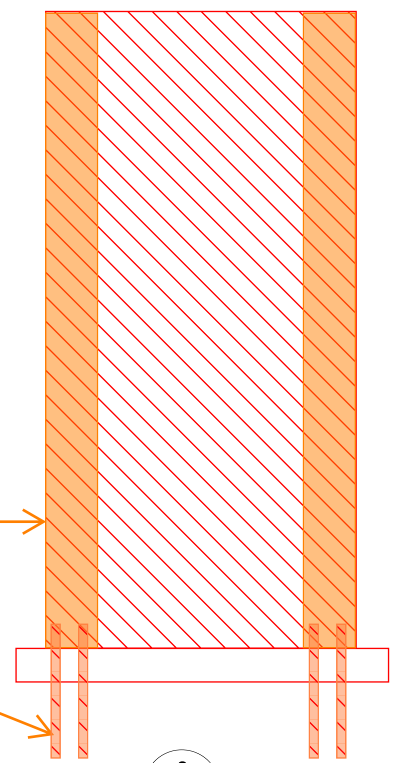
PLAN - TYPICAL FLOOR LEVEL

NOTES:

1.0 GENERAL
1.1 REFER TO ATTACHED SCHEDULE FOR SEISMIC STRENGTHENING SCOPE FOR OTHER REGIONS, USE AND GFA
1.2 BLUE COLOURED TEXT REPRESENTS SCOPE FOR 34%NBS. ORANGE COLOURED TEXT REPRESENTS SCOPE IN ADDITION TO 34%NBS SCOPE TO GET to 67%NBS



1 - SECTION NTS



2 - SECTION NTS

No.	Revision	By	Chk	Appd	Date
A	CONCEPT DESIGN				30.05.25

Drawing Originator: Beca

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Client: MINISTRY OF BUSINESS, INNOVATION & EMPLOYMENT HĪKINA WHAKATUTUKI

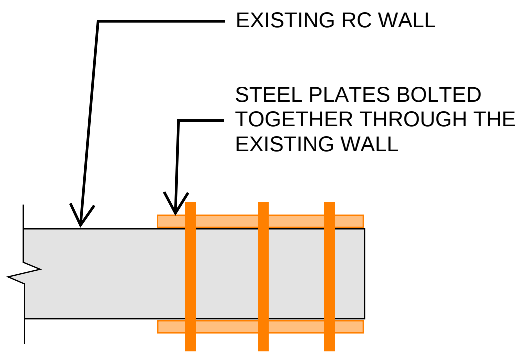
Project: COST BENEFIT ANALYSIS OF THE EARTHQUAKE PRONE BUILDINGS IN NZ

Title: SEISMIC RETROFIT CONCEPT DESIGN TYPOLOGY 6 - SHEAR WALLS MID-RISE 34 and 67%*NBS* - CHRISTCHURCH

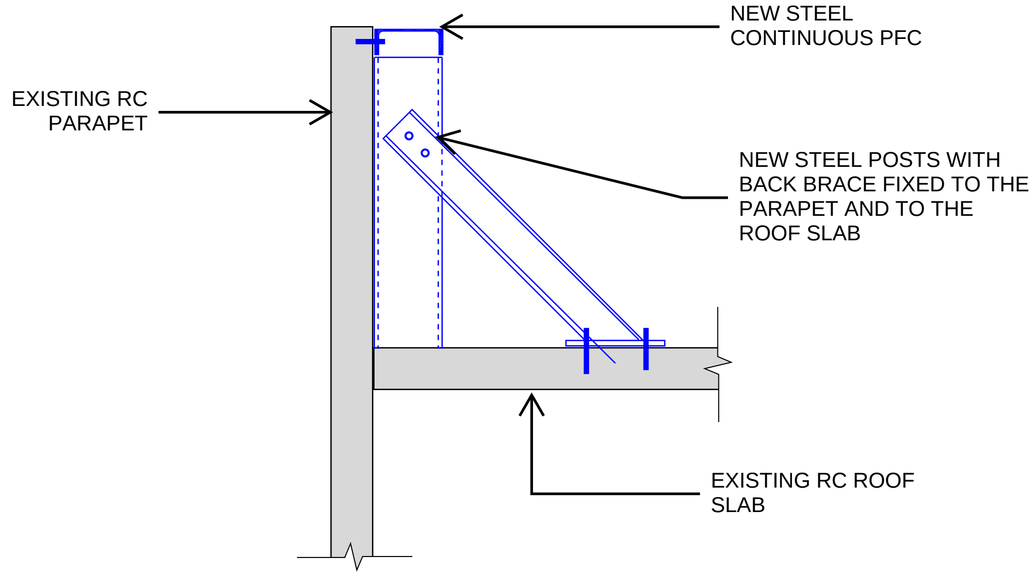
Discipline: STRUCTURAL

Drawing No.: SE-K06.1

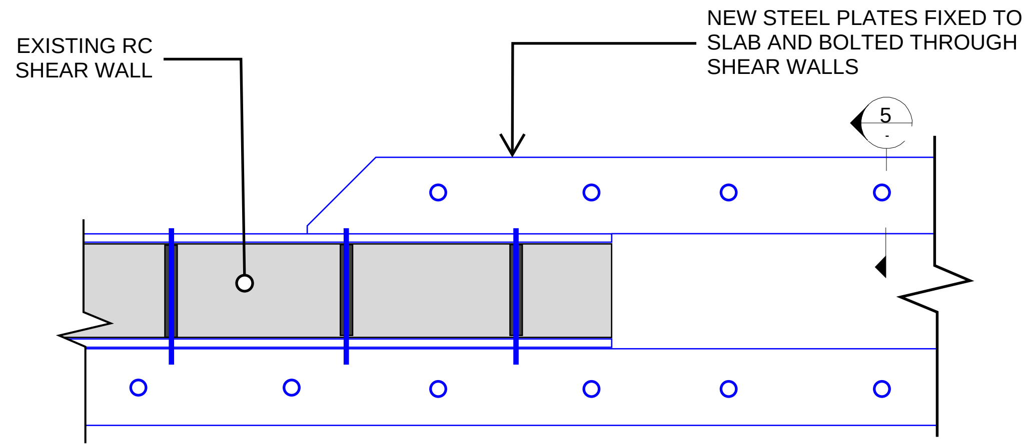
Rev.: A



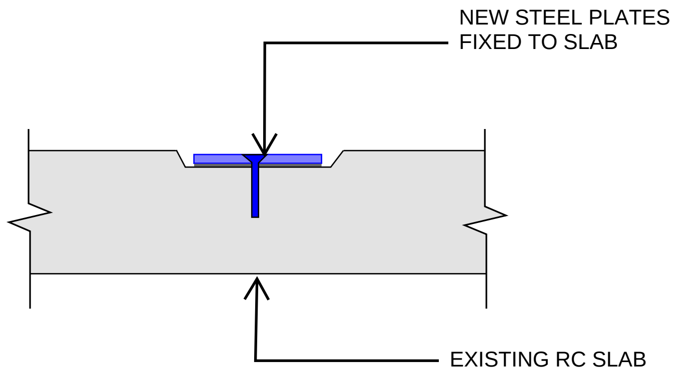
3 K06.1 WALL PLATE STRENGTHENING



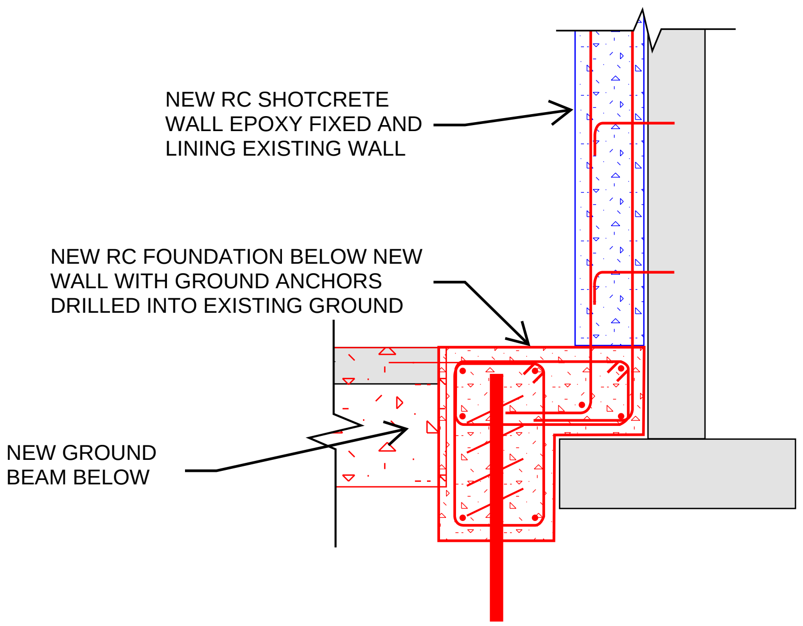
4 K06.1 PARAPET STRENGTHENING



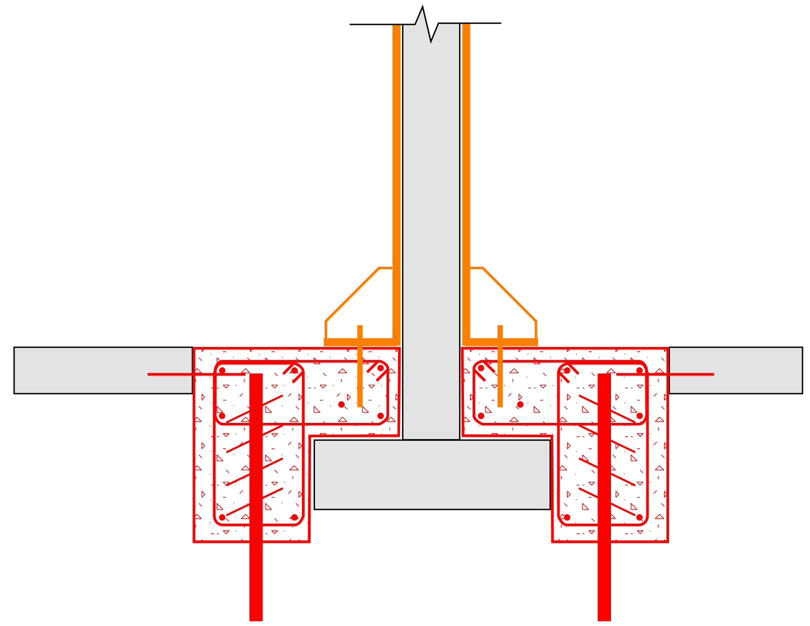
5 K06.1 DIAPHRAGM DRAG TIE STRENGTHENING



6 - SECTION THROUGH TIE



7 K06.1 NEW WALL INCLUDING GROUND ANCHORS



8 K06.1 NEW STEEL WALL TIES INCLUDING GROUND ANCHORS

No.	Revision	By	Chk	Appd	Date
A	CONCEPT DESIGN				30.05.25

Drawing Originator: Beca

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Design	
Drawn	
Dsg Verifier	
Dwg Check	

* Refer to Revision 1 for Original Signature

Client: MINISTRY OF BUSINESS, INNOVATION & EMPLOYMENT
HĪKINA WHAKATUTUKI

Project: COST BENEFIT ANALYSIS OF THE EARTHQUAKE PRONE BUILDINGS IN NZ

Title: SEISMIC RETROFIT CONCEPT DESIGN
TYPOLOGY 6 - SHEAR WALLS MID-RISE
34 and 67%*NBS* - CHRISTCHURCH

Discipline: STRUCTURAL

Drawing No.: SE-K06.2

Rev.: A

BLUEBEAM

DO NOT SCALE

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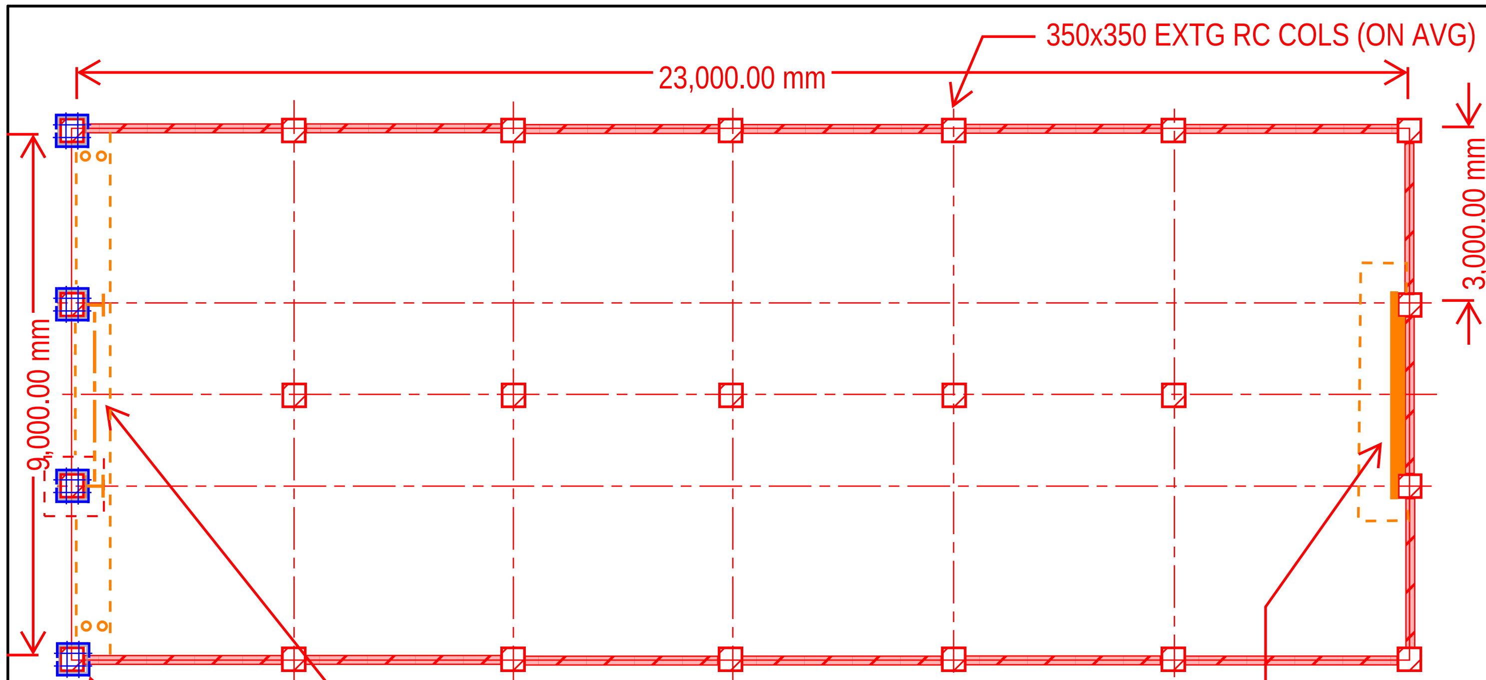
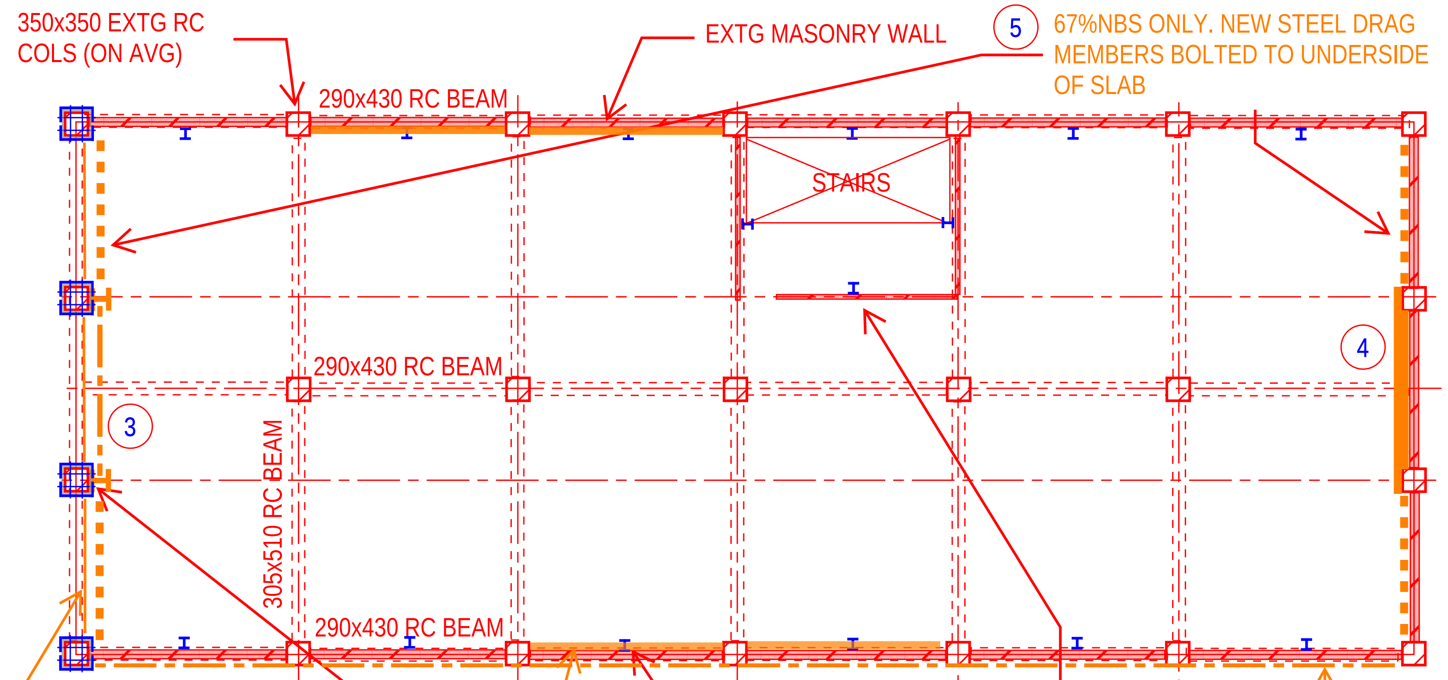


1 STEEL JACKETS AROUND COLUMNS GROUTED AND BOLTED IN PLACE. ALLOW FOR BTM AND TOP THIRD TO UNDERSIDE OF LEVEL 3.

3 67% ONLY. NEW STEEL TENSION/COMPRESSION FRAME AND ASSOCIATED PAD FOUNDATION EXTENSIONS AND GROUND BEAM. FOR WELLINGTON AND FIELDING ALLOW FOR 2 NO. GROUND ANCHORS AT ENDS OF GROUND BEAM (4 NO. TOTAL)

4 67%NBS ONLY. NEW STEEL TENSION/COMPRESSION FRAME AND ASSOCIATED PAD FOUNDATION EXTENSIONS AND GROUND BEAM. ALLOW FOR 2 NO. GROUND ANCHORS IN EACH PAD

PLAN - GROUND FLOOR PLAN



5 67%NBS ONLY. NEW STEEL DRAG MEMBERS BOLTED TO UNDERSIDE OF SLAB

1 STEEL THREADED ROD THROUGH COLUMN AND BOLTED TO STEEL PLATE. ALLOW FOR BTM AND TOP THIRD OF COLUMN

2 200UB VERTICAL POSTS FOR OUT-OF-PLANE RESTRAINT. DRILL AND EPOXY ANCHORS 2-M16 AT 600mm CRS UP HEIGHT. CONNECT TO SLAB AT BASE AND BEAM AT HIGH LEVEL.
APPLIES FROM LEVEL 2 TO UNDERSIDE OF ROOF

8 67% ONLY. ALLOW FOR HORIZONTAL 200PFC TO TOP OF URM SPANDREL AT EACH FLOOR LEVEL. CONNECT TO COLUMNS

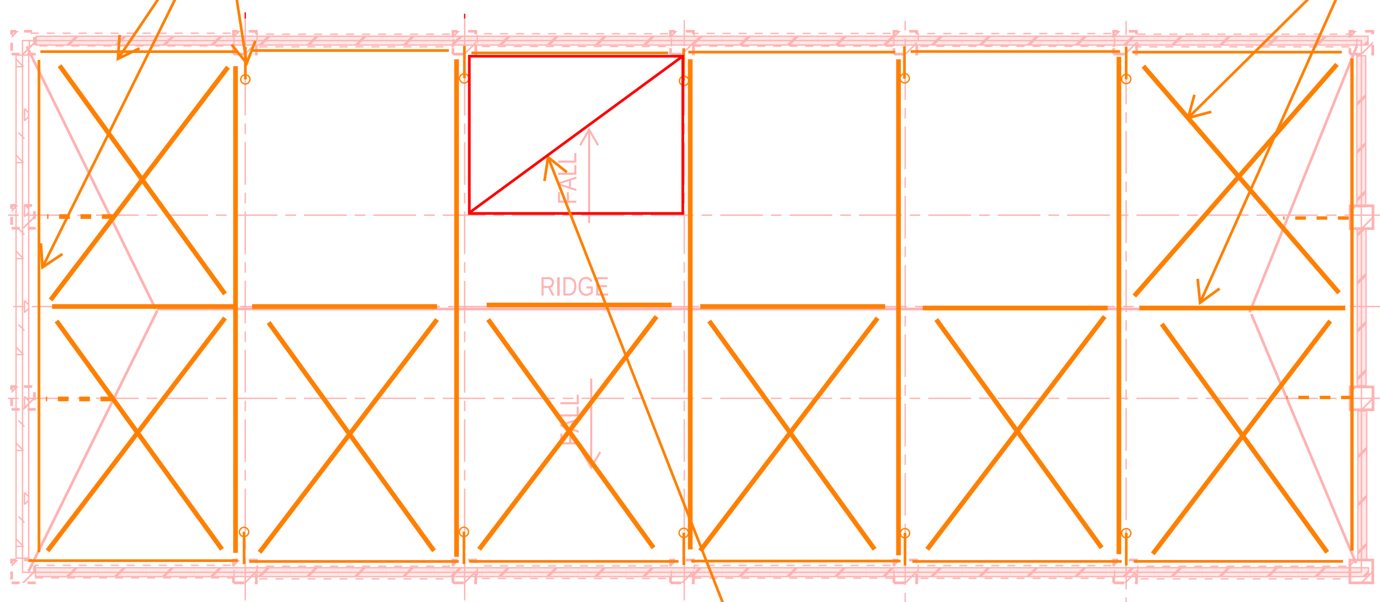
PLAN - LEVEL 1 (LEVEL 2 and 3 SIMILAR)

8 67% ONLY. TO ALLOW FOR VARIATION IN SOLID AND CAVITY URM WALL CONSTRUCTION, ALLOW FOR CAVITY TIES TO ONE LONGITUDINAL WALL AS INDICATED. PYTHON FIXINGS AT 600mm x 600mm CRS ACROSS LEVEL 1-3

10 67% ONLY. 200PFC AT TOP OF PARAPET BOLTED ALONG LENGTH. CHS STEEL STRUT AND VERTICAL MEMBER PENETRATING THROUGH ROOF.

6 67% ONLY. NEW STEEL ROOF BRACING SYSTEM. LOCATE TO UNDERSIDE OF ROOF LEVEL. STEEL EA CROSS BRACES AND STEEL SHS CHORD/STRUTS

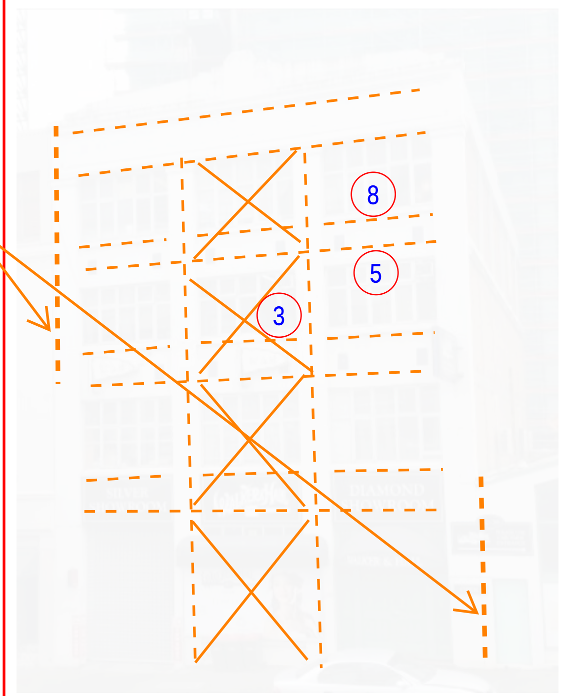
11 FOR 30% OF BUILDINGS ASSUME LONGITUDINAL WALLS INSUFFICIENT AND ADDITIONAL SHOTCRETE WALL OVERLAY REQUIRED (INTERNAL TO BUILDING). SCOPE ITEM 2 NOT REQUIRED IN THESE LOCALISED AREAS



9 67% ONLY. TO ADDRESS SEISMIC GAP ISSUES ALLOW FOR 15m OF VERTICAL LENGTH TO INCREASE SEISMIC GAP AT BOTH ENDS OF BUILDING (30m TOTAL)

7 67% ONLY. ALLOW FOR NOMINAL STEELWORK FOR ROOF TOP PLANT ROOM UPGRADES

PLAN - ROOF LEVEL



EXAMPLE PHOTO OF TYPICAL TYPOLOGY

NOTES:

1.0 GENERAL
1.1 REFER TO ATTACHED SCHEDULE FOR SEISMIC STRENGTHENING SCOPE FOR OTHER REGIONS, USE AND GFA
1.2 ALL WORKS TO COMPLY WITH RELEVANT CLAUSES OF THE NZBC AND THE NEW ZEALAND BUILDING ACT
1.3 BLUE COLOURED TEXT REPRESENTS SCOPE FOR 34%NBS. ORANGE COLOURED TEXT REPRESENTS SCOPE IN ADDITION TO 34%NBS SCOPE TO GET to 67%NBS

No.	Revision	By	Chk	Appd	Date
A	CONCEPT DESIGN				30.05.25

Drawing Originator: Beca

Original Scale (A1) | Reduced Scale (A3) | Design | Drawn | Dsg Verifier | Dwg Check | * Refer to Revision 1 for Original Signature

Client: MINISTRY OF BUSINESS, INNOVATION & EMPLOYMENT HĪKINA WHAKATUTUKI

Project: COST BENEFIT ANALYSIS OF THE EARTHQUAKE PRONE BUILDINGS IN NZ

Title: SEISMIC RETROFIT CONCEPT DESIGN TYPOLOGY 7 34 and 67%NBS - CHRISTCHURCH

Discipline: STRUCTURAL

Drawing No. SE-K007.1 Rev. A

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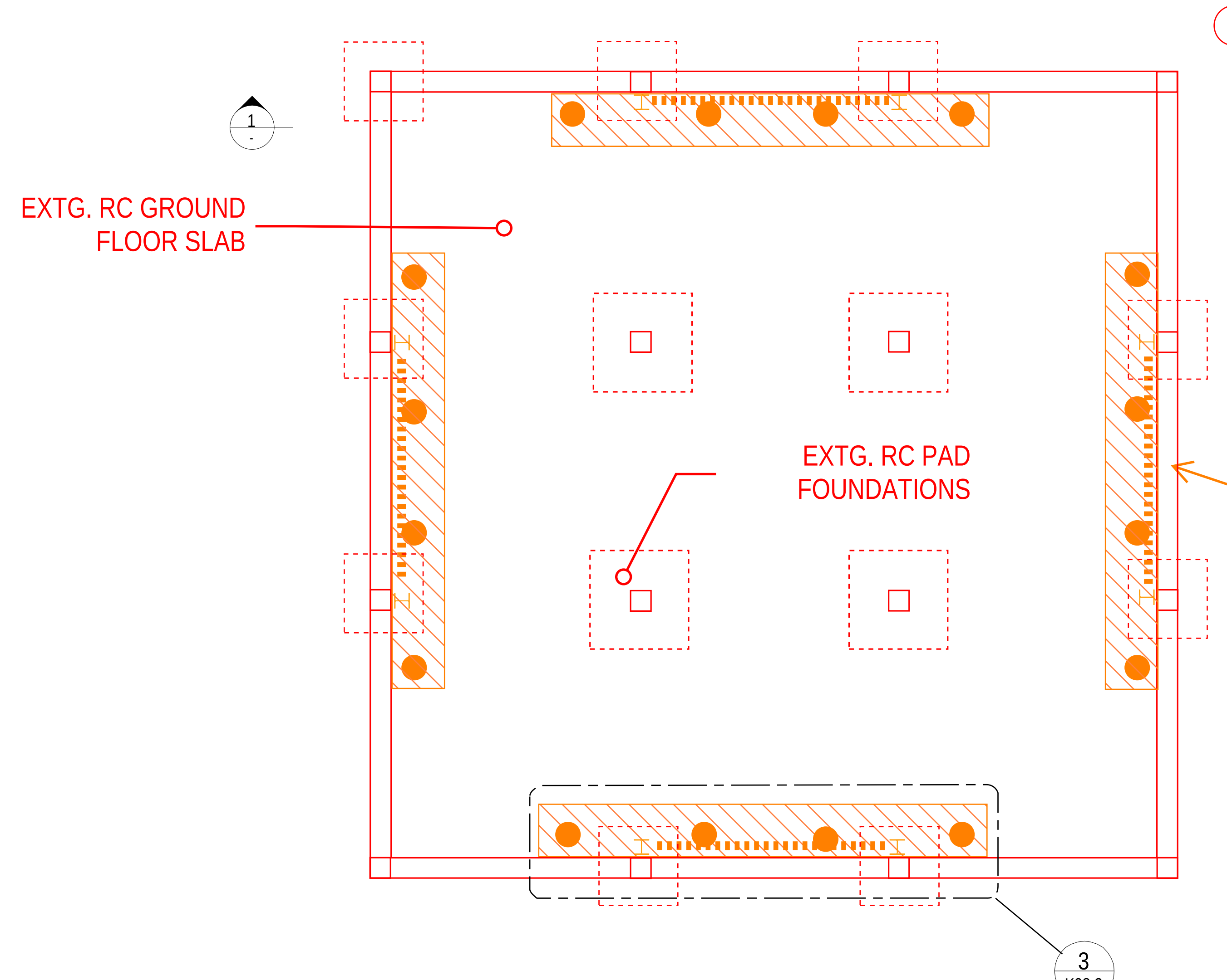
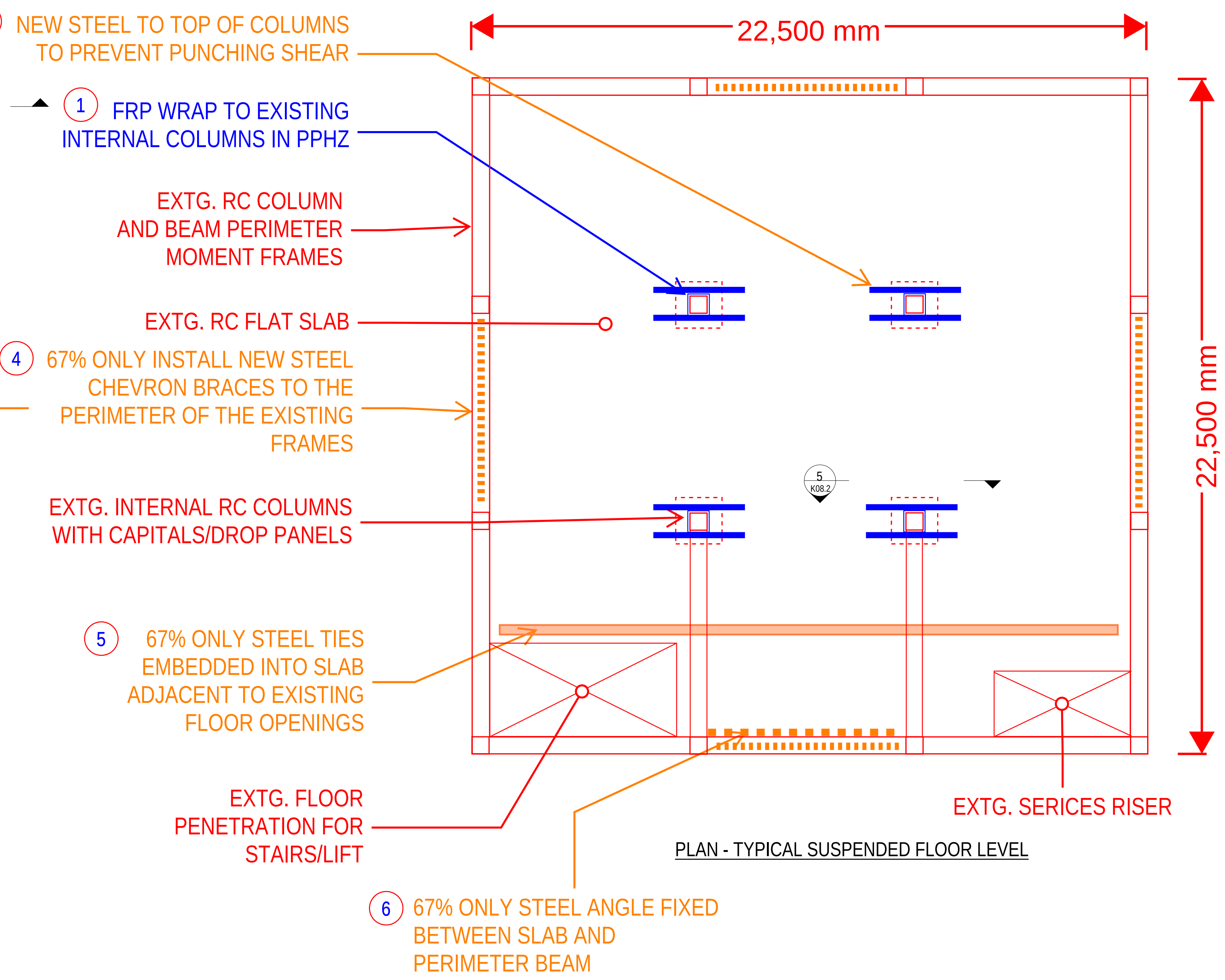
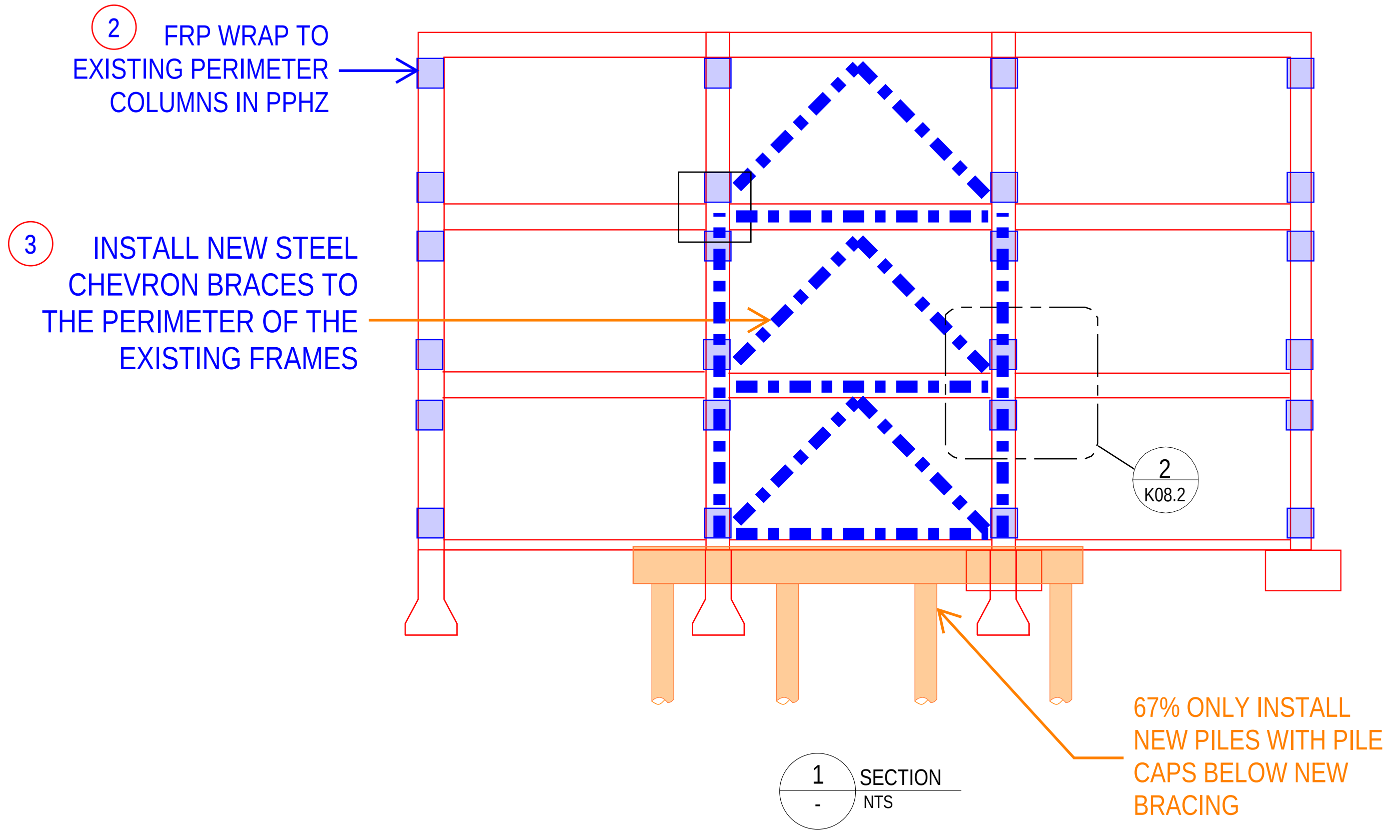


PLAN - GROUND FLOOR LEVEL



PLAN - TYPICAL SUSPENDED FLOOR LEVEL



1 SECTION NTS

EXAMPLE PHOTO OF TYPICAL TYPOLOGY

NOTES:

1.0 GENERAL
1.1 REFER TO ATTACHED SCHEDULE FOR SEISMIC STRENGTHENING SCOPE FOR OTHER REGIONS, USE AND GFA
1.2 BLUE COLOURED TEXT REPRESENTS SCOPE FOR 34%NBS. ORANGE COLOURED TEXT REPRESENTS SCOPE IN ADDITION TO 34%NBS SCOPE TO GET to 67%NBS

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A	CONCEPT DESIGN				30.05.25

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Project: COST BENEFIT ANALYSIS OF THE EARTHQUAKE PRONE BUILDINGS IN NZ

Title: SEISMIC RETROFIT CONCEPT DESIGN TYPOLOGY 8 - PRE 1976 RC FRAME 34 and 67%NBS - CHRISTCHURCH

Discipline: STRUCTURAL

Drawing No.: SE-K08.1 Rev.: A

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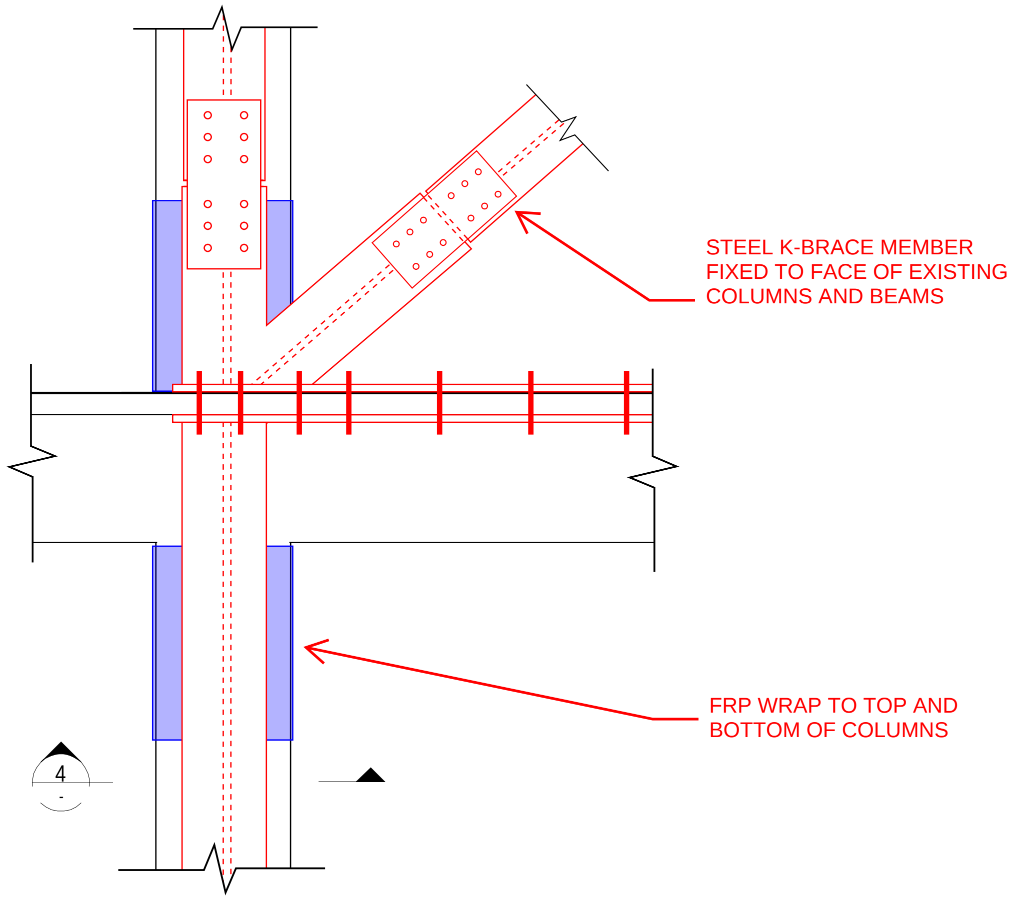
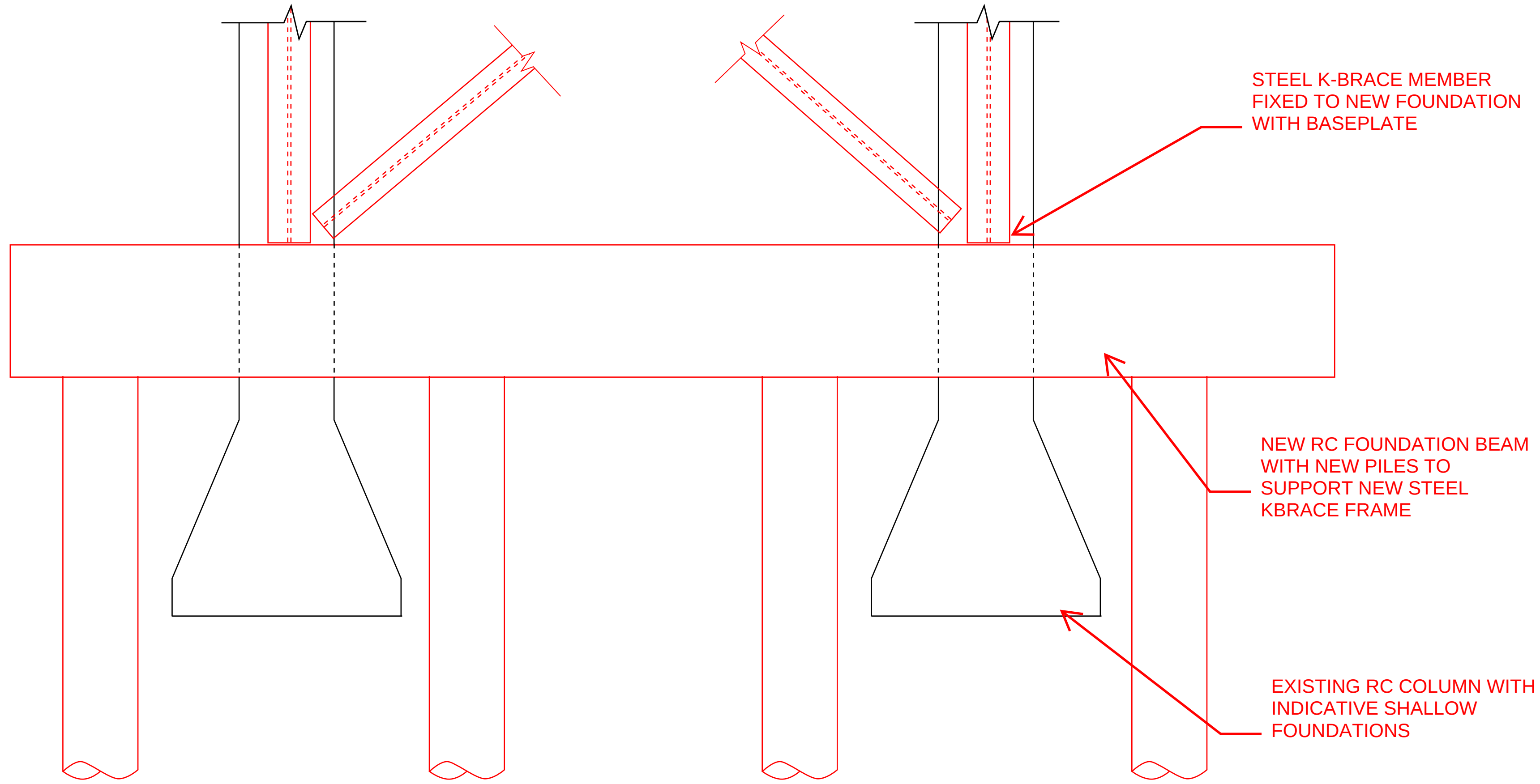
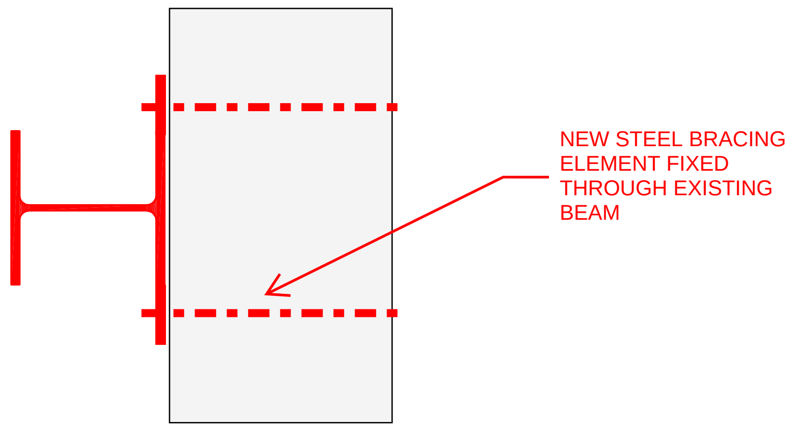


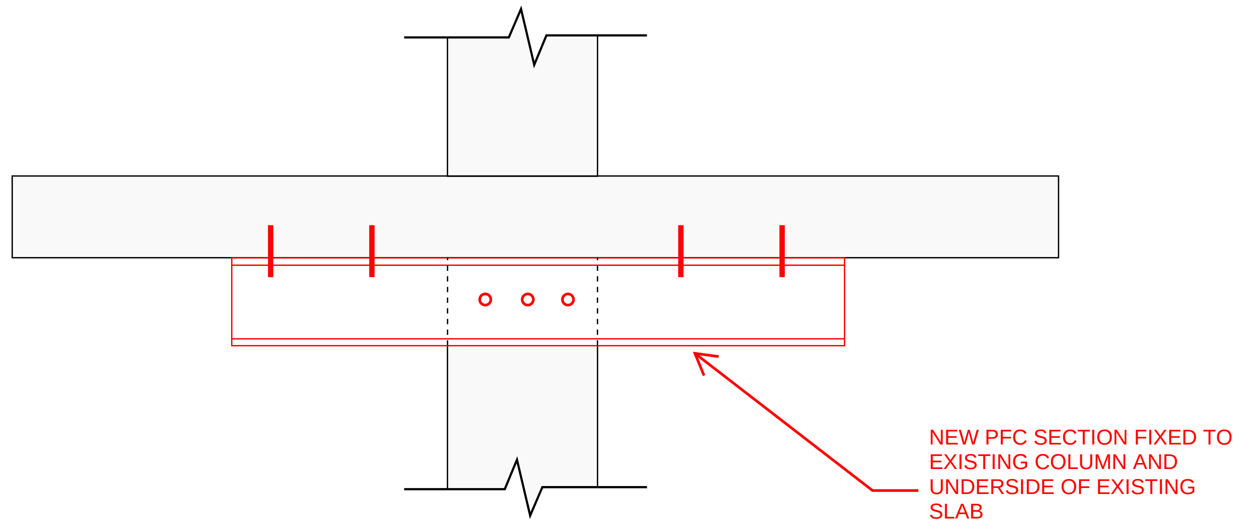
2 BRACE JOINT DETAIL
K08.1
NTS



3 FOUNDATION STRENGTHENING
K08.1
NTS



4 SECTION THROUGH KBRACE
-
NTS



5 SLAB PUNCHING SHEAR STRG
K08.1
NTS

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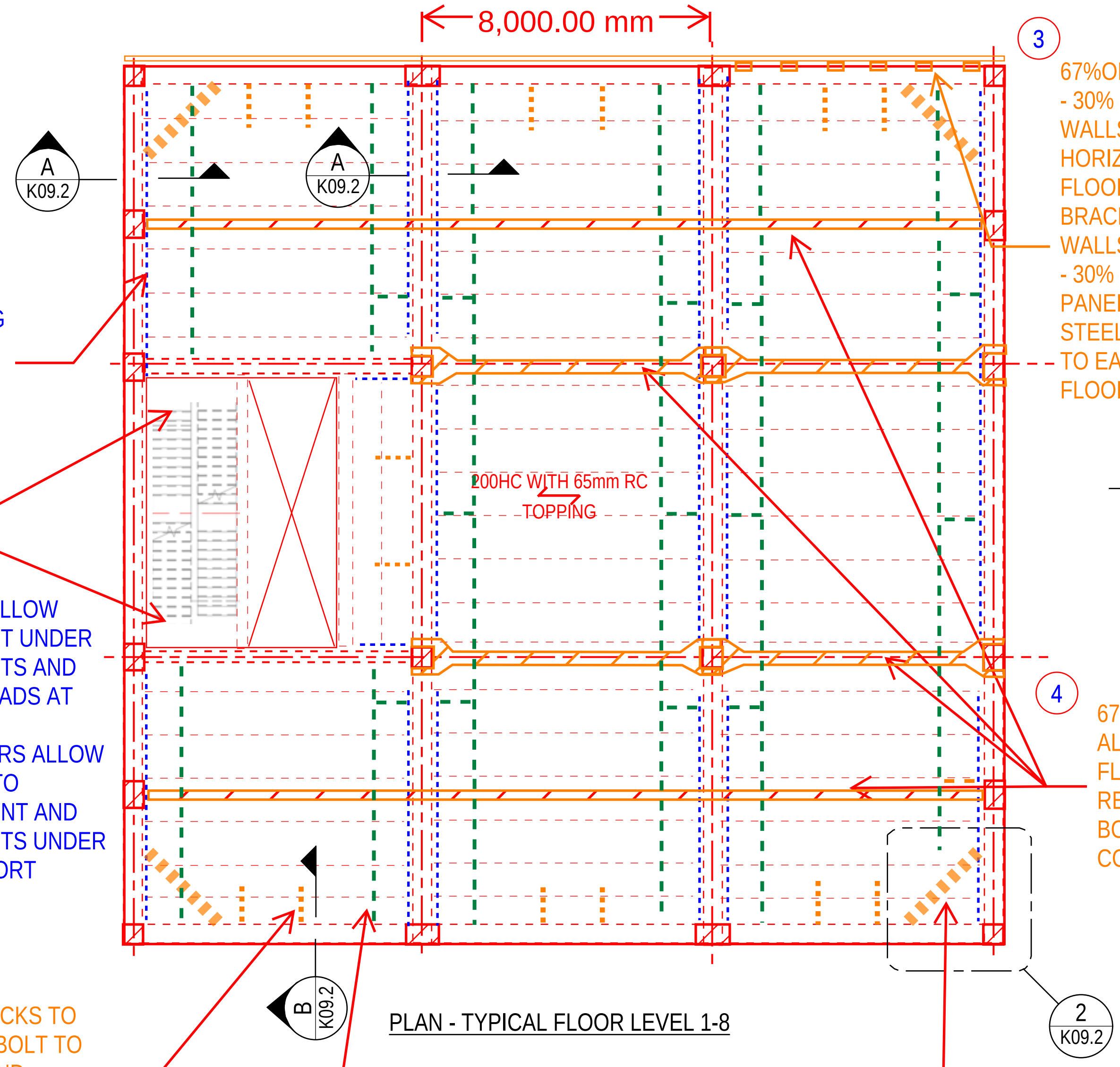
Project: COST BENEFIT ANALYSIS OF THE EARTHQUAKE PRONE BUILDINGS IN NZ

Title: SEISMIC RETROFIT CONCEPT DESIGN TYPOLOGY 8 - PRE 1976 RC FRAME 34 and 67%*NBS* - CHRISTCHURCH

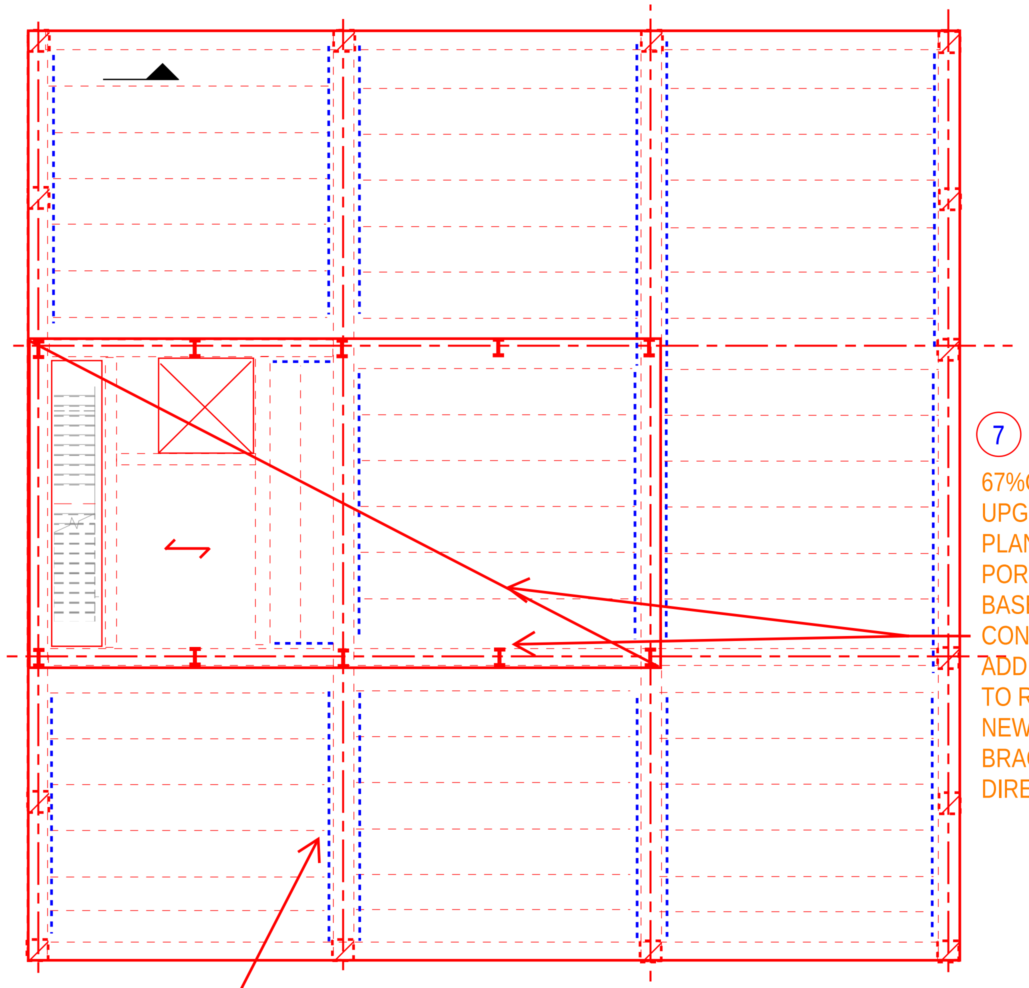
Discipline: STRUCTURAL

Drawing No.: SE-K08.2

Rev.: A



PLAN - TYPICAL FLOOR LEVEL 1-8



PLAN - ROOF LEVEL

1 150x12 EA SEATING ANGLES TO UNDERSIDE OF FLOOR UNITS

2 AT TOP OF STAIRS ALLOW NEW STEEL BRACKET UNDER WITH THROUGH BOLTS AND RECESSED BOLT HEADS AT TOP OF LANDING
AT BOTTOM OF STAIRS ALLOW FOR SAW CUTTING TO CREATE SLIDING JOINT AND NEW STEEL BRACKETS UNDER FOR GRAVITY SUPPORT

3 67%ONLY.
- 30% OF BUILDINGS ASSUME BLOCK WALLS TO ONE SIDE OF BUILDING. HORIZONTAL CUT AT INTERFACE WITH FLOOR LEVELS. NEW STEEL BRACKETS TO RESTRAIN TOP OF WALLS AT EVERY 3m CRS.
- 30% OF BUILDINGS ASSUME PC PANELS TO FULL PERIMETER. NEW STEEL BRACKETS TOP AND BOTTOM TO EACH PANEL FOR UPPER THREE FLOORS.

4 67%ONLY. FOR 30% OF BUILDINGS ALLOW COLUMN TIE PLATES TO ALL FLOORS. 200x8 STEEL TIE PLATE RECESSED INTO TOP OF SLAB AND BOLTED THROUGH ADJACENT COLS.

5 250PFC STRONGBACKS TO UNDERSIDE SLAB. BOLT TO ADJACENT BEAM AND THROUGH UNDERSIDE OF SLAB AT EACH END

6 67%ONLY.
HOLLOWCORE CORNER DETAIL. 219 CHS TO UNDERSIDE OF SLAB SUPPORTED ON STEEL CORBELS EACH END

7 67%ONLY.
UPGRADE OF PLANT ROOM PORTAL FRAME BASE CONNECTIONS, ADD FLY BRACING TO RAFTERS
NEW CROSS BRACING IN ONE DIRECTION

8 67% ONLY. NEW STEEL CATCH BEAMS TO UNDERSIDE OF FLOOR. NEW 310UB BEAM SPANNING BETWEEN EXTG RC BEAMS AND 310UB STUBS CANTILEVERING OFF EXTG RC BEAMS

REFER TYPICAL FLOOR PLAN FOR ALL BELOW SLAB WORKS. THESE APPLY TO THIS FLOOR AS WELL

EXAMPLE PHOTO OF TYPICAL TYPOLOGY

NOTES:

1.0 GENERAL
1.1 REFER TO ATTACHED SCHEDULE FOR SEISMIC STRENGTHENING SCOPE FOR OTHER REGIONS, USE AND GFA
1.2 BLUE COLOURED TEXT REPRESENTS SCOPE FOR 34%NBS. ORANGE COLOURED TEXT REPRESENTS SCOPE IN ADDITION TO 34%NBS SCOPE TO GET to 67%NBS
1.3 STRUCTURAL WORKS ONLY SHOWN. CONSEQUENTIAL WORKS AS A RESULT OF INSTALLING STRUCTURAL SCOPE SHALL BE ALLOWED FOR.

2.0 MISC STRENGTHENING COST ALLOWANCES FOR 67%NBS SCHEME TO ACCOUNT FOR OTHER LESS COMMON DEFECTS WITH THIS BUILDING TYPOLOGY ALLOW A PROVISIONAL SUM AMOUNT TO DEAL WITH SOME OF THE FOLLOWING ISSUES:
- DIAPHRAGMS
- INADEQUATE DETAILING OF COLUMNS OR BEAM COLUMN JOINTS
- INTERNAL GRAVITY FRAMES LIGHTLY REINFORCED AND POTENTIALLY NON-DUCTILE COLUMNS
HEAVY CEILING TILES. REMOVE AND REPLACE WITH LIGHT WEIGHT TILES

No.	Revision	By	Chk	Appd	Date
A	CONCEPT DESIGN				30.05.25

Drawing Originator: Beca

Original Scale (A1) | Reduced Scale (A3) | Design | Drawn | Dsg Verifier | Dwg Check
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Client: MINISTRY OF BUSINESS, INNOVATION & EMPLOYMENT HĪKINA WHAKATUTUKI

Project: COST BENEFIT ANALYSIS OF THE EARTHQUAKE PRONE BUILDINGS IN NZ

Title: SEISMIC RETROFIT CONCEPT DESIGN TYPOLOGY 9 - POST 1976 DUCTILE RC FRAME WITH PC FLOORS 34 and 67%*NBS* - CHRISTCHURCH

Discipline: STRUCTURAL

Drawing No.: SE-K009.1 Rev.: A

BLUEBEAM

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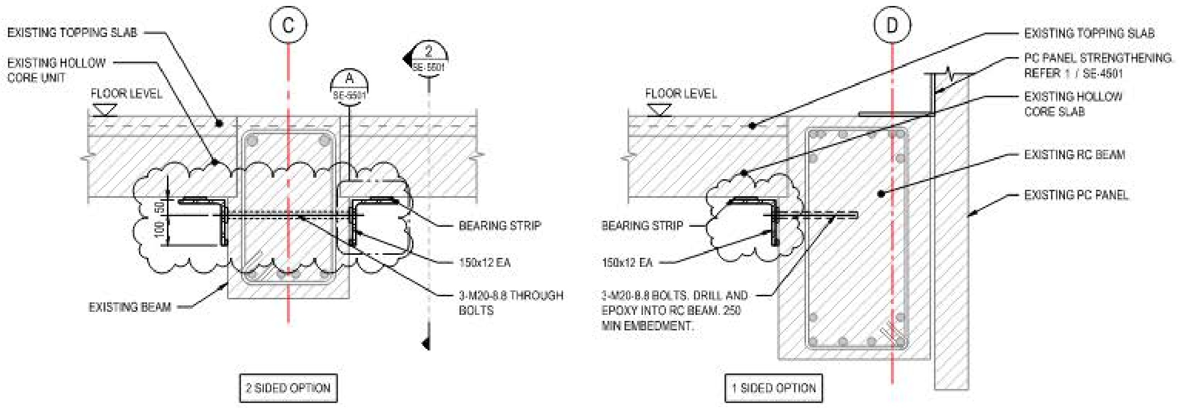
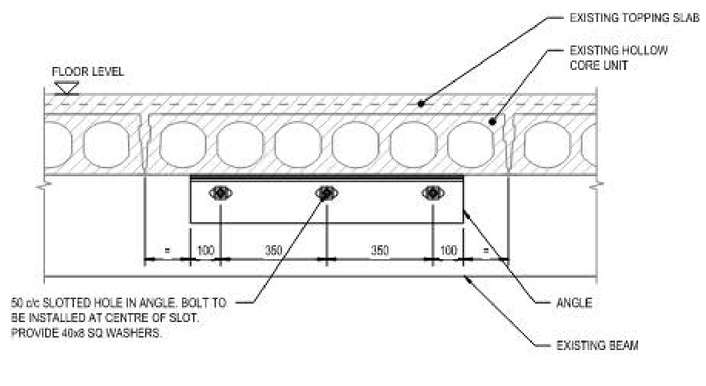
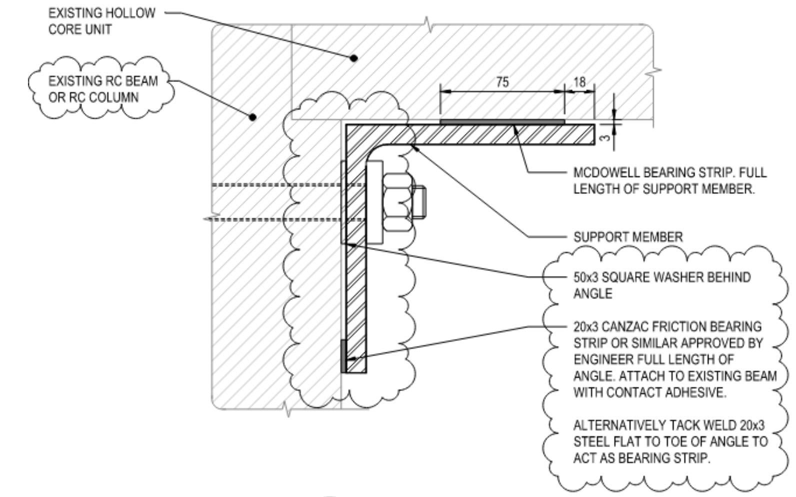


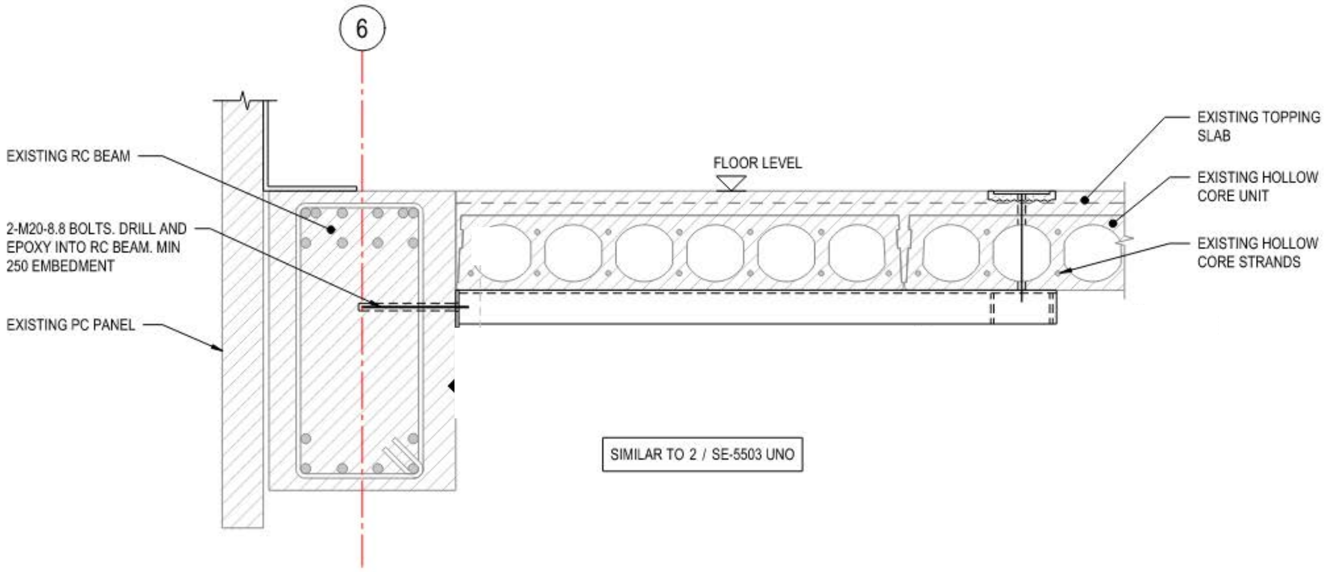
A K09.1 TYPICAL HOLLOWCORE SEATING DETAIL



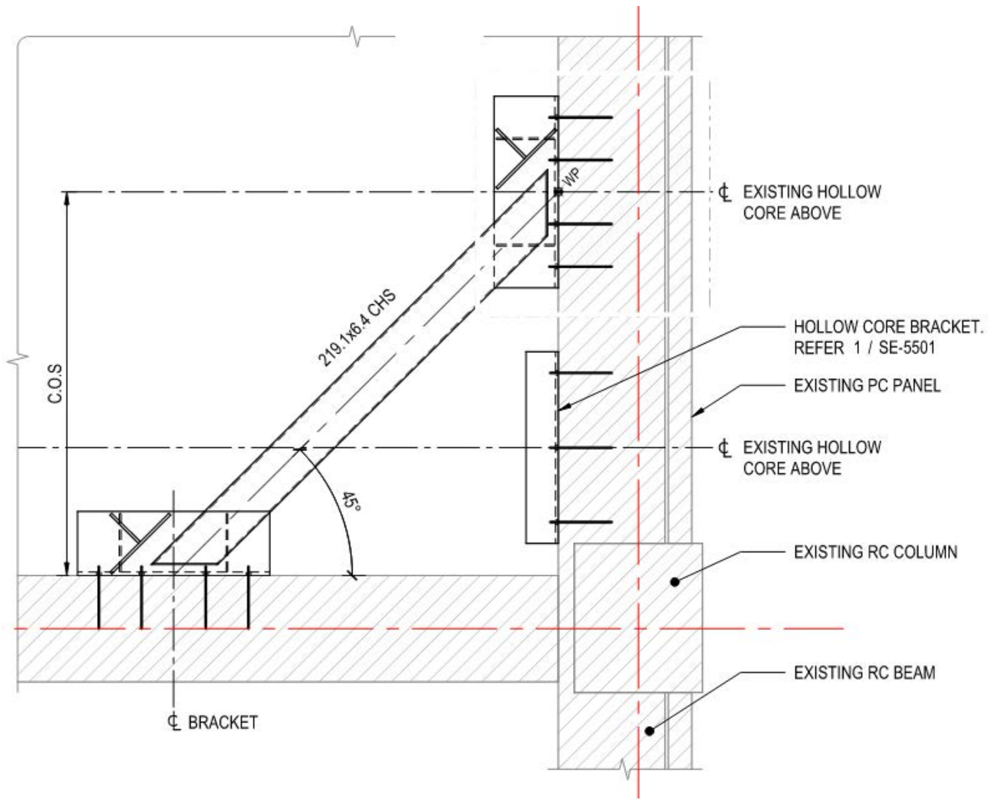
2 SECTION
1 : 10



A DETAIL - BEARING STRIP
1 : 2



B K09.1 TYPICAL ALPHA SLAB DETAIL



2 K09.1 TYPICAL HOLLOWCORE CORNER DETAIL

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A	CONCEPT DESIGN				30.05.25

Drawing Originator: Beca

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Project: COST BENEFIT ANALYSIS OF THE EARTHQUAKE PRONE BUILDINGS IN NZ

Title: SEISMIC RETROFIT CONCEPT DESIGN TYPOLOGY 9 34 and 67%*NBS* - CHRISTCHURCH

Discipline: STRUCTURAL

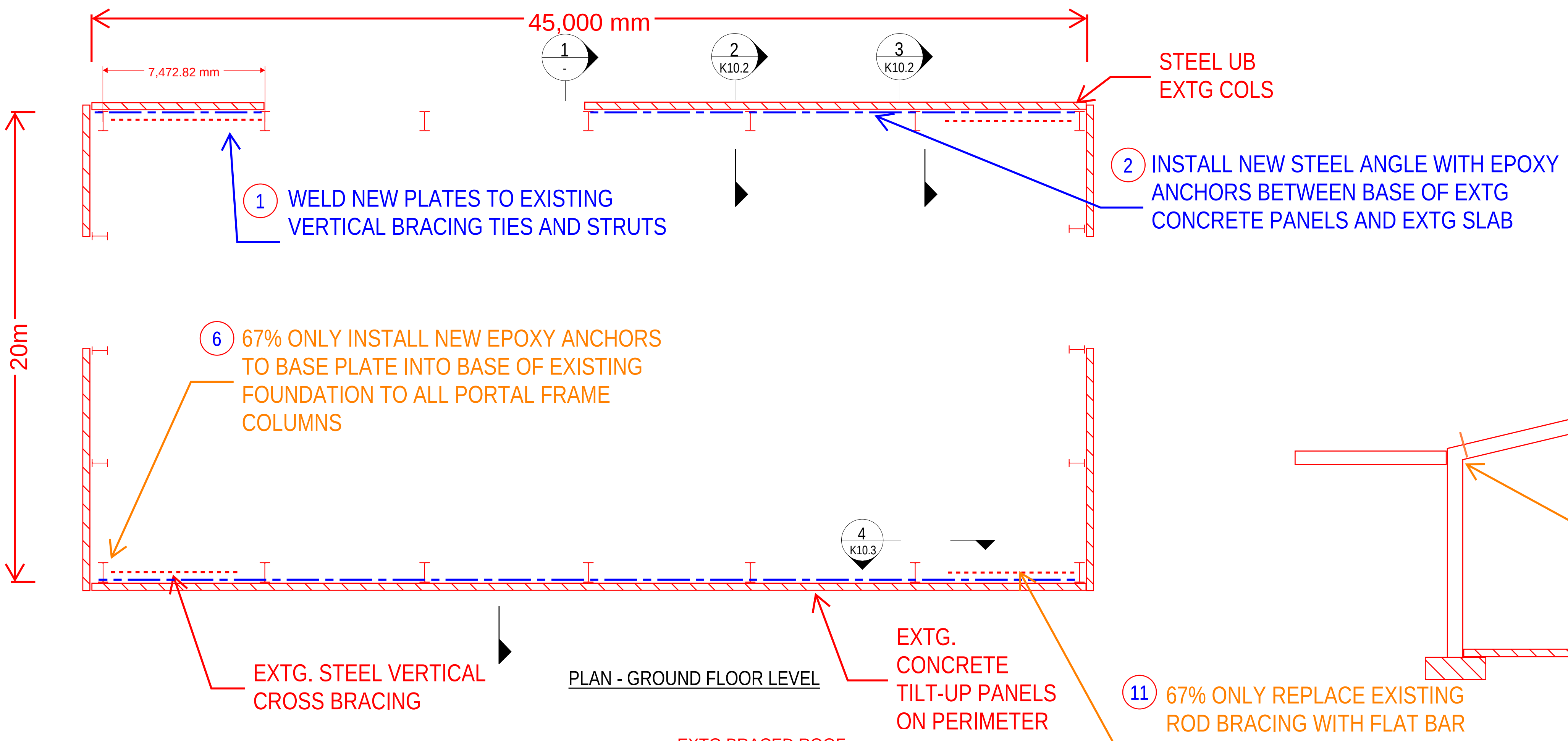
Drawing No.: SE-K009.2

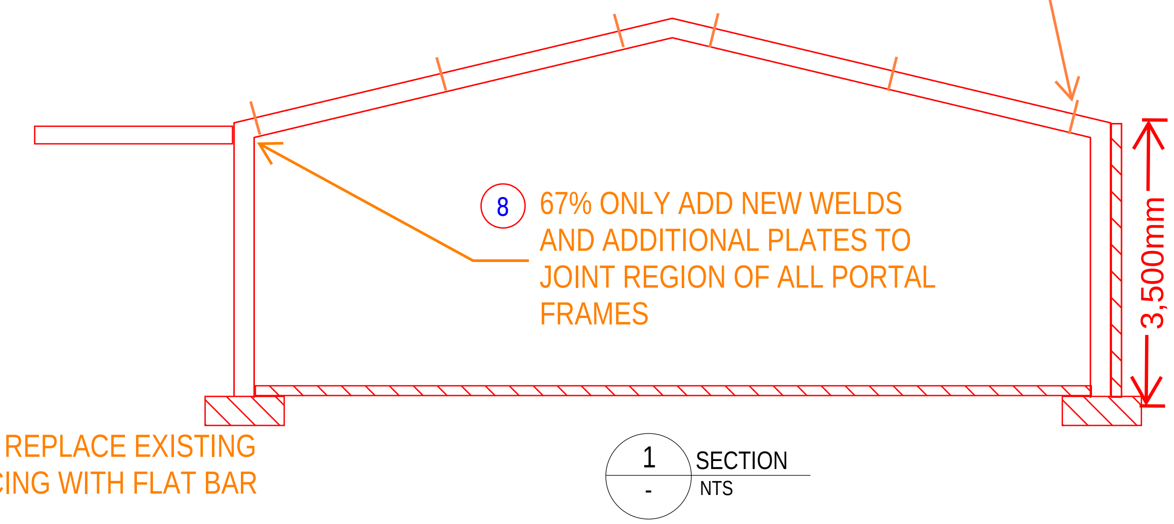
Rev.: A

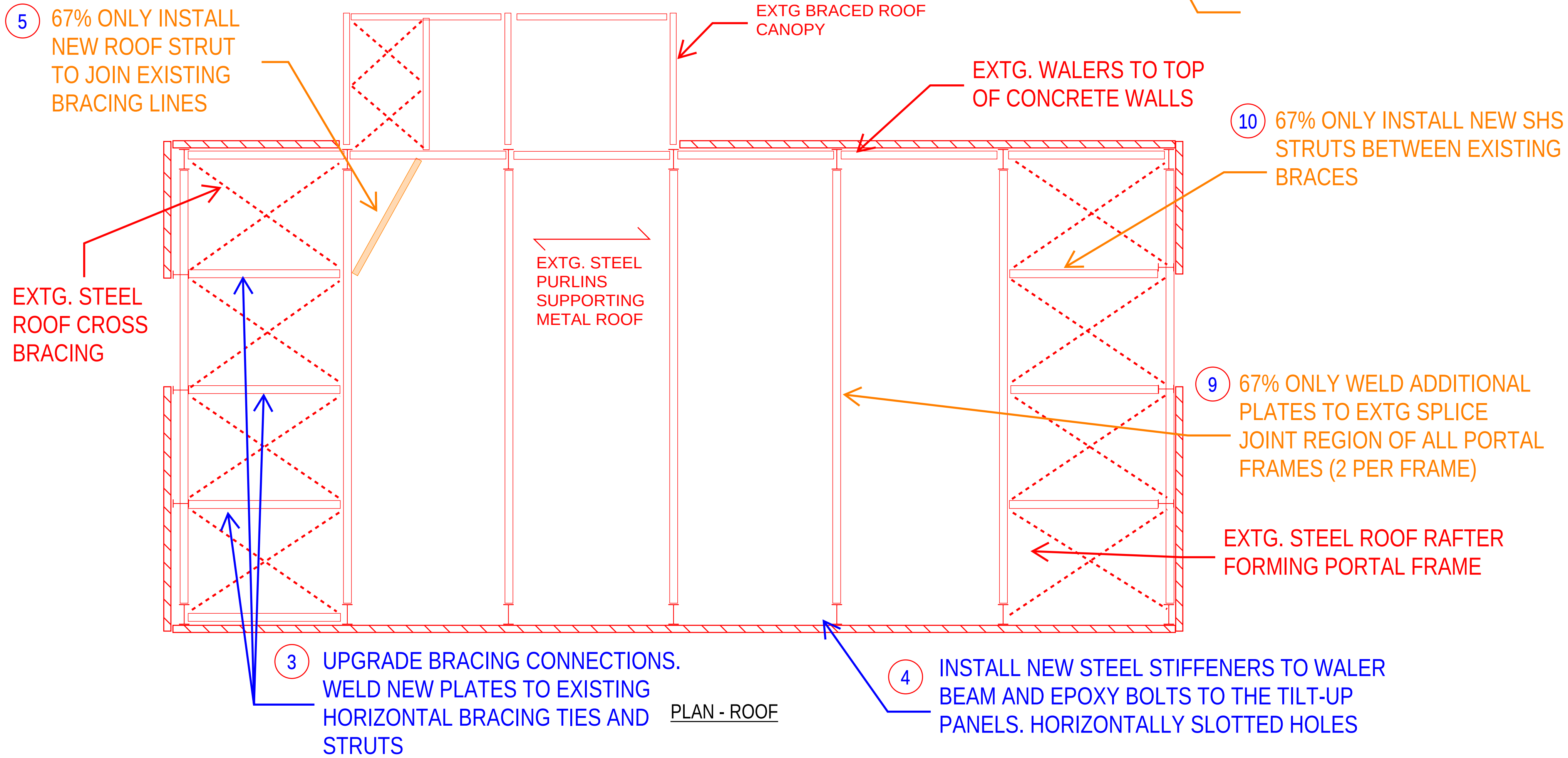
BLUEBEAM

DO NOT SCALE

IF IN DOUBT ASK.







NOTES:

1.0 GENERAL
1.1 REFER TO ATTACHED SCHEDULE FOR SEISMIC STRENGTHENING SCOPE FOR OTHER REGIONS, USE AND GFA
1.2 BLUE COLOURED TEXT REPRESENTS SCOPE FOR 34%NBS. ORANGE COLOURED TEXT REPRESENTS SCOPE IN ADDITION TO 34%NBS SCOPE TO GET to 67%NBS

EXAMPLE PHOTO OF TYPICAL TYPOLOGY

No.	Revision	By	Chk	Appd	Date
A	CONCEPT DESIGN				30.05.25

Drawing Originator: Beca

Original Scale (A1) | Reduced Scale (A3) | Design | Drawn | Dsg Verifier | Dwg Check | * Refer to Revision 1 for Original Signature

Client: MINISTRY OF BUSINESS, INNOVATION & EMPLOYMENT — HĪKINA WHAKATUTUKI

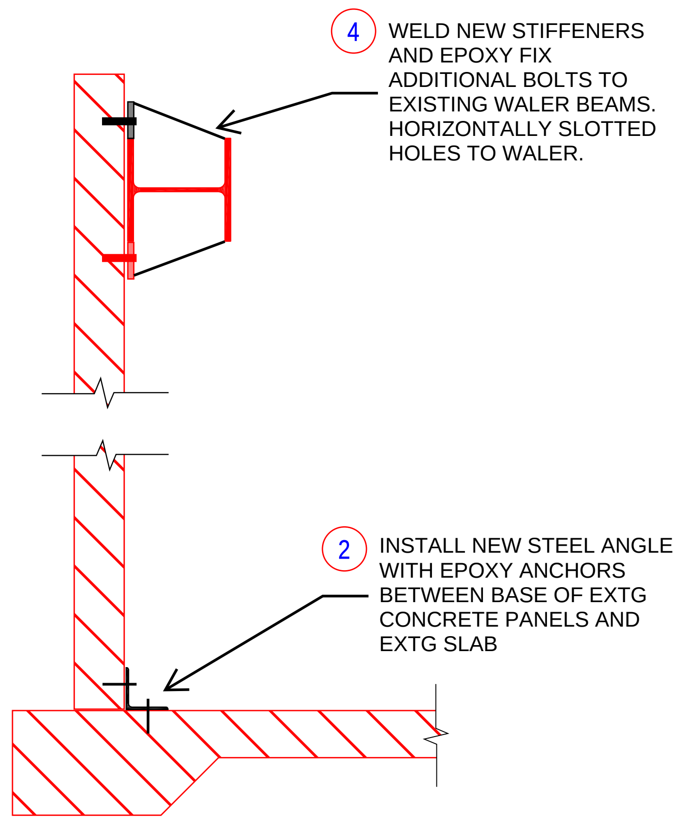
Project: COST BENEFIT ANALYSIS OF THE EARTHQUAKE PRONE BUILDINGS IN NZ

Title: SEISMIC RETROFIT CONCEPT DESIGN TYPOLOGY 10 - STEEL LOW RISE WITH HEAVY CLADDING 34 and 67%*NBS* - CHRISTCHURCH

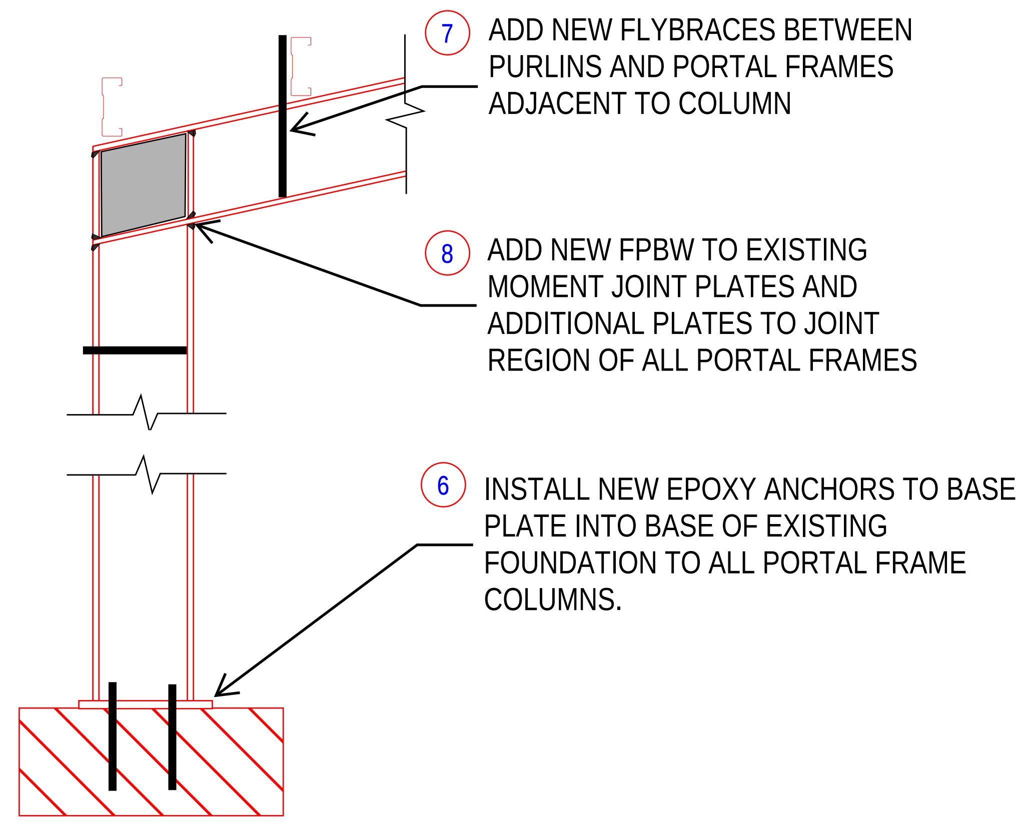
Discipline: STRUCTURAL

Drawing No.: SE-K10.1

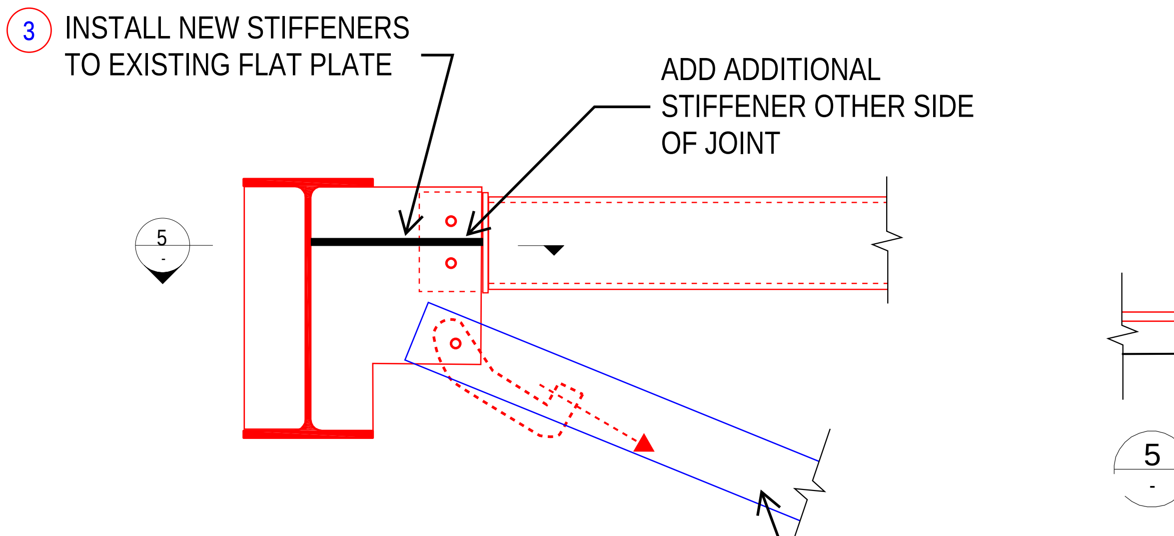
Rev.: A



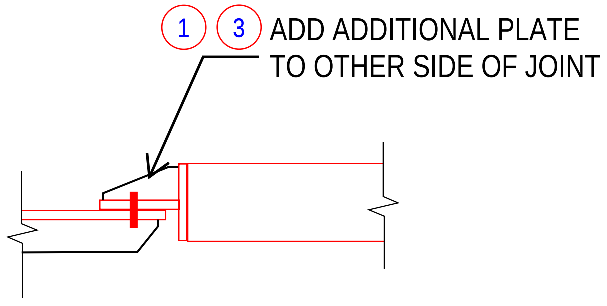
2 K10.1 TYPICAL HEAVY CLADDING REMEDIAL



3 K10.1 TYPICAL COLUMN REINSTATEMENT



4 K10.1 TYPICAL BRACING REINSTATEMENT



5 - STRUT REINSTATEMENT

No.	Revision	By	Chk	Appd	Date
A	CONCEPT DESIGN				30.05.25

Drawing Originator: Beca

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Client: MINISTRY OF BUSINESS, INNOVATION & EMPLOYMENT HĪKINA WHAKATUTUKI

Project: COST BENEFIT ANALYSIS OF THE EARTHQUAKE PRONE BUILDINGS IN NZ

Title: SEISMIC RETROFIT CONCEPT DESIGN TYPOLOGY 10 - STEEL LOW RISE WITH HEAVY CLADDING 34 and 67%*NBS* - CHRISTCHURCH

Discipline: STRUCTURAL

Drawing No. SE-K10.2 Rev. A

E

Appendix E

Summary of Cost Estimates For Seismic Retrofits

1 Cost Estimation Summary

1.1 Overview

Beca Cost Management have undertaken a feasibility study estimation exercise of scenario based indicative repair strategies for 10 generalised building typologies to achieve both 34% NBS and 67% NBS. These estimates have been subjected to cost modelling to determine aggregated fit out and building services costs, regional market differentiation and building occupancy/functional requirements i.e. *Commercial use building located in Wellington*. Risk contingency, fees and client consenting cost have been included as part of the cost model.

The change in regional seismic requirements (Z values) have been captured by the Beca Structural Team and were provided to Beca Cost Management within the **Strengthening Schedules 1-10**. These are represented in the Schedules as percentages of scope for each construction element with Christchurch set as a baseline of 100%.

Energy efficiency was included in the scope at a later date and is limited in its application to areas only impacted by construction activity. Allowances for fire upgrades have been quantified for 67% NBS options only.

Regions Included:

- Christchurch (base estimate)
- Dunedin
- Auckland
- Whanganui
- Feilding
- Wellington

Building Functions:

- Residential
- Commercial
- Industrial
- Hospitals (limited)

Please find attached a summary table of cost per m² in Appendix A.

1.2 Basis of Estimate

The estimate has been based on structural design information provided by Beca Structural Engineers.

These are high level single point estimates with each estimate being conducted using Christchurch market conditions and rates as a baseline. These estimates have been put through cost modelling to determine indicative cost for the other regions included in this study.

Design information provided by Beca Structural:

- Preliminary Sketches
  - **Typology 1**: 34% & 67% NBS - SE-K001.1, SE-K001.2
  - **Typology 2**: 34% & 67% NBS - SE-K002.1, SE-K002.2
  - **Typology 3**: 34% & 67% NBS - SE-K003.1, SE-K003.2
  - **Typology 4**: 34% & 67% NBS - SE-K004.1, SE-K004.2, SE-K004.3
  - **Typology 5**: 34% & 67% NBS - SE-K005.1, SE-K005.2
  - **Typology 6**: 34% & 67% NBS - SE-K006.1, SE-K006.2
  - **Typology 7**: 34% & 67% NBS - SE-K007.1
  - **Typology 8**: 34% & 67% NBS - SE-K008.1, SE-K008.2
  - **Typology 9**: 34% & 67% NBS - SE-K009.1, SE-K009.2
  - **Typology 10**: 34% & 67% NBS - SE-K0010.1, SE-K0010.2
  - **Strengthening Schedule**: Typ 1, 2, 3, 4 & 10 (Z values)
  - **Strengthening Schedule**: Typ 5, 6, 7, 8 & 9 (Z values)
  - Tender returned data from regional projects held by Beca
  - Various Market Indices, Including: RLB Indices, QV Indices, Beca Cost Management Market Indices

The costs are in NZD and exclude GST

The base estimation rates used in these estimates are based upon tender returned rates from Christchurch in Q4 2024

1.3 Project on costs

Due to the unique construction conditions for each region covered in this Cost Benefit Analysis Preliminaries and General allowances have been calculated independently for each of the regions and are included in the cost model summary for each typology. The Preliminary and General allowance is based on an average of market returned data for each region at the time of this analysis.

Market conditions and contractor availability are unique to each region and subject to fluctuations for this reason Contractor Margin has been calculated independently for each of the regions and is included in the cost model summary for each typology. This Margin is based on an average of market returned data for each region at the time of this analysis.

1.4 Assumptions

These general assumptions are applicable to all building typologies, regions and seismicity scope (34% NBS & 67% NBS):

- Assumed that buildings will be unoccupied for the duration of the construction activity
- All floor areas and building layouts are indicative and actual buildings will be subject to unique requirements not represented in this exercise
- All pricing is based on drawings provided by the engineers and does not make allowance for specialist areas unduly impacted by Construction activity i.e. Commercial kitchens, Laboratories, Server rooms etc.
- Assumed all works would be undertaken in a single phase
- Assumed work would be undertaken during normal working hours (7:30am – 5:00pm Monday – Friday)
- The base rate has been calculated based upon Christchurch Q4 2024 cost data, derived from average tender pricing for each of the itemised structural scope requirements as defined within the structural drawing details
- The costs values within the summary for each typology are provided as an indicative guide for the scope of seismic improvement works for each typology.
- No allowance has been made for upgrades or replacement of any fit-out fittings or fixtures or improvements to building services. The allowances are only for removal and reinstatement
- Assumed that reasonable site access is available
- The Energy Efficiency costs supplied as part of these cost estimates are only relative to the areas impacted by structural scope. And no allowances have been made to uplift adjoining areas or services improvements relating to energy efficiency.
- Energy Efficiency upgrades are limited to increased wall and roofing insulation along with window joinery (glazing included) to areas directly impacted by structural scope.
- Fire Compliance upgrades were only considered to be triggered with larger seismic upgrade strategies (67% NBS)

1.5 Exclusions

Unless specifically stated otherwise the following items are excluded from the estimated reinstatement costs:

- Goods and services tax (GST)
- Construction escalation beyond date of estimate

- Legal/accounting fees
- Client direct costs

- Costs associated with temporary decanting / relocation of existing building occupancy
- Fast track or accelerated programme
- Work outside normal hours
- Incurred costs to date
- No allowance made for testing, excavation, removal and disposal of contaminated materials
- Temporary protection / security as external wall opened
- Traffic Management
- Staging / phased work
- Insurances
- Site security
- Signage

- Geotechnical risk – The cost of additional depths of foundation pads and ground beams required by ground conditions – ranging from deeper foundations to gravel rafts or piled systems.
- No allowance for building improvements – all costs are based on replacing finishes with similar. appropriate linings and surface coverings.
- No allowance has been made for building services upgrades.
- No allowance for hard landscaping paths and access more than 1m from the face of the building.
- No allowance for landscaping and maintenance works.

1.6 Disclaimers

This report is solely for our client's use for the purpose for which it is intended in accordance with the agreed scope of work. It may not be disclosed to any person other than the Client and any use or reliance by any person contrary to the above, to which Beca has not given its prior written consent is at that person's own risk.

This report must be read in its entirety and no portion of it should be relied on without regard to the report as a whole, especially the assumptions, limitations and disclaimers set out in the estimate notes and elsewhere in the report.

While Beca believes that the use of the assumptions in the report are reasonable for the purposes of this study, Beca makes no assurances with respect to the accuracy of such assumptions, and some may vary significantly due to unforeseen events and circumstances.

In preparing this estimate, Beca has relied on the accuracy, completeness and currency of the information provided, therefore is not responsible for the information provided, and has not sought to independently verify it. To the extent that the information is inaccurate or incomplete, the opinions expressed by Beca may no longer be valid and should be reviewed.

A

Appendix A – Cost Per M^2 Summary

MBIE Seismically Prone Buildings - Cost Benefit Analysis - Cost Per M^2 Summary

Typology		Typ - 1		Typ - 2		Typ - 3		Typ - 4			Typ - 5		Typ - 6			Typ - 7	Typ - 8		Typ - 9		Typ - 10	
Building function		Comm	Res	Comm	Res	Comm	Res	Comm	Res	Ind	Comm	Res	Comm	Res	Ind	Comm	Comm	Res	Comm	Res	Comm	Ind
Christchurch																						
GFA		200		200		500		4320			336	300	1156			830	1500		5400		900	
34% NBS	$/m²	$ 39.00	$ 39.00	$1,937.00	$1,808.00	$2,044.00	$1,788.00	$2,527.00	$2,270.00	$1,805.00	$2,430.00	$2,342.00	$1,475.00	$1,218.00	$ 753.00	$2,081.00	$2,205.00	$1,948.00	$1,544.00	$1,288.00	$1,278.00	$ 556.00
67% NBS		$1,228.00	$ 982.00	$3,801.00	$3,331.00	$4,198.00	$3,743.00	$4,785.00	$4,329.00	$3,526.00	$4,832.00	$4,717.00	$2,994.00	$2,538.00	$1,735.00	$5,359.00	$4,728.00	$4,272.00	$3,490.00	$3,035.00	$2,541.00	$1,282.00
Auckland																						
GFA		200		200		500		4320			336		1156			830	1500		5400		900	
34% NBS	$/m²	$ 40.00	$ 40.00	$1,488.00	$1,354.00	$1,810.00	$1,543.00	$1,962.00	$1,695.00	$1,210.00	$2,040.00	$1,889.00	$1,492.00	$1,225.00	$ 740.00	$1,775.00	$1,987.00	$1,720.00	$1,499.00	$1,232.00	$1,230.00	$ 478.00
67% NBS		$ 968.00	$ 711.00	$2,569.00	$2,079.00	$3,213.00	$2,739.00	$3,688.00	$3,213.00	$2,378.00	$3,727.00	$3,451.00	$3,069.00	$2,594.00	$1,759.00	$4,667.00	$4,906.00	$4,432.00	$3,528.00	$3,054.00	$2,450.00	$1,140.00
Dunedin																						
GFA		200		200		500		4320			336		1156			830	1500		5400		900	
34% NBS	$/m²	$ 40.00	$ 40.00	$1,476.00	$1,344.00	$1,796.00	$1,531.00	$1,946.00	$1,681.00	$1,201.00	$2,024.00	$1,874.00	$1,480.00	$1,215.00	$ 735.00	$1,761.00	$1,971.00	$1,706.00	$1,487.00	$1,222.00	$1,220.00	$ 475.00
67% NBS		$ 960.00	$ 706.00	$2,472.00	$1,987.00	$3,188.00	$2,717.00	$3,658.00	$3,188.00	$2,359.00	$3,698.00	$3,423.00	$3,044.00	$2,574.00	$1,745.00	$4,631.00	$4,867.00	$4,397.00	$3,501.00	$3,030.00	$2,431.00	$1,131.00
Whanganui																						
GFA		200		200		500		4320			336		1156			830	1500		5400		900	
34% NBS	$/m²	$ 39.00	$ 39.00	$1,805.00	$1,675.00	$1,975.00	$1,716.00	$2,252.00	$1,993.00	$1,522.00	$2,338.00	$2,235.00	$1,450.00	$1,190.00	$ 719.00	$2,028.00	$2,229.00	$1,969.00	$1,464.00	$1,204.00	$1,340.00	$ 610.00
67% NBS		$1,131.00	$ 882.00	$3,310.00	$2,834.00	$3,972.00	$3,511.00	$4,399.00	$3,938.00	$3,126.00	$4,541.00	$4,383.00	$2,982.00	$2,521.00	$1,709.00	$5,051.00	$4,772.00	$4,311.00	$3,499.00	$3,038.00	$2,577.00	$1,304.00
Fielding																						
GFA		200		200		500		4320			336		1156			830	1500		5400		900	
34% NBS	$/m²	$ 643.00	$ 554.00	$2,165.00	$2,035.00	$2,191.00	$1,931.00	$2,620.00	$2,361.00	$1,890.00	$2,617.00	$2,547.00	$1,491.00	$1,232.00	$ 761.00	$2,207.00	$2,229.00	$1,969.00	$1,466.00	$1,207.00	$1,340.00	$ 610.00
67% NBS		$1,328.00	$1,078.00	$4,362.00	$3,886.00	$4,631.00	$4,170.00	$5,040.00	$4,580.00	$3,767.00	$5,368.00	$5,309.00	$3,027.00	$2,566.00	$1,754.00	$5,605.00	$4,780.00	$4,319.00	$3,569.00	$3,108.00	$2,656.00	$1,383.00
Wellington																						
GFA		200		200		500		4320			336		1156			830	1500		5400		900	
34% NBS	$/m²	$ 711.00	$ 612.00	$2,300.00	$2,156.00	$2,416.00	$2,128.00	$2,977.00	$2,690.00	$2,169.00	$2,972.00	$2,903.00	$1,650.00	$1,362.00	$ 842.00	$2,491.00	$2,465.00	$2,178.00	$1,622.00	$1,335.00	$1,482.00	$ 675.00
67% NBS		$1,491.00	$1,215.00	$4,862.00	$4,336.00	$5,222.00	$4,712.00	$5,694.00	$5,185.00	$4,286.00	$6,166.00	$6,128.00	$3,348.00	$2,838.00	$1,940.00	$6,344.00	$5,287.00	$4,777.00	$3,967.00	$3,458.00	$2,937.00	$1,529.00

F

Appendix F

Fragility Curves – Comparison With HAZUS And CEBA

Appendix F – Fragility Curves - Comparison with HAZUS and CEBA

The following figures show comparison of DBM fragility curves (this study) for each type versus Hazus and fragility curves based on the CEBA data from Christchurch February 2011 event. The exercise of this was to test and review the derived DBM fragility curves carefully by comparing them with international standards and Christchurch data.

For the Christchurch 2011 data, we used NZ research papers, which already tested and calibrated fragility curves with CEBA actual observed damage data from Christchurch event.

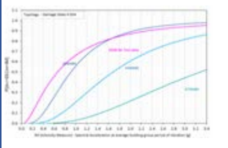
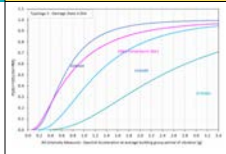
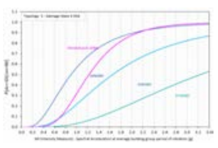
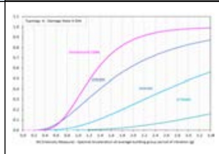
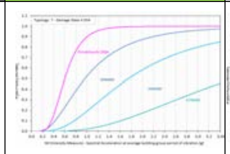
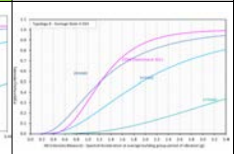
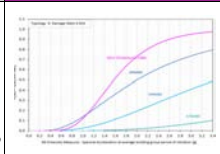
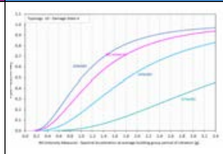
As part of the fragility review, we allocated the building type to the Hazus structural type. Key difference in the comparison of fragility curves is the allocation of the Hazus structural type and spectral displacement associated with each type. The observed differences were attributed to the choice of equivalent Hazus structural types and their associated DS4 spectral displacement capacities. These displacement capacities strongly correlate with the spectral acceleration values observed, confirming that Hazus appropriately reflects the relative collapse capacities of these structural types.

Additionally, the high spectral acceleration values for retrofitted buildings align well with observations from Christchurch, where unstrengthened buildings experienced partial collapses but very few fully collapsed. This supports our calibration, indicating that strengthened structures require higher intensities to reach full collapse. Thus, we believe Hazus is applicable and provides a robust framework for assessing relative building performance in this context.

Fragility Curve - Comparsion of Beca's Displ-Based Method (DBM) vs Christchurch 2011 data vs HAZUS data

Sensitivity: General

Comparision Beca s DBM vs NZ research papers (Christchurch 2011 data)

Structura System	T mber frames w th URM e ements	URM	Pre 1976 RC wa bu d ngs (non duct e)		Pre 1976 RC frame bu d ngs (non duct e)		Post 1976 RC frame bu d ngs (duct e)	Stee MRF + precast parts governed
Typo ogy #	1	2, 3, 4	5	6	7	8	9	10
Mater a	T mber frames+ URM e e	Unreinforced Masonry (URM)	RC walls - lowrise	RC wa s m dr se	RC frames with masonry infill	Pre-1976 RC frames	Post 1976 RC frames	Stee
Compar s on Beca s DBM and Research paper Chr stchurch 2011								
Research paper:	2008 SR Uma, Bothara J, Jury R, King A, Performance Assessment of Existing Buildings in New Zealand	2018, Vaculik, Griffith, "Final report on fragility curves for retrofitted URM buildings"	2017, S.R. Uma(1), V. Sadashiva(2), S.L. Lin(3), M. Nayyerloo(4) , Fragitlity curves for New Zeland buildings with reflections with from Canterbury Earthquake Sequence	2017, S.R. Uma(1), V. Sadashiva(2), S.L. Lin(3), M. Nayyerloo(4) , Fragitlity curves for New Zeland buildings with reflections with from Canterbury Earthquake Sequence	2022, Fikri, R and Ingham, J: Seismic response and aftershock fragility curves for Non-ductile Mid-rise buildings comprised of reinforced concrete frame with masonry infill	2017, S.R. Uma(1), V. Sadashiva(2), S.L. Lin(3), M. Nayyerloo(4) , Fragitlity curves for New Zeland buildings with reflections with from Canterbury Earthquake Sequence	2017, S.R. Uma(1), V. Sadashiva(2), S.L. Lin(3), M. Nayyerloo(4) , Fragitlity curves for New Zeland buildings with reflections with from Canterbury Earthquake Sequence	SR Uma, Brendon A Bradley Displacement based fragility functions for New Zealand buildings subject to ground motion hazard

New Zealand Literature Research data (incl Christchurch 2011 observed data CEBA)

CEBA

Typo ogy #	1		2, 3, 4		5		6		7		8		9		10	
Typo ogy	T mber + URM e ements		Unre nforced Masonry (URM)		RC wa s owr se		RC wa s m dr se		RC frames w th masonry nf		Pre 1976 RC frames		Post 1976 RC frames		Stee	
Unknown *%NBS*	Median θ	Standard deviation β	Median θ	Standard deviation β	Median θ	Standard deviation β	Median θ	Standard deviation β	Median θ	Standard deviation β	Median θ	Standard deviation β	Median θ	Standard deviation β	Median θ	Standard deviation β
DS1 – Slight	0.17	0.8	0.19	0.83	0.189	0.553	0.189	0.553	0.070	0.480	0.189	0.553	0.233	0.571	0.58	0.65
DS2 – Modreate	0.262	0.87	0.37	0.83	0.606	0.433	0.606	0.433	0.180	0.390	0.606	0.443	0.783	0.493	0.73	0.65
DS3 – Extensive	0.42	0.92	0.535	0.83	0.880	0.450	0.880	0.450	0.400	0.390	0.880	0.450	0.804	0.444	0.99	0.65
DS4 – Complete	0.663	0.97	0.735	0.83	1.223	0.425	1.223	0.425	0.600	0.400	1.223	0.425	1.575	0.390	1.24	0.65

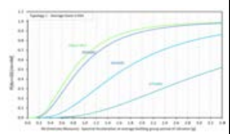
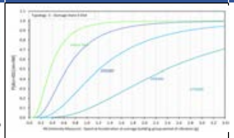
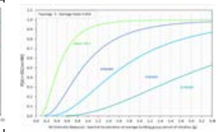
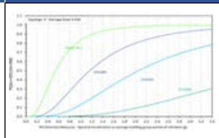
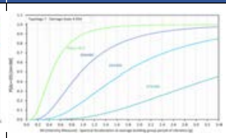
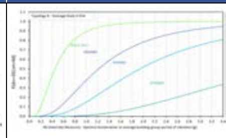
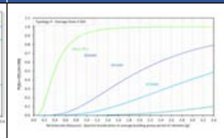
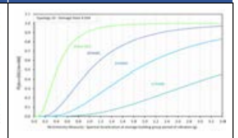
Beca s Displacement Based Method (DBM)

DBM

Typo ogy #	1		2, 3, 4		5		6		7		8		9		10	
Mater a	T mber + URM e ements		Unre nforced Masonry (URM)		RC wa s owr se		RC wa s m dr se		RC frames w th masonry nf		Pre 1976 RC frames		Post 1976 RC frames		Stee	
***20%NBS* Auckland**	Median θ	Standard deviation β	Median θ	Standard deviation β	Median θ	Standard deviation β	Median θ	Standard deviation β	Median θ	Standard deviation β	Median θ	Standard deviation β	Median θ	Standard deviation β	Median θ	Standard deviation β
DS1 – Slight	0.191	0.64	0.169	0.64	0.238	0.64	0.200	0.64	0.230	0.64	0.285	0.64	0.297	0.64	0.300	0.64
DS2 – Modreate	0.320	0.64	0.258	0.64	0.338	0.64	0.308	0.64	0.346	0.64	0.383	0.64	0.435	0.64	0.392	0.64
DS3 – Extensive	0.577	0.64	0.422	0.64	0.556	0.64	0.594	0.64	0.589	0.64	0.680	0.64	0.929	0.64	0.603	0.64
DS4 – Complete	0.908	0.64	0.653	0.64	0.897	0.64	1.165	0.64	0.961	0.64	1.215	0.64	2.003	0.64	1.011	0.64

HAZUS v6.1 Fragility Curve data

Hazus

Typo ogy #	1		2, 3, 4		5		6		7		8		9		10	
Mater a	T mber + URM e ements		Unre nforced Masonry (URM)		RC wa s owr se		RC wa s m dr se		RC frames w th masonry nf		Pre 1976 RC frames		Post 1976 RC frames		Stee	
Compar s on Hazus vs Beca s DBM frag ty curves																
	Median θ	Standard deviation β	Median θ	Standard deviation β	Median θ	Standard deviation β	Median θ	Standard deviation β	Median θ	Standard deviation β	Median θ	Standard deviation β	Median θ	Standard deviation β	Median θ	Standard deviation β
DS1 – Slight	0.187	0.64	0.128	0.64	0.113	0.64	0.108	0.64	0.097	0.64	0.094	0.64	0.089	0.64	0.098	0.64
DS2 – Modreate	0.301	0.64	0.167	0.64	0.153	0.64	0.162	0.64	0.152	0.64	0.136	0.64	0.134	0.64	0.141	0.64
DS3 – Extensive	0.530	0.64	0.256	0.64	0.245	0.64	0.324	0.64	0.271	0.64	0.272	0.64	0.234	0.64	0.238	0.64
DS4 – Complete	0.799	0.64	0.364	0.64	0.430	0.64	0.539	0.64	0.444	0.64	0.451	0.64	0.391	0.64	0.412	0.64

Fragility papers - per Typology

1) Timber lightweight structures with or withuout URM elements

1[1] **2008 SR Uma, Bothara J, Jury R, King A, *Performance Assessment of Existing Buildings in New Zealand***

2) 3) 4) URM buildings

2 [1] **2018, Vaculik, Griffith, "Final report on fragility curves for retrofitted URM buildings"**

2 [2] 2024, Swidan M. 1, and Ingham, J.M., *Empirical clay brick URM building fragility curves based on the 2011 Christchurch Earthquake*

5) + 6) RC wall buildings (low and mid-rise buildings)

5 [1] **2017, S.R. Uma(1), V. Sadashiva(2), S.L. Lin(3), M. Nayyerloo(4) , Fragitlity curves for New Zeland buildings with reflections with from Canterbury Earthquake Sequence**

5 [2] 2011, Uma et al - comparision DS vs main shock NZ (fig 4, T=1.3s)

7) RC frames with masonry infill (low and midrise)

7 [1] 2022, Fikri, R; Dizhur, D and Ingham, J: Empirical vulnerability assessment of reinforced concrete frame with masonry infill buildings in the Canterbury earthquake sequence

7 [2] 2011, S.R Uma, H. Ryu, N. Luco, A.B. Liel, M. Raghunandan, *Comparison of main-shock and aftershock fragility curves developed for New Zealand and US buildings*

7 [3] 2022, R Fikiri, J Ingham: *Seismic response and aftershock fragility curves for non-ductile mid-rise buildings comprised of reinforced concrete frames with masonry infill*

7 [4] 2024, Fikri R, ·Gerstenberger M, Ingham J *Seismic risk assessment for commercial masonry infill buildings within the Auckland region of New Zealand*

8) Pre-1976 RC frames

8 [1] **2017, S.R. Uma(1), V. Sadashiva(2), S.L. Lin(3), M. Nayyerloo(4) , Fragitlity curves for New Zeland buildings with reflections with from Canterbury Earthquake Sequence**

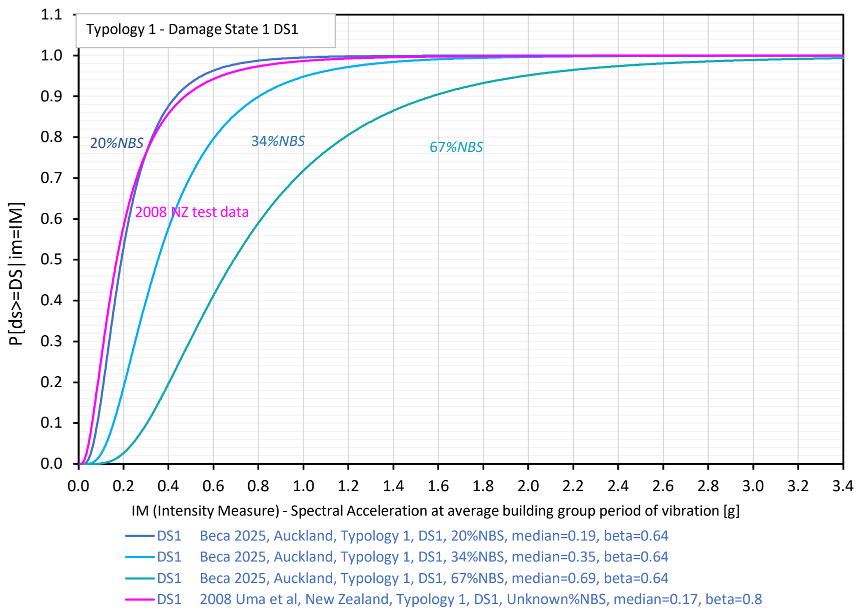
9) Post 1976 RC frames

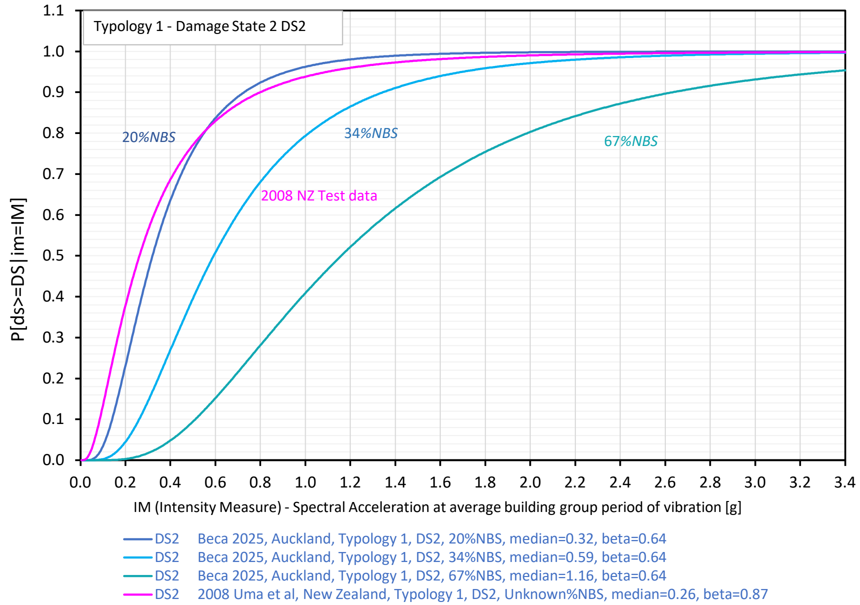
9 [1] **2017, S.R. Uma(1), V. Sadashiva(2), S.L. Lin(3), M. Nayyerloo(4) , Fragitlity curves for New Zeland buildings with reflections with from Canterbury Earthquake Sequence**

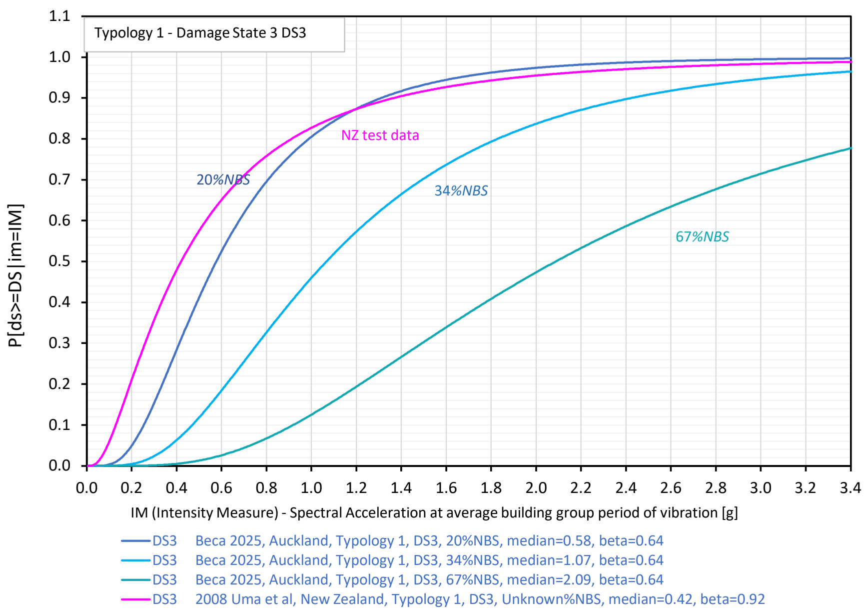
10) Steel MRF buildings

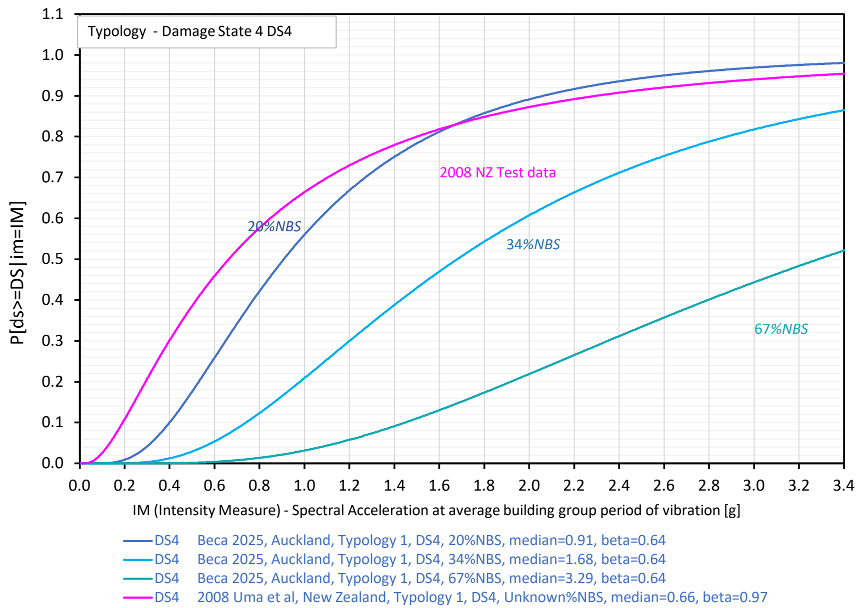
10 [1] **SR Uma, Brendon A Bradley Displacement based fragility functions for New Zealand buildings subject to ground motion hazard**

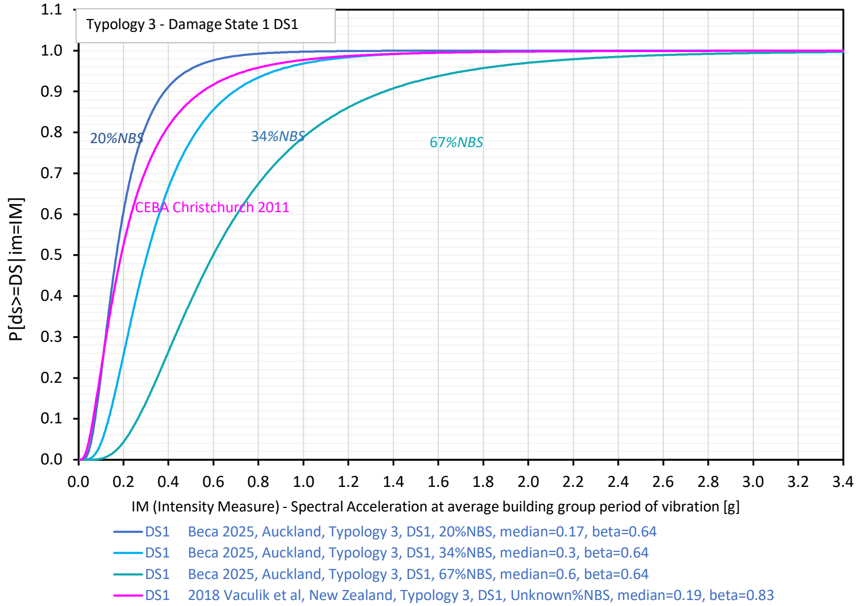
Christchurch 02/2011 (CEBA) comparisons vs DBM fragility curves


Typology 1 - Damage State 1 DS1
P[ds>=DS|im=IM]
IM (Intensity Measure) - Spectral Acceleration at average building group period of vibration [g]
20%NBS
34%NBS
67%NBS
2008 NZ test data
DS1 Beca 2025, Auckland, Typology 1, DS1, 20%NBS, median=0.19, beta=0.64
DS1 Beca 2025, Auckland, Typology 1, DS1, 34%NBS, median=0.35, beta=0.64
DS1 Beca 2025, Auckland, Typology 1, DS1, 67%NBS, median=0.69, beta=0.64
DS1 2008 Uma et al, New Zealand, Typology 1, DS1, Unknown%NBS, median=0.17, beta=0.8

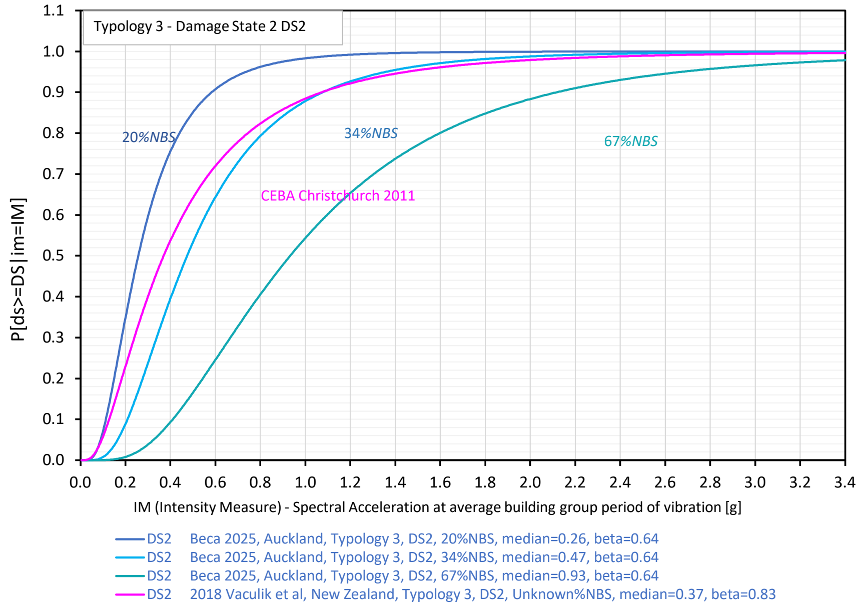

Typology 1 - Damage State 2 DS2
P[ds>=DS|im=IM]
IM (Intensity Measure) - Spectral Acceleration at average building group period of vibration [g]
20%NBS
34%NBS
67%NBS
2008 NZ Test data
DS2 Beca 2025, Auckland, Typology 1, DS2, 20%NBS, median=0.32, beta=0.64
DS2 Beca 2025, Auckland, Typology 1, DS2, 34%NBS, median=0.59, beta=0.64
DS2 Beca 2025, Auckland, Typology 1, DS2, 67%NBS, median=1.16, beta=0.64
DS2 2008 Uma et al, New Zealand, Typology 1, DS2, Unknown%NBS, median=0.26, beta=0.87


Typology 1 - Damage State 3 DS3
P[ds>=DS|im=IM]
IM (Intensity Measure) - Spectral Acceleration at average building group period of vibration [g]
NZ test data
20%NBS
34%NBS
67%NBS
DS3 Beca 2025, Auckland, Typology 1, DS3, 20%NBS, median=0.58, beta=0.64
DS3 Beca 2025, Auckland, Typology 1, DS3, 34%NBS, median=1.07, beta=0.64
DS3 Beca 2025, Auckland, Typology 1, DS3, 67%NBS, median=2.09, beta=0.64
DS3 2008 Uma et al, New Zealand, Typology 1, DS3, Unknown%NBS, median=0.42, beta=0.92

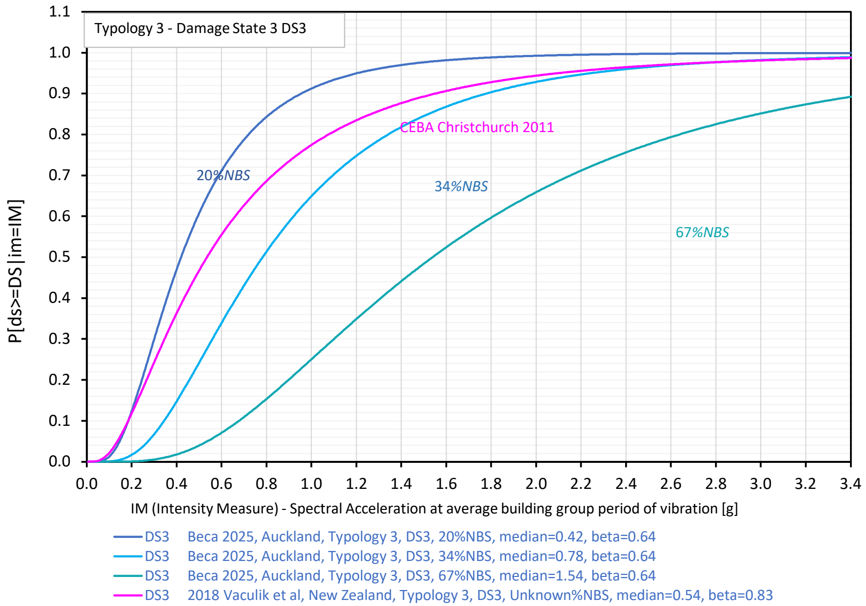

Typology - Damage State 4 DS4
P[ds>=DS|im=IM]
IM (Intensity Measure) - Spectral Acceleration at average building group period of vibration [g]
2008 NZ Test data
20%NBS
34%NBS
67%NBS
DS4 Beca 2025, Auckland, Typology 1, DS4, 20%NBS, median=0.91, beta=0.64
DS4 Beca 2025, Auckland, Typology 1, DS4, 34%NBS, median=1.68, beta=0.64
DS4 Beca 2025, Auckland, Typology 1, DS4, 67%NBS, median=3.29, beta=0.64
DS4 2008 Uma et al, New Zealand, Typology 1, DS4, Unknown%NBS, median=0.66, beta=0.97



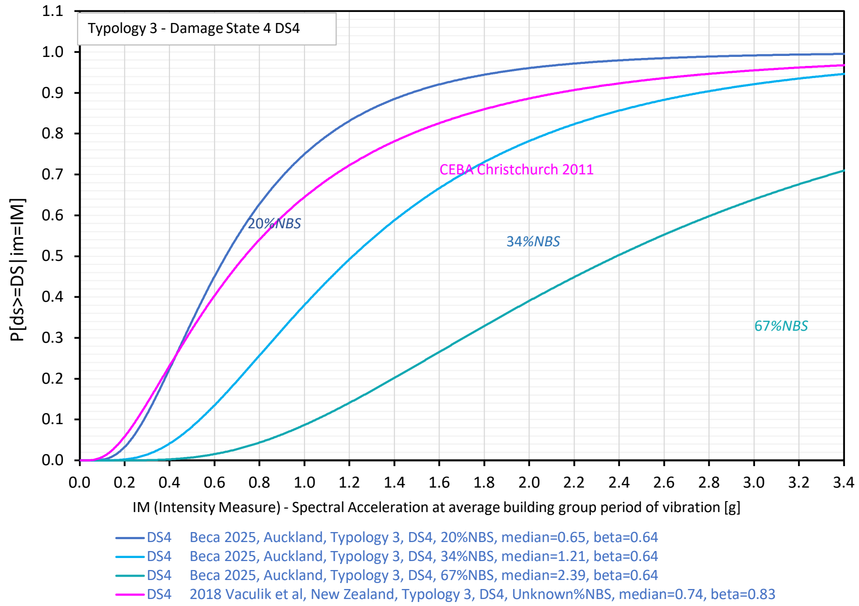
Typology 3 - Damage State 1 DS1
P[ds>=DS|im=IM]
IM (Intensity Measure) - Spectral Acceleration at average building group period of vibration [g]
20%NBS
34%NBS
67%NBS
CEBA Christchurch 2011
DS1 Beca 2025, Auckland, Typology 3, DS1, 20%NBS, median=0.17, beta=0.64
DS1 Beca 2025, Auckland, Typology 3, DS1, 34%NBS, median=0.3, beta=0.64
DS1 Beca 2025, Auckland, Typology 3, DS1, 67%NBS, median=0.6, beta=0.64
DS1 2018 Vaculik et al, New Zealand, Typology 3, DS1, Unknown%NBS, median=0.19, beta=0.83



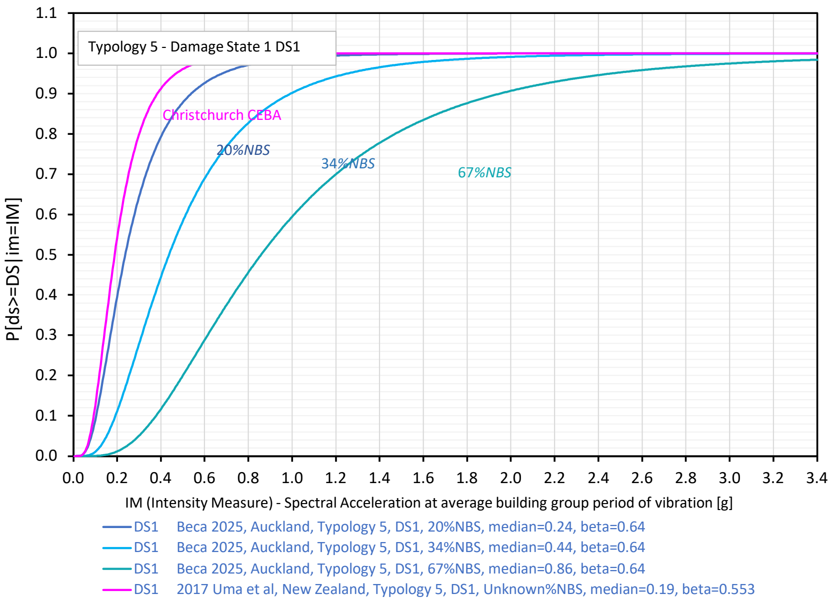
Typology 3 - Damage State 2 DS2
P[ds>=DS|im=IM]
IM (Intensity Measure) - Spectral Acceleration at average building group period of vibration [g]
20%NBS
34%NBS
67%NBS
CEBA Christchurch 2011
DS2 Beca 2025, Auckland, Typology 3, DS2, 20%NBS, median=0.26, beta=0.64
DS2 Beca 2025, Auckland, Typology 3, DS2, 34%NBS, median=0.47, beta=0.64
DS2 Beca 2025, Auckland, Typology 3, DS2, 67%NBS, median=0.93, beta=0.64
DS2 2018 Vaculik et al, New Zealand, Typology 3, DS2, Unknown%NBS, median=0.37, beta=0.83

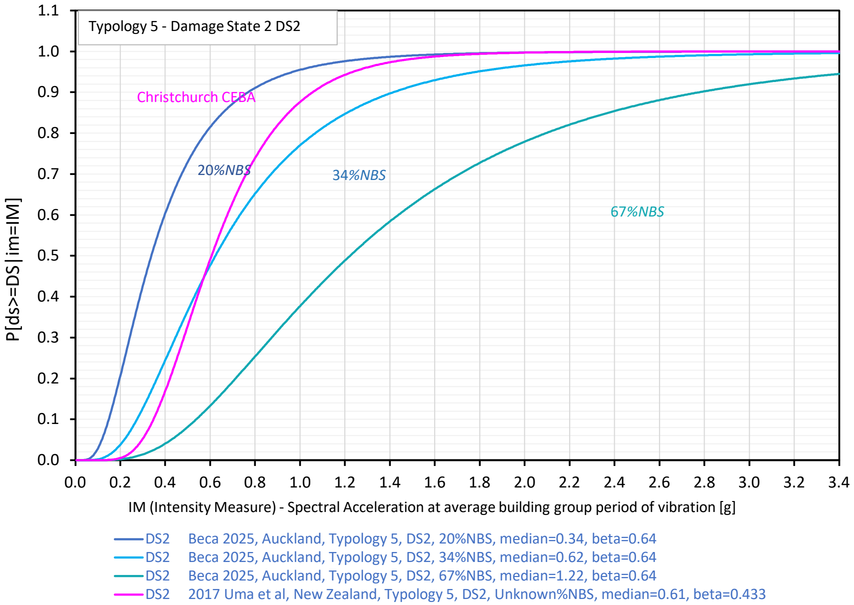


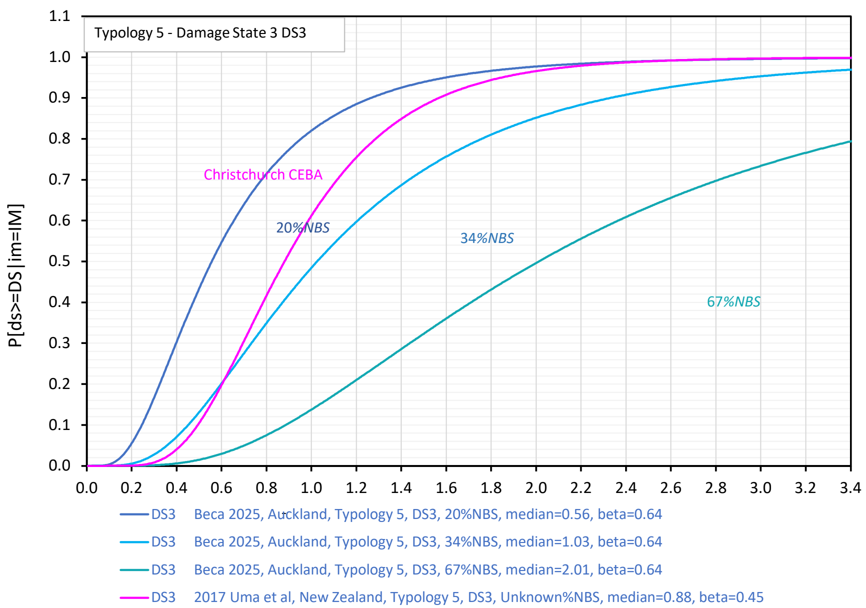
Typology 3 - Damage State 3 DS3
P[ds>=DS|im=IM]
IM (Intensity Measure) - Spectral Acceleration at average building group period of vibration [g]
20%NBS
34%NBS
67%NBS
CEBA Christchurch 2011
DS3 Beca 2025, Auckland, Typology 3, DS3, 20%NBS, median=0.42, beta=0.64
DS3 Beca 2025, Auckland, Typology 3, DS3, 34%NBS, median=0.78, beta=0.64
DS3 Beca 2025, Auckland, Typology 3, DS3, 67%NBS, median=1.54, beta=0.64
DS3 2018 Vaculik et al, New Zealand, Typology 3, DS3, Unknown%NBS, median=0.54, beta=0.83

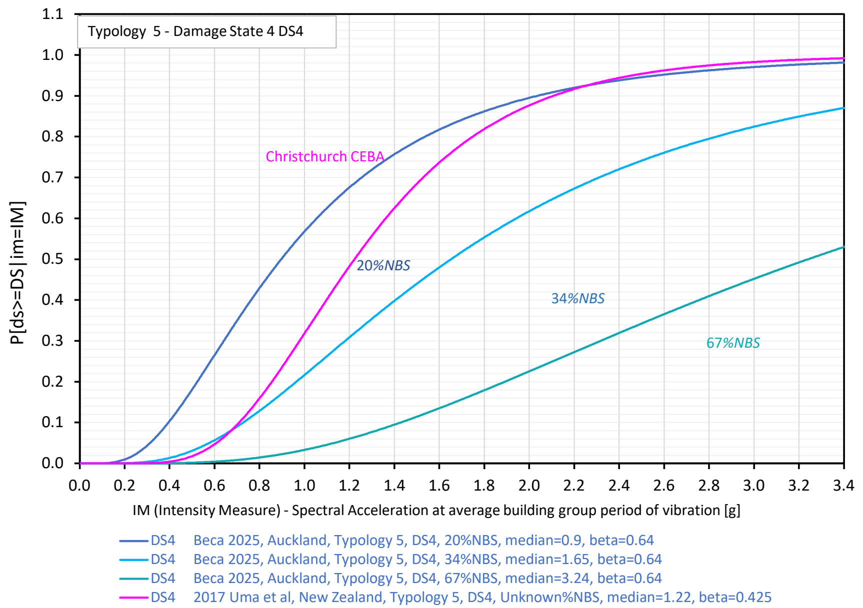


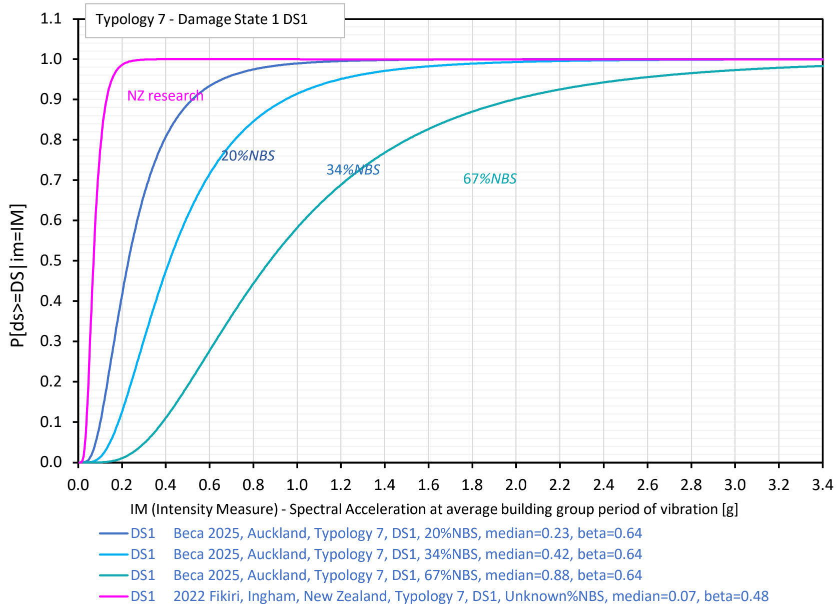
Typology 3 - Damage State 4 DS4
P[ds>=DS|im=IM]
IM (Intensity Measure) - Spectral Acceleration at average building group period of vibration [g]
20%NBS
34%NBS
67%NBS
CEBA Christchurch 2011
DS4 Beca 2025, Auckland, Typology 3, DS4, 20%NBS, median=0.65, beta=0.64
DS4 Beca 2025, Auckland, Typology 3, DS4, 34%NBS, median=1.21, beta=0.64
DS4 Beca 2025, Auckland, Typology 3, DS4, 67%NBS, median=2.39, beta=0.64
DS4 2018 Vaculik et al, New Zealand, Typology 3, DS4, Unknown%NBS, median=0.74, beta=0.83


Typology 5 - Damage State 1 DS1
Christchurch CEBA
20%NBS
34%NBS
67%NBS
P[ds>=DS|im=IM]
IM (Intensity Measure) - Spectral Acceleration at average building group period of vibration [g]
DS1 Beca 2025, Auckland, Typology 5, DS1, 20%NBS, median=0.24, beta=0.64
DS1 Beca 2025, Auckland, Typology 5, DS1, 34%NBS, median=0.44, beta=0.64
DS1 Beca 2025, Auckland, Typology 5, DS1, 67%NBS, median=0.86, beta=0.64
DS1 2017 Uma et al, New Zealand, Typology 5, DS1, Unknown%NBS, median=0.19, beta=0.553

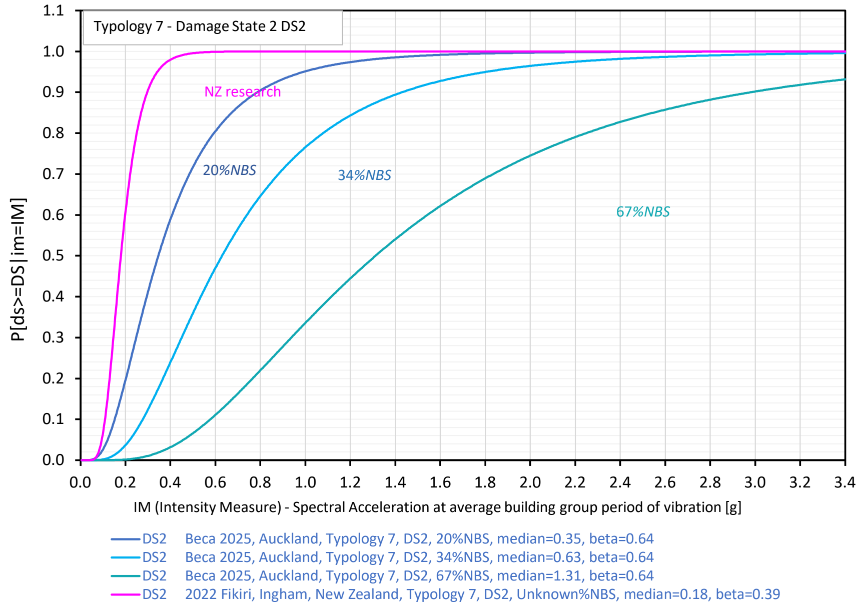

Typology 5 - Damage State 2 DS2
Christchurch CEBA
20%NBS
34%NBS
67%NBS
P[ds>=DS|im=IM]
IM (Intensity Measure) - Spectral Acceleration at average building group period of vibration [g]
DS2 Beca 2025, Auckland, Typology 5, DS2, 20%NBS, median=0.34, beta=0.64
DS2 Beca 2025, Auckland, Typology 5, DS2, 34%NBS, median=0.62, beta=0.64
DS2 Beca 2025, Auckland, Typology 5, DS2, 67%NBS, median=1.22, beta=0.64
DS2 2017 Uma et al, New Zealand, Typology 5, DS2, Unknown%NBS, median=0.61, beta=0.433


Typology 5 - Damage State 3 DS3
Christchurch CEBA
20%NBS
34%NBS
67%NBS
P[ds>=DS|im=IM]
DS3 Beca 2025, Auckland, Typology 5, DS3, 20%NBS, median=0.56, beta=0.64
DS3 Beca 2025, Auckland, Typology 5, DS3, 34%NBS, median=1.03, beta=0.64
DS3 Beca 2025, Auckland, Typology 5, DS3, 67%NBS, median=2.01, beta=0.64
DS3 2017 Uma et al, New Zealand, Typology 5, DS3, Unknown%NBS, median=0.88, beta=0.45

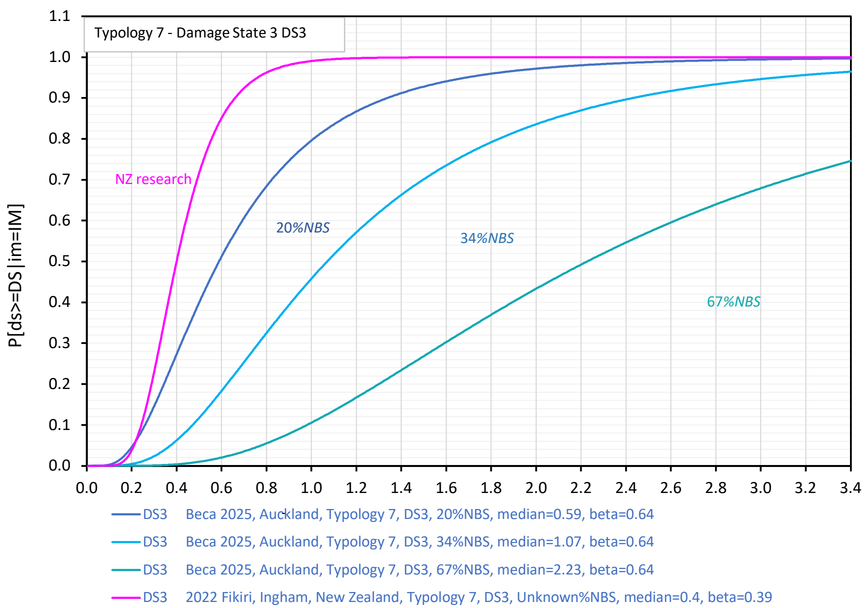

Typology 5 - Damage State 4 DS4
Christchurch CEBA
20%NBS
34%NBS
67%NBS
P[ds>=DS|im=IM]
IM (Intensity Measure) - Spectral Acceleration at average building group period of vibration [g]
DS4 Beca 2025, Auckland, Typology 5, DS4, 20%NBS, median=0.9, beta=0.64
DS4 Beca 2025, Auckland, Typology 5, DS4, 34%NBS, median=1.65, beta=0.64
DS4 Beca 2025, Auckland, Typology 5, DS4, 67%NBS, median=3.24, beta=0.64
DS4 2017 Uma et al, New Zealand, Typology 5, DS4, Unknown%NBS, median=1.22, beta=0.425



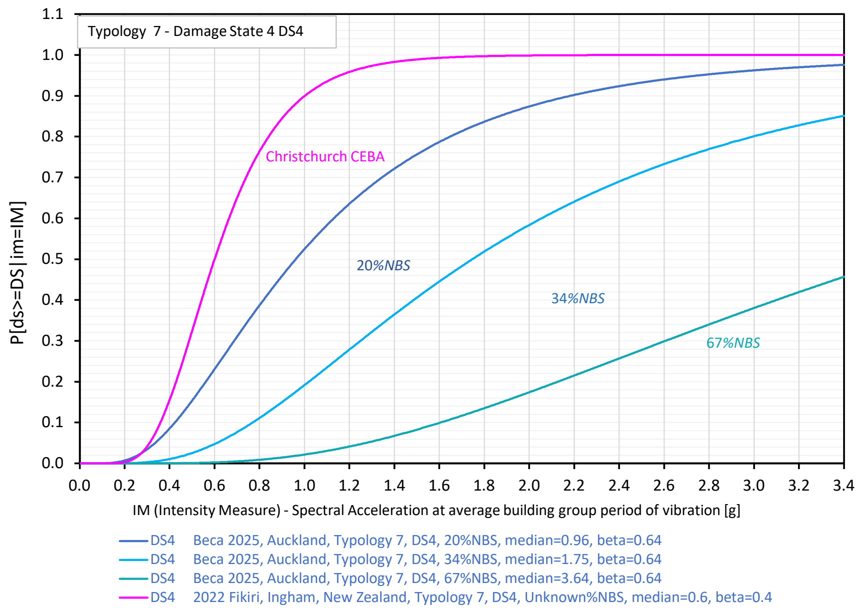
Typology 7 - Damage State 1 DS1
NZ research
20%NBS
34%NBS
67%NBS
P[ds>=DS|im=IM]
IM (Intensity Measure) - Spectral Acceleration at average building group period of vibration [g]
DS1 Beca 2025, Auckland, Typology 7, DS1, 20%NBS, median=0.23, beta=0.64
DS1 Beca 2025, Auckland, Typology 7, DS1, 34%NBS, median=0.42, beta=0.64
DS1 Beca 2025, Auckland, Typology 7, DS1, 67%NBS, median=0.88, beta=0.64
DS1 2022 Fikiri, Ingham, New Zealand, Typology 7, DS1, Unknown%NBS, median=0.07, beta=0.48



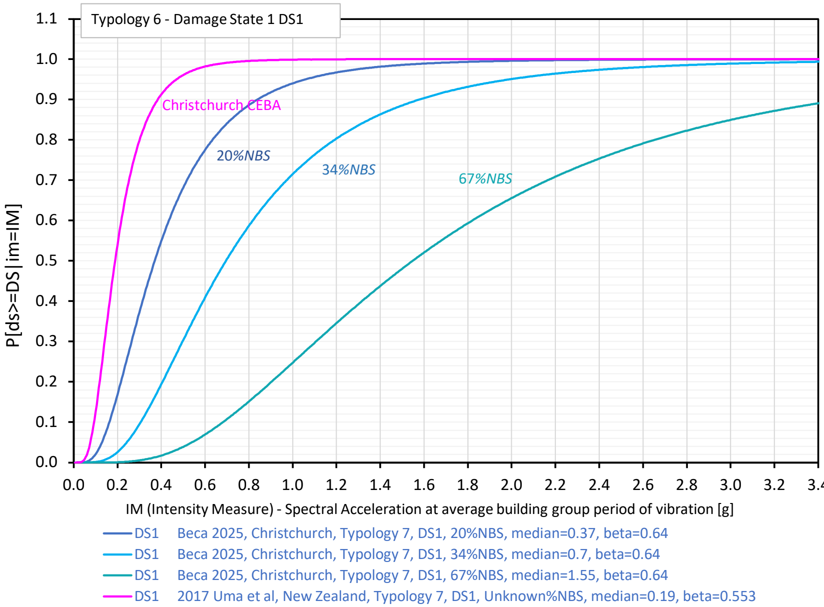
Typology 7 - Damage State 2 DS2
NZ research
20%NBS
34%NBS
67%NBS
P[ds>=DS|im=IM]
IM (Intensity Measure) - Spectral Acceleration at average building group period of vibration [g]
DS2 Beca 2025, Auckland, Typology 7, DS2, 20%NBS, median=0.35, beta=0.64
DS2 Beca 2025, Auckland, Typology 7, DS2, 34%NBS, median=0.63, beta=0.64
DS2 Beca 2025, Auckland, Typology 7, DS2, 67%NBS, median=1.31, beta=0.64
DS2 2022 Fikiri, Ingham, New Zealand, Typology 7, DS2, Unknown%NBS, median=0.18, beta=0.39



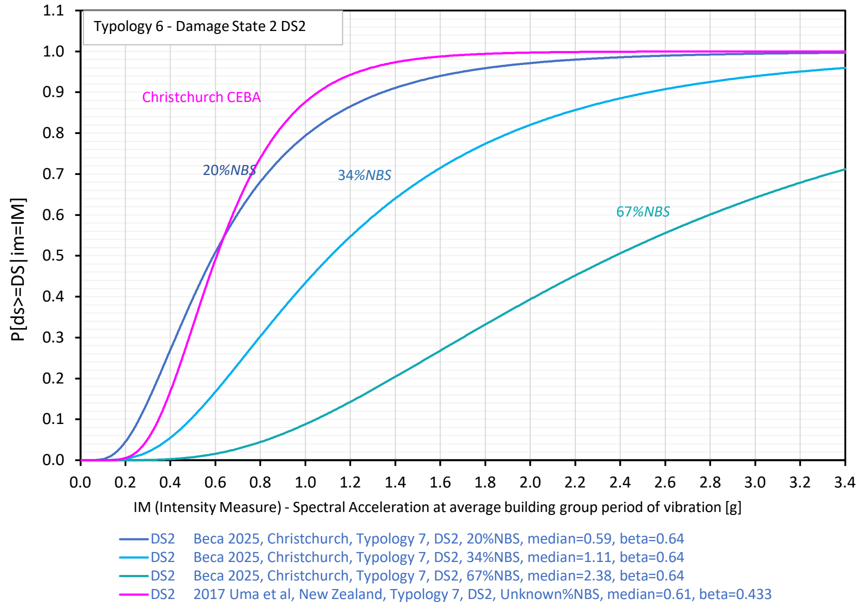
Typology 7 - Damage State 3 DS3
NZ research
20%NBS
34%NBS
67%NBS
P[ds>=DS|im=IM]
DS3 Beca 2025, Auckland, Typology 7, DS3, 20%NBS, median=0.59, beta=0.64
DS3 Beca 2025, Auckland, Typology 7, DS3, 34%NBS, median=1.07, beta=0.64
DS3 Beca 2025, Auckland, Typology 7, DS3, 67%NBS, median=2.23, beta=0.64
DS3 2022 Fikiri, Ingham, New Zealand, Typology 7, DS3, Unknown%NBS, median=0.4, beta=0.39



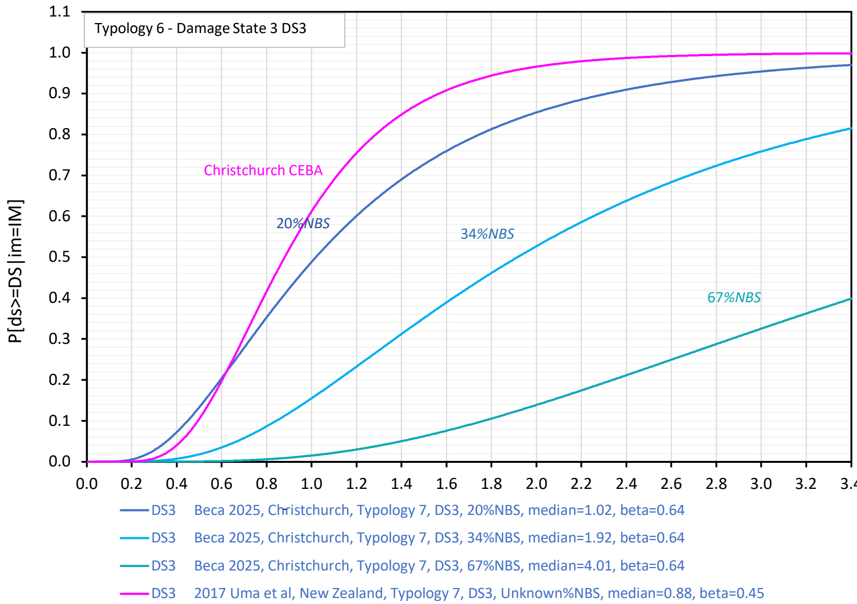
Typology 7 - Damage State 4 DS4
Christchurch CEBA
20%NBS
34%NBS
67%NBS
P[ds>=DS|im=IM]
IM (Intensity Measure) - Spectral Acceleration at average building group period of vibration [g]
DS4 Beca 2025, Auckland, Typology 7, DS4, 20%NBS, median=0.96, beta=0.64
DS4 Beca 2025, Auckland, Typology 7, DS4, 34%NBS, median=1.75, beta=0.64
DS4 Beca 2025, Auckland, Typology 7, DS4, 67%NBS, median=3.64, beta=0.64
DS4 2022 Fikiri, Ingham, New Zealand, Typology 7, DS4, Unknown%NBS, median=0.6, beta=0.4



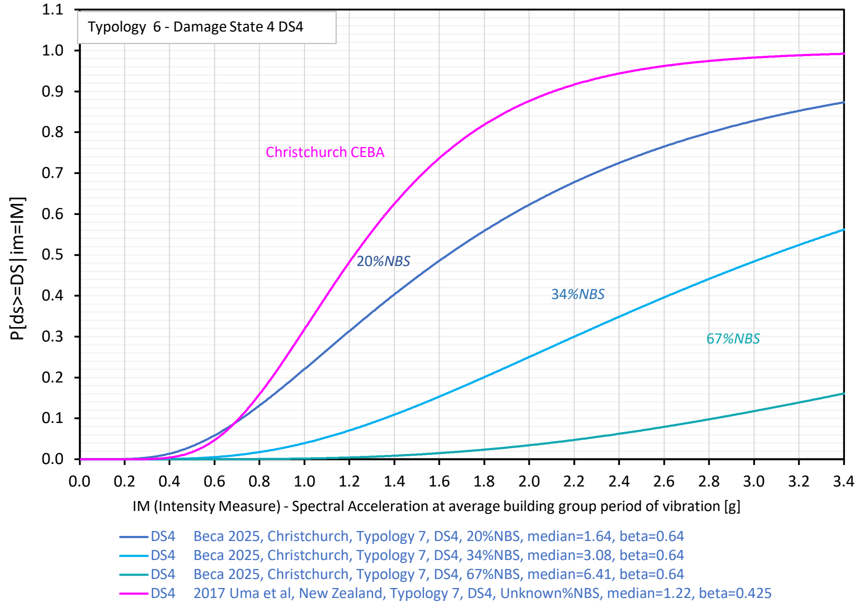
Typology 6 - Damage State 1 DS1
Christchurch CEBA
20%NBS
34%NBS
67%NBS
P[ds>=DS|im=IM]
IM (Intensity Measure) - Spectral Acceleration at average building group period of vibration [g]
DS1 Beca 2025, Christchurch, Typology 7, DS1, 20%NBS, median=0.37, beta=0.64
DS1 Beca 2025, Christchurch, Typology 7, DS1, 34%NBS, median=0.7, beta=0.64
DS1 Beca 2025, Christchurch, Typology 7, DS1, 67%NBS, median=1.55, beta=0.64
DS1 2017 Uma et al, New Zealand, Typology 7, DS1, Unknown%NBS, median=0.19, beta=0.553



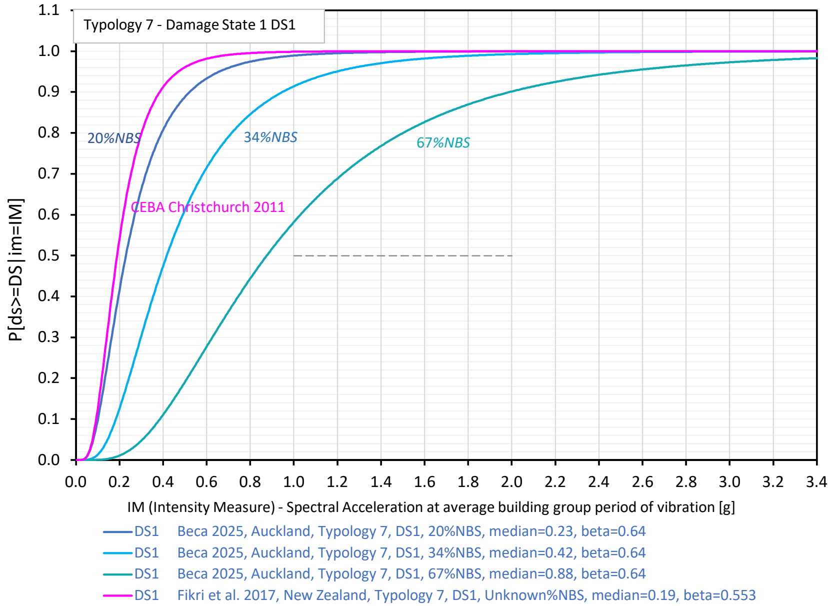
Typology 6 - Damage State 2 DS2
Christchurch CEBA
20%NBS
34%NBS
67%NBS
P[ds>=DS|im=IM]
IM (Intensity Measure) - Spectral Acceleration at average building group period of vibration [g]
DS2 Beca 2025, Christchurch, Typology 7, DS2, 20%NBS, median=0.59, beta=0.64
DS2 Beca 2025, Christchurch, Typology 7, DS2, 34%NBS, median=1.11, beta=0.64
DS2 Beca 2025, Christchurch, Typology 7, DS2, 67%NBS, median=2.38, beta=0.64
DS2 2017 Uma et al, New Zealand, Typology 7, DS2, Unknown%NBS, median=0.61, beta=0.433

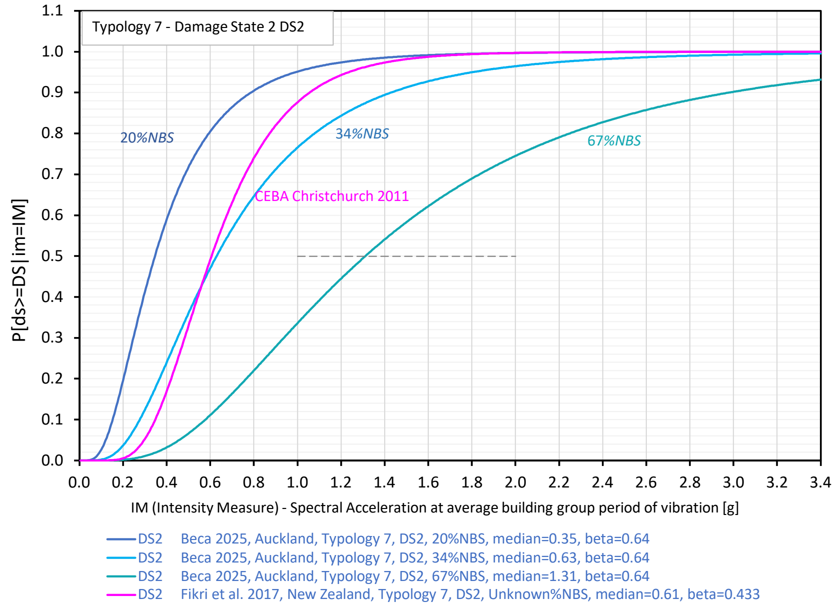


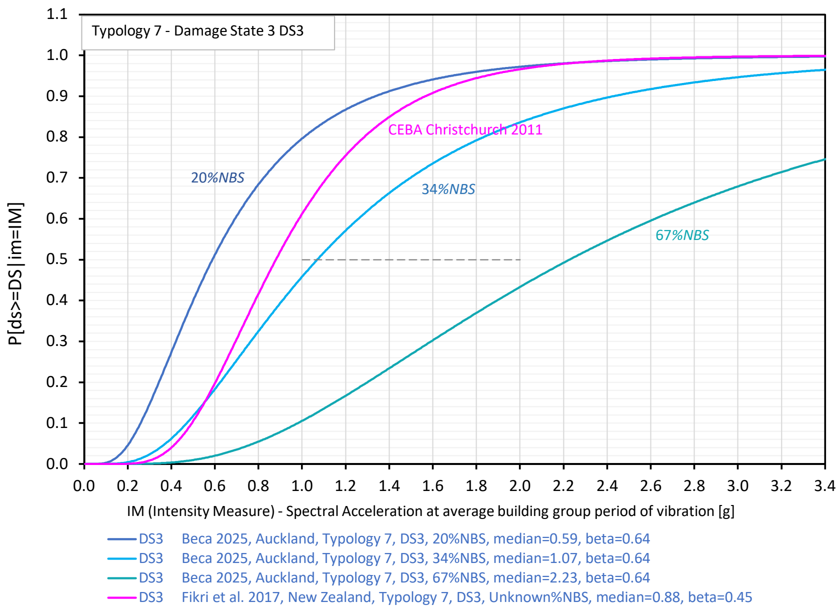
Typology 6 - Damage State 3 DS3
Christchurch CEBA
20%NBS
34%NBS
67%NBS
P[ds>=DS|im=IM]
DS3 Beca 2025, Christchurch, Typology 7, DS3, 20%NBS, median=1.02, beta=0.64
DS3 Beca 2025, Christchurch, Typology 7, DS3, 34%NBS, median=1.92, beta=0.64
DS3 Beca 2025, Christchurch, Typology 7, DS3, 67%NBS, median=4.01, beta=0.64
DS3 2017 Uma et al, New Zealand, Typology 7, DS3, Unknown%NBS, median=0.88, beta=0.45

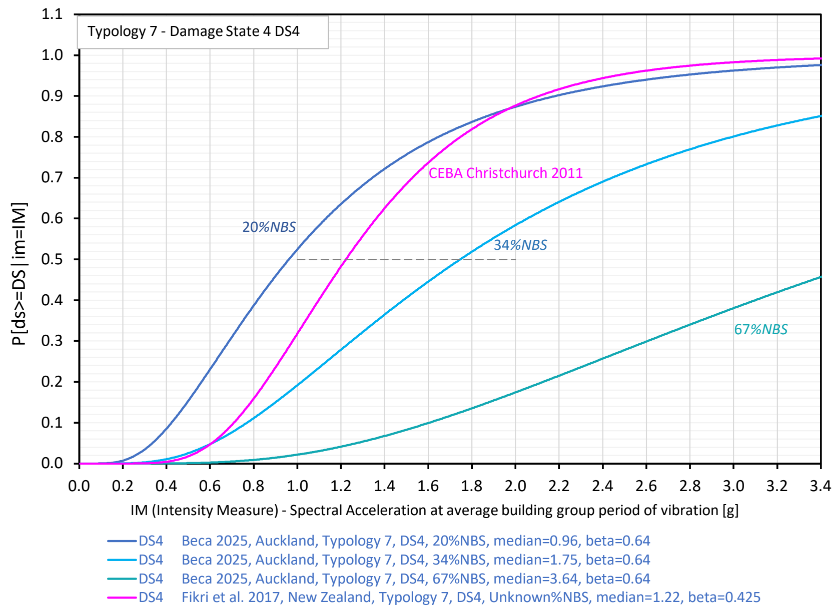


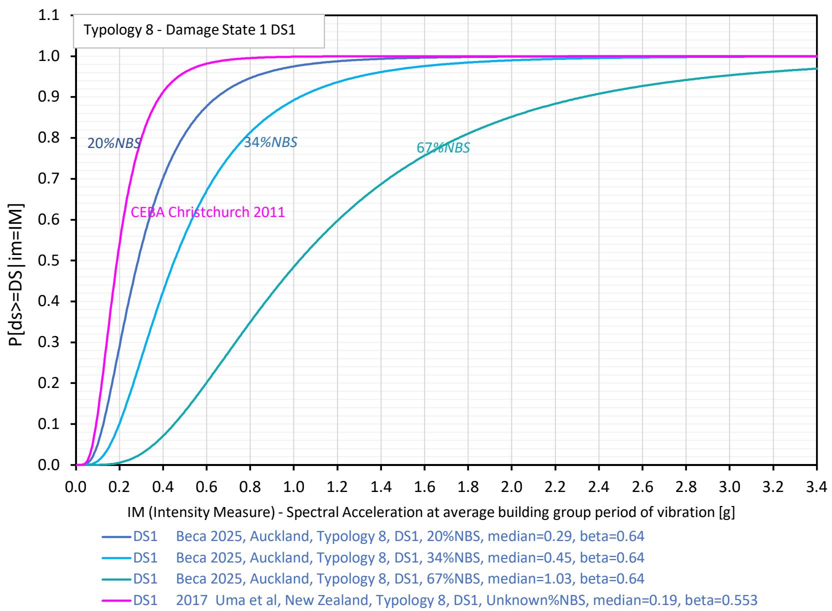
Typology 6 - Damage State 4 DS4
Christchurch CEBA
20%NBS
34%NBS
67%NBS
P[ds>=DS|im=IM]
IM (Intensity Measure) - Spectral Acceleration at average building group period of vibration [g]
DS4 Beca 2025, Christchurch, Typology 7, DS4, 20%NBS, median=1.64, beta=0.64
DS4 Beca 2025, Christchurch, Typology 7, DS4, 34%NBS, median=3.08, beta=0.64
DS4 Beca 2025, Christchurch, Typology 7, DS4, 67%NBS, median=6.41, beta=0.64
DS4 2017 Uma et al, New Zealand, Typology 7, DS4, Unknown%NBS, median=1.22, beta=0.425

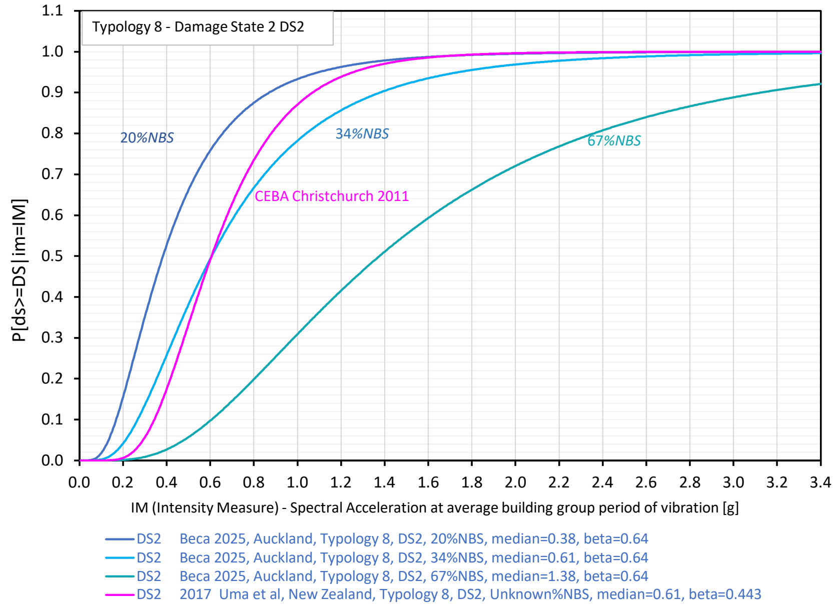

Typology 7 - Damage State 1 DS1
20%NBS
34%NBS
67%NBS
CEBA Christchurch 2011
P[ds>=DS|im=IM]
IM (Intensity Measure) - Spectral Acceleration at average building group period of vibration [g]
DS1 Beca 2025, Auckland, Typology 7, DS1, 20%NBS, median=0.23, beta=0.64
DS1 Beca 2025, Auckland, Typology 7, DS1, 34%NBS, median=0.42, beta=0.64
DS1 Beca 2025, Auckland, Typology 7, DS1, 67%NBS, median=0.88, beta=0.64
DS1 Fikri et al. 2017, New Zealand, Typology 7, DS1, Unknown%NBS, median=0.19, beta=0.553

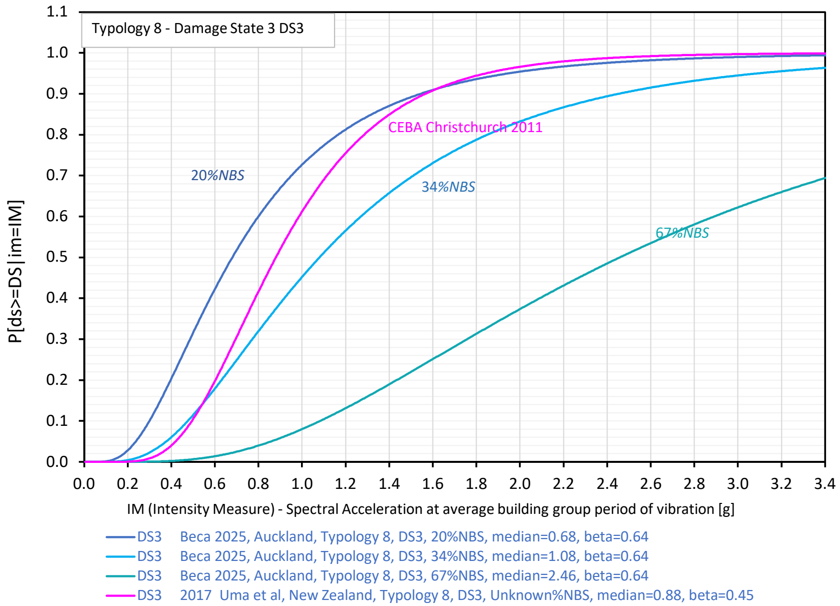

Typology 7 - Damage State 2 DS2
20%NBS
34%NBS
67%NBS
CEBA Christchurch 2011
P[ds>=DS|im=IM]
IM (Intensity Measure) - Spectral Acceleration at average building group period of vibration [g]
DS2 Beca 2025, Auckland, Typology 7, DS2, 20%NBS, median=0.35, beta=0.64
DS2 Beca 2025, Auckland, Typology 7, DS2, 34%NBS, median=0.63, beta=0.64
DS2 Beca 2025, Auckland, Typology 7, DS2, 67%NBS, median=1.31, beta=0.64
DS2 Fikri et al. 2017, New Zealand, Typology 7, DS2, Unknown%NBS, median=0.61, beta=0.433

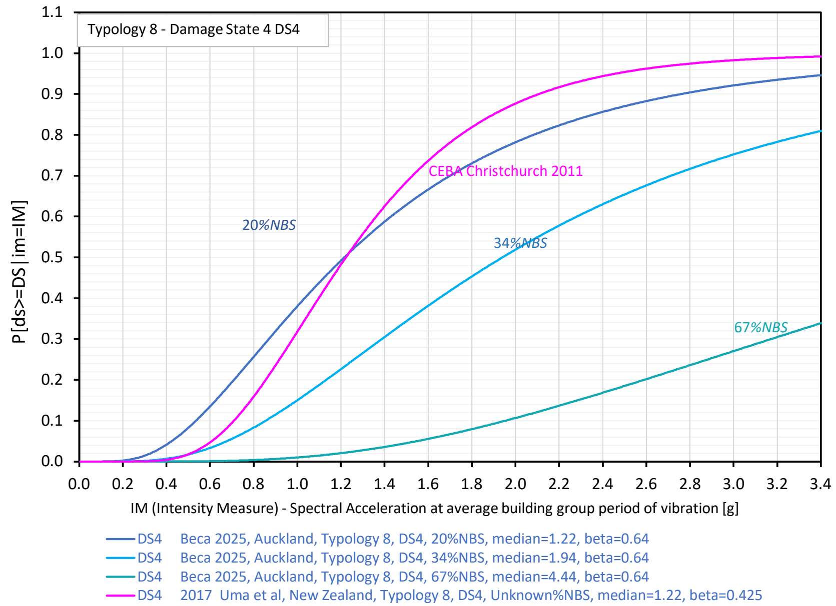

Typology 7 - Damage State 3 DS3
CEBA Christchurch 2011
20%NBS
34%NBS
67%NBS
P[ds>=DS|im=IM]
IM (Intensity Measure) - Spectral Acceleration at average building group period of vibration [g]
DS3 Beca 2025, Auckland, Typology 7, DS3, 20%NBS, median=0.59, beta=0.64
DS3 Beca 2025, Auckland, Typology 7, DS3, 34%NBS, median=1.07, beta=0.64
DS3 Beca 2025, Auckland, Typology 7, DS3, 67%NBS, median=2.23, beta=0.64
DS3 Fikri et al. 2017, New Zealand, Typology 7, DS3, Unknown%NBS, median=0.88, beta=0.45

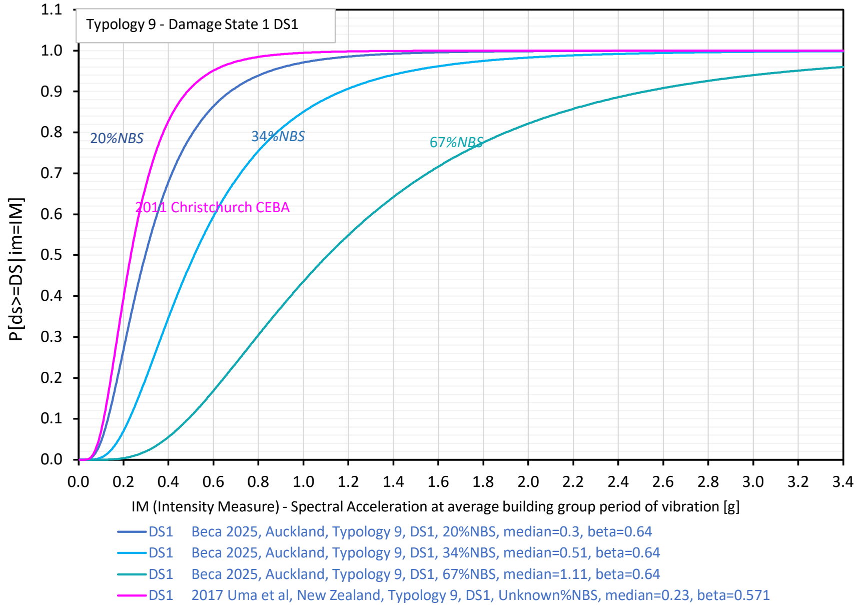

Typology 7 - Damage State 4 DS4
CEBA Christchurch 2011
20%NBS
34%NBS
67%NBS
P[ds>=DS|im=IM]
IM (Intensity Measure) - Spectral Acceleration at average building group period of vibration [g]
DS4 Beca 2025, Auckland, Typology 7, DS4, 20%NBS, median=0.96, beta=0.64
DS4 Beca 2025, Auckland, Typology 7, DS4, 34%NBS, median=1.75, beta=0.64
DS4 Beca 2025, Auckland, Typology 7, DS4, 67%NBS, median=3.64, beta=0.64
DS4 Fikri et al. 2017, New Zealand, Typology 7, DS4, Unknown%NBS, median=1.22, beta=0.425

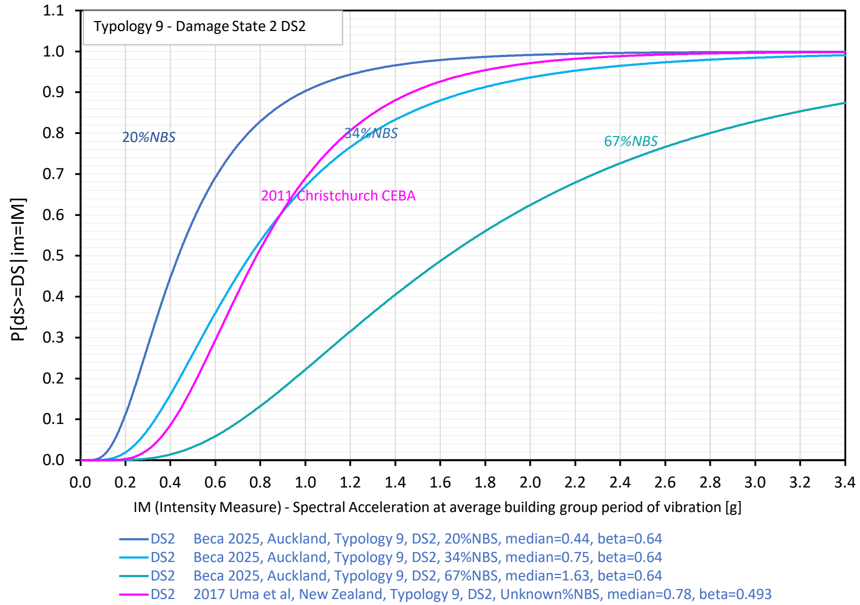

Typology 8 - Damage State 1 DS1
P[ds>=DS|im=IM]
IM (Intensity Measure) - Spectral Acceleration at average building group period of vibration [g]
20%NBS
34%NBS
67%NBS
CEBA Christchurch 2011
DS1 Beca 2025, Auckland, Typology 8, DS1, 20%NBS, median=0.29, beta=0.64
DS1 Beca 2025, Auckland, Typology 8, DS1, 34%NBS, median=0.45, beta=0.64
DS1 Beca 2025, Auckland, Typology 8, DS1, 67%NBS, median=1.03, beta=0.64
DS1 2017 Uma et al, New Zealand, Typology 8, DS1, Unknown%NBS, median=0.19, beta=0.553

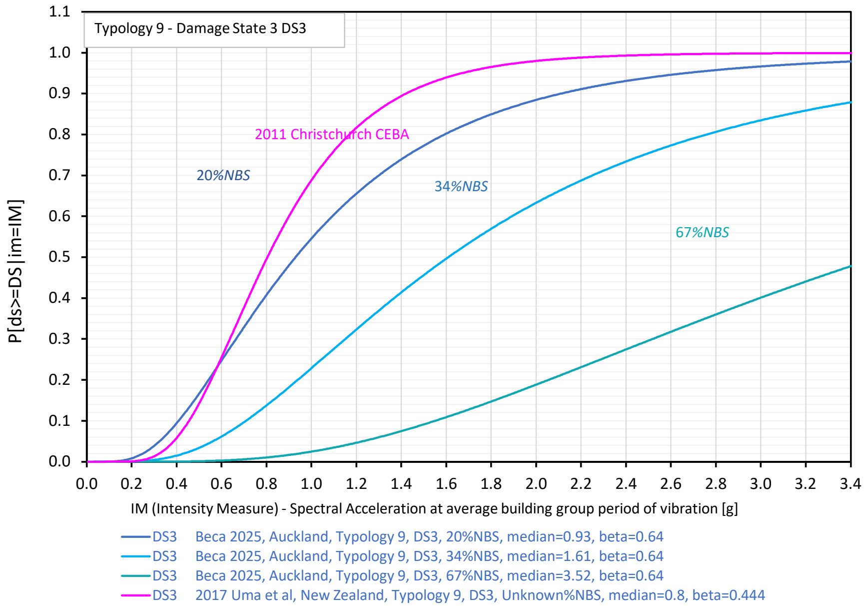

Typology 8 - Damage State 2 DS2
P[ds>=DS|im=IM]
IM (Intensity Measure) - Spectral Acceleration at average building group period of vibration [g]
20%NBS
34%NBS
67%NBS
CEBA Christchurch 2011
DS2 Beca 2025, Auckland, Typology 8, DS2, 20%NBS, median=0.38, beta=0.64
DS2 Beca 2025, Auckland, Typology 8, DS2, 34%NBS, median=0.61, beta=0.64
DS2 Beca 2025, Auckland, Typology 8, DS2, 67%NBS, median=1.38, beta=0.64
DS2 2017 Uma et al, New Zealand, Typology 8, DS2, Unknown%NBS, median=0.61, beta=0.443

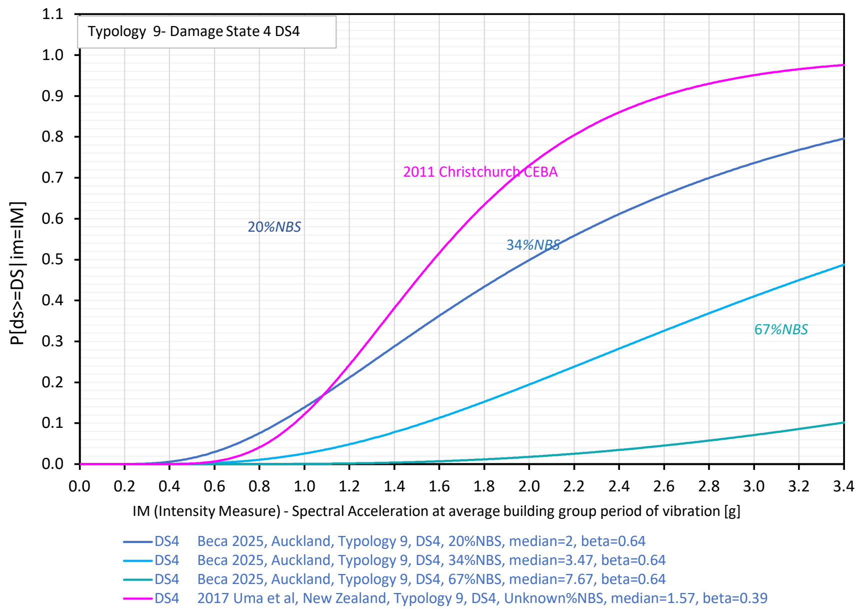

Typology 8 - Damage State 3 DS3
P[ds>=DS|im=IM]
IM (Intensity Measure) - Spectral Acceleration at average building group period of vibration [g]
CEBA Christchurch 2011
20%NBS
34%NBS
67%NBS
DS3 Beca 2025, Auckland, Typology 8, DS3, 20%NBS, median=0.68, beta=0.64
DS3 Beca 2025, Auckland, Typology 8, DS3, 34%NBS, median=1.08, beta=0.64
DS3 Beca 2025, Auckland, Typology 8, DS3, 67%NBS, median=2.46, beta=0.64
DS3 2017 Uma et al, New Zealand, Typology 8, DS3, Unknown%NBS, median=0.88, beta=0.45

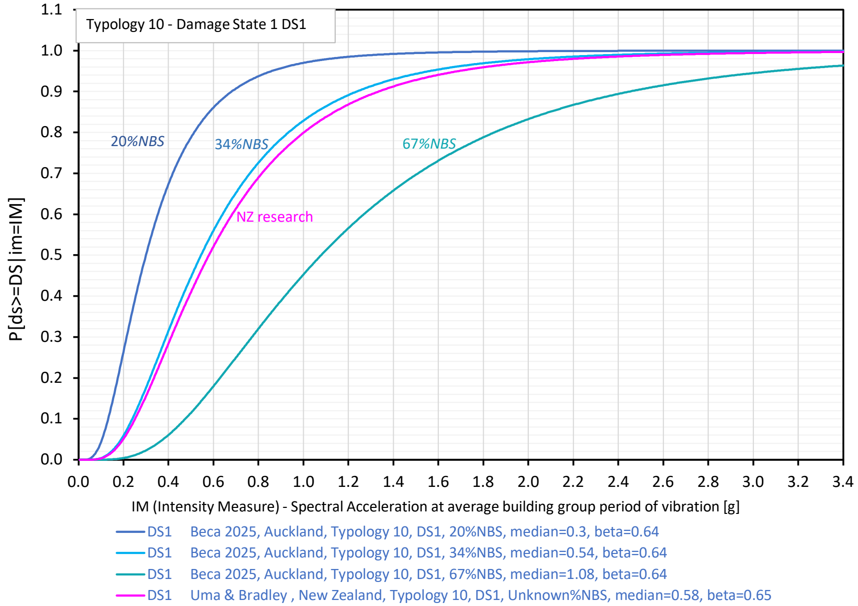

Typology 8 - Damage State 4 DS4
P[ds>=DS|im=IM]
IM (Intensity Measure) - Spectral Acceleration at average building group period of vibration [g]
CEBA Christchurch 2011
20%NBS
34%NBS
67%NBS
DS4 Beca 2025, Auckland, Typology 8, DS4, 20%NBS, median=1.22, beta=0.64
DS4 Beca 2025, Auckland, Typology 8, DS4, 34%NBS, median=1.94, beta=0.64
DS4 Beca 2025, Auckland, Typology 8, DS4, 67%NBS, median=4.44, beta=0.64
DS4 2017 Uma et al, New Zealand, Typology 8, DS4, Unknown%NBS, median=1.22, beta=0.425

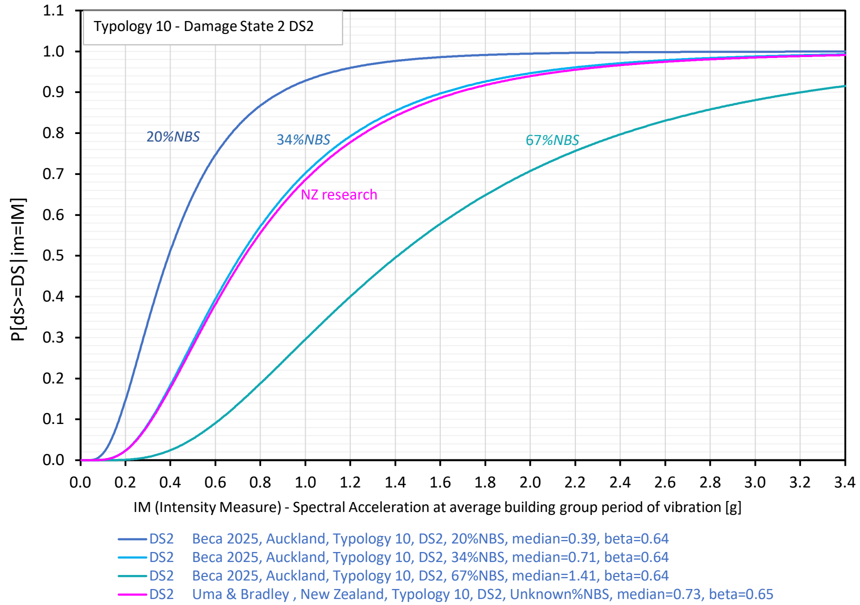

Typology 9 - Damage State 1 DS1
P[ds>=DS|im=IM]
IM (Intensity Measure) - Spectral Acceleration at average building group period of vibration [g]
20%NBS
34%NBS
67%NBS
2011 Christchurch CEBA
DS1 Beca 2025, Auckland, Typology 9, DS1, 20%NBS, median=0.3, beta=0.64
DS1 Beca 2025, Auckland, Typology 9, DS1, 34%NBS, median=0.51, beta=0.64
DS1 Beca 2025, Auckland, Typology 9, DS1, 67%NBS, median=1.11, beta=0.64
DS1 2017 Uma et al, New Zealand, Typology 9, DS1, Unknown%NBS, median=0.23, beta=0.571

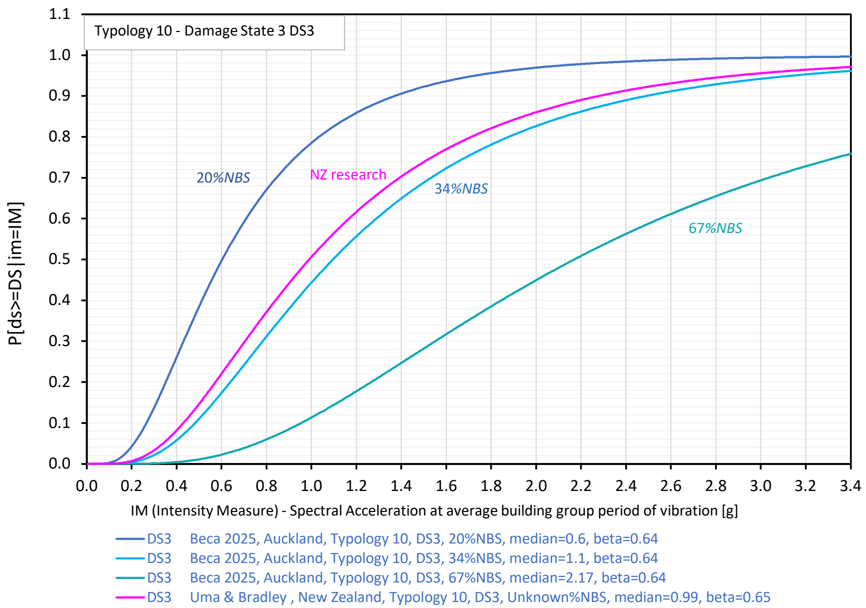

Typology 9 - Damage State 2 DS2
P[ds>=DS|im=IM]
IM (Intensity Measure) - Spectral Acceleration at average building group period of vibration [g]
20%NBS
34%NBS
67%NBS
2011 Christchurch CEBA
DS2 Beca 2025, Auckland, Typology 9, DS2, 20%NBS, median=0.44, beta=0.64
DS2 Beca 2025, Auckland, Typology 9, DS2, 34%NBS, median=0.75, beta=0.64
DS2 Beca 2025, Auckland, Typology 9, DS2, 67%NBS, median=1.63, beta=0.64
DS2 2017 Uma et al, New Zealand, Typology 9, DS2, Unknown%NBS, median=0.78, beta=0.493

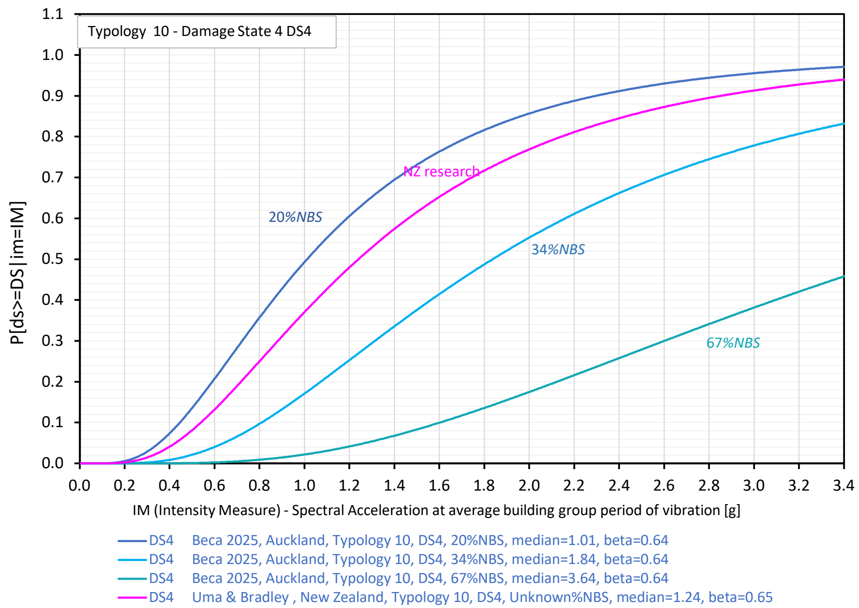

Typology 9 - Damage State 3 DS3
P[ds>=DS|im=IM]
IM (Intensity Measure) - Spectral Acceleration at average building group period of vibration [g]
2011 Christchurch CEBA
20%NBS
34%NBS
67%NBS
DS3 Beca 2025, Auckland, Typology 9, DS3, 20%NBS, median=0.93, beta=0.64
DS3 Beca 2025, Auckland, Typology 9, DS3, 34%NBS, median=1.61, beta=0.64
DS3 Beca 2025, Auckland, Typology 9, DS3, 67%NBS, median=3.52, beta=0.64
DS3 2017 Uma et al, New Zealand, Typology 9, DS3, Unknown%NBS, median=0.8, beta=0.444

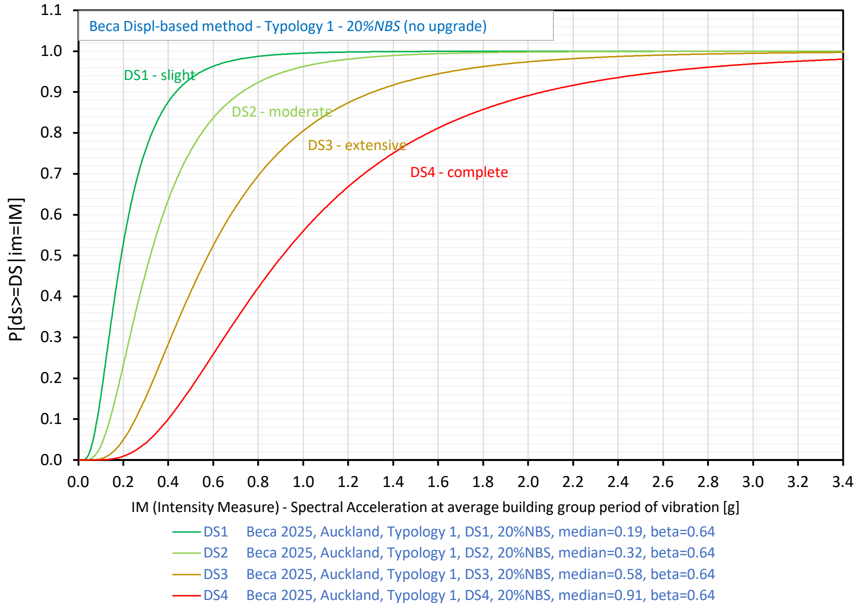

Typology 9- Damage State 4 DS4
P[ds>=DS|im=IM]
IM (Intensity Measure) - Spectral Acceleration at average building group period of vibration [g]
2011 Christchurch CEBA
20%NBS
34%NBS
67%NBS
DS4 Beca 2025, Auckland, Typology 9, DS4, 20%NBS, median=2, beta=0.64
DS4 Beca 2025, Auckland, Typology 9, DS4, 34%NBS, median=3.47, beta=0.64
DS4 Beca 2025, Auckland, Typology 9, DS4, 67%NBS, median=7.67, beta=0.64
DS4 2017 Uma et al, New Zealand, Typology 9, DS4, Unknown%NBS, median=1.57, beta=0.39


Typology 10 - Damage State 1 DS1
P[ds>=DS|im=IM]
IM (Intensity Measure) - Spectral Acceleration at average building group period of vibration [g]
20%NBS
34%NBS
67%NBS
NZ research
DS1 Beca 2025, Auckland, Typology 10, DS1, 20%NBS, median=0.3, beta=0.64
DS1 Beca 2025, Auckland, Typology 10, DS1, 34%NBS, median=0.54, beta=0.64
DS1 Beca 2025, Auckland, Typology 10, DS1, 67%NBS, median=1.08, beta=0.64
DS1 Uma & Bradley , New Zealand, Typology 10, DS1, Unknown%NBS, median=0.58, beta=0.65

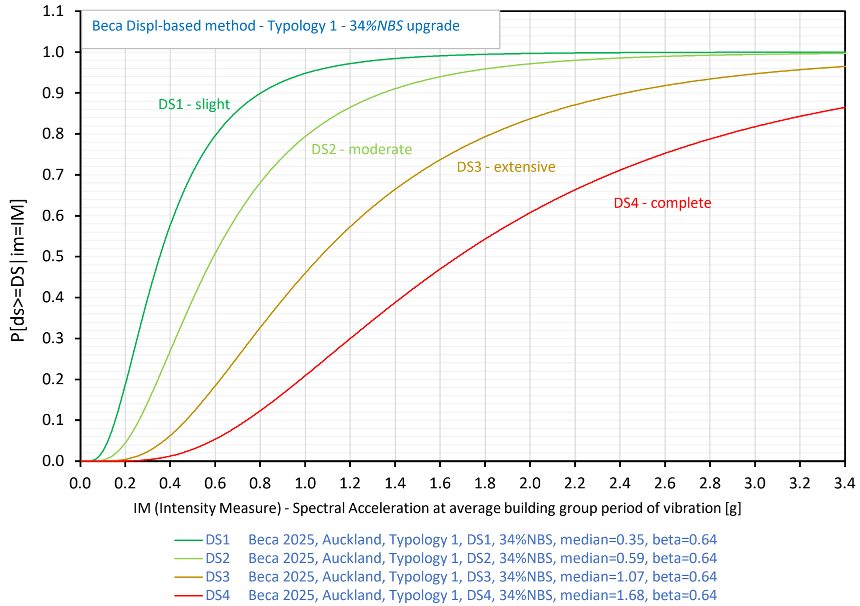

Typology 10 - Damage State 2 DS2
P[ds>=DS|im=IM]
IM (Intensity Measure) - Spectral Acceleration at average building group period of vibration [g]
20%NBS
34%NBS
67%NBS
NZ research
DS2 Beca 2025, Auckland, Typology 10, DS2, 20%NBS, median=0.39, beta=0.64
DS2 Beca 2025, Auckland, Typology 10, DS2, 34%NBS, median=0.71, beta=0.64
DS2 Beca 2025, Auckland, Typology 10, DS2, 67%NBS, median=1.41, beta=0.64
DS2 Uma & Bradley , New Zealand, Typology 10, DS2, Unknown%NBS, median=0.73, beta=0.65


Typology 10 - Damage State 3 DS3
P[ds>=DS|im=IM]
IM (Intensity Measure) - Spectral Acceleration at average building group period of vibration [g]
20%NBS
NZ research
34%NBS
67%NBS
DS3 Beca 2025, Auckland, Typology 10, DS3, 20%NBS, median=0.6, beta=0.64
DS3 Beca 2025, Auckland, Typology 10, DS3, 34%NBS, median=1.1, beta=0.64
DS3 Beca 2025, Auckland, Typology 10, DS3, 67%NBS, median=2.17, beta=0.64
DS3 Uma & Bradley , New Zealand, Typology 10, DS3, Unknown%NBS, median=0.99, beta=0.65

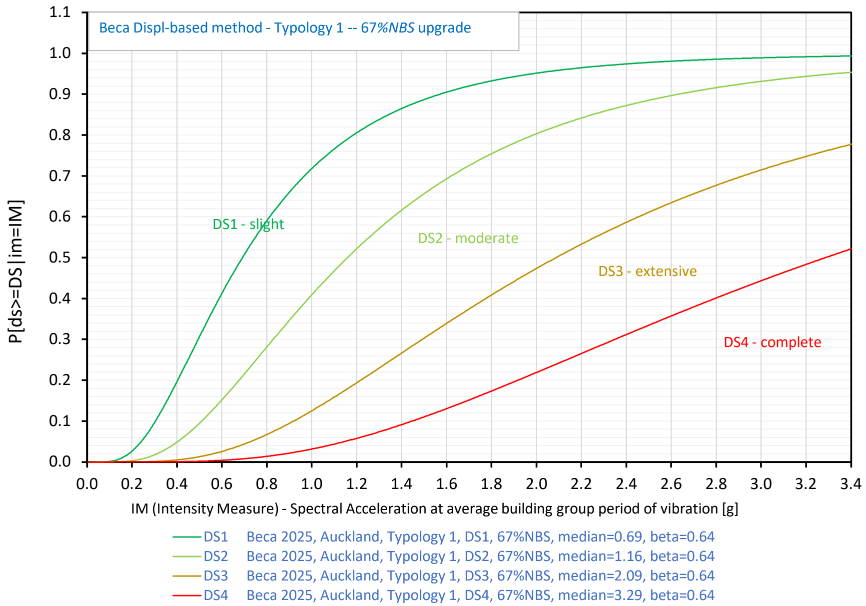

Typology 10 - Damage State 4 DS4
P[ds>=DS|im=IM]
IM (Intensity Measure) - Spectral Acceleration at average building group period of vibration [g]
NZ research
20%NBS
34%NBS
67%NBS
DS4 Beca 2025, Auckland, Typology 10, DS4, 20%NBS, median=1.01, beta=0.64
DS4 Beca 2025, Auckland, Typology 10, DS4, 34%NBS, median=1.84, beta=0.64
DS4 Beca 2025, Auckland, Typology 10, DS4, 67%NBS, median=3.64, beta=0.64
DS4 Uma & Bradley , New Zealand, Typology 10, DS4, Unknown%NBS, median=1.24, beta=0.65



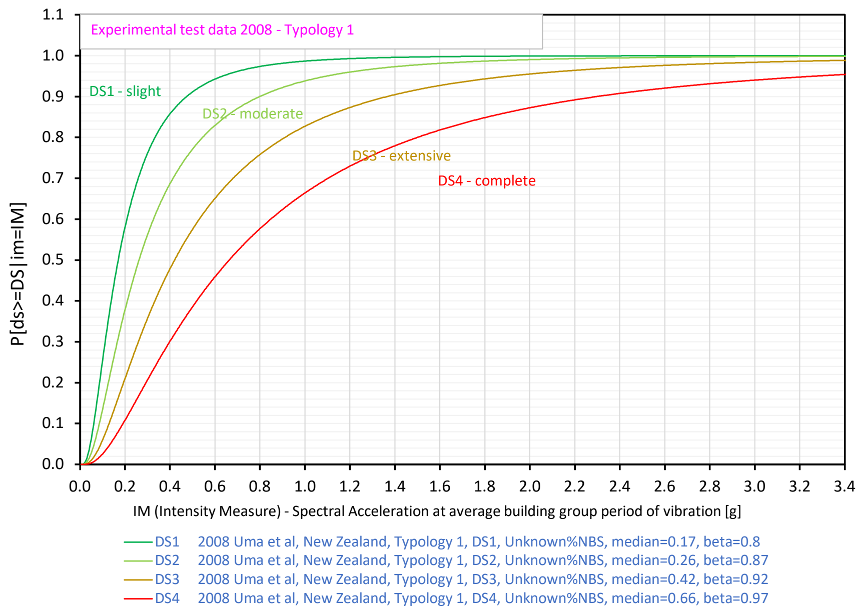
Beca Displ-based method - Typology 1 - 20%*NBS* (no upgrade)
DS1 - slight
DS2 - moderate
DS3 - extensive
DS4 - complete
P[ds>=DS|im=IM]
IM (Intensity Measure) - Spectral Acceleration at average building group period of vibration [g]
DS1 Beca 2025, Auckland, Typology 1, DS1, 20%NBS, median=0.19, beta=0.64
DS2 Beca 2025, Auckland, Typology 1, DS2, 20%NBS, median=0.32, beta=0.64
DS3 Beca 2025, Auckland, Typology 1, DS3, 20%NBS, median=0.58, beta=0.64
DS4 Beca 2025, Auckland, Typology 1, DS4, 20%NBS, median=0.91, beta=0.64



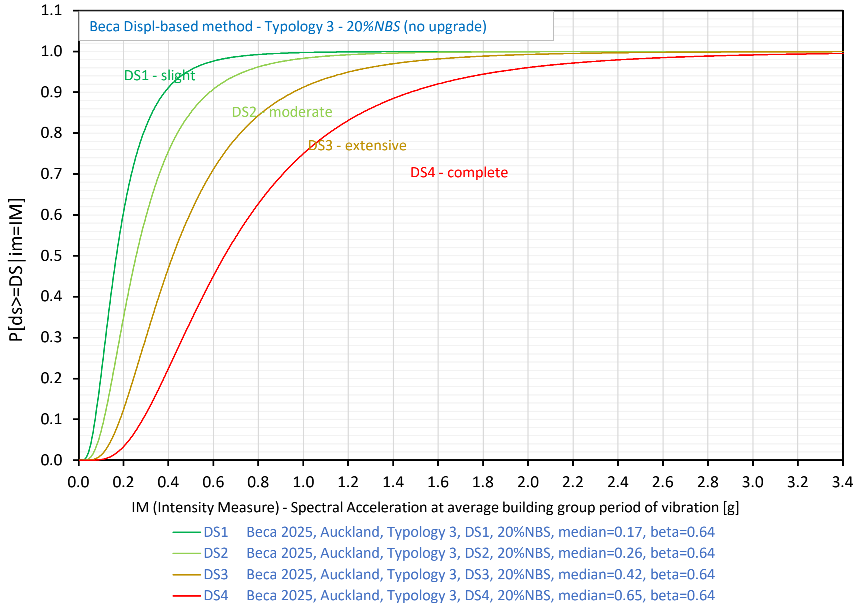
Beca Displ-based method - Typology 1 - 34%*NBS* upgrade
DS1 - slight
DS2 - moderate
DS3 - extensive
DS4 - complete
P[ds>=DS|im=IM]
IM (Intensity Measure) - Spectral Acceleration at average building group period of vibration [g]
DS1 Beca 2025, Auckland, Typology 1, DS1, 34%NBS, median=0.35, beta=0.64
DS2 Beca 2025, Auckland, Typology 1, DS2, 34%NBS, median=0.59, beta=0.64
DS3 Beca 2025, Auckland, Typology 1, DS3, 34%NBS, median=1.07, beta=0.64
DS4 Beca 2025, Auckland, Typology 1, DS4, 34%NBS, median=1.68, beta=0.64

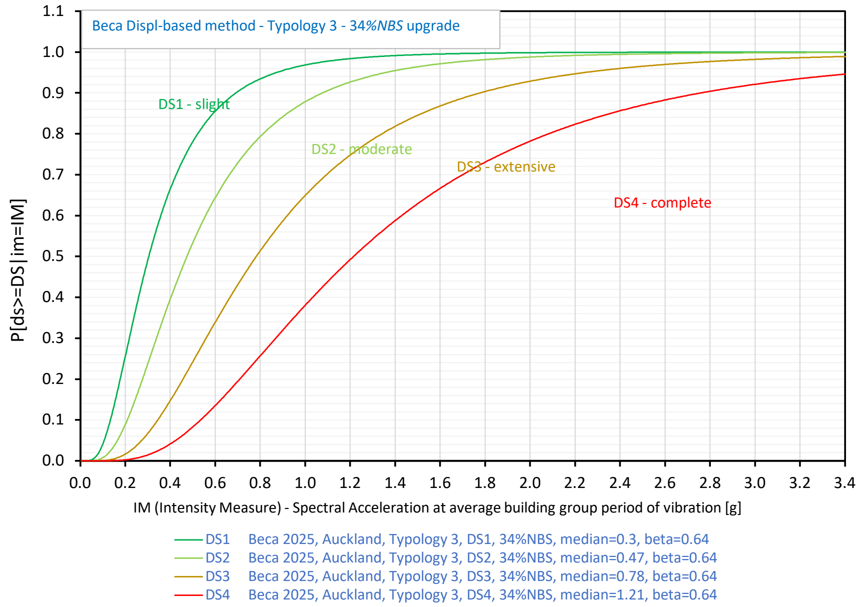


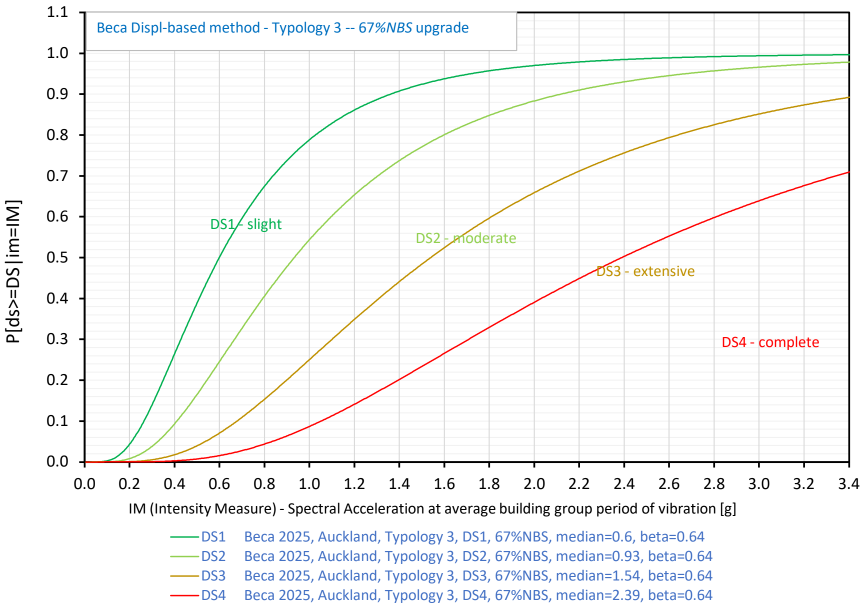
Beca Displ-based method - Typology 1 -- 67%*NBS* upgrade
DS1 - slight
DS2 - moderate
DS3 - extensive
DS4 - complete
P[ds>=DS|im=IM]
IM (Intensity Measure) - Spectral Acceleration at average building group period of vibration [g]
DS1 Beca 2025, Auckland, Typology 1, DS1, 67%NBS, median=0.69, beta=0.64
DS2 Beca 2025, Auckland, Typology 1, DS2, 67%NBS, median=1.16, beta=0.64
DS3 Beca 2025, Auckland, Typology 1, DS3, 67%NBS, median=2.09, beta=0.64
DS4 Beca 2025, Auckland, Typology 1, DS4, 67%NBS, median=3.29, beta=0.64

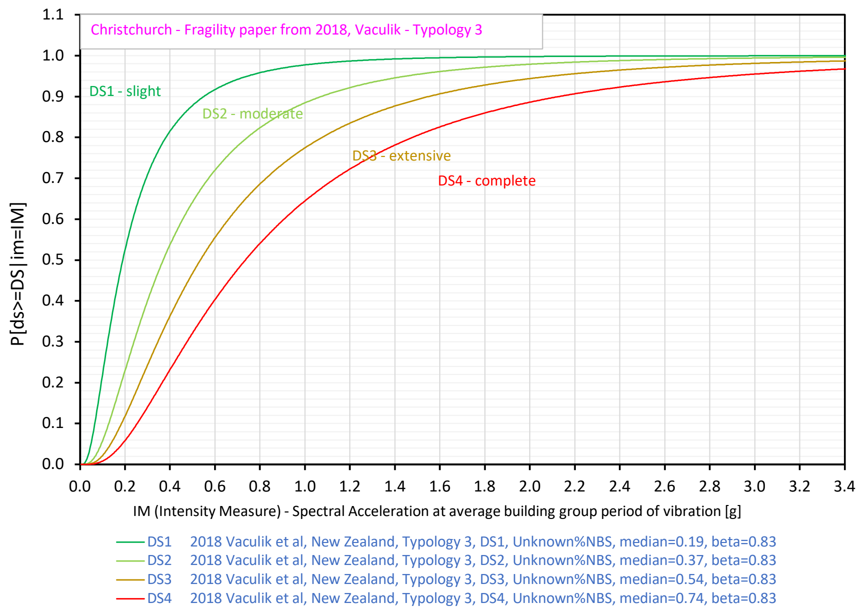


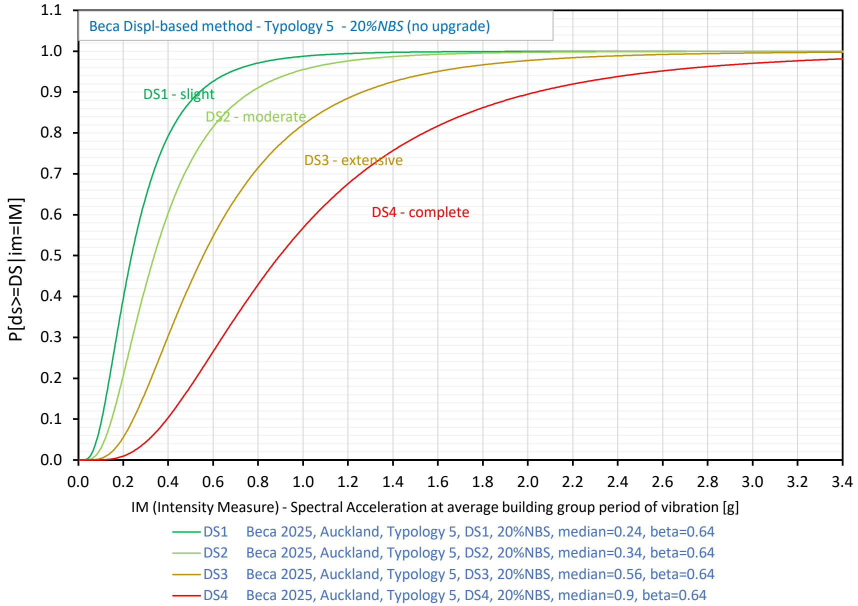
Experimental test data 2008 - Typology 1
DS1 - slight
DS2 - moderate
DS3 - extensive
DS4 - complete
P[ds>=DS|im=IM]
IM (Intensity Measure) - Spectral Acceleration at average building group period of vibration [g]
DS1 2008 Uma et al, New Zealand, Typology 1, DS1, Unknown%NBS, median=0.17, beta=0.8
DS2 2008 Uma et al, New Zealand, Typology 1, DS2, Unknown%NBS, median=0.26, beta=0.87
DS3 2008 Uma et al, New Zealand, Typology 1, DS3, Unknown%NBS, median=0.42, beta=0.92
DS4 2008 Uma et al, New Zealand, Typology 1, DS4, Unknown%NBS, median=0.66, beta=0.97

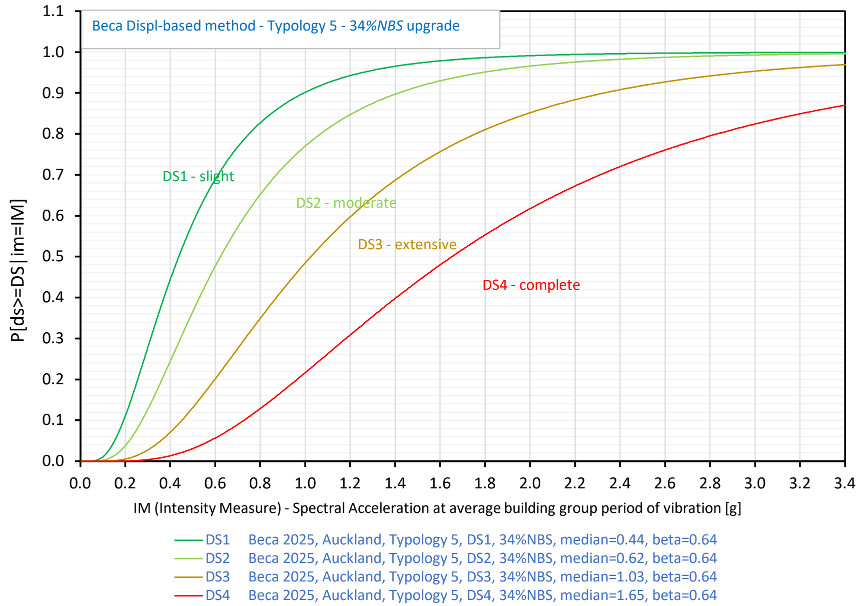

Beca Displ-based method - Typology 3 - 20%NBS (no upgrade)
DS1 - slight
DS2 - moderate
DS3 - extensive
DS4 - complete
P[ds>=DS|im=IM]
IM (Intensity Measure) - Spectral Acceleration at average building group period of vibration [g]
DS1 Beca 2025, Auckland, Typology 3, DS1, 20%NBS, median=0.17, beta=0.64
DS2 Beca 2025, Auckland, Typology 3, DS2, 20%NBS, median=0.26, beta=0.64
DS3 Beca 2025, Auckland, Typology 3, DS3, 20%NBS, median=0.42, beta=0.64
DS4 Beca 2025, Auckland, Typology 3, DS4, 20%NBS, median=0.65, beta=0.64

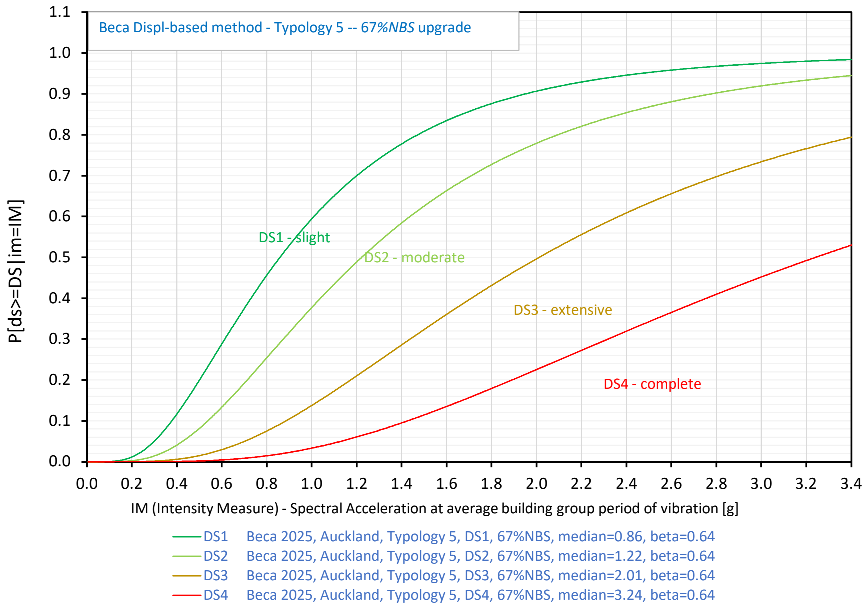

Beca Displ-based method - Typology 3 - 34%NBS upgrade
DS1 - slight
DS2 - moderate
DS3 - extensive
DS4 - complete
P[ds>=DS|im=IM]
IM (Intensity Measure) - Spectral Acceleration at average building group period of vibration [g]
DS1 Beca 2025, Auckland, Typology 3, DS1, 34%NBS, median=0.3, beta=0.64
DS2 Beca 2025, Auckland, Typology 3, DS2, 34%NBS, median=0.47, beta=0.64
DS3 Beca 2025, Auckland, Typology 3, DS3, 34%NBS, median=0.78, beta=0.64
DS4 Beca 2025, Auckland, Typology 3, DS4, 34%NBS, median=1.21, beta=0.64

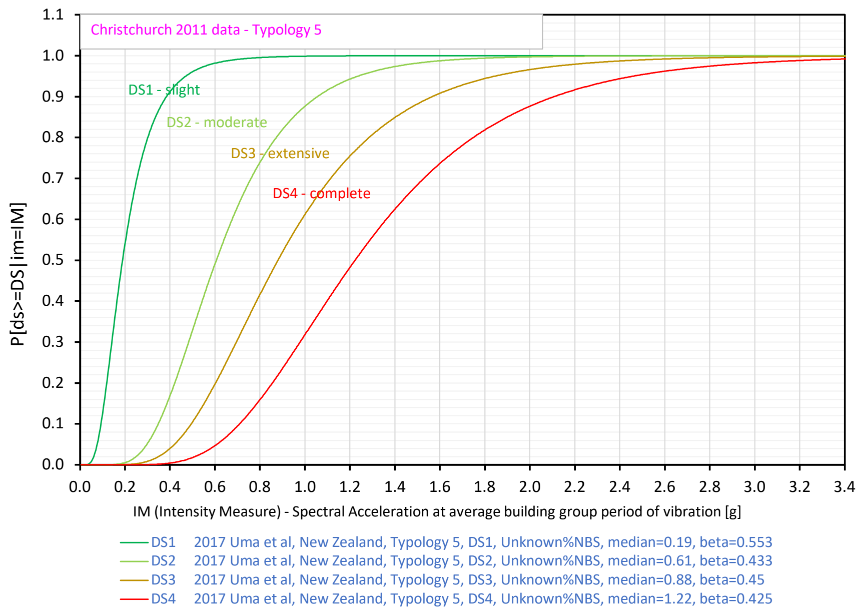

Beca Displ-based method - Typology 3 -- 67%NBS upgrade
DS1 - slight
DS2 - moderate
DS3 - extensive
DS4 - complete
P[ds>=DS|im=IM]
IM (Intensity Measure) - Spectral Acceleration at average building group period of vibration [g]
DS1 Beca 2025, Auckland, Typology 3, DS1, 67%NBS, median=0.6, beta=0.64
DS2 Beca 2025, Auckland, Typology 3, DS2, 67%NBS, median=0.93, beta=0.64
DS3 Beca 2025, Auckland, Typology 3, DS3, 67%NBS, median=1.54, beta=0.64
DS4 Beca 2025, Auckland, Typology 3, DS4, 67%NBS, median=2.39, beta=0.64

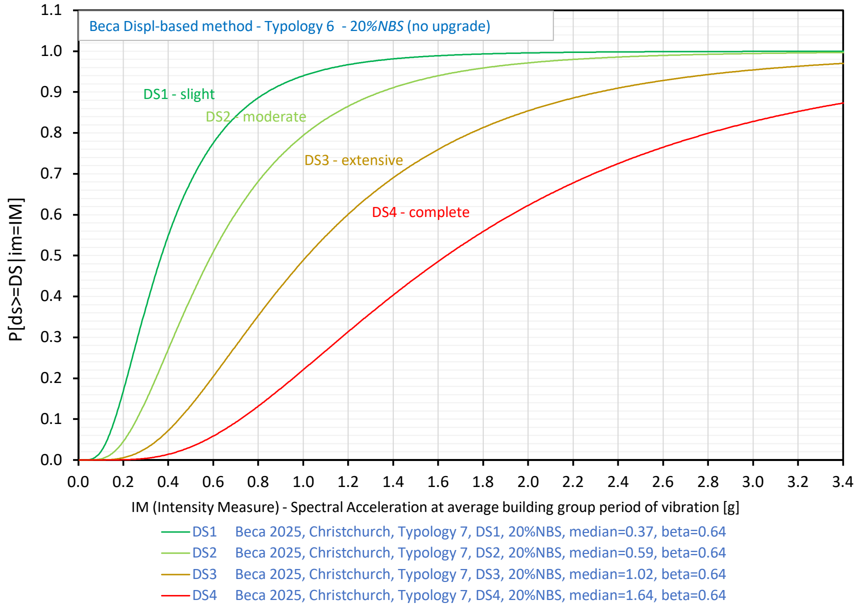

Christchurch - Fragility paper from 2018, Vaculik - Typology 3
DS1 - slight
DS2 - moderate
DS3 - extensive
DS4 - complete
P[ds>=DS|im=IM]
IM (Intensity Measure) - Spectral Acceleration at average building group period of vibration [g]
DS1 2018 Vaculik et al, New Zealand, Typology 3, DS1, Unknown%NBS, median=0.19, beta=0.83
DS2 2018 Vaculik et al, New Zealand, Typology 3, DS2, Unknown%NBS, median=0.37, beta=0.83
DS3 2018 Vaculik et al, New Zealand, Typology 3, DS3, Unknown%NBS, median=0.54, beta=0.83
DS4 2018 Vaculik et al, New Zealand, Typology 3, DS4, Unknown%NBS, median=0.74, beta=0.83

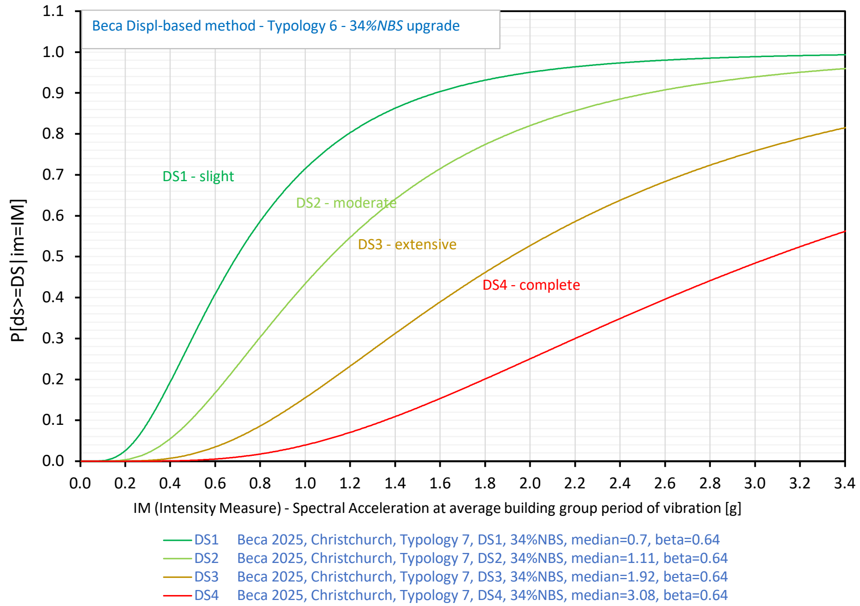

Beca Displ-based method - Typology 5 - 20%NBS (no upgrade)
DS1 - slight
DS2 - moderate
DS3 - extensive
DS4 - complete
P[ds>=DS|im=IM]
IM (Intensity Measure) - Spectral Acceleration at average building group period of vibration [g]
DS1 Beca 2025, Auckland, Typology 5, DS1, 20%NBS, median=0.24, beta=0.64
DS2 Beca 2025, Auckland, Typology 5, DS2, 20%NBS, median=0.34, beta=0.64
DS3 Beca 2025, Auckland, Typology 5, DS3, 20%NBS, median=0.56, beta=0.64
DS4 Beca 2025, Auckland, Typology 5, DS4, 20%NBS, median=0.9, beta=0.64

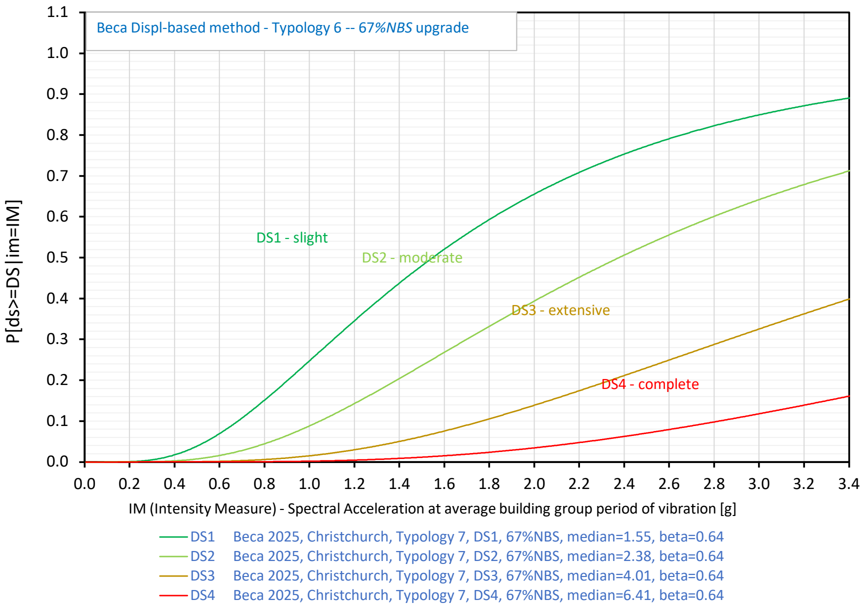

Beca Displ-based method - Typology 5 - 34%NBS upgrade
DS1 - slight
DS2 - moderate
DS3 - extensive
DS4 - complete
P[ds>=DS|im=IM]
IM (Intensity Measure) - Spectral Acceleration at average building group period of vibration [g]
DS1 Beca 2025, Auckland, Typology 5, DS1, 34%NBS, median=0.44, beta=0.64
DS2 Beca 2025, Auckland, Typology 5, DS2, 34%NBS, median=0.62, beta=0.64
DS3 Beca 2025, Auckland, Typology 5, DS3, 34%NBS, median=1.03, beta=0.64
DS4 Beca 2025, Auckland, Typology 5, DS4, 34%NBS, median=1.65, beta=0.64

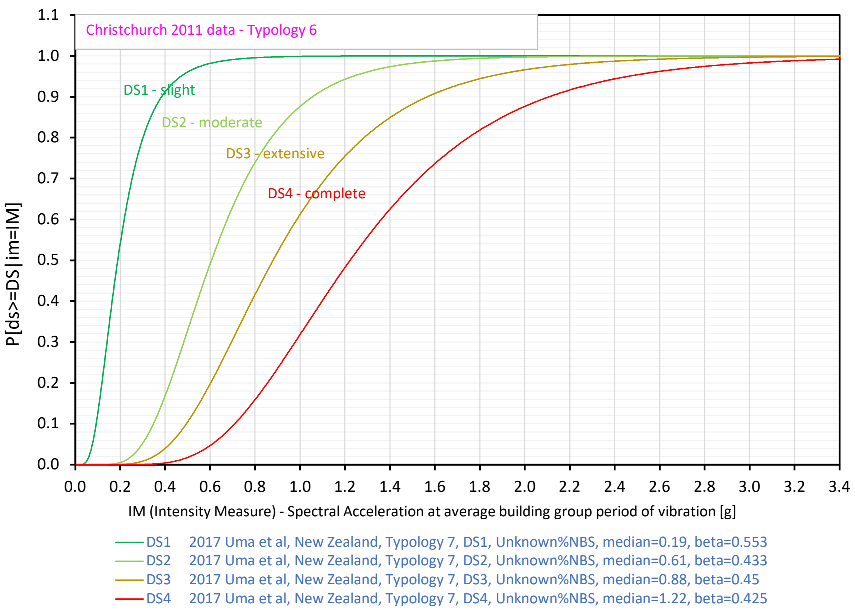

Beca Displ-based method - Typology 5 -- 67%NBS upgrade
DS1 - slight
DS2 - moderate
DS3 - extensive
DS4 - complete
P[ds>=DS|im=IM]
IM (Intensity Measure) - Spectral Acceleration at average building group period of vibration [g]
DS1 Beca 2025, Auckland, Typology 5, DS1, 67%NBS, median=0.86, beta=0.64
DS2 Beca 2025, Auckland, Typology 5, DS2, 67%NBS, median=1.22, beta=0.64
DS3 Beca 2025, Auckland, Typology 5, DS3, 67%NBS, median=2.01, beta=0.64
DS4 Beca 2025, Auckland, Typology 5, DS4, 67%NBS, median=3.24, beta=0.64

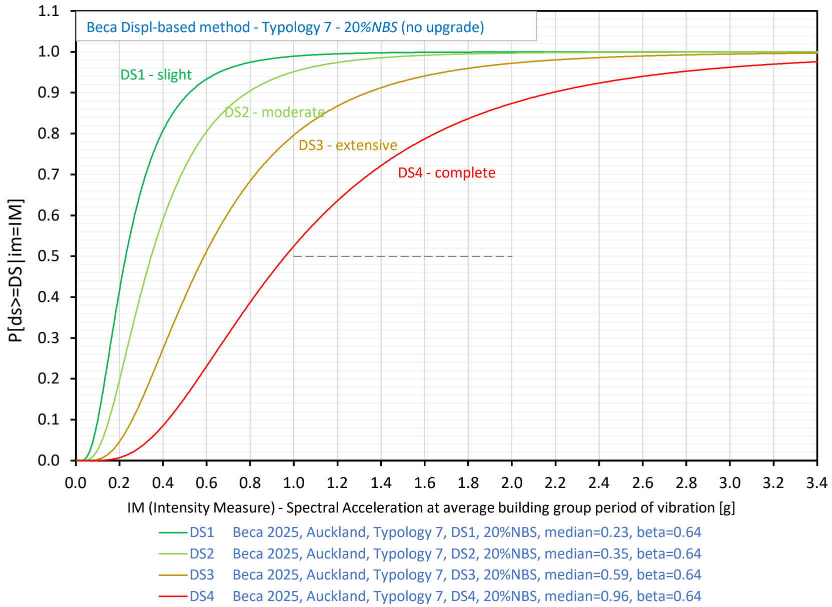

Christchurch 2011 data - Typology 5
DS1 - slight
DS2 - moderate
DS3 - extensive
DS4 - complete
P[ds>=DS|im=IM]
IM (Intensity Measure) - Spectral Acceleration at average building group period of vibration [g]
DS1 2017 Uma et al, New Zealand, Typology 5, DS1, Unknown%NBS, median=0.19, beta=0.553
DS2 2017 Uma et al, New Zealand, Typology 5, DS2, Unknown%NBS, median=0.61, beta=0.433
DS3 2017 Uma et al, New Zealand, Typology 5, DS3, Unknown%NBS, median=0.88, beta=0.45
DS4 2017 Uma et al, New Zealand, Typology 5, DS4, Unknown%NBS, median=1.22, beta=0.425

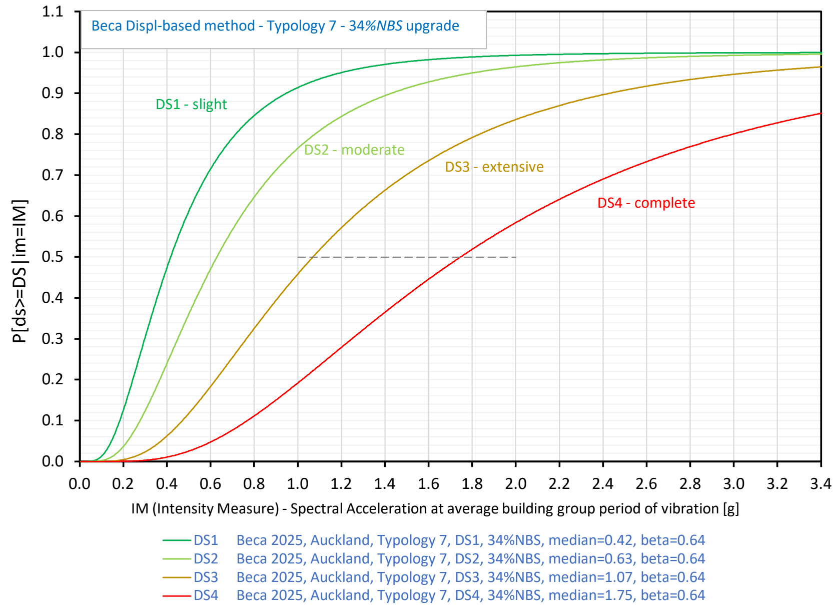

Beca Displ-based method - Typology 6 - 20%*NBS* (no upgrade)
DS1 - slight
DS2 - moderate
DS3 - extensive
DS4 - complete
P[ds>=DS|im=IM]
IM (Intensity Measure) - Spectral Acceleration at average building group period of vibration [g]
DS1 Beca 2025, Christchurch, Typology 7, DS1, 20%NBS, median=0.37, beta=0.64
DS2 Beca 2025, Christchurch, Typology 7, DS2, 20%NBS, median=0.59, beta=0.64
DS3 Beca 2025, Christchurch, Typology 7, DS3, 20%NBS, median=1.02, beta=0.64
DS4 Beca 2025, Christchurch, Typology 7, DS4, 20%NBS, median=1.64, beta=0.64

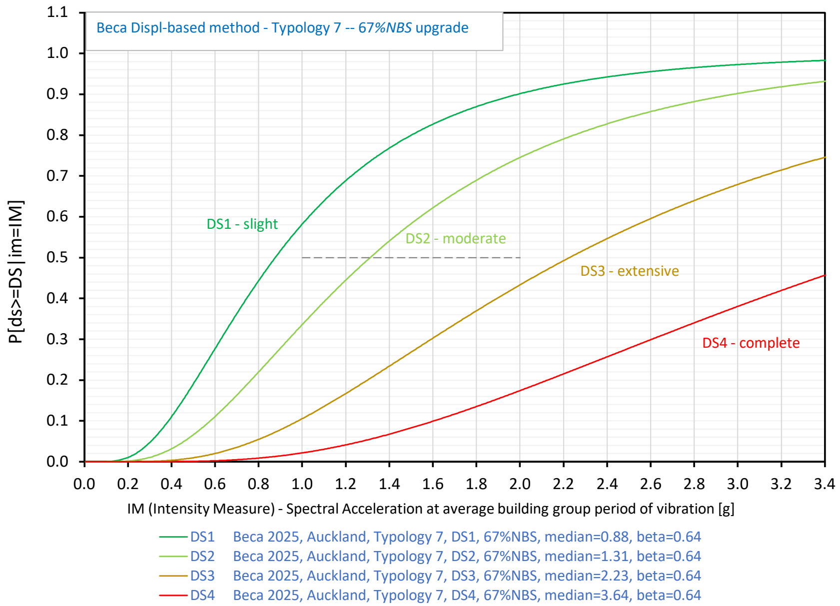

Beca Displ-based method - Typology 6 - 34%*NBS* upgrade
DS1 - slight
DS2 - moderate
DS3 - extensive
DS4 - complete
P[ds>=DS|im=IM]
IM (Intensity Measure) - Spectral Acceleration at average building group period of vibration [g]
DS1 Beca 2025, Christchurch, Typology 7, DS1, 34%NBS, median=0.7, beta=0.64
DS2 Beca 2025, Christchurch, Typology 7, DS2, 34%NBS, median=1.11, beta=0.64
DS3 Beca 2025, Christchurch, Typology 7, DS3, 34%NBS, median=1.92, beta=0.64
DS4 Beca 2025, Christchurch, Typology 7, DS4, 34%NBS, median=3.08, beta=0.64

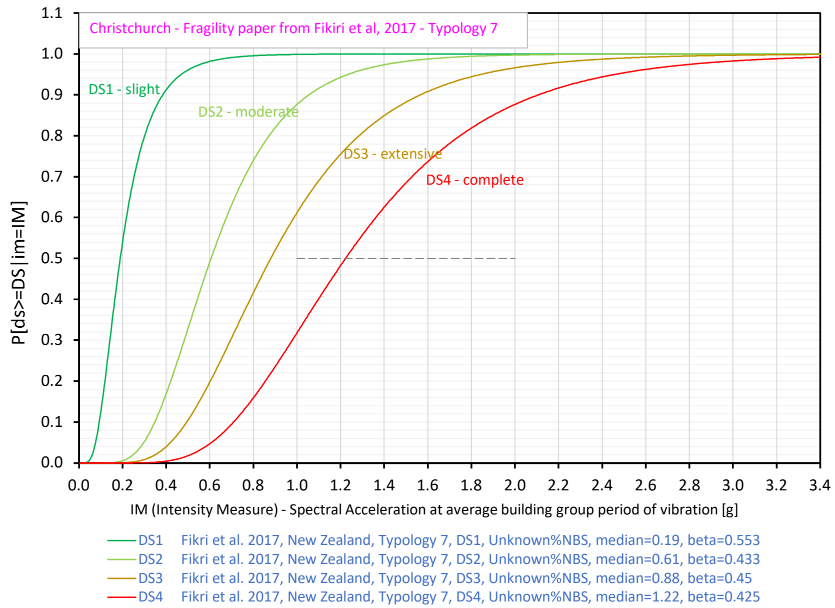

Beca Displ-based method - Typology 6 -- 67%*NBS* upgrade
DS1 - slight
DS2 - moderate
DS3 - extensive
DS4 - complete
P[ds>=DS|im=IM]
IM (Intensity Measure) - Spectral Acceleration at average building group period of vibration [g]
DS1 Beca 2025, Christchurch, Typology 7, DS1, 67%NBS, median=1.55, beta=0.64
DS2 Beca 2025, Christchurch, Typology 7, DS2, 67%NBS, median=2.38, beta=0.64
DS3 Beca 2025, Christchurch, Typology 7, DS3, 67%NBS, median=4.01, beta=0.64
DS4 Beca 2025, Christchurch, Typology 7, DS4, 67%NBS, median=6.41, beta=0.64

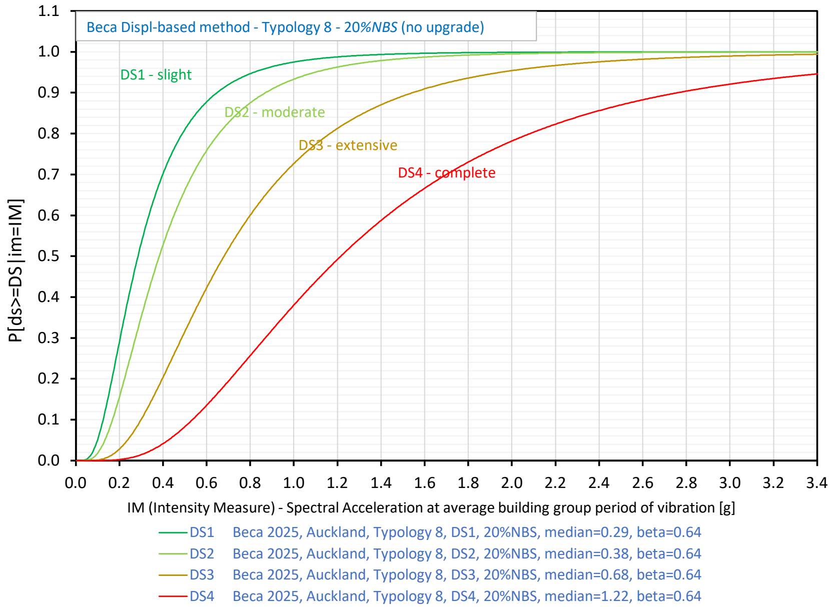

Christchurch 2011 data - Typology 6
DS1 - slight
DS2 - moderate
DS3 - extensive
DS4 - complete
P[ds>=DS|im=IM]
IM (Intensity Measure) - Spectral Acceleration at average building group period of vibration [g]
DS1 2017 Uma et al, New Zealand, Typology 7, DS1, Unknown%NBS, median=0.19, beta=0.553
DS2 2017 Uma et al, New Zealand, Typology 7, DS2, Unknown%NBS, median=0.61, beta=0.433
DS3 2017 Uma et al, New Zealand, Typology 7, DS3, Unknown%NBS, median=0.88, beta=0.45
DS4 2017 Uma et al, New Zealand, Typology 7, DS4, Unknown%NBS, median=1.22, beta=0.425

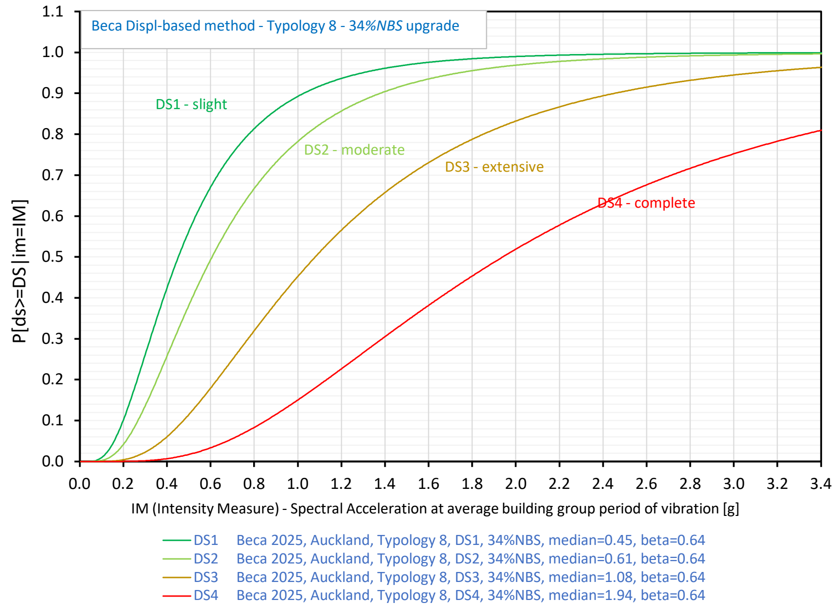

Beca Displ-based method - Typology 7 - 20%NBS (no upgrade)
DS1 - slight
DS2 - moderate
DS3 - extensive
DS4 - complete
P[ds>=DS|im=IM]
IM (Intensity Measure) - Spectral Acceleration at average building group period of vibration [g]
DS1 Beca 2025, Auckland, Typology 7, DS1, 20%NBS, median=0.23, beta=0.64
DS2 Beca 2025, Auckland, Typology 7, DS2, 20%NBS, median=0.35, beta=0.64
DS3 Beca 2025, Auckland, Typology 7, DS3, 20%NBS, median=0.59, beta=0.64
DS4 Beca 2025, Auckland, Typology 7, DS4, 20%NBS, median=0.96, beta=0.64

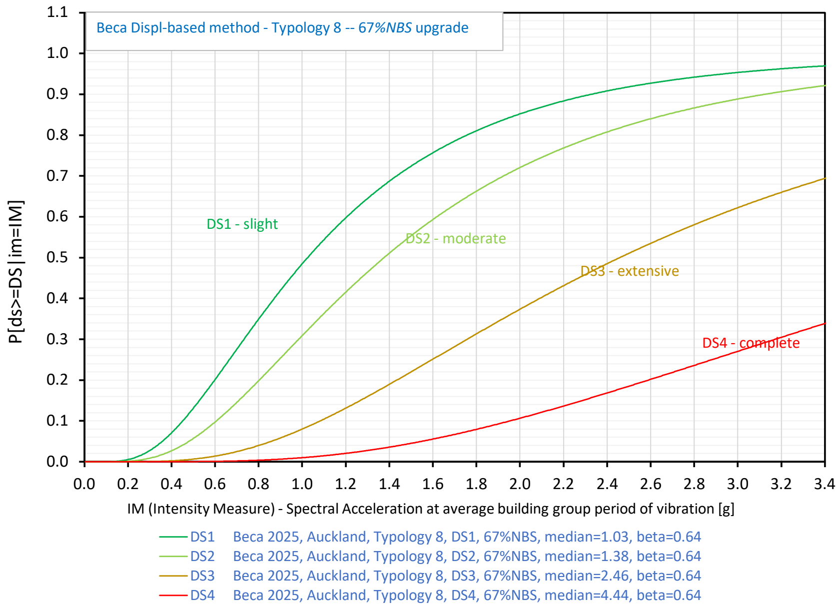

Beca Displ-based method - Typology 7 - 34%NBS upgrade
DS1 - slight
DS2 - moderate
DS3 - extensive
DS4 - complete
P[ds>=DS|im=IM]
IM (Intensity Measure) - Spectral Acceleration at average building group period of vibration [g]
DS1 Beca 2025, Auckland, Typology 7, DS1, 34%NBS, median=0.42, beta=0.64
DS2 Beca 2025, Auckland, Typology 7, DS2, 34%NBS, median=0.63, beta=0.64
DS3 Beca 2025, Auckland, Typology 7, DS3, 34%NBS, median=1.07, beta=0.64
DS4 Beca 2025, Auckland, Typology 7, DS4, 34%NBS, median=1.75, beta=0.64

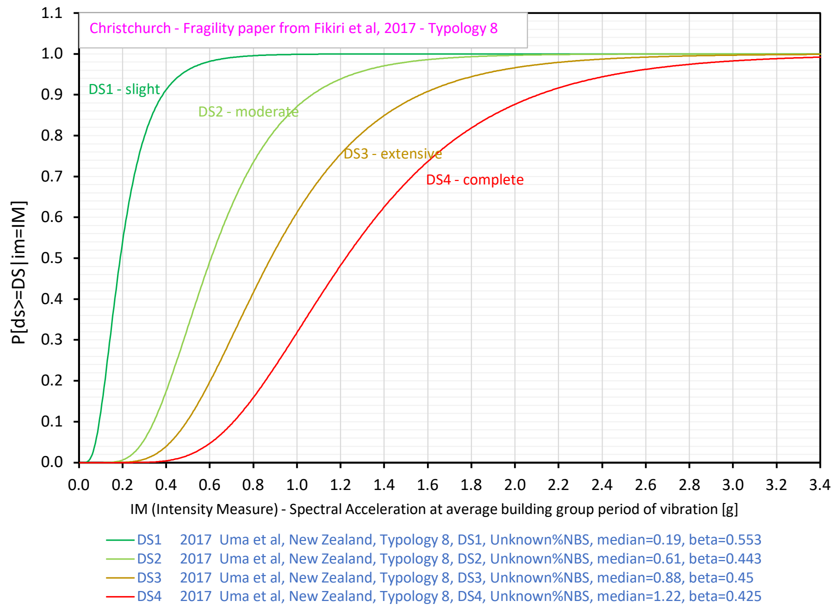

Beca Displ-based method - Typology 7 -- 67%NBS upgrade
DS1 - slight
DS2 - moderate
DS3 - extensive
DS4 - complete
P[ds>=DS|im=IM]
IM (Intensity Measure) - Spectral Acceleration at average building group period of vibration [g]
DS1 Beca 2025, Auckland, Typology 7, DS1, 67%NBS, median=0.88, beta=0.64
DS2 Beca 2025, Auckland, Typology 7, DS2, 67%NBS, median=1.31, beta=0.64
DS3 Beca 2025, Auckland, Typology 7, DS3, 67%NBS, median=2.23, beta=0.64
DS4 Beca 2025, Auckland, Typology 7, DS4, 67%NBS, median=3.64, beta=0.64

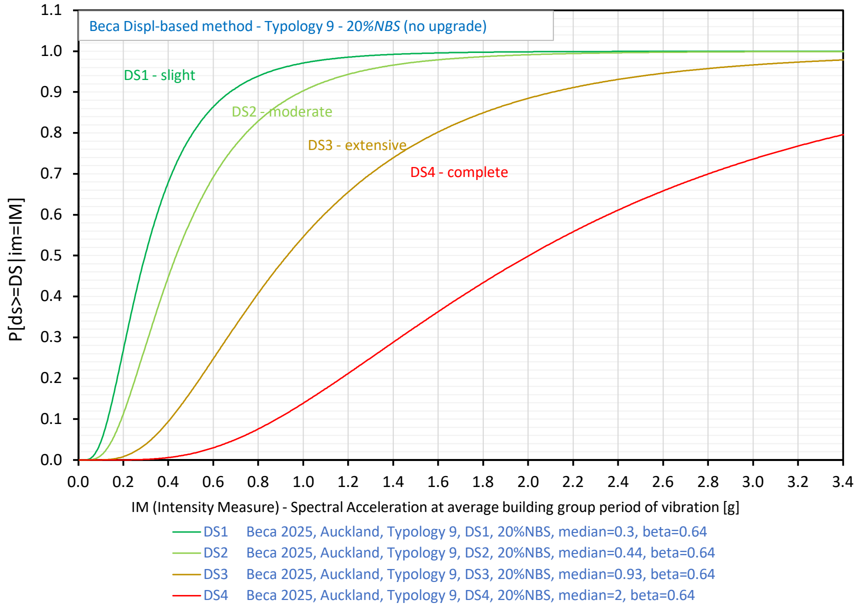

Christchurch - Fragility paper from Fikiri et al, 2017 - Typology 7
DS1 - slight
DS2 - moderate
DS3 - extensive
DS4 - complete
P[ds>=DS|im=IM]
IM (Intensity Measure) - Spectral Acceleration at average building group period of vibration [g]
DS1 Fikri et al. 2017, New Zealand, Typology 7, DS1, Unknown%NBS, median=0.19, beta=0.553
DS2 Fikri et al. 2017, New Zealand, Typology 7, DS2, Unknown%NBS, median=0.61, beta=0.433
DS3 Fikri et al. 2017, New Zealand, Typology 7, DS3, Unknown%NBS, median=0.88, beta=0.45
DS4 Fikri et al. 2017, New Zealand, Typology 7, DS4, Unknown%NBS, median=1.22, beta=0.425

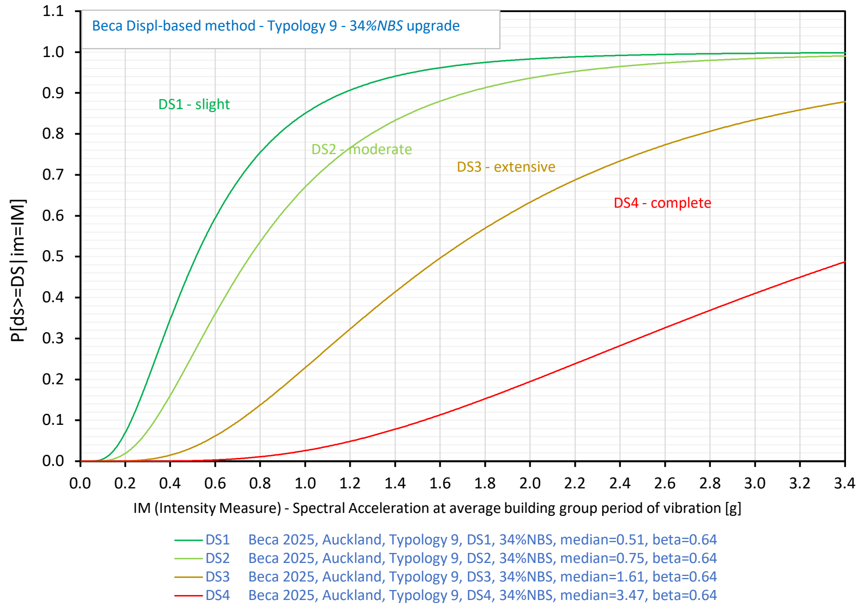

Beca Displ-based method - Typology 8 - 20%NBS (no upgrade)
DS1 - slight
DS2 - moderate
DS3 - extensive
DS4 - complete
P[ds>=DS|im=IM]
IM (Intensity Measure) - Spectral Acceleration at average building group period of vibration [g]
DS1 Beca 2025, Auckland, Typology 8, DS1, 20%NBS, median=0.29, beta=0.64
DS2 Beca 2025, Auckland, Typology 8, DS2, 20%NBS, median=0.38, beta=0.64
DS3 Beca 2025, Auckland, Typology 8, DS3, 20%NBS, median=0.68, beta=0.64
DS4 Beca 2025, Auckland, Typology 8, DS4, 20%NBS, median=1.22, beta=0.64

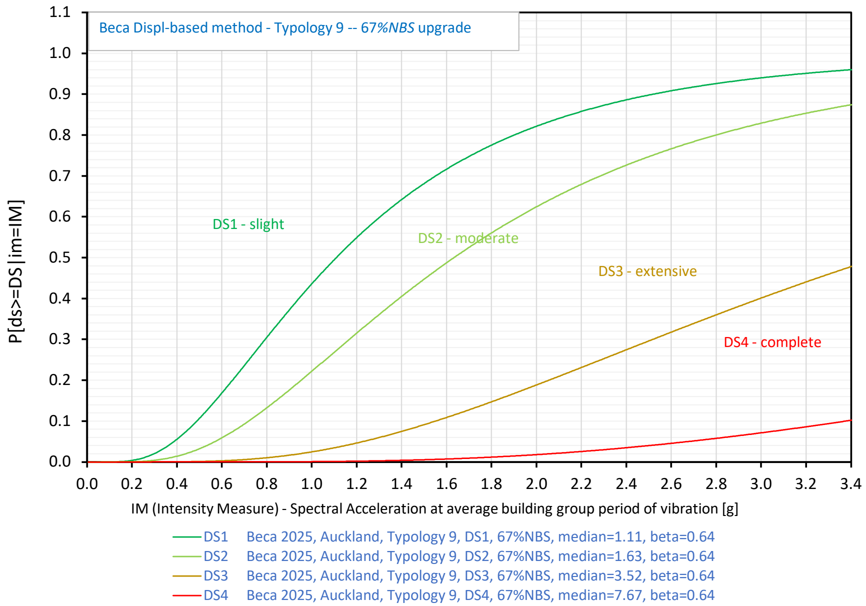

Beca Displ-based method - Typology 8 - 34%NBS upgrade
DS1 - slight
DS2 - moderate
DS3 - extensive
DS4 - complete
P[ds>=DS|im=IM]
IM (Intensity Measure) - Spectral Acceleration at average building group period of vibration [g]
DS1 Beca 2025, Auckland, Typology 8, DS1, 34%NBS, median=0.45, beta=0.64
DS2 Beca 2025, Auckland, Typology 8, DS2, 34%NBS, median=0.61, beta=0.64
DS3 Beca 2025, Auckland, Typology 8, DS3, 34%NBS, median=1.08, beta=0.64
DS4 Beca 2025, Auckland, Typology 8, DS4, 34%NBS, median=1.94, beta=0.64

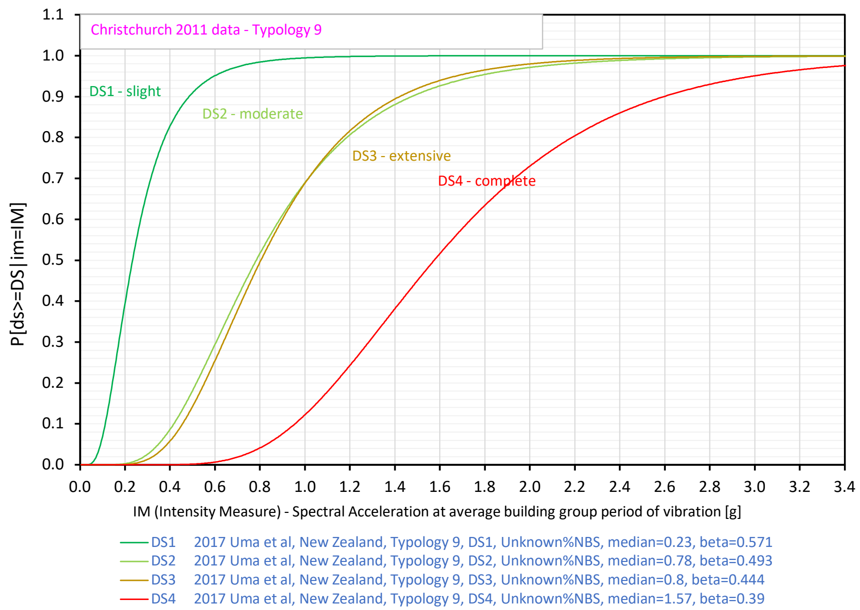

Beca Displ-based method - Typology 8 -- 67%NBS upgrade
DS1 - slight
DS2 - moderate
DS3 - extensive
DS4 - complete
P[ds>=DS|im=IM]
IM (Intensity Measure) - Spectral Acceleration at average building group period of vibration [g]
DS1 Beca 2025, Auckland, Typology 8, DS1, 67%NBS, median=1.03, beta=0.64
DS2 Beca 2025, Auckland, Typology 8, DS2, 67%NBS, median=1.38, beta=0.64
DS3 Beca 2025, Auckland, Typology 8, DS3, 67%NBS, median=2.46, beta=0.64
DS4 Beca 2025, Auckland, Typology 8, DS4, 67%NBS, median=4.44, beta=0.64

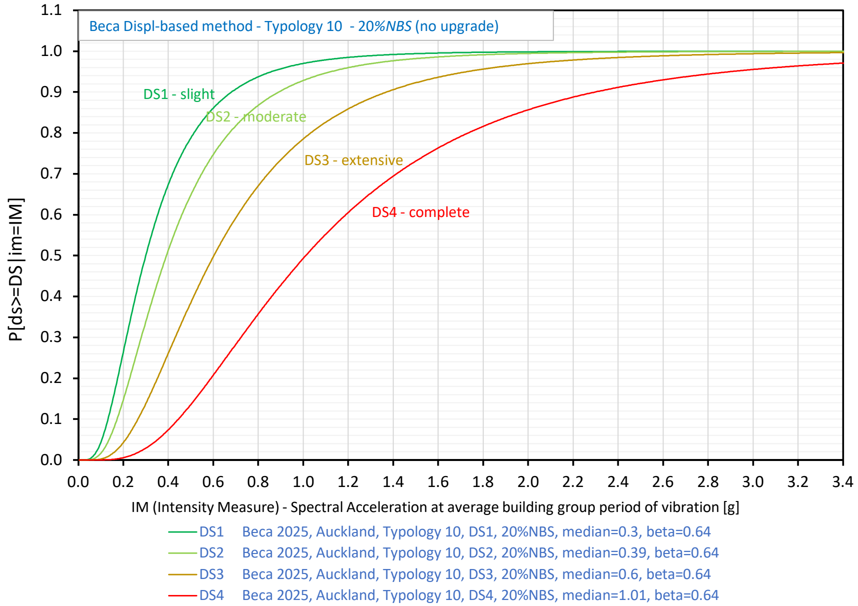

Christchurch - Fragility paper from Fikiri et al, 2017 - Typology 8
DS1 - slight
DS2 - moderate
DS3 - extensive
DS4 - complete
P[ds>=DS|im=IM]
IM (Intensity Measure) - Spectral Acceleration at average building group period of vibration [g]
DS1 2017 Uma et al, New Zealand, Typology 8, DS1, Unknown%NBS, median=0.19, beta=0.553
DS2 2017 Uma et al, New Zealand, Typology 8, DS2, Unknown%NBS, median=0.61, beta=0.443
DS3 2017 Uma et al, New Zealand, Typology 8, DS3, Unknown%NBS, median=0.88, beta=0.45
DS4 2017 Uma et al, New Zealand, Typology 8, DS4, Unknown%NBS, median=1.22, beta=0.425

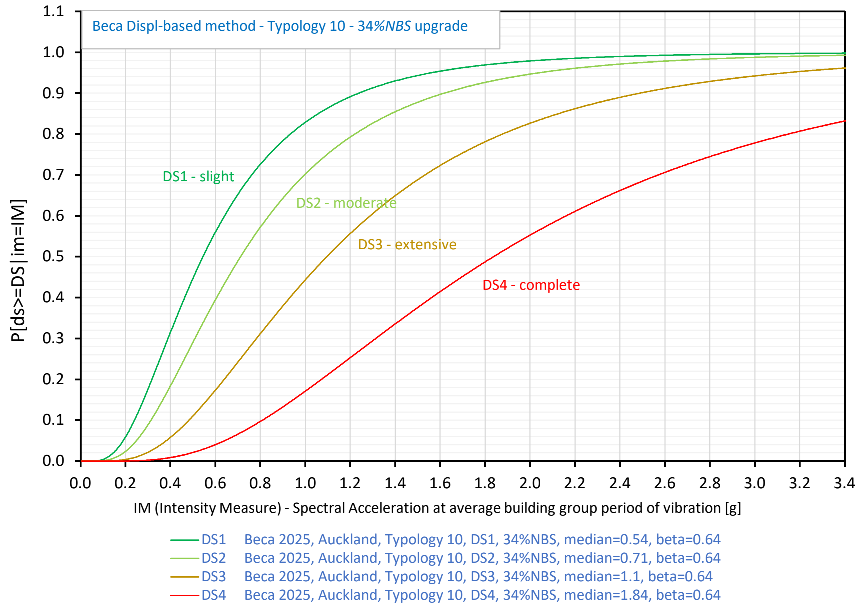

Beca Displ-based method - Typology 9 - 20%NBS (no upgrade)
DS1 - slight
DS2 - moderate
DS3 - extensive
DS4 - complete
P[ds>=DS|im=IM]
IM (Intensity Measure) - Spectral Acceleration at average building group period of vibration [g]
DS1 Beca 2025, Auckland, Typology 9, DS1, 20%NBS, median=0.3, beta=0.64
DS2 Beca 2025, Auckland, Typology 9, DS2, 20%NBS, median=0.44, beta=0.64
DS3 Beca 2025, Auckland, Typology 9, DS3, 20%NBS, median=0.93, beta=0.64
DS4 Beca 2025, Auckland, Typology 9, DS4, 20%NBS, median=2, beta=0.64

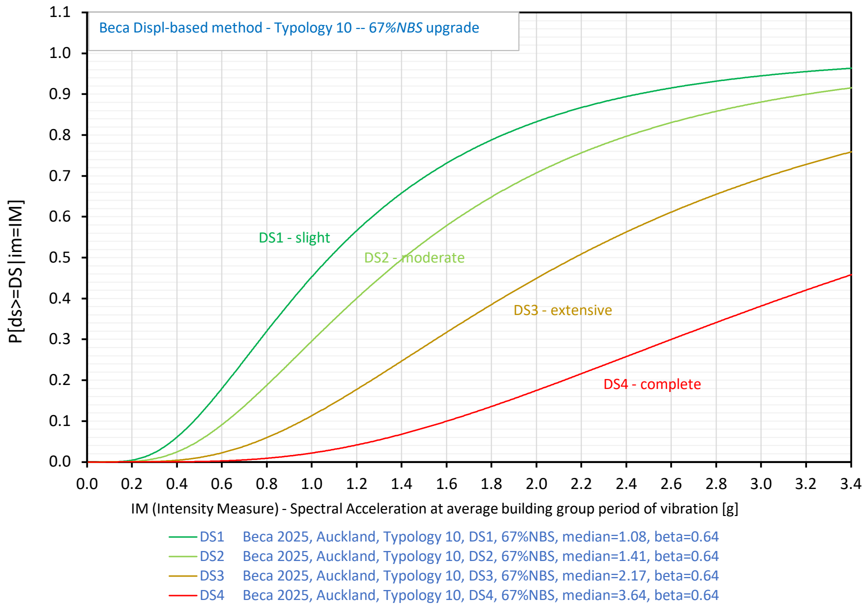

Beca Displ-based method - Typology 9 - 34%NBS upgrade
DS1 - slight
DS2 - moderate
DS3 - extensive
DS4 - complete
P[ds>=DS|im=IM]
IM (Intensity Measure) - Spectral Acceleration at average building group period of vibration [g]
DS1 Beca 2025, Auckland, Typology 9, DS1, 34%NBS, median=0.51, beta=0.64
DS2 Beca 2025, Auckland, Typology 9, DS2, 34%NBS, median=0.75, beta=0.64
DS3 Beca 2025, Auckland, Typology 9, DS3, 34%NBS, median=1.61, beta=0.64
DS4 Beca 2025, Auckland, Typology 9, DS4, 34%NBS, median=3.47, beta=0.64

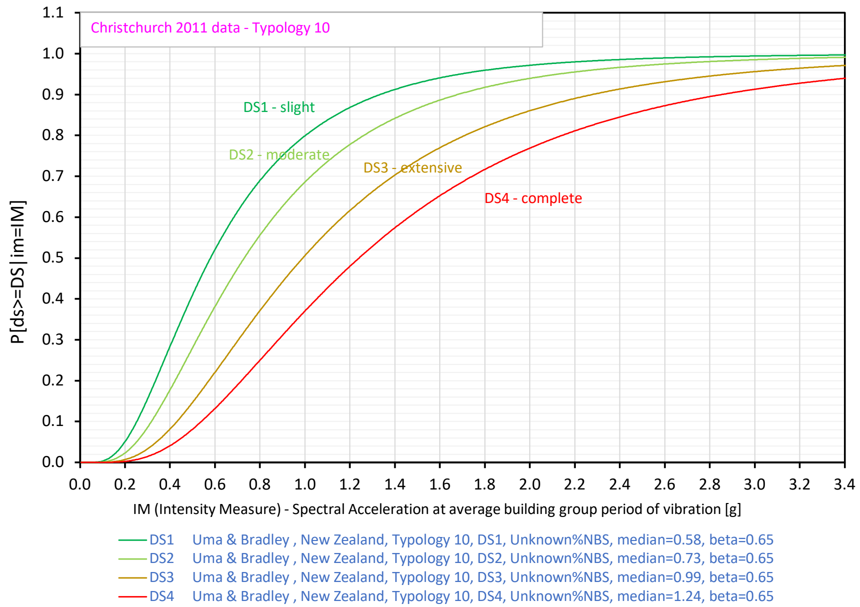

Beca Displ-based method - Typology 9 -- 67%NBS upgrade
DS1 - slight
DS2 - moderate
DS3 - extensive
DS4 - complete
P[ds>=DS|im=IM]
IM (Intensity Measure) - Spectral Acceleration at average building group period of vibration [g]
DS1 Beca 2025, Auckland, Typology 9, DS1, 67%NBS, median=1.11, beta=0.64
DS2 Beca 2025, Auckland, Typology 9, DS2, 67%NBS, median=1.63, beta=0.64
DS3 Beca 2025, Auckland, Typology 9, DS3, 67%NBS, median=3.52, beta=0.64
DS4 Beca 2025, Auckland, Typology 9, DS4, 67%NBS, median=7.67, beta=0.64


Christchurch 2011 data - Typology 9
DS1 - slight
DS2 - moderate
DS3 - extensive
DS4 - complete
P[ds>=DS|im=IM]
IM (Intensity Measure) - Spectral Acceleration at average building group period of vibration [g]
DS1 2017 Uma et al, New Zealand, Typology 9, DS1, Unknown%NBS, median=0.23, beta=0.571
DS2 2017 Uma et al, New Zealand, Typology 9, DS2, Unknown%NBS, median=0.78, beta=0.493
DS3 2017 Uma et al, New Zealand, Typology 9, DS3, Unknown%NBS, median=0.8, beta=0.444
DS4 2017 Uma et al, New Zealand, Typology 9, DS4, Unknown%NBS, median=1.57, beta=0.39

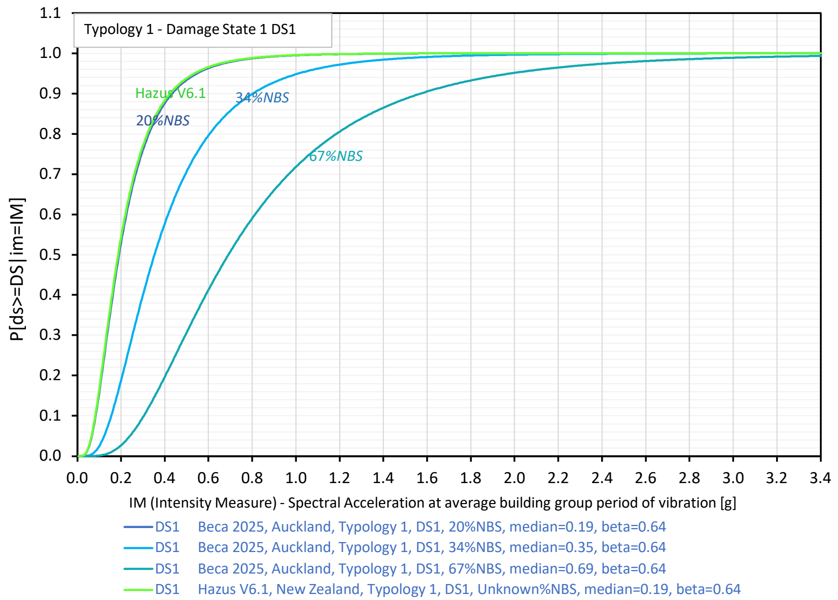

Beca Displ-based method - Typology 10 - 20%NBS (no upgrade)
DS1 - slight
DS2 - moderate
DS3 - extensive
DS4 - complete
P[ds>=DS|im=IM]
IM (Intensity Measure) - Spectral Acceleration at average building group period of vibration [g]
DS1 Beca 2025, Auckland, Typology 10, DS1, 20%NBS, median=0.3, beta=0.64
DS2 Beca 2025, Auckland, Typology 10, DS2, 20%NBS, median=0.39, beta=0.64
DS3 Beca 2025, Auckland, Typology 10, DS3, 20%NBS, median=0.6, beta=0.64
DS4 Beca 2025, Auckland, Typology 10, DS4, 20%NBS, median=1.01, beta=0.64


Beca Displ-based method - Typology 10 - 34%NBS upgrade
DS1 - slight
DS2 - moderate
DS3 - extensive
DS4 - complete
P[ds>=DS|im=IM]
IM (Intensity Measure) - Spectral Acceleration at average building group period of vibration [g]
DS1 Beca 2025, Auckland, Typology 10, DS1, 34%NBS, median=0.54, beta=0.64
DS2 Beca 2025, Auckland, Typology 10, DS2, 34%NBS, median=0.71, beta=0.64
DS3 Beca 2025, Auckland, Typology 10, DS3, 34%NBS, median=1.1, beta=0.64
DS4 Beca 2025, Auckland, Typology 10, DS4, 34%NBS, median=1.84, beta=0.64

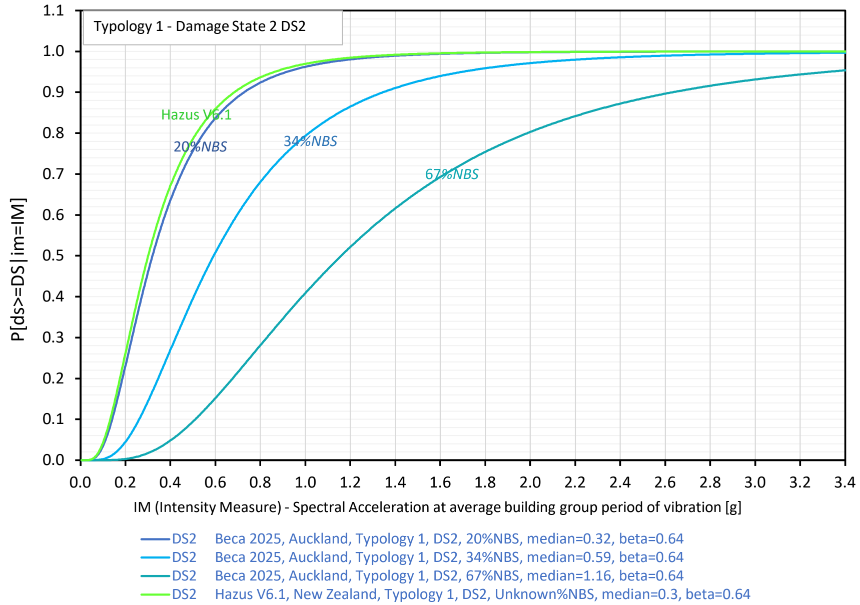

Beca Displ-based method - Typology 10 -- 67%NBS upgrade
DS1 - slight
DS2 - moderate
DS3 - extensive
DS4 - complete
P[ds>=DS|im=IM]
IM (Intensity Measure) - Spectral Acceleration at average building group period of vibration [g]
DS1 Beca 2025, Auckland, Typology 10, DS1, 67%NBS, median=1.08, beta=0.64
DS2 Beca 2025, Auckland, Typology 10, DS2, 67%NBS, median=1.41, beta=0.64
DS3 Beca 2025, Auckland, Typology 10, DS3, 67%NBS, median=2.17, beta=0.64
DS4 Beca 2025, Auckland, Typology 10, DS4, 67%NBS, median=3.64, beta=0.64


Christchurch 2011 data - Typology 10
DS1 - slight
DS2 - moderate
DS3 - extensive
DS4 - complete
P[ds>=DS|im=IM]
IM (Intensity Measure) - Spectral Acceleration at average building group period of vibration [g]
DS1 Uma & Bradley , New Zealand, Typology 10, DS1, Unknown%NBS, median=0.58, beta=0.65
DS2 Uma & Bradley , New Zealand, Typology 10, DS2, Unknown%NBS, median=0.73, beta=0.65
DS3 Uma & Bradley , New Zealand, Typology 10, DS3, Unknown%NBS, median=0.99, beta=0.65
DS4 Uma & Bradley , New Zealand, Typology 10, DS4, Unknown%NBS, median=1.24, beta=0.65

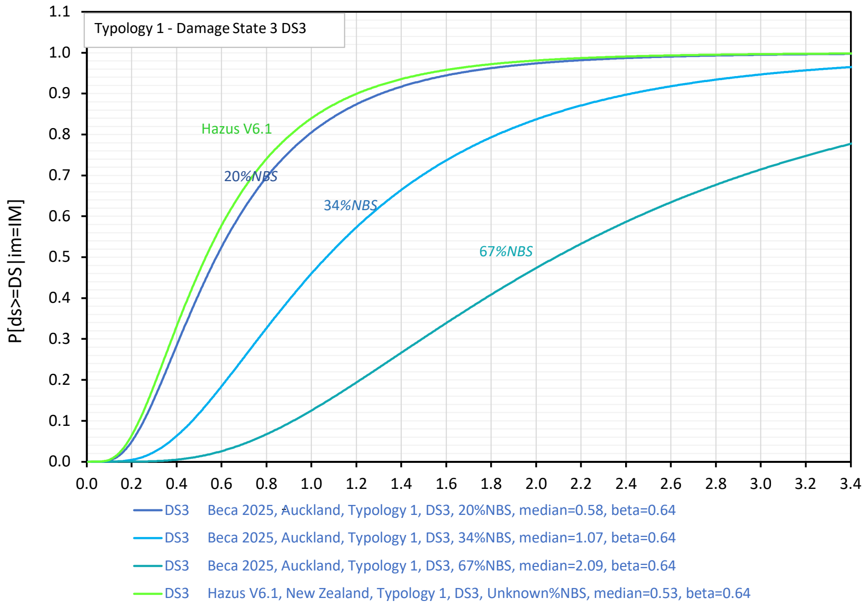
HAZUS v6.1 comparisons vs. DBM fragility curves



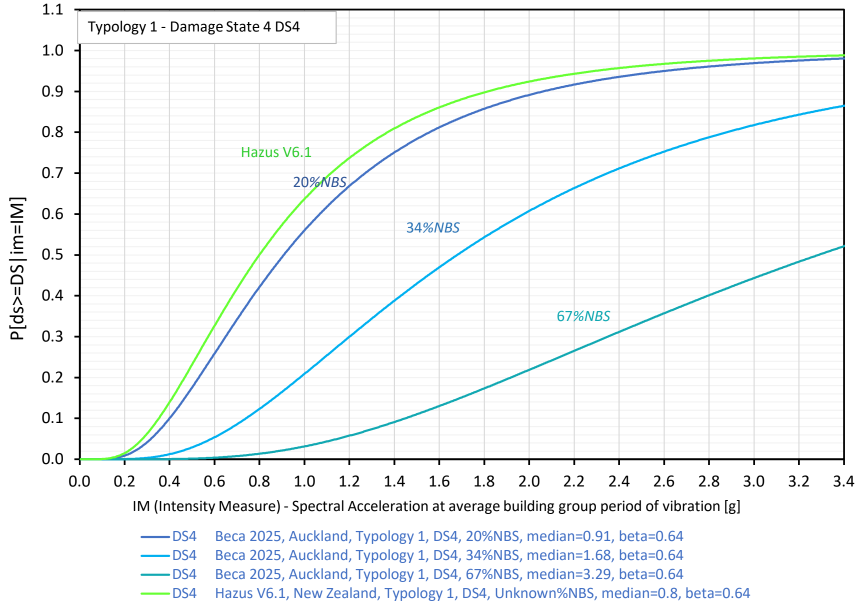
Typology 1 - Damage State 1 DS1
P[ds>=DS|im=IM]
IM (Intensity Measure) - Spectral Acceleration at average building group period of vibration [g]
Hazus V6.1
20%NBS
34%NBS
67%NBS
DS1 Beca 2025, Auckland, Typology 1, DS1, 20%NBS, median=0.19, beta=0.64
DS1 Beca 2025, Auckland, Typology 1, DS1, 34%NBS, median=0.35, beta=0.64
DS1 Beca 2025, Auckland, Typology 1, DS1, 67%NBS, median=0.69, beta=0.64
DS1 Hazus V6.1, New Zealand, Typology 1, DS1, Unknown%NBS, median=0.19, beta=0.64



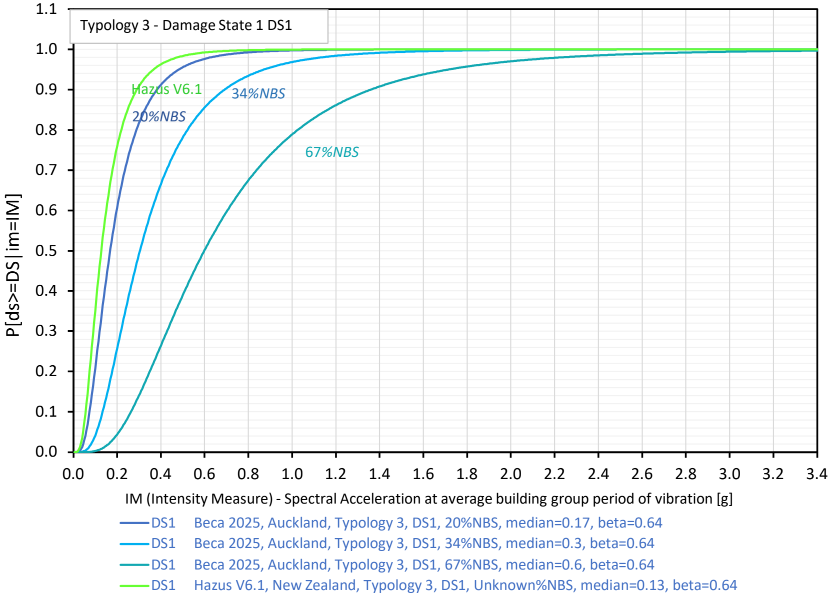
Typology 1 - Damage State 2 DS2
P[ds>=DS|im=IM]
IM (Intensity Measure) - Spectral Acceleration at average building group period of vibration [g]
Hazus V6.1
20%NBS
34%NBS
67%NBS
DS2 Beca 2025, Auckland, Typology 1, DS2, 20%NBS, median=0.32, beta=0.64
DS2 Beca 2025, Auckland, Typology 1, DS2, 34%NBS, median=0.59, beta=0.64
DS2 Beca 2025, Auckland, Typology 1, DS2, 67%NBS, median=1.16, beta=0.64
DS2 Hazus V6.1, New Zealand, Typology 1, DS2, Unknown%NBS, median=0.3, beta=0.64

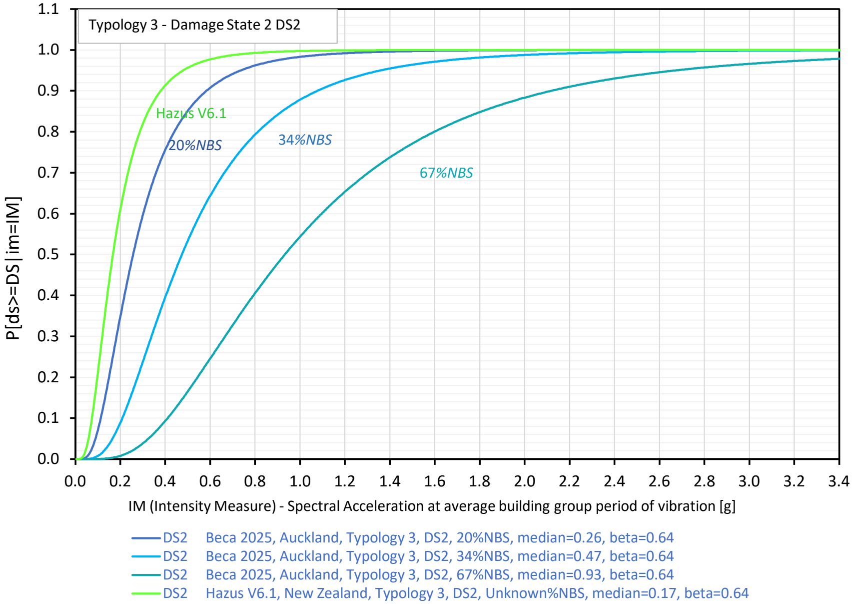


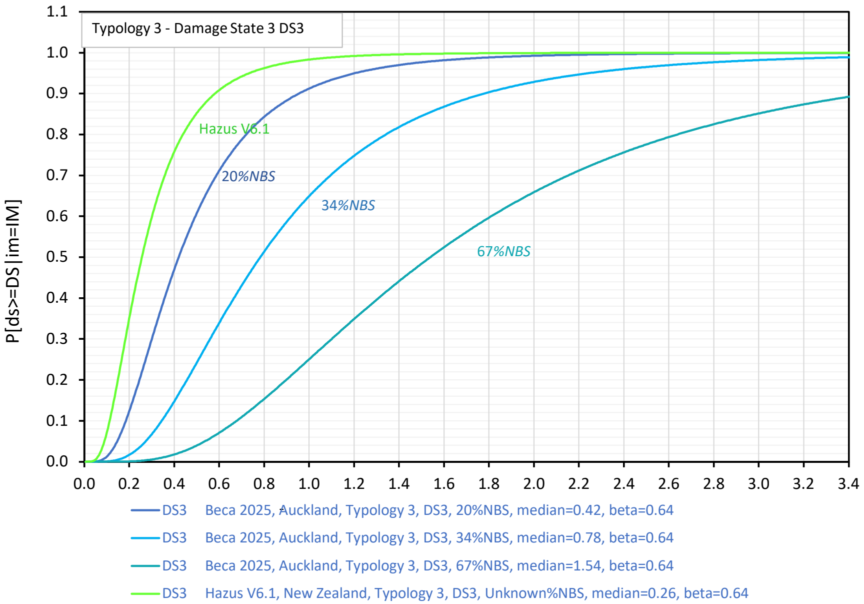
Typology 1 - Damage State 3 DS3
P[ds>=DS|im=IM]
Hazus V6.1
20%NBS
34%NBS
67%NBS
DS3 Beca 2025, Auckland, Typology 1, DS3, 20%NBS, median=0.58, beta=0.64
DS3 Beca 2025, Auckland, Typology 1, DS3, 34%NBS, median=1.07, beta=0.64
DS3 Beca 2025, Auckland, Typology 1, DS3, 67%NBS, median=2.09, beta=0.64
DS3 Hazus V6.1, New Zealand, Typology 1, DS3, Unknown%NBS, median=0.53, beta=0.64

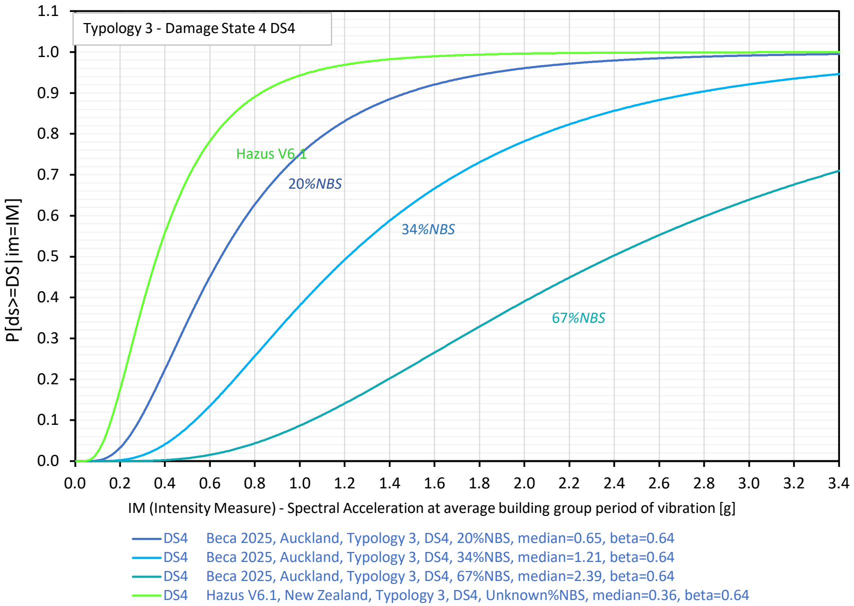


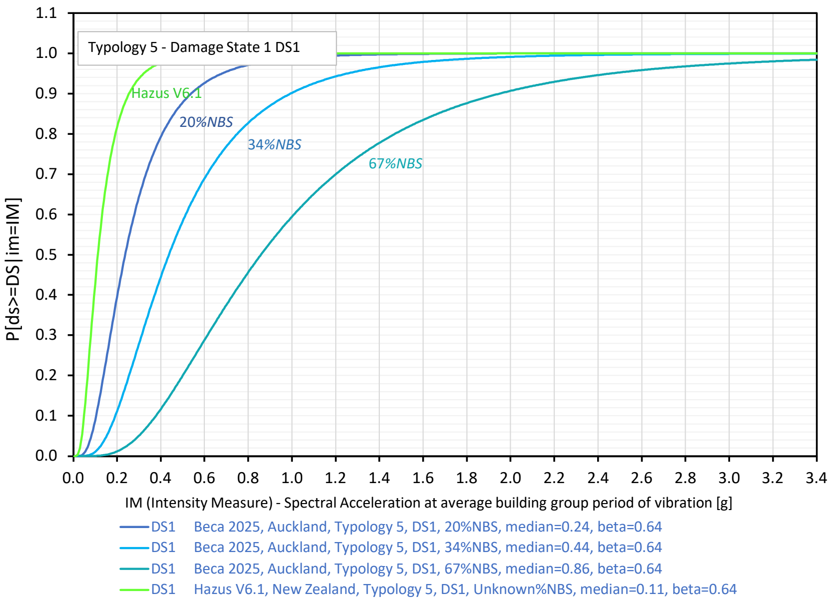
Typology 1 - Damage State 4 DS4
P[ds>=DS|im=IM]
IM (Intensity Measure) - Spectral Acceleration at average building group period of vibration [g]
Hazus V6.1
20%NBS
34%NBS
67%NBS
DS4 Beca 2025, Auckland, Typology 1, DS4, 20%NBS, median=0.91, beta=0.64
DS4 Beca 2025, Auckland, Typology 1, DS4, 34%NBS, median=1.68, beta=0.64
DS4 Beca 2025, Auckland, Typology 1, DS4, 67%NBS, median=3.29, beta=0.64
DS4 Hazus V6.1, New Zealand, Typology 1, DS4, Unknown%NBS, median=0.8, beta=0.64

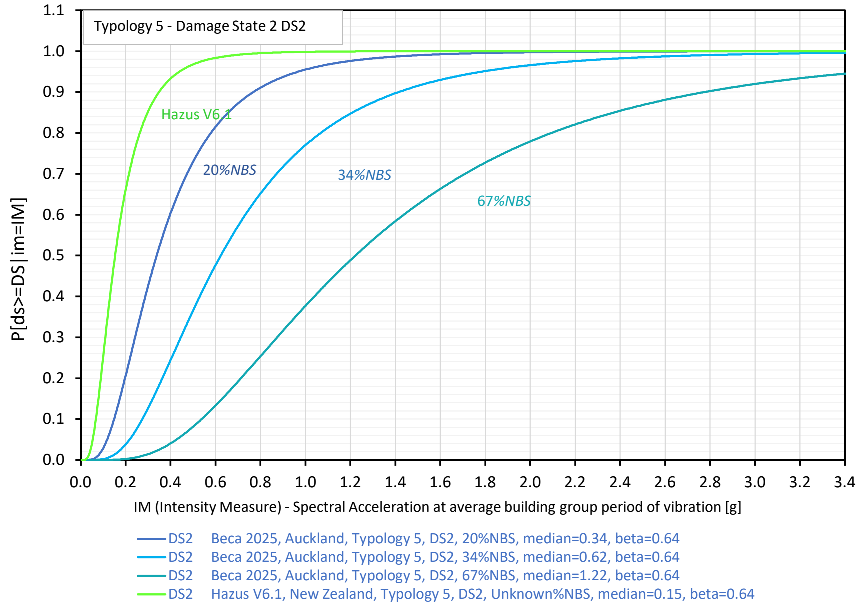

Typology 3 - Damage State 1 DS1
P[ds>=DS|im=IM]
IM (Intensity Measure) - Spectral Acceleration at average building group period of vibration [g]
Hazus V6.1
20%NBS
34%NBS
67%NBS
DS1 Beca 2025, Auckland, Typology 3, DS1, 20%NBS, median=0.17, beta=0.64
DS1 Beca 2025, Auckland, Typology 3, DS1, 34%NBS, median=0.3, beta=0.64
DS1 Beca 2025, Auckland, Typology 3, DS1, 67%NBS, median=0.6, beta=0.64
DS1 Hazus V6.1, New Zealand, Typology 3, DS1, Unknown%NBS, median=0.13, beta=0.64

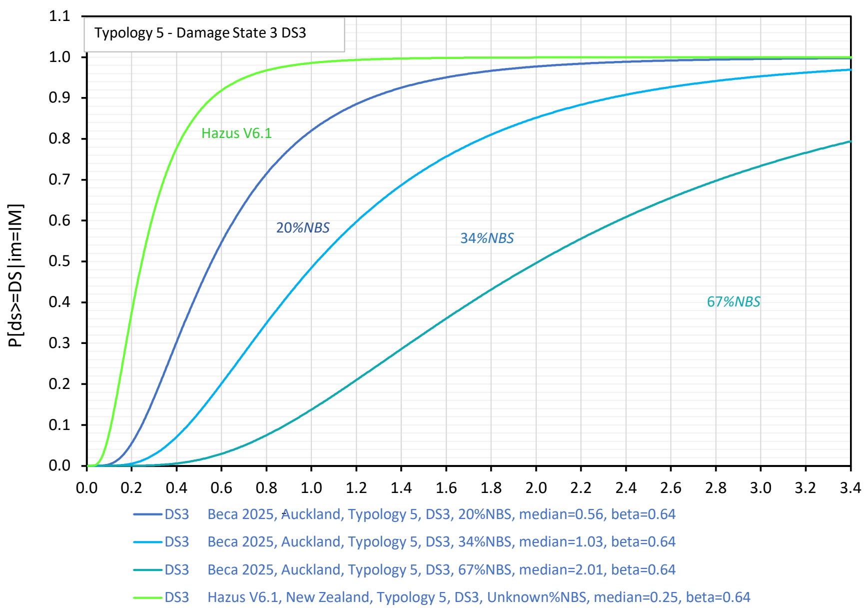

Typology 3 - Damage State 2 DS2
P[ds>=DS|im=IM]
IM (Intensity Measure) - Spectral Acceleration at average building group period of vibration [g]
Hazus V6.1
20%NBS
34%NBS
67%NBS
DS2 Beca 2025, Auckland, Typology 3, DS2, 20%NBS, median=0.26, beta=0.64
DS2 Beca 2025, Auckland, Typology 3, DS2, 34%NBS, median=0.47, beta=0.64
DS2 Beca 2025, Auckland, Typology 3, DS2, 67%NBS, median=0.93, beta=0.64
DS2 Hazus V6.1, New Zealand, Typology 3, DS2, Unknown%NBS, median=0.17, beta=0.64

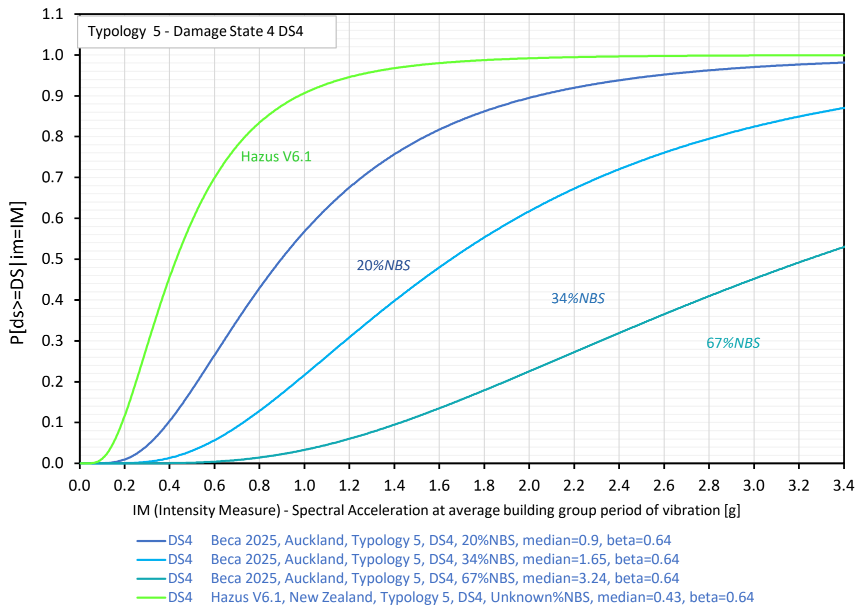

Typology 3 - Damage State 3 DS3
P[ds>=DS|im=IM]
Hazus V6.1
20%NBS
34%NBS
67%NBS
DS3 Beca 2025, Auckland, Typology 3, DS3, 20%NBS, median=0.42, beta=0.64
DS3 Beca 2025, Auckland, Typology 3, DS3, 34%NBS, median=0.78, beta=0.64
DS3 Beca 2025, Auckland, Typology 3, DS3, 67%NBS, median=1.54, beta=0.64
DS3 Hazus V6.1, New Zealand, Typology 3, DS3, Unknown%NBS, median=0.26, beta=0.64

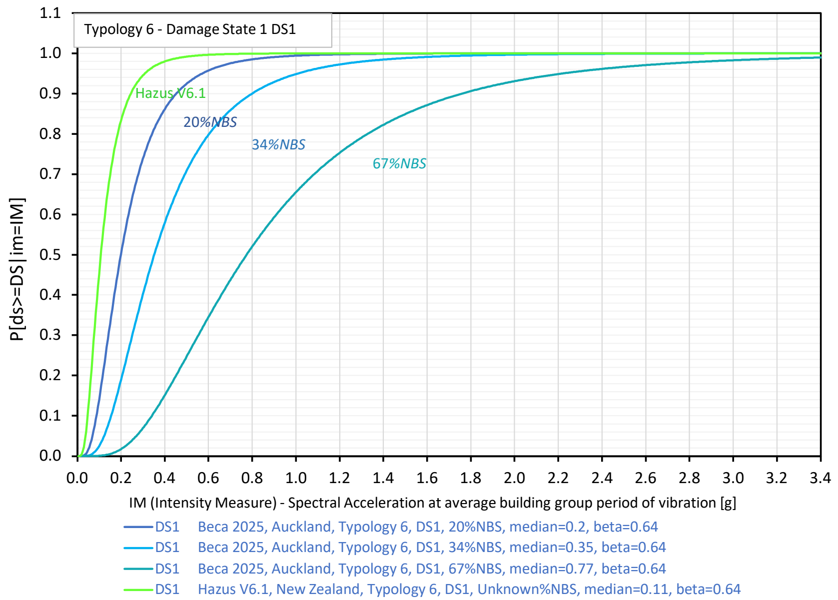

Typology 3 - Damage State 4 DS4
P[ds>=DS|im=IM]
IM (Intensity Measure) - Spectral Acceleration at average building group period of vibration [g]
Hazus V6.1
20%NBS
34%NBS
67%NBS
DS4 Beca 2025, Auckland, Typology 3, DS4, 20%NBS, median=0.65, beta=0.64
DS4 Beca 2025, Auckland, Typology 3, DS4, 34%NBS, median=1.21, beta=0.64
DS4 Beca 2025, Auckland, Typology 3, DS4, 67%NBS, median=2.39, beta=0.64
DS4 Hazus V6.1, New Zealand, Typology 3, DS4, Unknown%NBS, median=0.36, beta=0.64

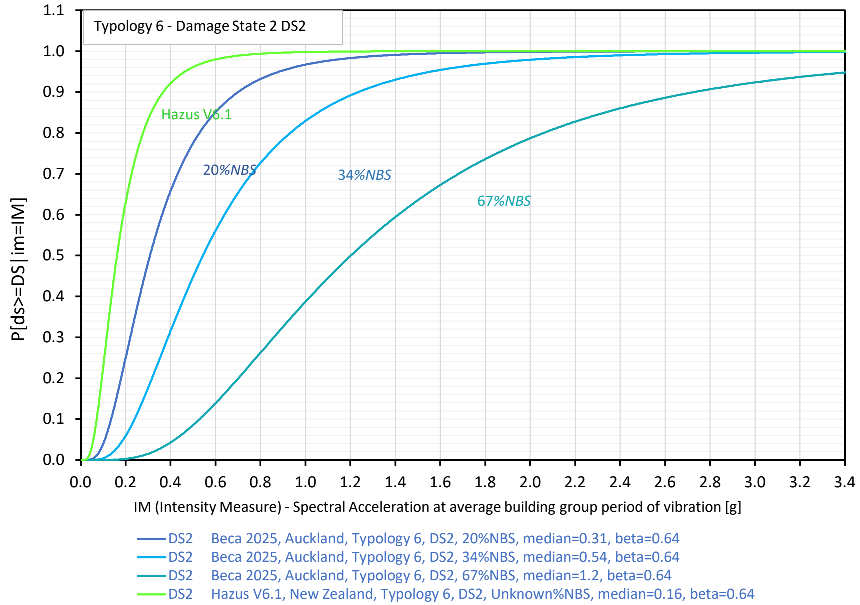

Typology 5 - Damage State 1 DS1
Hazus V6.1
20%NBS
34%NBS
67%NBS
P[ds>=DS|im=IM]
IM (Intensity Measure) - Spectral Acceleration at average building group period of vibration [g]
DS1 Beca 2025, Auckland, Typology 5, DS1, 20%NBS, median=0.24, beta=0.64
DS1 Beca 2025, Auckland, Typology 5, DS1, 34%NBS, median=0.44, beta=0.64
DS1 Beca 2025, Auckland, Typology 5, DS1, 67%NBS, median=0.86, beta=0.64
DS1 Hazus V6.1, New Zealand, Typology 5, DS1, Unknown%NBS, median=0.11, beta=0.64

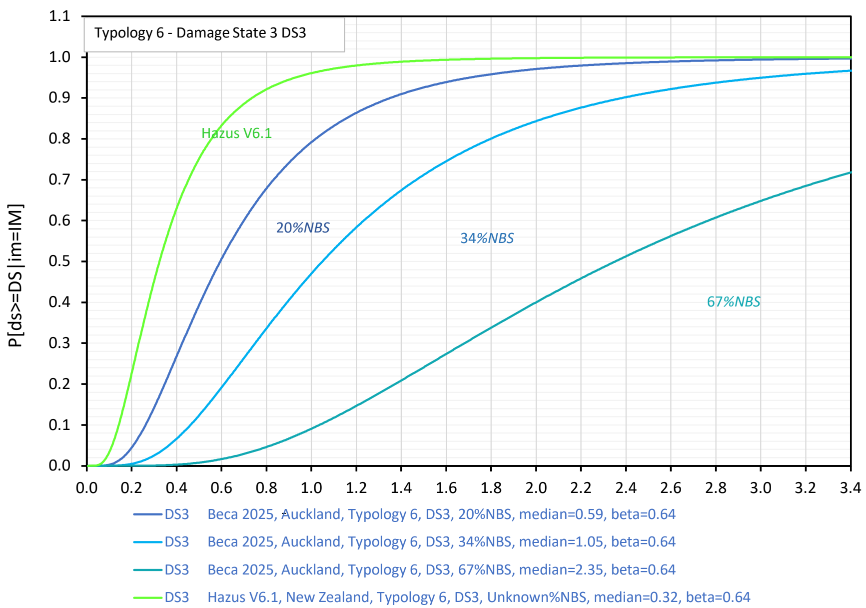

Typology 5 - Damage State 2 DS2
Hazus V6.1
20%NBS
34%NBS
67%NBS
P[ds>=DS|im=IM]
IM (Intensity Measure) - Spectral Acceleration at average building group period of vibration [g]
DS2 Beca 2025, Auckland, Typology 5, DS2, 20%NBS, median=0.34, beta=0.64
DS2 Beca 2025, Auckland, Typology 5, DS2, 34%NBS, median=0.62, beta=0.64
DS2 Beca 2025, Auckland, Typology 5, DS2, 67%NBS, median=1.22, beta=0.64
DS2 Hazus V6.1, New Zealand, Typology 5, DS2, Unknown%NBS, median=0.15, beta=0.64

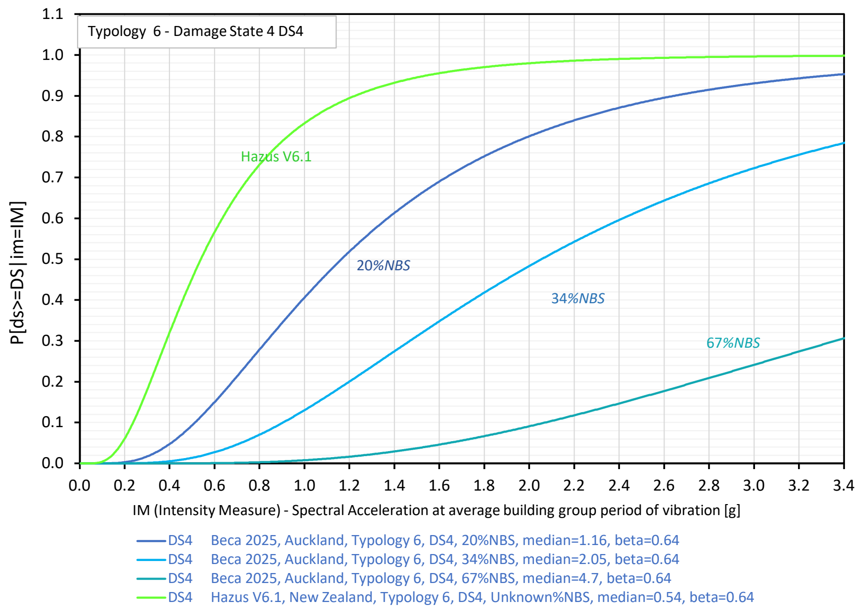

Typology 5 - Damage State 3 DS3
Hazus V6.1
20%NBS
34%NBS
67%NBS
P[ds>=DS|im=IM]
DS3 Beca 2025, Auckland, Typology 5, DS3, 20%NBS, median=0.56, beta=0.64
DS3 Beca 2025, Auckland, Typology 5, DS3, 34%NBS, median=1.03, beta=0.64
DS3 Beca 2025, Auckland, Typology 5, DS3, 67%NBS, median=2.01, beta=0.64
DS3 Hazus V6.1, New Zealand, Typology 5, DS3, Unknown%NBS, median=0.25, beta=0.64

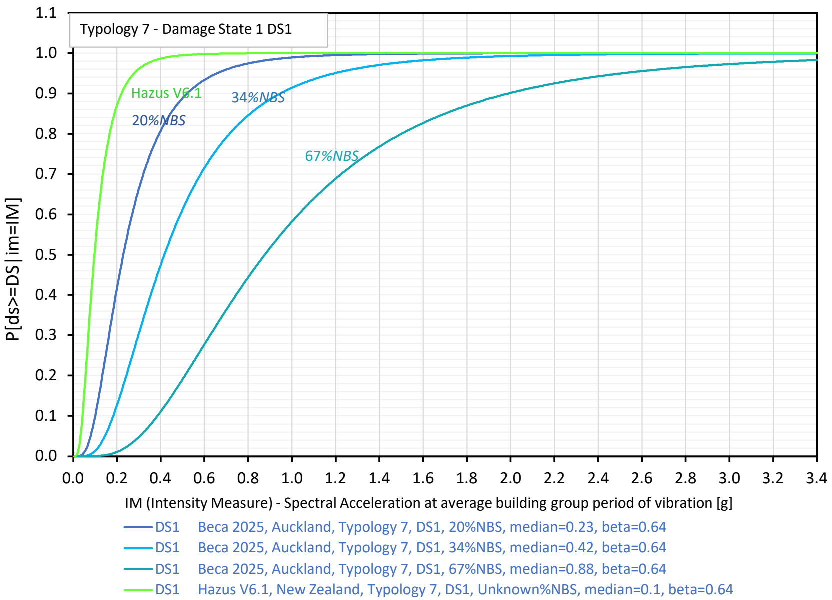

Typology 5 - Damage State 4 DS4
Hazus V6.1
20%NBS
34%NBS
67%NBS
P[ds>=DS|im=IM]
IM (Intensity Measure) - Spectral Acceleration at average building group period of vibration [g]
DS4 Beca 2025, Auckland, Typology 5, DS4, 20%NBS, median=0.9, beta=0.64
DS4 Beca 2025, Auckland, Typology 5, DS4, 34%NBS, median=1.65, beta=0.64
DS4 Beca 2025, Auckland, Typology 5, DS4, 67%NBS, median=3.24, beta=0.64
DS4 Hazus V6.1, New Zealand, Typology 5, DS4, Unknown%NBS, median=0.43, beta=0.64

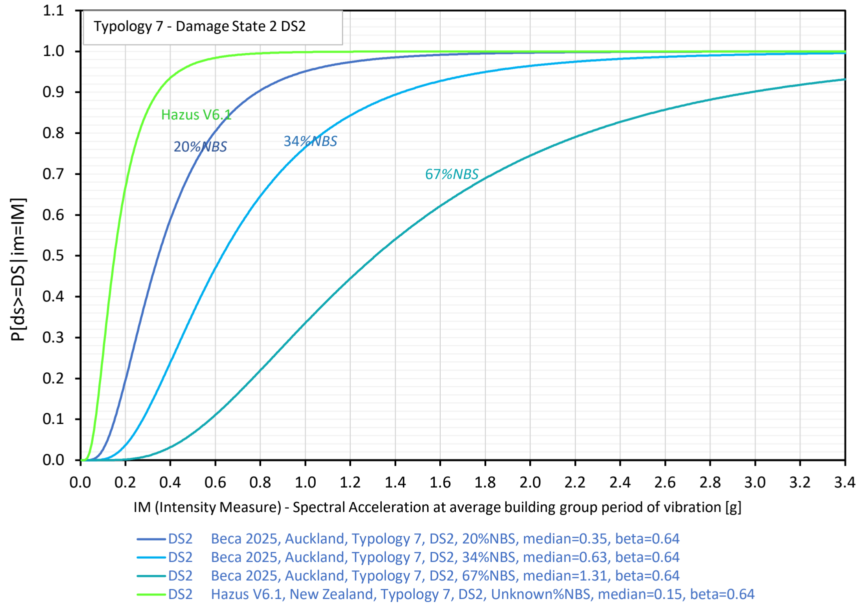

Typology 6 - Damage State 1 DS1
Hazus V6.1
20%NBS
34%NBS
67%NBS
P[ds>=DS|im=IM]
IM (Intensity Measure) - Spectral Acceleration at average building group period of vibration [g]
DS1 Beca 2025, Auckland, Typology 6, DS1, 20%NBS, median=0.2, beta=0.64
DS1 Beca 2025, Auckland, Typology 6, DS1, 34%NBS, median=0.35, beta=0.64
DS1 Beca 2025, Auckland, Typology 6, DS1, 67%NBS, median=0.77, beta=0.64
DS1 Hazus V6.1, New Zealand, Typology 6, DS1, Unknown%NBS, median=0.11, beta=0.64

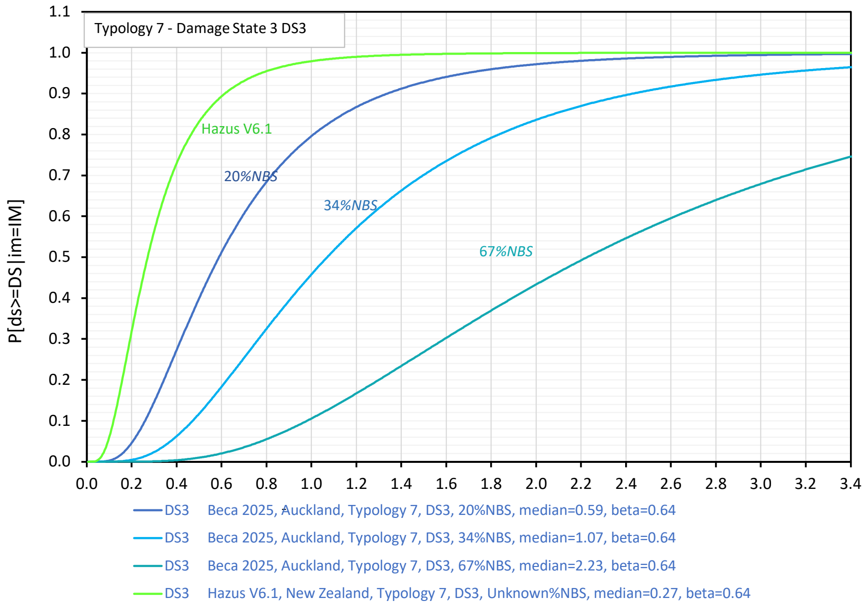

Typology 6 - Damage State 2 DS2
Hazus V6.1
20%NBS
34%NBS
67%NBS
P[ds>=DS|im=IM]
IM (Intensity Measure) - Spectral Acceleration at average building group period of vibration [g]
DS2 Beca 2025, Auckland, Typology 6, DS2, 20%NBS, median=0.31, beta=0.64
DS2 Beca 2025, Auckland, Typology 6, DS2, 34%NBS, median=0.54, beta=0.64
DS2 Beca 2025, Auckland, Typology 6, DS2, 67%NBS, median=1.2, beta=0.64
DS2 Hazus V6.1, New Zealand, Typology 6, DS2, Unknown%NBS, median=0.16, beta=0.64

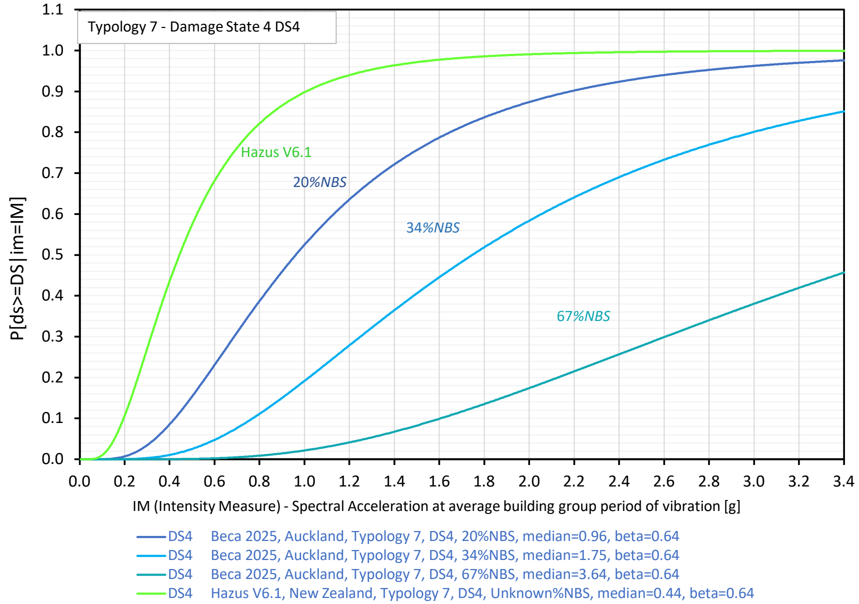

Typology 6 - Damage State 3 DS3
Hazus V6.1
20%NBS
34%NBS
67%NBS
P[ds>=DS|im=IM]
DS3 Beca 2025, Auckland, Typology 6, DS3, 20%NBS, median=0.59, beta=0.64
DS3 Beca 2025, Auckland, Typology 6, DS3, 34%NBS, median=1.05, beta=0.64
DS3 Beca 2025, Auckland, Typology 6, DS3, 67%NBS, median=2.35, beta=0.64
DS3 Hazus V6.1, New Zealand, Typology 6, DS3, Unknown%NBS, median=0.32, beta=0.64

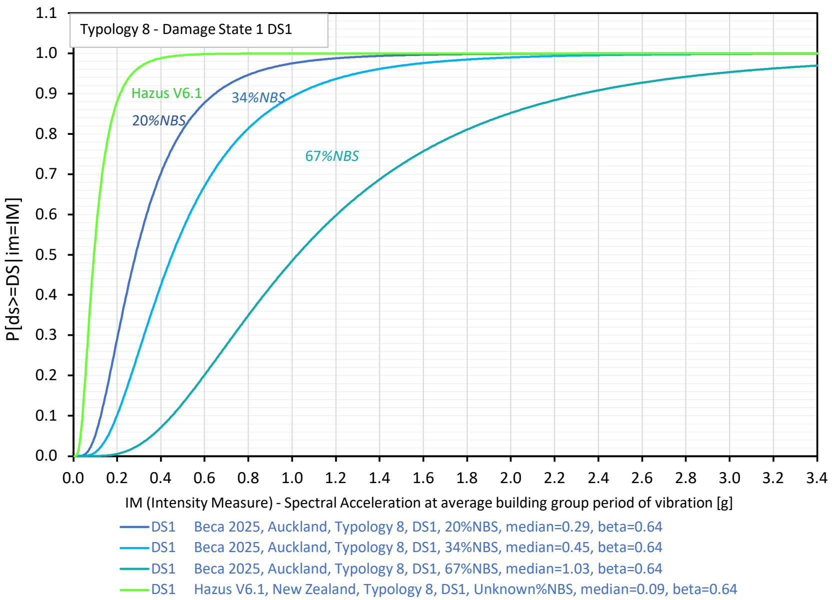

Typology 6 - Damage State 4 DS4
Hazus V6.1
20%NBS
34%NBS
67%NBS
P[ds>=DS|im=IM]
IM (Intensity Measure) - Spectral Acceleration at average building group period of vibration [g]
DS4 Beca 2025, Auckland, Typology 6, DS4, 20%NBS, median=1.16, beta=0.64
DS4 Beca 2025, Auckland, Typology 6, DS4, 34%NBS, median=2.05, beta=0.64
DS4 Beca 2025, Auckland, Typology 6, DS4, 67%NBS, median=4.7, beta=0.64
DS4 Hazus V6.1, New Zealand, Typology 6, DS4, Unknown%NBS, median=0.54, beta=0.64

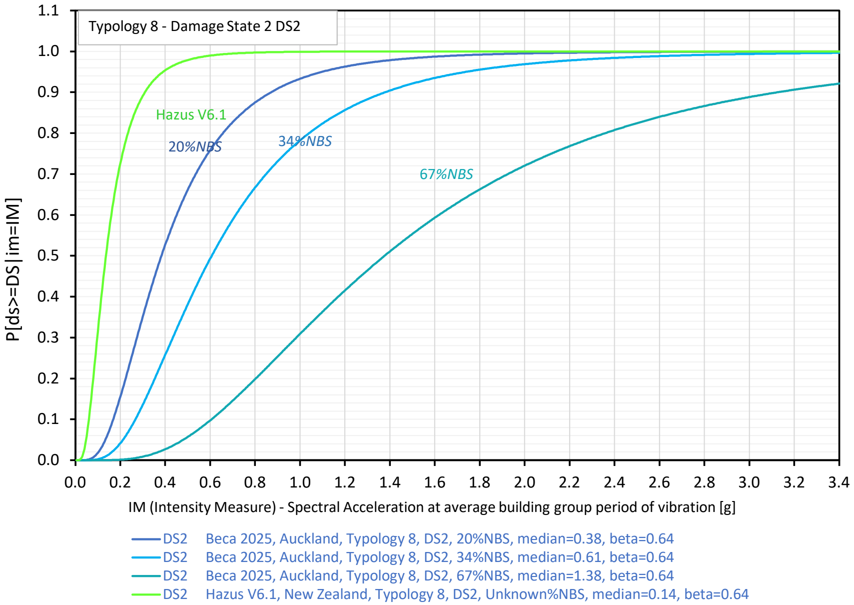

Typology 7 - Damage State 1 DS1
Hazus V6.1
34%NBS
20%NBS
67%NBS
P[ds>=DS|im=IM]
IM (Intensity Measure) - Spectral Acceleration at average building group period of vibration [g]
DS1 Beca 2025, Auckland, Typology 7, DS1, 20%NBS, median=0.23, beta=0.64
DS1 Beca 2025, Auckland, Typology 7, DS1, 34%NBS, median=0.42, beta=0.64
DS1 Beca 2025, Auckland, Typology 7, DS1, 67%NBS, median=0.88, beta=0.64
DS1 Hazus V6.1, New Zealand, Typology 7, DS1, Unknown%NBS, median=0.1, beta=0.64

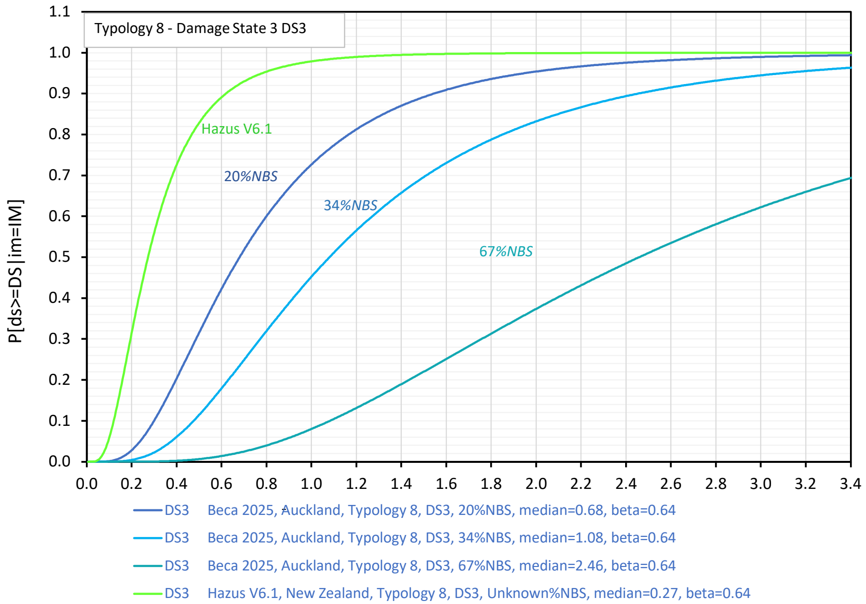

Typology 7 - Damage State 2 DS2
Hazus V6.1
20%NBS
34%NBS
67%NBS
P[ds>=DS|im=IM]
IM (Intensity Measure) - Spectral Acceleration at average building group period of vibration [g]
DS2 Beca 2025, Auckland, Typology 7, DS2, 20%NBS, median=0.35, beta=0.64
DS2 Beca 2025, Auckland, Typology 7, DS2, 34%NBS, median=0.63, beta=0.64
DS2 Beca 2025, Auckland, Typology 7, DS2, 67%NBS, median=1.31, beta=0.64
DS2 Hazus V6.1, New Zealand, Typology 7, DS2, Unknown%NBS, median=0.15, beta=0.64

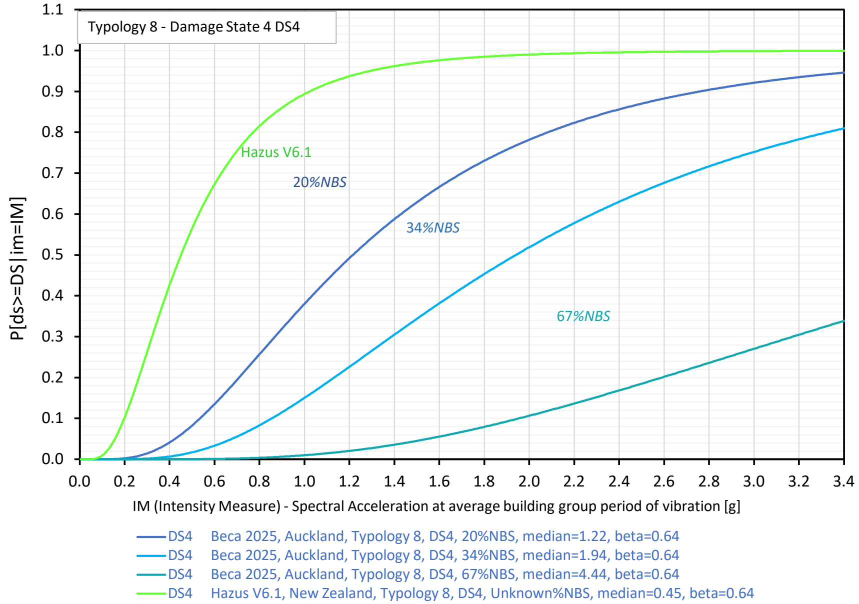

Typology 7 - Damage State 3 DS3
Hazus V6.1
20%NBS
34%NBS
67%NBS
P[ds>=DS|im=IM]
DS3 Beca 2025, Auckland, Typology 7, DS3, 20%NBS, median=0.59, beta=0.64
DS3 Beca 2025, Auckland, Typology 7, DS3, 34%NBS, median=1.07, beta=0.64
DS3 Beca 2025, Auckland, Typology 7, DS3, 67%NBS, median=2.23, beta=0.64
DS3 Hazus V6.1, New Zealand, Typology 7, DS3, Unknown%NBS, median=0.27, beta=0.64

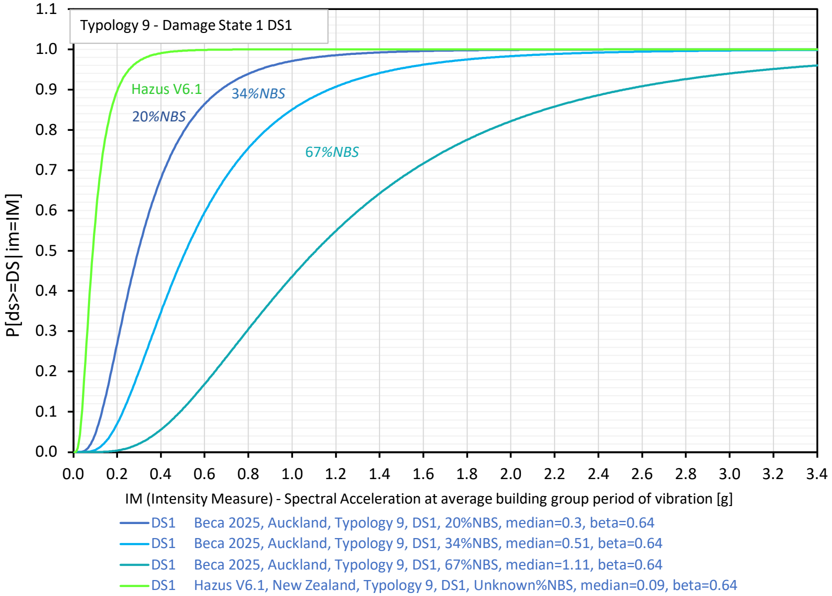

Typology 7 - Damage State 4 DS4
Hazus V6.1
20%NBS
34%NBS
67%NBS
P[ds>=DS|im=IM]
IM (Intensity Measure) - Spectral Acceleration at average building group period of vibration [g]
DS4 Beca 2025, Auckland, Typology 7, DS4, 20%NBS, median=0.96, beta=0.64
DS4 Beca 2025, Auckland, Typology 7, DS4, 34%NBS, median=1.75, beta=0.64
DS4 Beca 2025, Auckland, Typology 7, DS4, 67%NBS, median=3.64, beta=0.64
DS4 Hazus V6.1, New Zealand, Typology 7, DS4, Unknown%NBS, median=0.44, beta=0.64

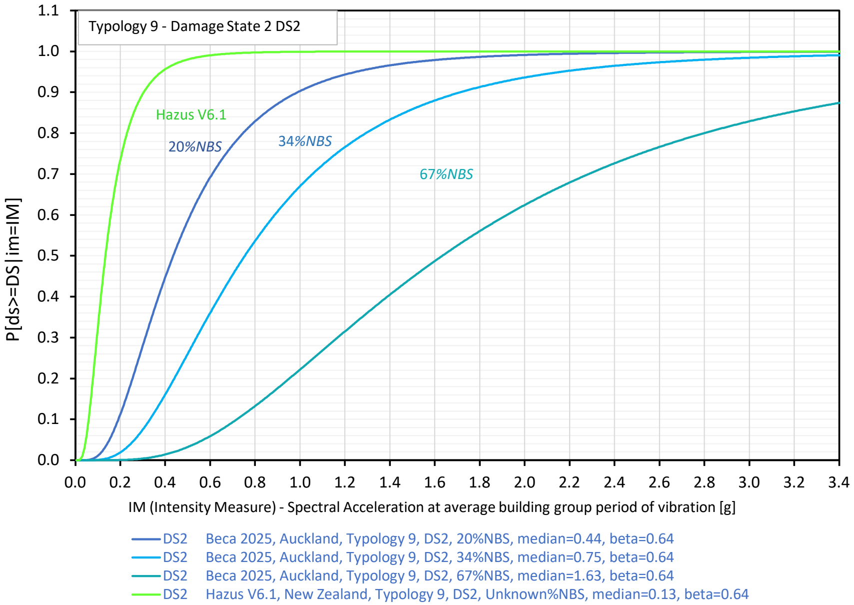

Typology 8 - Damage State 1 DS1
Hazus V6.1
34%NBS
20%NBS
67%NBS
P[ds>=DS|im=IM]
IM (Intensity Measure) - Spectral Acceleration at average building group period of vibration [g]
DS1 Beca 2025, Auckland, Typology 8, DS1, 20%NBS, median=0.29, beta=0.64
DS1 Beca 2025, Auckland, Typology 8, DS1, 34%NBS, median=0.45, beta=0.64
DS1 Beca 2025, Auckland, Typology 8, DS1, 67%NBS, median=1.03, beta=0.64
DS1 Hazus V6.1, New Zealand, Typology 8, DS1, Unknown%NBS, median=0.09, beta=0.64

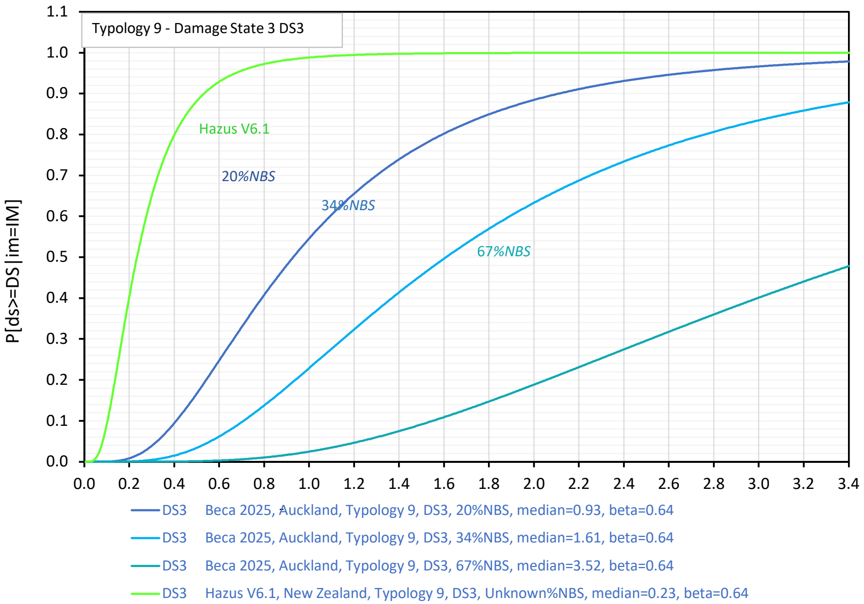

Typology 8 - Damage State 2 DS2
Hazus V6.1
20%NBS
34%NBS
67%NBS
P[ds>=DS|im=IM]
IM (Intensity Measure) - Spectral Acceleration at average building group period of vibration [g]
DS2 Beca 2025, Auckland, Typology 8, DS2, 20%NBS, median=0.38, beta=0.64
DS2 Beca 2025, Auckland, Typology 8, DS2, 34%NBS, median=0.61, beta=0.64
DS2 Beca 2025, Auckland, Typology 8, DS2, 67%NBS, median=1.38, beta=0.64
DS2 Hazus V6.1, New Zealand, Typology 8, DS2, Unknown%NBS, median=0.14, beta=0.64

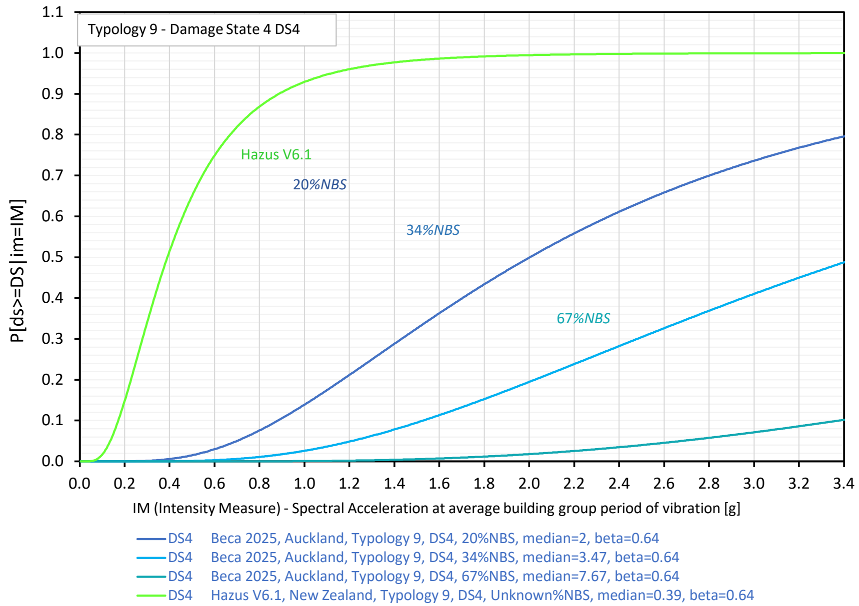

Typology 8 - Damage State 3 DS3
Hazus V6.1
20%NBS
34%NBS
67%NBS
P[ds>=DS|im=IM]
DS3 Beca 2025, Auckland, Typology 8, DS3, 20%NBS, median=0.68, beta=0.64
DS3 Beca 2025, Auckland, Typology 8, DS3, 34%NBS, median=1.08, beta=0.64
DS3 Beca 2025, Auckland, Typology 8, DS3, 67%NBS, median=2.46, beta=0.64
DS3 Hazus V6.1, New Zealand, Typology 8, DS3, Unknown%NBS, median=0.27, beta=0.64

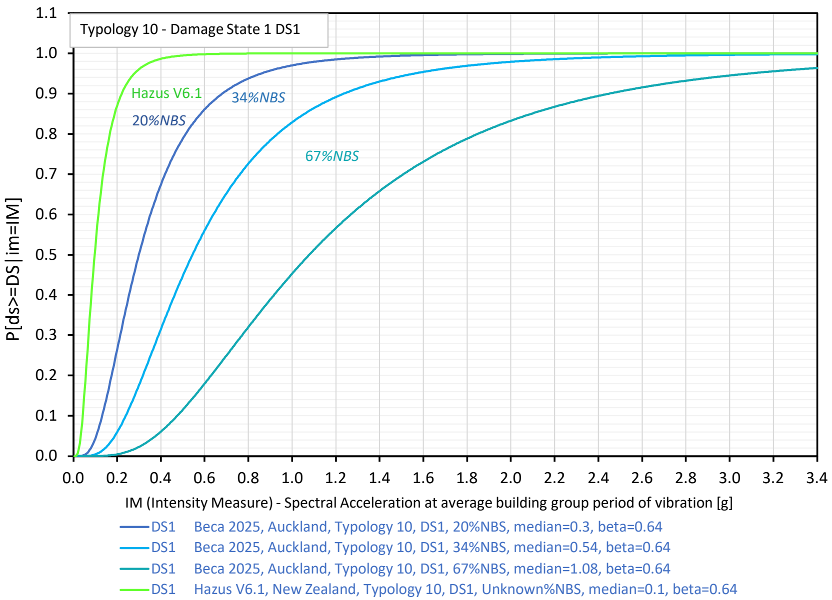

Typology 8 - Damage State 4 DS4
Hazus V6.1
20%NBS
34%NBS
67%NBS
P[ds>=DS|im=IM]
IM (Intensity Measure) - Spectral Acceleration at average building group period of vibration [g]
DS4 Beca 2025, Auckland, Typology 8, DS4, 20%NBS, median=1.22, beta=0.64
DS4 Beca 2025, Auckland, Typology 8, DS4, 34%NBS, median=1.94, beta=0.64
DS4 Beca 2025, Auckland, Typology 8, DS4, 67%NBS, median=4.44, beta=0.64
DS4 Hazus V6.1, New Zealand, Typology 8, DS4, Unknown%NBS, median=0.45, beta=0.64

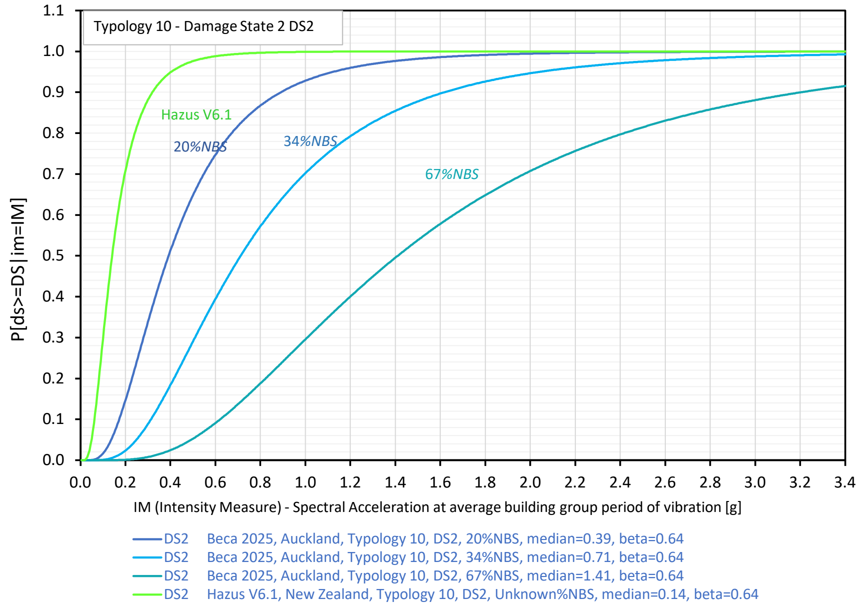

Typology 9 - Damage State 1 DS1
Hazus V6.1
34%NBS
20%NBS
67%NBS
P[ds>=DS|im=IM]
IM (Intensity Measure) - Spectral Acceleration at average building group period of vibration [g]
DS1 Beca 2025, Auckland, Typology 9, DS1, 20%NBS, median=0.3, beta=0.64
DS1 Beca 2025, Auckland, Typology 9, DS1, 34%NBS, median=0.51, beta=0.64
DS1 Beca 2025, Auckland, Typology 9, DS1, 67%NBS, median=1.11, beta=0.64
DS1 Hazus V6.1, New Zealand, Typology 9, DS1, Unknown%NBS, median=0.09, beta=0.64

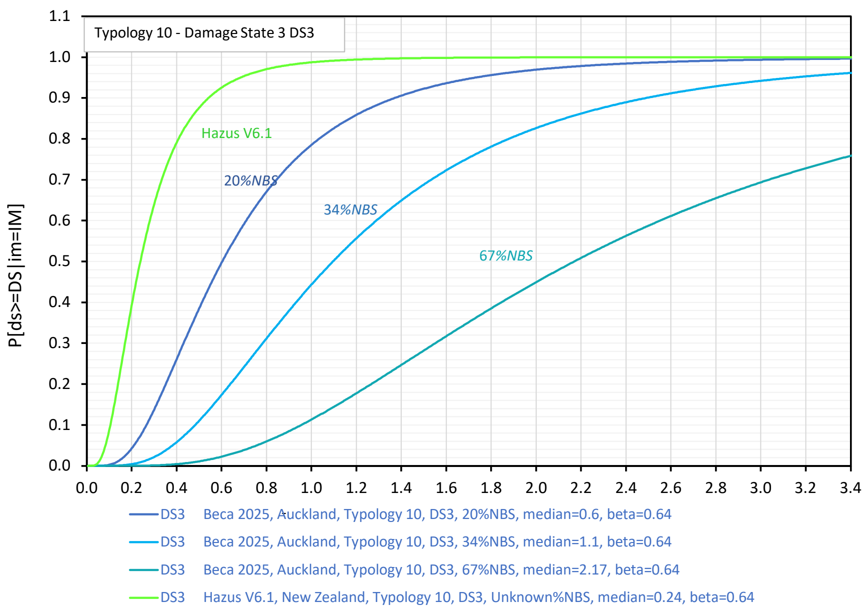

Typology 9 - Damage State 2 DS2
Hazus V6.1
20%NBS
34%NBS
67%NBS
P[ds>=DS|im=IM]
IM (Intensity Measure) - Spectral Acceleration at average building group period of vibration [g]
DS2 Beca 2025, Auckland, Typology 9, DS2, 20%NBS, median=0.44, beta=0.64
DS2 Beca 2025, Auckland, Typology 9, DS2, 34%NBS, median=0.75, beta=0.64
DS2 Beca 2025, Auckland, Typology 9, DS2, 67%NBS, median=1.63, beta=0.64
DS2 Hazus V6.1, New Zealand, Typology 9, DS2, Unknown%NBS, median=0.13, beta=0.64

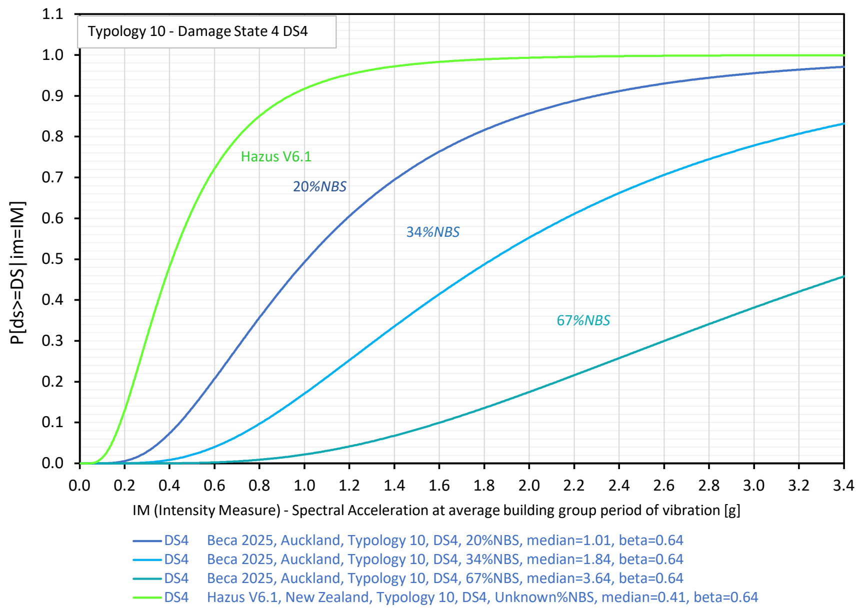

Typology 9 - Damage State 3 DS3
Hazus V6.1
20%NBS
34%NBS
67%NBS
P[ds>=DS|im=IM]
DS3 Beca 2025, Auckland, Typology 9, DS3, 20%NBS, median=0.93, beta=0.64
DS3 Beca 2025, Auckland, Typology 9, DS3, 34%NBS, median=1.61, beta=0.64
DS3 Beca 2025, Auckland, Typology 9, DS3, 67%NBS, median=3.52, beta=0.64
DS3 Hazus V6.1, New Zealand, Typology 9, DS3, Unknown%NBS, median=0.23, beta=0.64

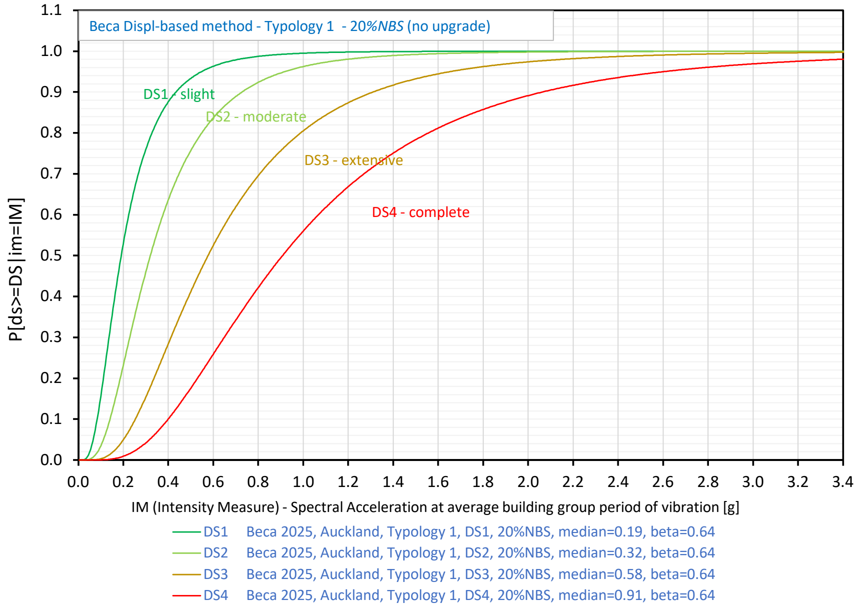

Typology 9 - Damage State 4 DS4
Hazus V6.1
20%NBS
34%NBS
67%NBS
P[ds>=DS|im=IM]
IM (Intensity Measure) - Spectral Acceleration at average building group period of vibration [g]
DS4 Beca 2025, Auckland, Typology 9, DS4, 20%NBS, median=2, beta=0.64
DS4 Beca 2025, Auckland, Typology 9, DS4, 34%NBS, median=3.47, beta=0.64
DS4 Beca 2025, Auckland, Typology 9, DS4, 67%NBS, median=7.67, beta=0.64
DS4 Hazus V6.1, New Zealand, Typology 9, DS4, Unknown%NBS, median=0.39, beta=0.64


Typology 10 - Damage State 1 DS1
P[ds>=DS|im=IM]
IM (Intensity Measure) - Spectral Acceleration at average building group period of vibration [g]
Hazus V6.1
20%NBS
34%NBS
67%NBS
DS1 Beca 2025, Auckland, Typology 10, DS1, 20%NBS, median=0.3, beta=0.64
DS1 Beca 2025, Auckland, Typology 10, DS1, 34%NBS, median=0.54, beta=0.64
DS1 Beca 2025, Auckland, Typology 10, DS1, 67%NBS, median=1.08, beta=0.64
DS1 Hazus V6.1, New Zealand, Typology 10, DS1, Unknown%NBS, median=0.1, beta=0.64

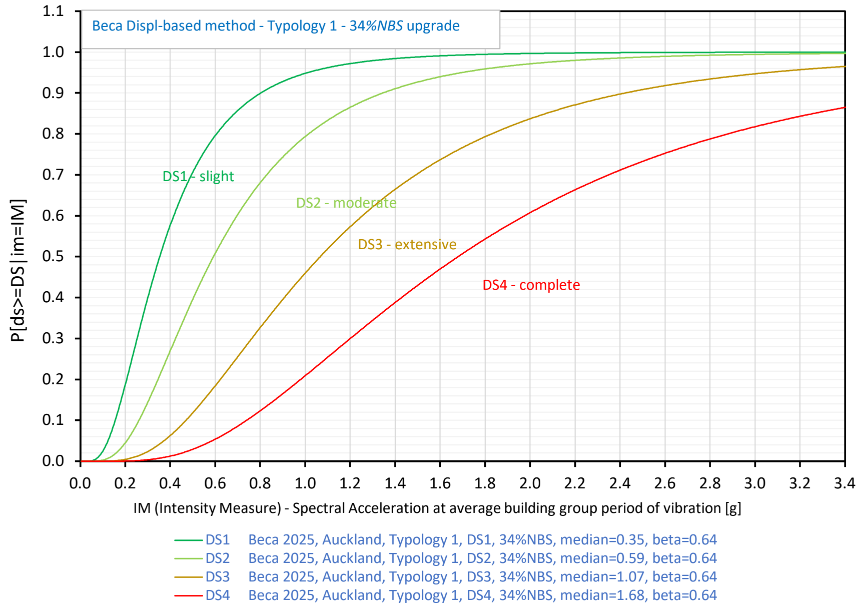

Typology 10 - Damage State 2 DS2
P[ds>=DS|im=IM]
IM (Intensity Measure) - Spectral Acceleration at average building group period of vibration [g]
Hazus V6.1
20%NBS
34%NBS
67%NBS
DS2 Beca 2025, Auckland, Typology 10, DS2, 20%NBS, median=0.39, beta=0.64
DS2 Beca 2025, Auckland, Typology 10, DS2, 34%NBS, median=0.71, beta=0.64
DS2 Beca 2025, Auckland, Typology 10, DS2, 67%NBS, median=1.41, beta=0.64
DS2 Hazus V6.1, New Zealand, Typology 10, DS2, Unknown%NBS, median=0.14, beta=0.64


Typology 10 - Damage State 3 DS3
P[ds>=DS|im=IM]
Hazus V6.1
20%NBS
34%NBS
67%NBS
DS3 Beca 2025, Auckland, Typology 10, DS3, 20%NBS, median=0.6, beta=0.64
DS3 Beca 2025, Auckland, Typology 10, DS3, 34%NBS, median=1.1, beta=0.64
DS3 Beca 2025, Auckland, Typology 10, DS3, 67%NBS, median=2.17, beta=0.64
DS3 Hazus V6.1, New Zealand, Typology 10, DS3, Unknown%NBS, median=0.24, beta=0.64

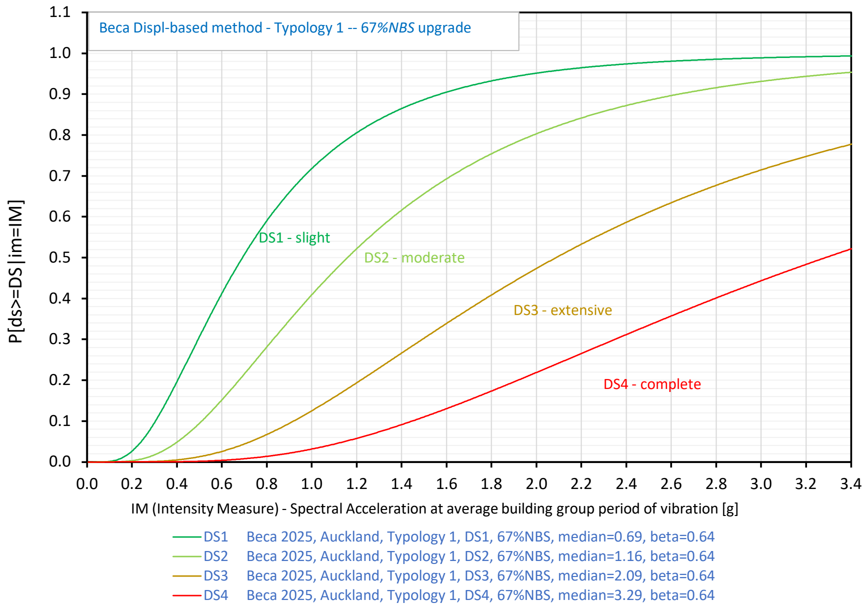

Typology 10 - Damage State 4 DS4
P[ds>=DS|im=IM]
IM (Intensity Measure) - Spectral Acceleration at average building group period of vibration [g]
Hazus V6.1
20%NBS
34%NBS
67%NBS
DS4 Beca 2025, Auckland, Typology 10, DS4, 20%NBS, median=1.01, beta=0.64
DS4 Beca 2025, Auckland, Typology 10, DS4, 34%NBS, median=1.84, beta=0.64
DS4 Beca 2025, Auckland, Typology 10, DS4, 67%NBS, median=3.64, beta=0.64
DS4 Hazus V6.1, New Zealand, Typology 10, DS4, Unknown%NBS, median=0.41, beta=0.64



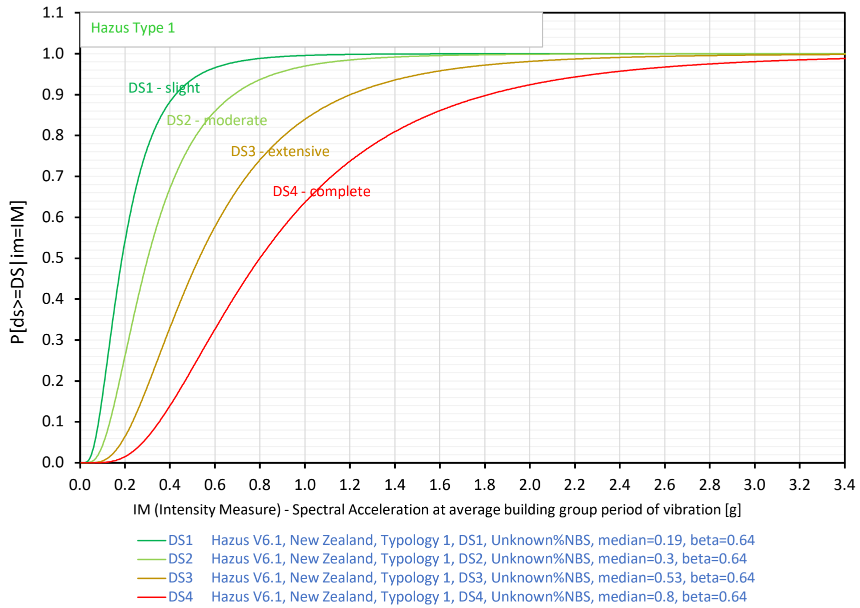
Beca Displ-based method - Typology 1 - 20%NBS (no upgrade)
DS1 - slight
DS2 - moderate
DS3 - extensive
DS4 - complete
P[ds>=DS|im=IM]
IM (Intensity Measure) - Spectral Acceleration at average building group period of vibration [g]
DS1 Beca 2025, Auckland, Typology 1, DS1, 20%NBS, median=0.19, beta=0.64
DS2 Beca 2025, Auckland, Typology 1, DS2, 20%NBS, median=0.32, beta=0.64
DS3 Beca 2025, Auckland, Typology 1, DS3, 20%NBS, median=0.58, beta=0.64
DS4 Beca 2025, Auckland, Typology 1, DS4, 20%NBS, median=0.91, beta=0.64



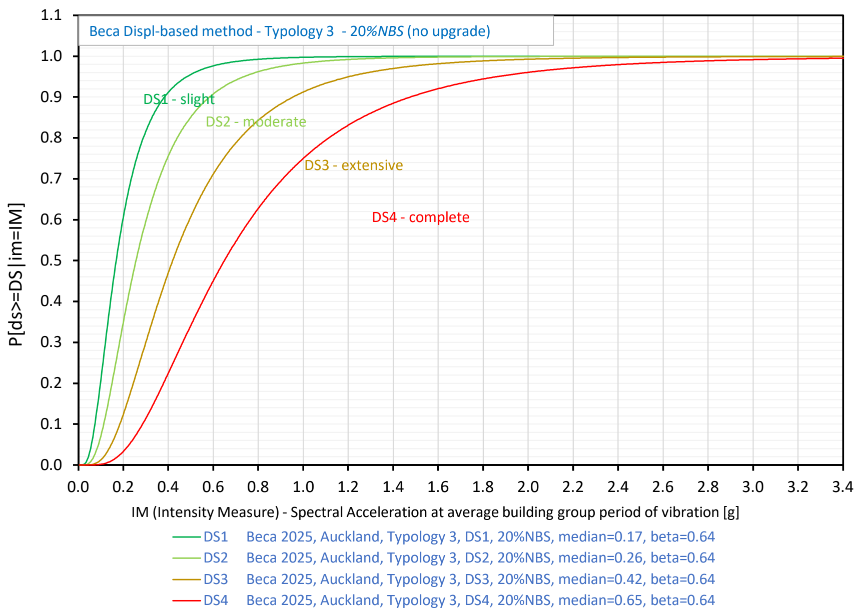
Beca Displ-based method - Typology 1 - 34%NBS upgrade
DS1 - slight
DS2 - moderate
DS3 - extensive
DS4 - complete
P[ds>=DS|im=IM]
IM (Intensity Measure) - Spectral Acceleration at average building group period of vibration [g]
DS1 Beca 2025, Auckland, Typology 1, DS1, 34%NBS, median=0.35, beta=0.64
DS2 Beca 2025, Auckland, Typology 1, DS2, 34%NBS, median=0.59, beta=0.64
DS3 Beca 2025, Auckland, Typology 1, DS3, 34%NBS, median=1.07, beta=0.64
DS4 Beca 2025, Auckland, Typology 1, DS4, 34%NBS, median=1.68, beta=0.64

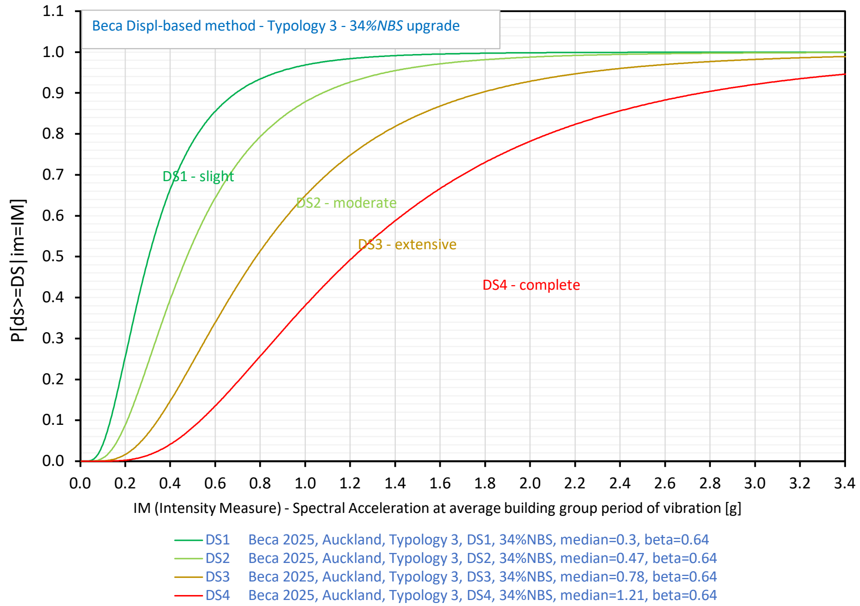


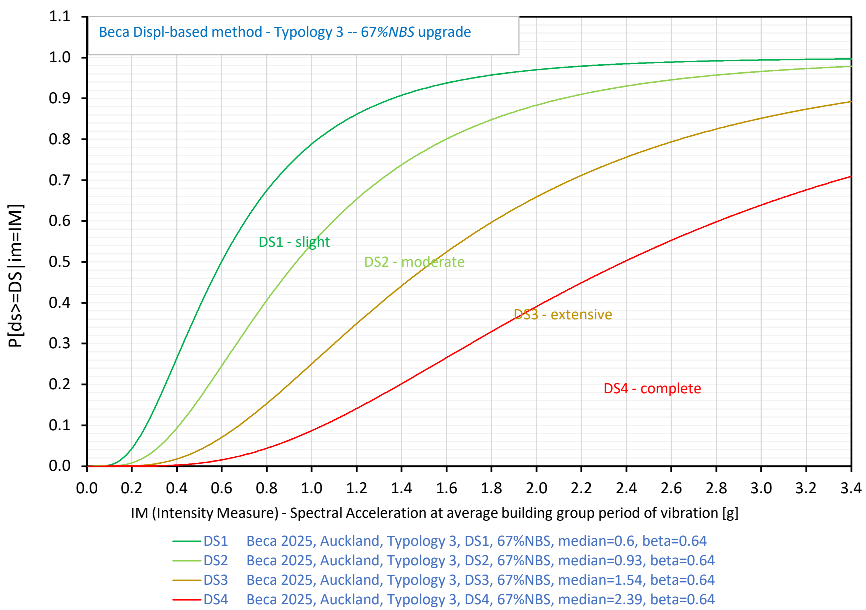
Beca Displ-based method - Typology 1 -- 67%NBS upgrade
DS1 - slight
DS2 - moderate
DS3 - extensive
DS4 - complete
P[ds>=DS|im=IM]
IM (Intensity Measure) - Spectral Acceleration at average building group period of vibration [g]
DS1 Beca 2025, Auckland, Typology 1, DS1, 67%NBS, median=0.69, beta=0.64
DS2 Beca 2025, Auckland, Typology 1, DS2, 67%NBS, median=1.16, beta=0.64
DS3 Beca 2025, Auckland, Typology 1, DS3, 67%NBS, median=2.09, beta=0.64
DS4 Beca 2025, Auckland, Typology 1, DS4, 67%NBS, median=3.29, beta=0.64

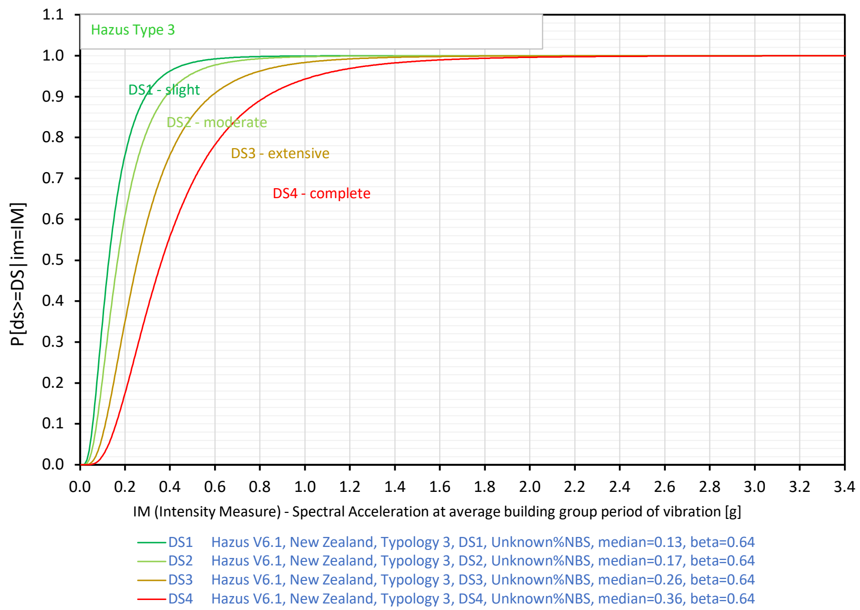


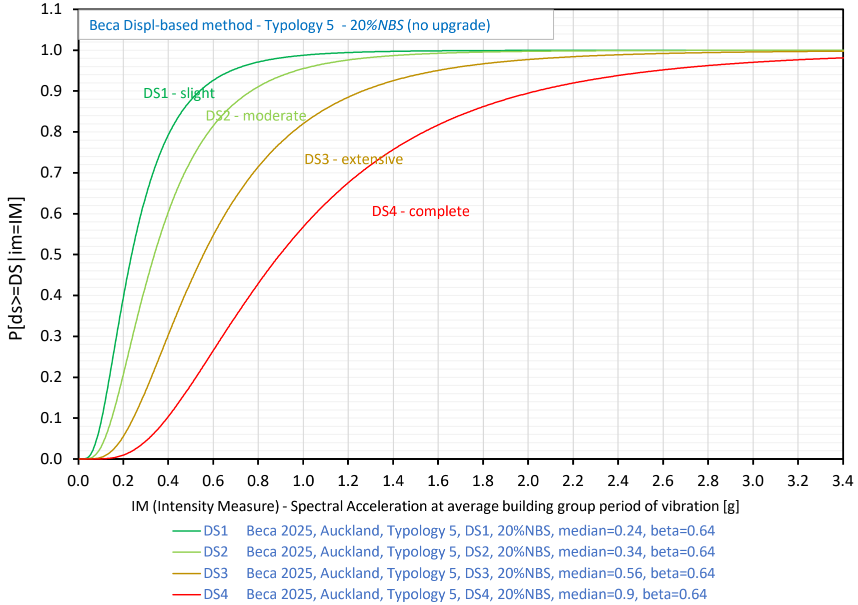
Hazus Type 1
DS1 - slight
DS2 - moderate
DS3 - extensive
DS4 - complete
P[ds>=DS|im=IM]
IM (Intensity Measure) - Spectral Acceleration at average building group period of vibration [g]
DS1 Hazus V6.1, New Zealand, Typology 1, DS1, Unknown%NBS, median=0.19, beta=0.64
DS2 Hazus V6.1, New Zealand, Typology 1, DS2, Unknown%NBS, median=0.3, beta=0.64
DS3 Hazus V6.1, New Zealand, Typology 1, DS3, Unknown%NBS, median=0.53, beta=0.64
DS4 Hazus V6.1, New Zealand, Typology 1, DS4, Unknown%NBS, median=0.8, beta=0.64

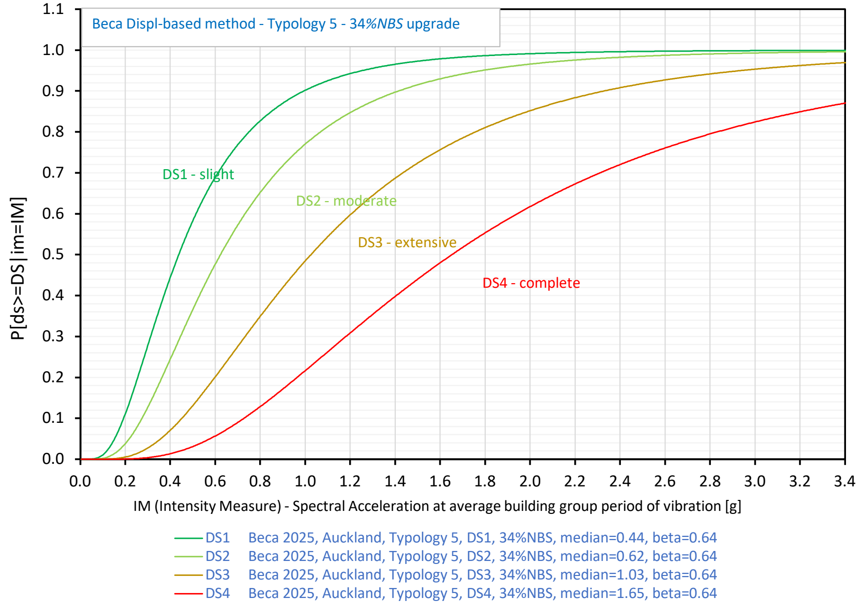

Beca Displ-based method - Typology 3 - 20%*NBS* (no upgrade)
DS1 - slight
DS2 - moderate
DS3 - extensive
DS4 - complete
P[ds>=DS|im=IM]
IM (Intensity Measure) - Spectral Acceleration at average building group period of vibration [g]
DS1 Beca 2025, Auckland, Typology 3, DS1, 20%NBS, median=0.17, beta=0.64
DS2 Beca 2025, Auckland, Typology 3, DS2, 20%NBS, median=0.26, beta=0.64
DS3 Beca 2025, Auckland, Typology 3, DS3, 20%NBS, median=0.42, beta=0.64
DS4 Beca 2025, Auckland, Typology 3, DS4, 20%NBS, median=0.65, beta=0.64

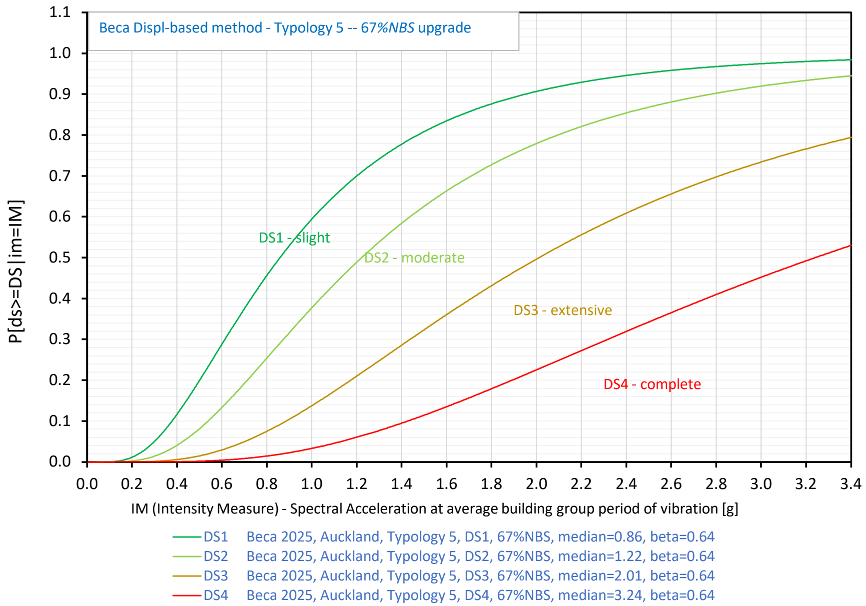

Beca Displ-based method - Typology 3 - 34%*NBS* upgrade
DS1 - slight
DS2 - moderate
DS3 - extensive
DS4 - complete
P[ds>=DS|im=IM]
IM (Intensity Measure) - Spectral Acceleration at average building group period of vibration [g]
DS1 Beca 2025, Auckland, Typology 3, DS1, 34%NBS, median=0.3, beta=0.64
DS2 Beca 2025, Auckland, Typology 3, DS2, 34%NBS, median=0.47, beta=0.64
DS3 Beca 2025, Auckland, Typology 3, DS3, 34%NBS, median=0.78, beta=0.64
DS4 Beca 2025, Auckland, Typology 3, DS4, 34%NBS, median=1.21, beta=0.64

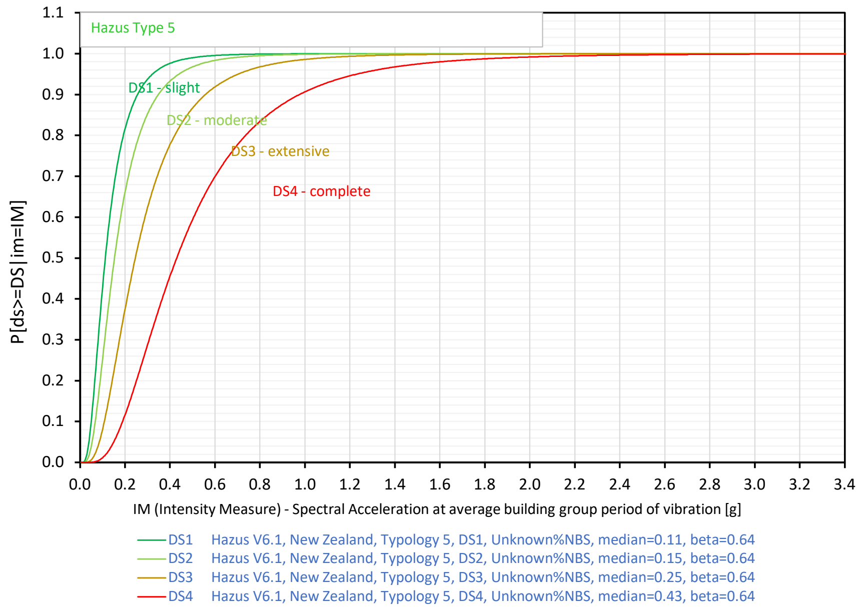

Beca Displ-based method - Typology 3 -- 67%*NBS* upgrade
DS1 - slight
DS2 - moderate
DS3 - extensive
DS4 - complete
P[ds>=DS|im=IM]
IM (Intensity Measure) - Spectral Acceleration at average building group period of vibration [g]
DS1 Beca 2025, Auckland, Typology 3, DS1, 67%NBS, median=0.6, beta=0.64
DS2 Beca 2025, Auckland, Typology 3, DS2, 67%NBS, median=0.93, beta=0.64
DS3 Beca 2025, Auckland, Typology 3, DS3, 67%NBS, median=1.54, beta=0.64
DS4 Beca 2025, Auckland, Typology 3, DS4, 67%NBS, median=2.39, beta=0.64

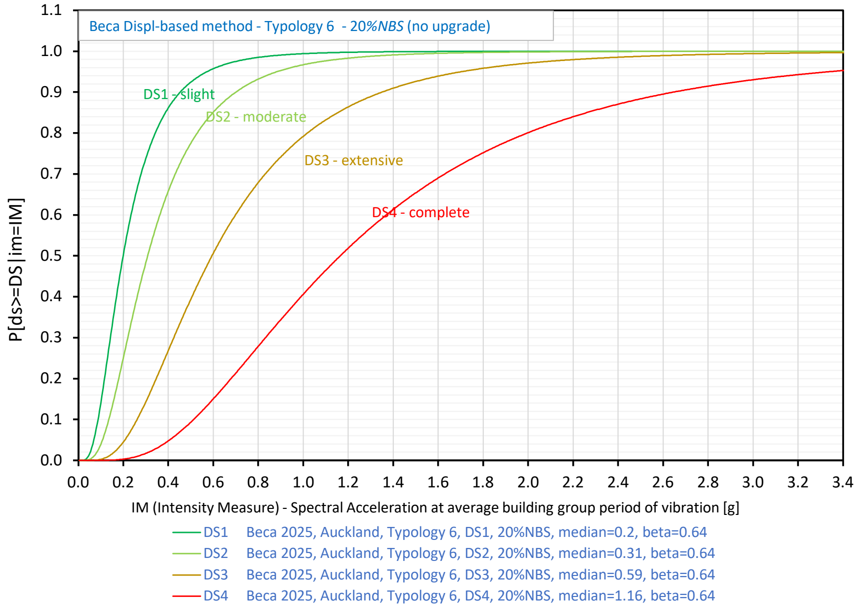

Hazus Type 3
DS1 - slight
DS2 - moderate
DS3 - extensive
DS4 - complete
P[ds>=DS|im=IM]
IM (Intensity Measure) - Spectral Acceleration at average building group period of vibration [g]
DS1 Hazus V6.1, New Zealand, Typology 3, DS1, Unknown%NBS, median=0.13, beta=0.64
DS2 Hazus V6.1, New Zealand, Typology 3, DS2, Unknown%NBS, median=0.17, beta=0.64
DS3 Hazus V6.1, New Zealand, Typology 3, DS3, Unknown%NBS, median=0.26, beta=0.64
DS4 Hazus V6.1, New Zealand, Typology 3, DS4, Unknown%NBS, median=0.36, beta=0.64

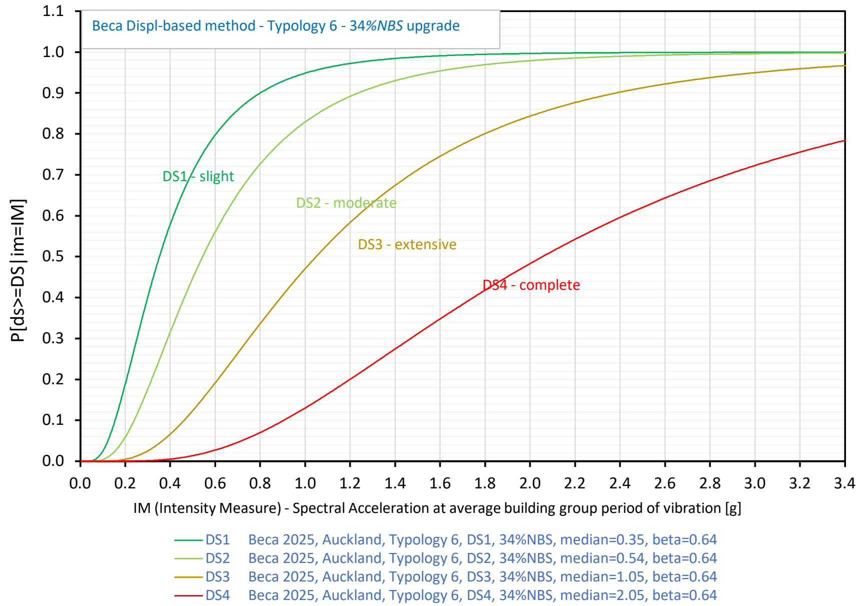

Beca Displ-based method - Typology 5 - 20%NBS (no upgrade)
DS1 - slight
DS2 - moderate
DS3 - extensive
DS4 - complete
P[ds>=DS|im=IM]
IM (Intensity Measure) - Spectral Acceleration at average building group period of vibration [g]
DS1 Beca 2025, Auckland, Typology 5, DS1, 20%NBS, median=0.24, beta=0.64
DS2 Beca 2025, Auckland, Typology 5, DS2, 20%NBS, median=0.34, beta=0.64
DS3 Beca 2025, Auckland, Typology 5, DS3, 20%NBS, median=0.56, beta=0.64
DS4 Beca 2025, Auckland, Typology 5, DS4, 20%NBS, median=0.9, beta=0.64

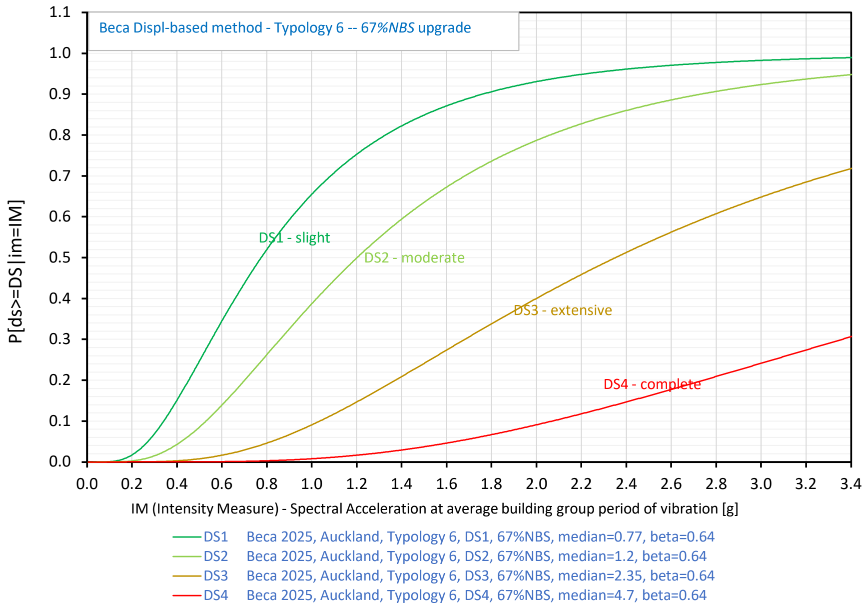

Beca Displ-based method - Typology 5 - 34%NBS upgrade
DS1 - slight
DS2 - moderate
DS3 - extensive
DS4 - complete
P[ds>=DS|im=IM]
IM (Intensity Measure) - Spectral Acceleration at average building group period of vibration [g]
DS1 Beca 2025, Auckland, Typology 5, DS1, 34%NBS, median=0.44, beta=0.64
DS2 Beca 2025, Auckland, Typology 5, DS2, 34%NBS, median=0.62, beta=0.64
DS3 Beca 2025, Auckland, Typology 5, DS3, 34%NBS, median=1.03, beta=0.64
DS4 Beca 2025, Auckland, Typology 5, DS4, 34%NBS, median=1.65, beta=0.64

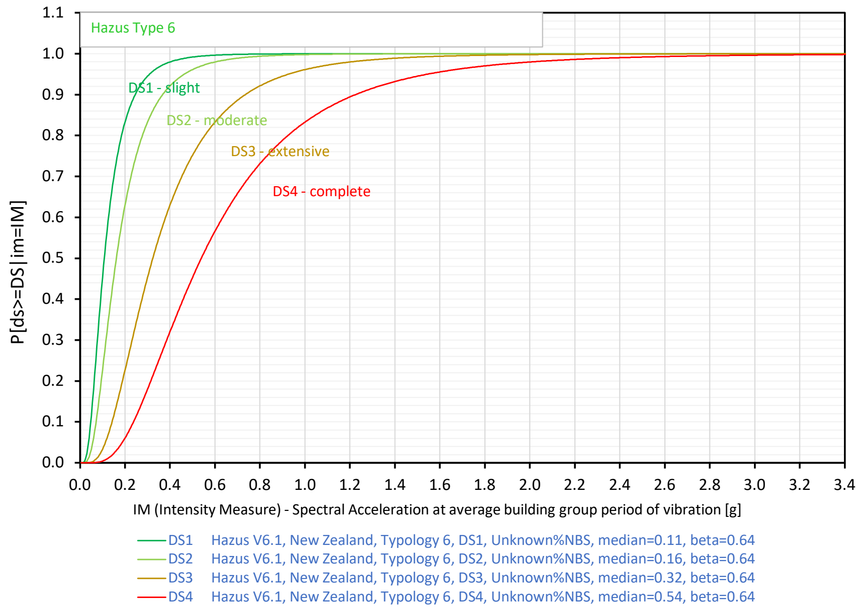

Beca Displ-based method - Typology 5 -- 67%NBS upgrade
DS1 - slight
DS2 - moderate
DS3 - extensive
DS4 - complete
P[ds>=DS|im=IM]
IM (Intensity Measure) - Spectral Acceleration at average building group period of vibration [g]
DS1 Beca 2025, Auckland, Typology 5, DS1, 67%NBS, median=0.86, beta=0.64
DS2 Beca 2025, Auckland, Typology 5, DS2, 67%NBS, median=1.22, beta=0.64
DS3 Beca 2025, Auckland, Typology 5, DS3, 67%NBS, median=2.01, beta=0.64
DS4 Beca 2025, Auckland, Typology 5, DS4, 67%NBS, median=3.24, beta=0.64

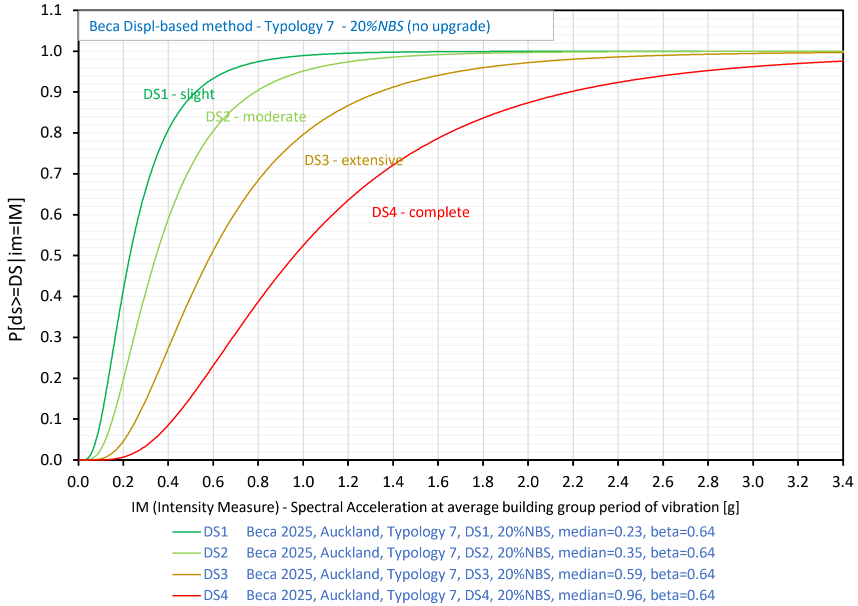

Hazus Type 5
DS1 - slight
DS2 - moderate
DS3 - extensive
DS4 - complete
P[ds>=DS|im=IM]
IM (Intensity Measure) - Spectral Acceleration at average building group period of vibration [g]
DS1 Hazus V6.1, New Zealand, Typology 5, DS1, Unknown%NBS, median=0.11, beta=0.64
DS2 Hazus V6.1, New Zealand, Typology 5, DS2, Unknown%NBS, median=0.15, beta=0.64
DS3 Hazus V6.1, New Zealand, Typology 5, DS3, Unknown%NBS, median=0.25, beta=0.64
DS4 Hazus V6.1, New Zealand, Typology 5, DS4, Unknown%NBS, median=0.43, beta=0.64


Beca Displ-based method - Typology 6 - 20%*NBS* (no upgrade)
DS1 - slight
DS2 - moderate
DS3 - extensive
DS4 - complete
P[ds>=DS|im=IM]
IM (Intensity Measure) - Spectral Acceleration at average building group period of vibration [g]
DS1 Beca 2025, Auckland, Typology 6, DS1, 20%NBS, median=0.2, beta=0.64
DS2 Beca 2025, Auckland, Typology 6, DS2, 20%NBS, median=0.31, beta=0.64
DS3 Beca 2025, Auckland, Typology 6, DS3, 20%NBS, median=0.59, beta=0.64
DS4 Beca 2025, Auckland, Typology 6, DS4, 20%NBS, median=1.16, beta=0.64

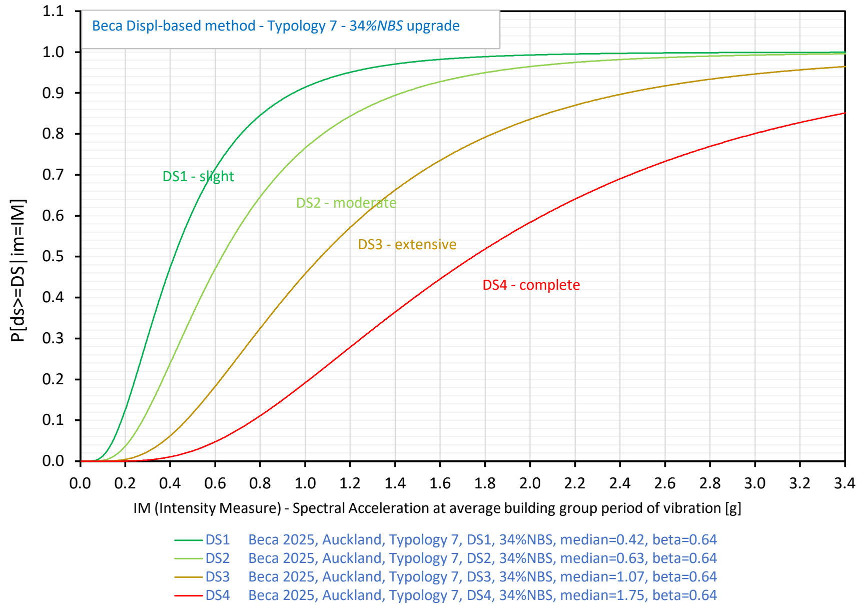

Beca Displ-based method - Typology 6 - 34%*NBS* upgrade
DS1 - slight
DS2 - moderate
DS3 - extensive
DS4 - complete
P[ds>=DS|im=IM]
IM (Intensity Measure) - Spectral Acceleration at average building group period of vibration [g]
DS1 Beca 2025, Auckland, Typology 6, DS1, 34%NBS, median=0.35, beta=0.64
DS2 Beca 2025, Auckland, Typology 6, DS2, 34%NBS, median=0.54, beta=0.64
DS3 Beca 2025, Auckland, Typology 6, DS3, 34%NBS, median=1.05, beta=0.64
DS4 Beca 2025, Auckland, Typology 6, DS4, 34%NBS, median=2.05, beta=0.64


Beca Displ-based method - Typology 6 -- 67%*NBS* upgrade
DS1 - slight
DS2 - moderate
DS3 - extensive
DS4 - complete
P[ds>=DS|im=IM]
IM (Intensity Measure) - Spectral Acceleration at average building group period of vibration [g]
DS1 Beca 2025, Auckland, Typology 6, DS1, 67%NBS, median=0.77, beta=0.64
DS2 Beca 2025, Auckland, Typology 6, DS2, 67%NBS, median=1.2, beta=0.64
DS3 Beca 2025, Auckland, Typology 6, DS3, 67%NBS, median=2.35, beta=0.64
DS4 Beca 2025, Auckland, Typology 6, DS4, 67%NBS, median=4.7, beta=0.64

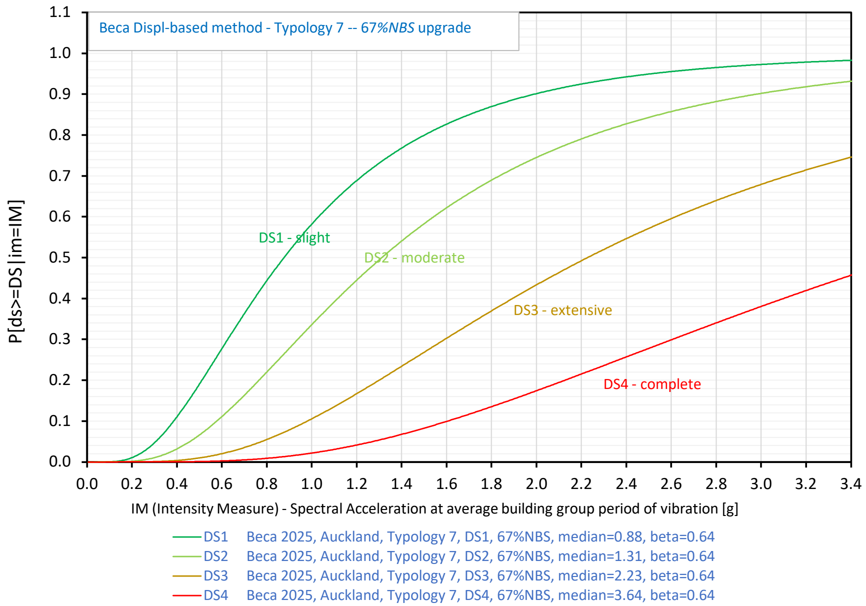

Hazus Type 6
DS1 - slight
DS2 - moderate
DS3 - extensive
DS4 - complete
P[ds>=DS|im=IM]
IM (Intensity Measure) - Spectral Acceleration at average building group period of vibration [g]
DS1 Hazus V6.1, New Zealand, Typology 6, DS1, Unknown%NBS, median=0.11, beta=0.64
DS2 Hazus V6.1, New Zealand, Typology 6, DS2, Unknown%NBS, median=0.16, beta=0.64
DS3 Hazus V6.1, New Zealand, Typology 6, DS3, Unknown%NBS, median=0.32, beta=0.64
DS4 Hazus V6.1, New Zealand, Typology 6, DS4, Unknown%NBS, median=0.54, beta=0.64



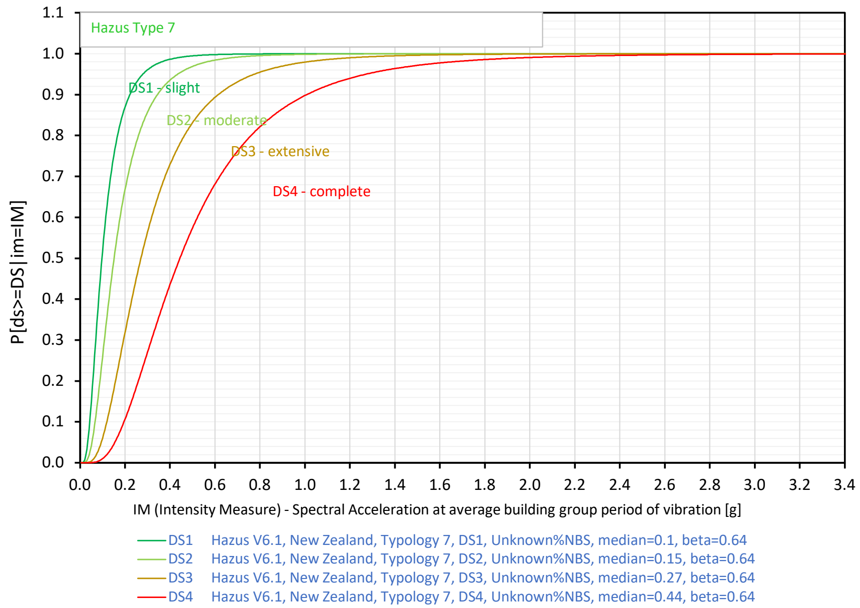
Beca Displ-based method - Typology 7 - 20%NBS (no upgrade)
DS1 - slight
DS2 - moderate
DS3 - extensive
DS4 - complete
P[ds>=DS|im=IM]
IM (Intensity Measure) - Spectral Acceleration at average building group period of vibration [g]
DS1 Beca 2025, Auckland, Typology 7, DS1, 20%NBS, median=0.23, beta=0.64
DS2 Beca 2025, Auckland, Typology 7, DS2, 20%NBS, median=0.35, beta=0.64
DS3 Beca 2025, Auckland, Typology 7, DS3, 20%NBS, median=0.59, beta=0.64
DS4 Beca 2025, Auckland, Typology 7, DS4, 20%NBS, median=0.96, beta=0.64



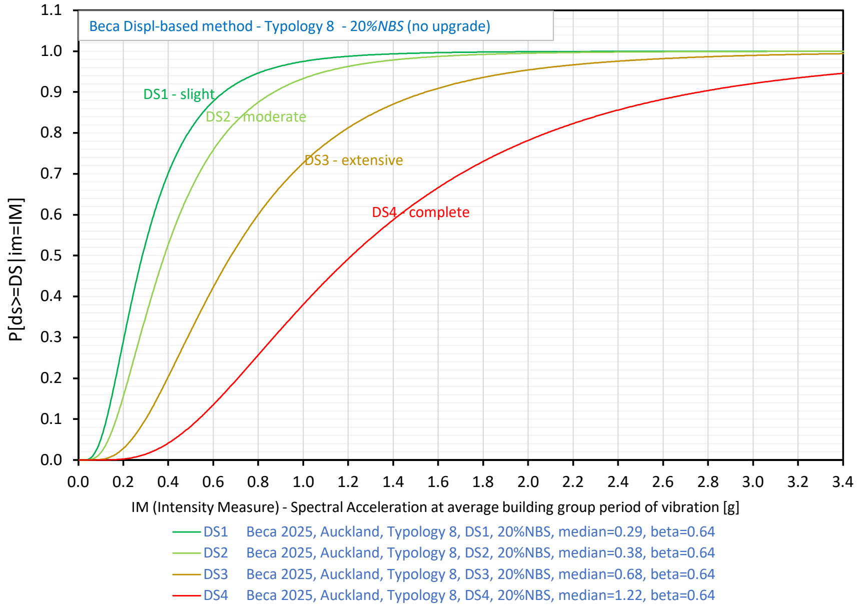
Beca Displ-based method - Typology 7 - 34%NBS upgrade
DS1 - slight
DS2 - moderate
DS3 - extensive
DS4 - complete
P[ds>=DS|im=IM]
IM (Intensity Measure) - Spectral Acceleration at average building group period of vibration [g]
DS1 Beca 2025, Auckland, Typology 7, DS1, 34%NBS, median=0.42, beta=0.64
DS2 Beca 2025, Auckland, Typology 7, DS2, 34%NBS, median=0.63, beta=0.64
DS3 Beca 2025, Auckland, Typology 7, DS3, 34%NBS, median=1.07, beta=0.64
DS4 Beca 2025, Auckland, Typology 7, DS4, 34%NBS, median=1.75, beta=0.64

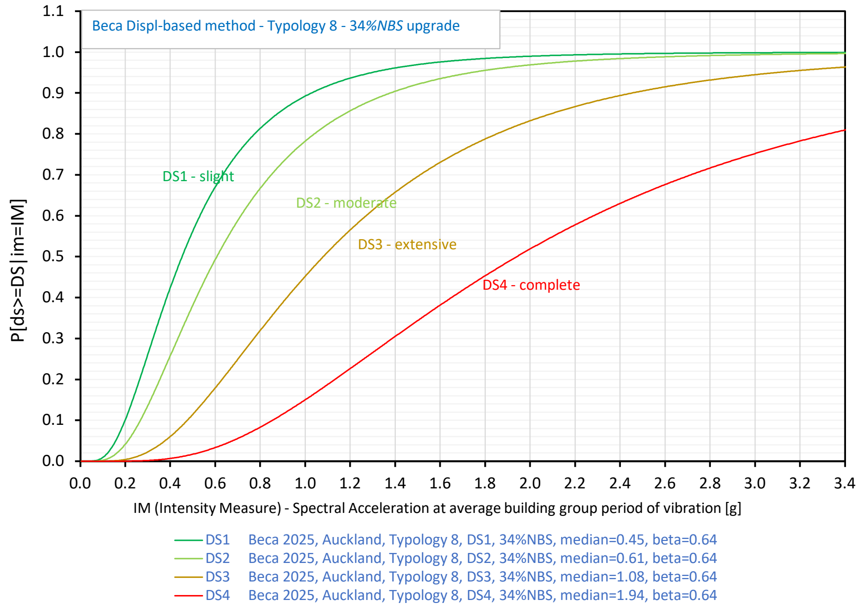


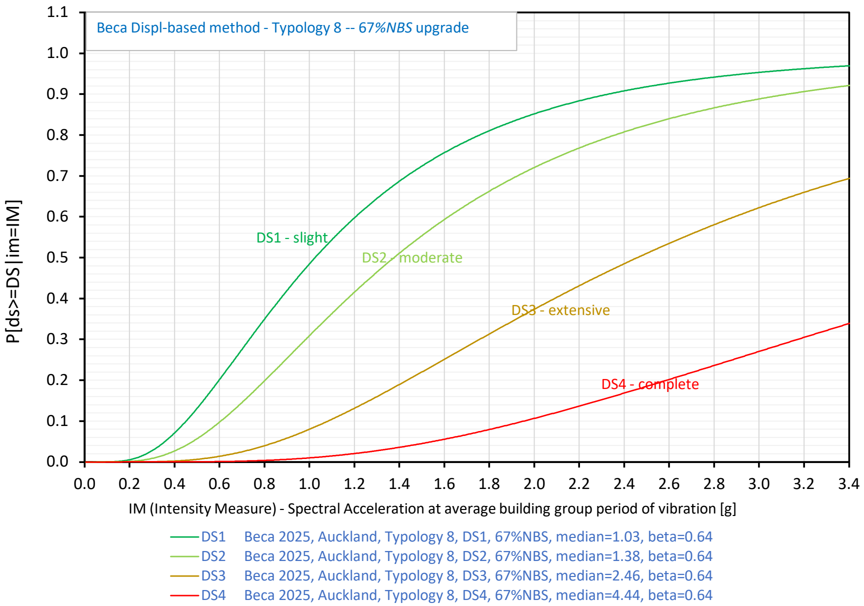
Beca Displ-based method - Typology 7 -- 67%NBS upgrade
DS1 - slight
DS2 - moderate
DS3 - extensive
DS4 - complete
P[ds>=DS|im=IM]
IM (Intensity Measure) - Spectral Acceleration at average building group period of vibration [g]
DS1 Beca 2025, Auckland, Typology 7, DS1, 67%NBS, median=0.88, beta=0.64
DS2 Beca 2025, Auckland, Typology 7, DS2, 67%NBS, median=1.31, beta=0.64
DS3 Beca 2025, Auckland, Typology 7, DS3, 67%NBS, median=2.23, beta=0.64
DS4 Beca 2025, Auckland, Typology 7, DS4, 67%NBS, median=3.64, beta=0.64

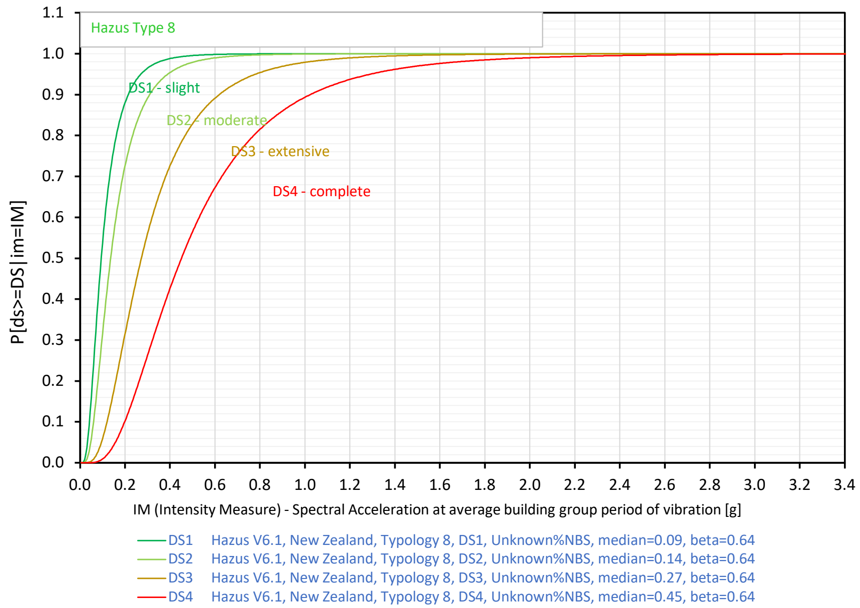


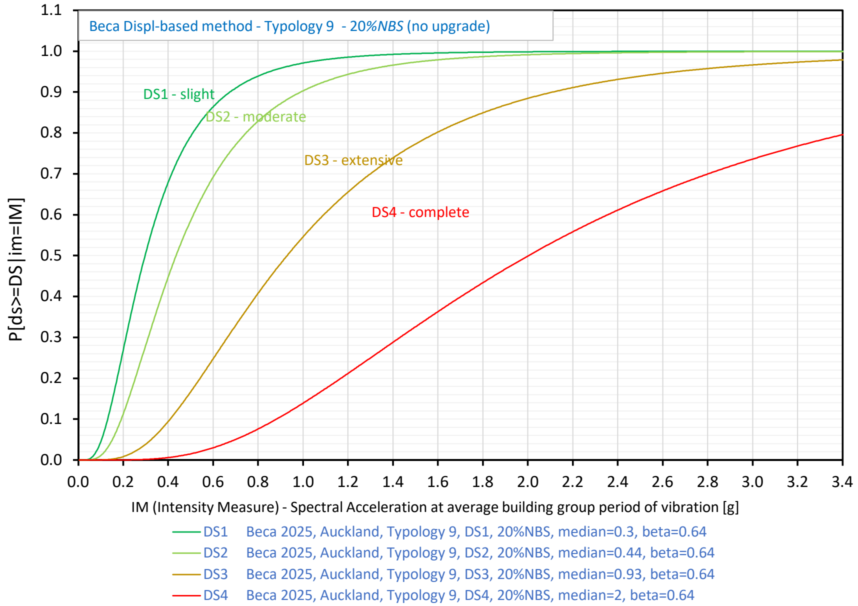
Hazus Type 7
DS1 - slight
DS2 - moderate
DS3 - extensive
DS4 - complete
P[ds>=DS|im=IM]
IM (Intensity Measure) - Spectral Acceleration at average building group period of vibration [g]
DS1 Hazus V6.1, New Zealand, Typology 7, DS1, Unknown%NBS, median=0.1, beta=0.64
DS2 Hazus V6.1, New Zealand, Typology 7, DS2, Unknown%NBS, median=0.15, beta=0.64
DS3 Hazus V6.1, New Zealand, Typology 7, DS3, Unknown%NBS, median=0.27, beta=0.64
DS4 Hazus V6.1, New Zealand, Typology 7, DS4, Unknown%NBS, median=0.44, beta=0.64

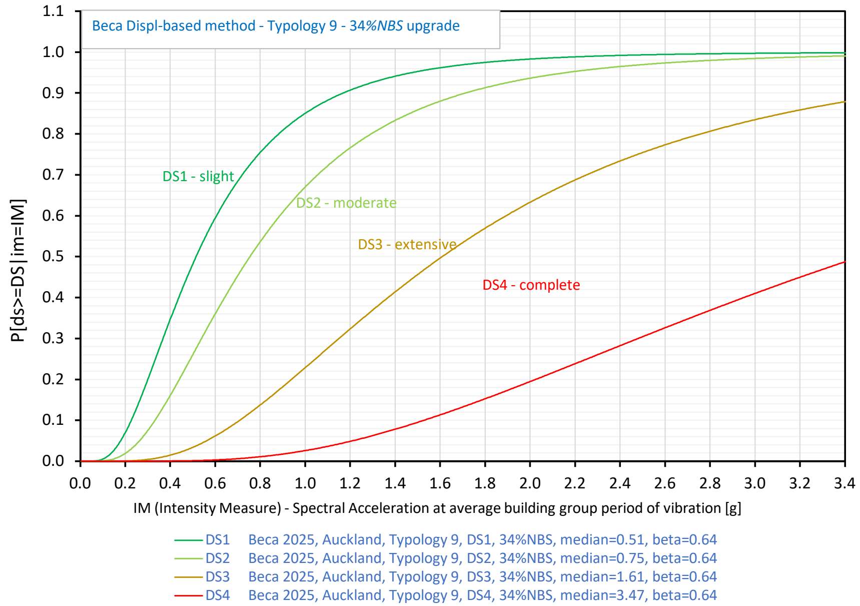

Beca Displ-based method - Typology 8 - 20%*NBS* (no upgrade)
DS1 - slight
DS2 - moderate
DS3 - extensive
DS4 - complete
P[ds>=DS|im=IM]
IM (Intensity Measure) - Spectral Acceleration at average building group period of vibration [g]
DS1 Beca 2025, Auckland, Typology 8, DS1, 20%NBS, median=0.29, beta=0.64
DS2 Beca 2025, Auckland, Typology 8, DS2, 20%NBS, median=0.38, beta=0.64
DS3 Beca 2025, Auckland, Typology 8, DS3, 20%NBS, median=0.68, beta=0.64
DS4 Beca 2025, Auckland, Typology 8, DS4, 20%NBS, median=1.22, beta=0.64

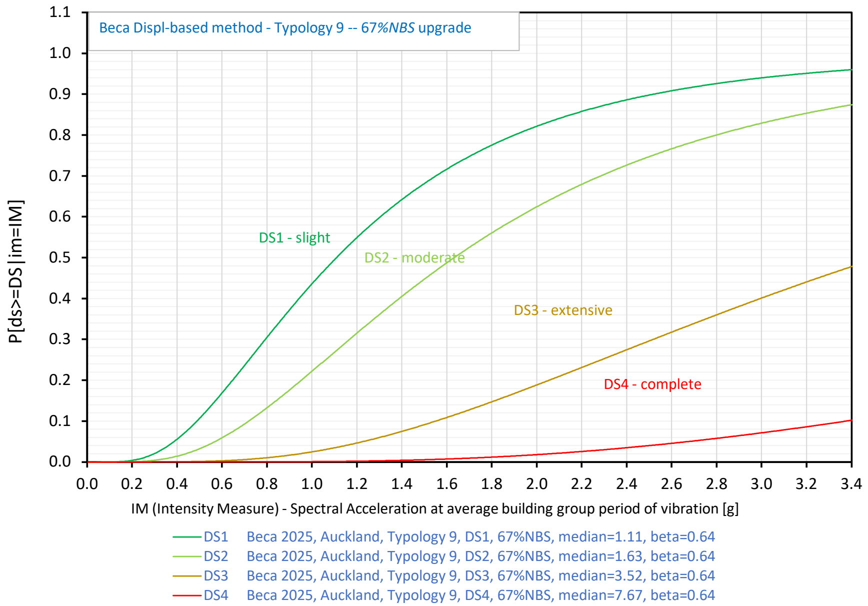

Beca Displ-based method - Typology 8 - 34%*NBS* upgrade
DS1 - slight
DS2 - moderate
DS3 - extensive
DS4 - complete
P[ds>=DS|im=IM]
IM (Intensity Measure) - Spectral Acceleration at average building group period of vibration [g]
DS1 Beca 2025, Auckland, Typology 8, DS1, 34%NBS, median=0.45, beta=0.64
DS2 Beca 2025, Auckland, Typology 8, DS2, 34%NBS, median=0.61, beta=0.64
DS3 Beca 2025, Auckland, Typology 8, DS3, 34%NBS, median=1.08, beta=0.64
DS4 Beca 2025, Auckland, Typology 8, DS4, 34%NBS, median=1.94, beta=0.64

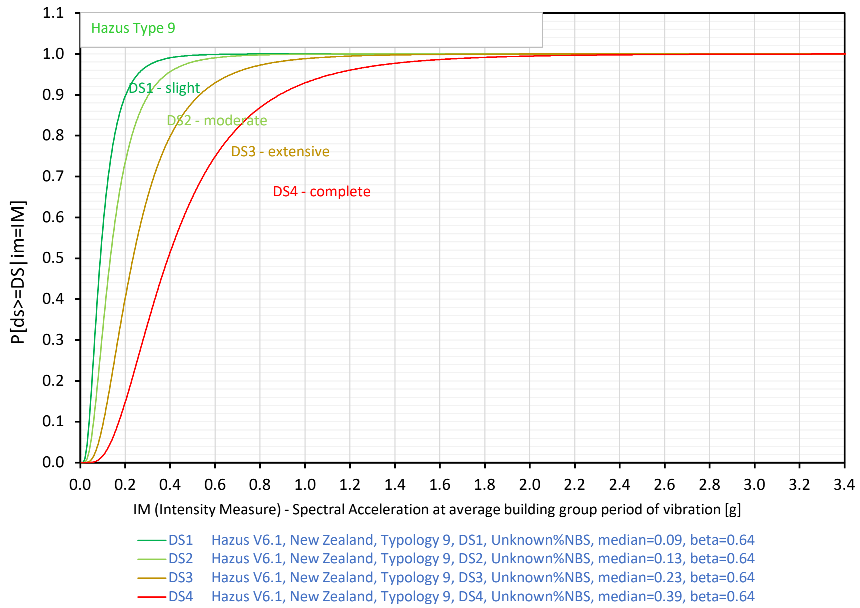

Beca Displ-based method - Typology 8 -- 67%*NBS* upgrade
DS1 - slight
DS2 - moderate
DS3 - extensive
DS4 - complete
P[ds>=DS|im=IM]
IM (Intensity Measure) - Spectral Acceleration at average building group period of vibration [g]
DS1 Beca 2025, Auckland, Typology 8, DS1, 67%NBS, median=1.03, beta=0.64
DS2 Beca 2025, Auckland, Typology 8, DS2, 67%NBS, median=1.38, beta=0.64
DS3 Beca 2025, Auckland, Typology 8, DS3, 67%NBS, median=2.46, beta=0.64
DS4 Beca 2025, Auckland, Typology 8, DS4, 67%NBS, median=4.44, beta=0.64

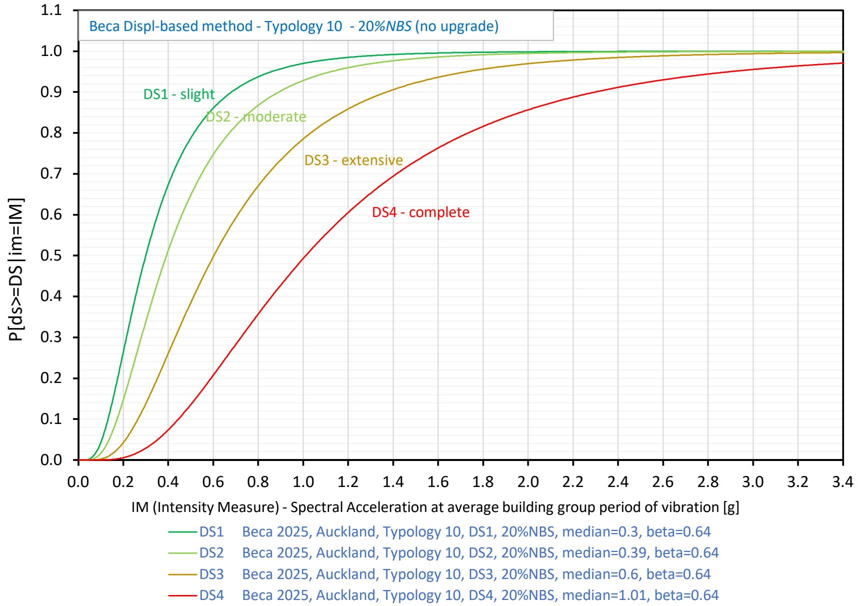

Hazus Type 8
DS1 - slight
DS2 - moderate
DS3 - extensive
DS4 - complete
P[ds>=DS|im=IM]
IM (Intensity Measure) - Spectral Acceleration at average building group period of vibration [g]
DS1 Hazus V6.1, New Zealand, Typology 8, DS1, Unknown%NBS, median=0.09, beta=0.64
DS2 Hazus V6.1, New Zealand, Typology 8, DS2, Unknown%NBS, median=0.14, beta=0.64
DS3 Hazus V6.1, New Zealand, Typology 8, DS3, Unknown%NBS, median=0.27, beta=0.64
DS4 Hazus V6.1, New Zealand, Typology 8, DS4, Unknown%NBS, median=0.45, beta=0.64

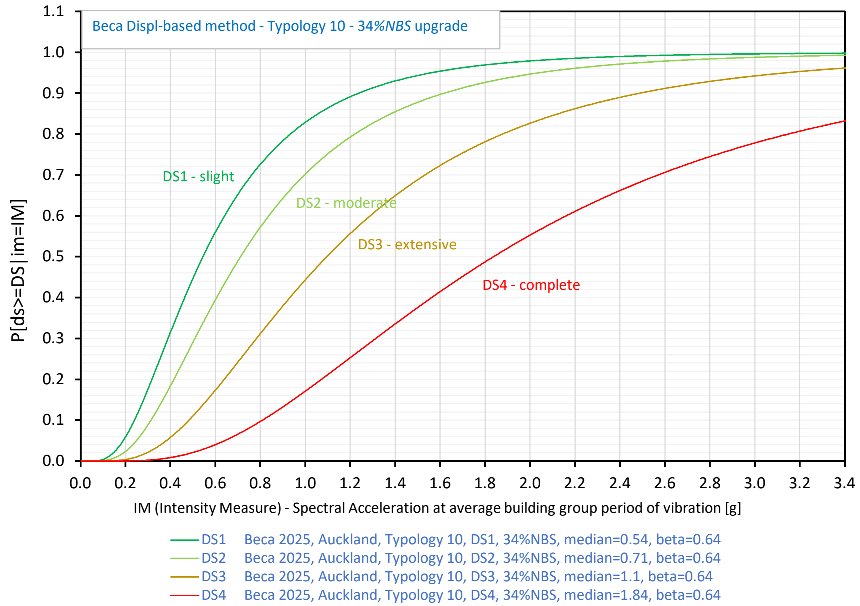

Beca Displ-based method - Typology 9 - 20%*NBS* (no upgrade)
DS1 - slight
DS2 - moderate
DS3 - extensive
DS4 - complete
P[ds>=DS|im=IM]
IM (Intensity Measure) - Spectral Acceleration at average building group period of vibration [g]
DS1 Beca 2025, Auckland, Typology 9, DS1, 20%NBS, median=0.3, beta=0.64
DS2 Beca 2025, Auckland, Typology 9, DS2, 20%NBS, median=0.44, beta=0.64
DS3 Beca 2025, Auckland, Typology 9, DS3, 20%NBS, median=0.93, beta=0.64
DS4 Beca 2025, Auckland, Typology 9, DS4, 20%NBS, median=2, beta=0.64

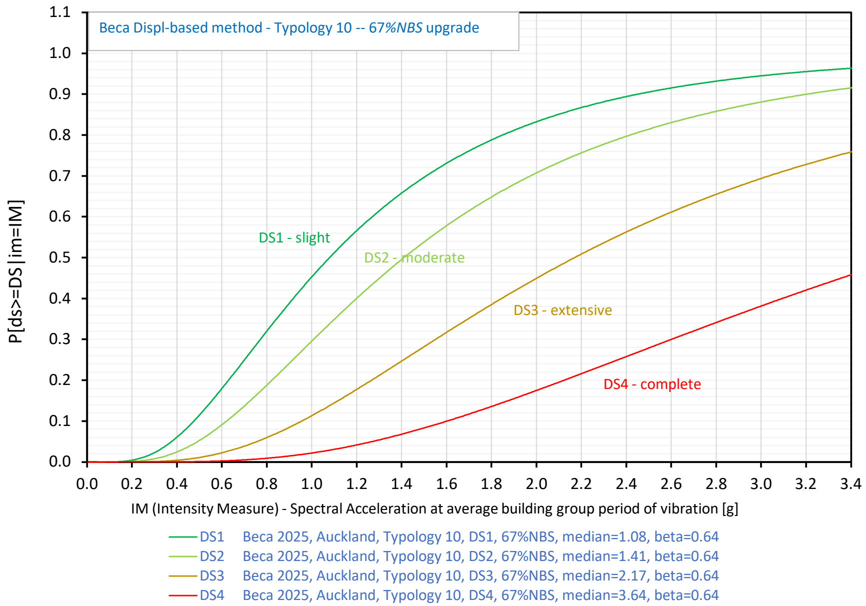

Beca Displ-based method - Typology 9 - 34%*NBS* upgrade
DS1 - slight
DS2 - moderate
DS3 - extensive
DS4 - complete
P[ds>=DS|im=IM]
IM (Intensity Measure) - Spectral Acceleration at average building group period of vibration [g]
DS1 Beca 2025, Auckland, Typology 9, DS1, 34%NBS, median=0.51, beta=0.64
DS2 Beca 2025, Auckland, Typology 9, DS2, 34%NBS, median=0.75, beta=0.64
DS3 Beca 2025, Auckland, Typology 9, DS3, 34%NBS, median=1.61, beta=0.64
DS4 Beca 2025, Auckland, Typology 9, DS4, 34%NBS, median=3.47, beta=0.64

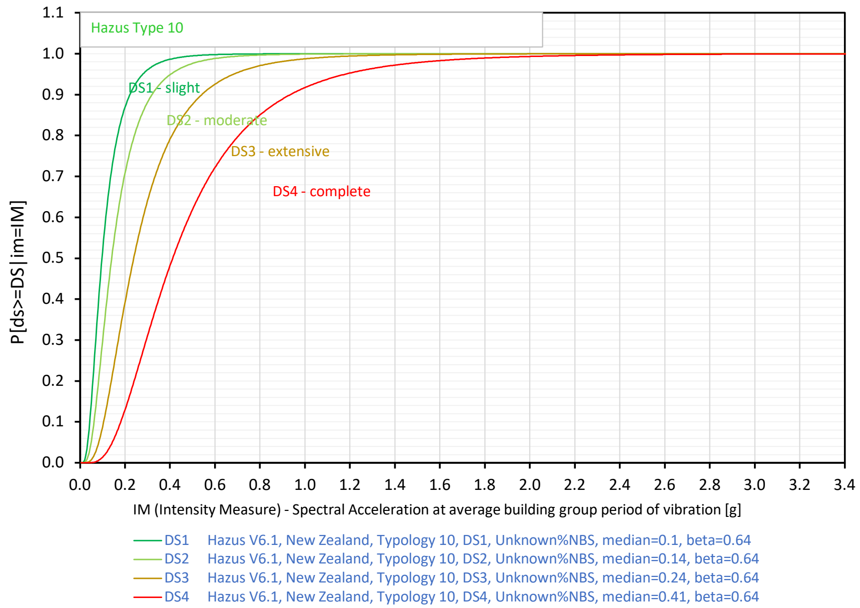

Beca Displ-based method - Typology 9 -- 67%*NBS* upgrade
DS1 - slight
DS2 - moderate
DS3 - extensive
DS4 - complete
P[ds>=DS|im=IM]
IM (Intensity Measure) - Spectral Acceleration at average building group period of vibration [g]
DS1 Beca 2025, Auckland, Typology 9, DS1, 67%NBS, median=1.11, beta=0.64
DS2 Beca 2025, Auckland, Typology 9, DS2, 67%NBS, median=1.63, beta=0.64
DS3 Beca 2025, Auckland, Typology 9, DS3, 67%NBS, median=3.52, beta=0.64
DS4 Beca 2025, Auckland, Typology 9, DS4, 67%NBS, median=7.67, beta=0.64


Hazus Type 9
DS1 - slight
DS2 - moderate
DS3 - extensive
DS4 - complete
P[ds>=DS|im=IM]
IM (Intensity Measure) - Spectral Acceleration at average building group period of vibration [g]
DS1 Hazus V6.1, New Zealand, Typology 9, DS1, Unknown%NBS, median=0.09, beta=0.64
DS2 Hazus V6.1, New Zealand, Typology 9, DS2, Unknown%NBS, median=0.13, beta=0.64
DS3 Hazus V6.1, New Zealand, Typology 9, DS3, Unknown%NBS, median=0.23, beta=0.64
DS4 Hazus V6.1, New Zealand, Typology 9, DS4, Unknown%NBS, median=0.39, beta=0.64


Beca Displ-based method - Typology 10 - 20%NBS (no upgrade)
DS1 - slight
DS2 - moderate
DS3 - extensive
DS4 - complete
P[ds>=DS|im=IM]
IM (Intensity Measure) - Spectral Acceleration at average building group period of vibration [g]
DS1 Beca 2025, Auckland, Typology 10, DS1, 20%NBS, median=0.3, beta=0.64
DS2 Beca 2025, Auckland, Typology 10, DS2, 20%NBS, median=0.39, beta=0.64
DS3 Beca 2025, Auckland, Typology 10, DS3, 20%NBS, median=0.6, beta=0.64
DS4 Beca 2025, Auckland, Typology 10, DS4, 20%NBS, median=1.01, beta=0.64


Beca Displ-based method - Typology 10 - 34%NBS upgrade
DS1 - slight
DS2 - moderate
DS3 - extensive
DS4 - complete
P[ds>=DS|im=IM]
IM (Intensity Measure) - Spectral Acceleration at average building group period of vibration [g]
DS1 Beca 2025, Auckland, Typology 10, DS1, 34%NBS, median=0.54, beta=0.64
DS2 Beca 2025, Auckland, Typology 10, DS2, 34%NBS, median=0.71, beta=0.64
DS3 Beca 2025, Auckland, Typology 10, DS3, 34%NBS, median=1.1, beta=0.64
DS4 Beca 2025, Auckland, Typology 10, DS4, 34%NBS, median=1.84, beta=0.64


Beca Displ-based method - Typology 10 -- 67%NBS upgrade
DS1 - slight
DS2 - moderate
DS3 - extensive
DS4 - complete
P[ds>=DS|im=IM]
IM (Intensity Measure) - Spectral Acceleration at average building group period of vibration [g]
DS1 Beca 2025, Auckland, Typology 10, DS1, 67%NBS, median=1.08, beta=0.64
DS2 Beca 2025, Auckland, Typology 10, DS2, 67%NBS, median=1.41, beta=0.64
DS3 Beca 2025, Auckland, Typology 10, DS3, 67%NBS, median=2.17, beta=0.64
DS4 Beca 2025, Auckland, Typology 10, DS4, 67%NBS, median=3.64, beta=0.64


Hazus Type 10
DS1 - slight
DS2 - moderate
DS3 - extensive
DS4 - complete
P[ds>=DS|im=IM]
IM (Intensity Measure) - Spectral Acceleration at average building group period of vibration [g]
DS1 Hazus V6.1, New Zealand, Typology 10, DS1, Unknown%NBS, median=0.1, beta=0.64
DS2 Hazus V6.1, New Zealand, Typology 10, DS2, Unknown%NBS, median=0.14, beta=0.64
DS3 Hazus V6.1, New Zealand, Typology 10, DS3, Unknown%NBS, median=0.24, beta=0.64
DS4 Hazus V6.1, New Zealand, Typology 10, DS4, Unknown%NBS, median=0.41, beta=0.64

G

Appendix G

Past Earthquakes Comparison

Appendix G – Past earthquakes – comparison

The following table was utilised as one of several high-level tools to assess the risk model and test input parameters versus loss estimates; however, this tool was not relied upon exclusively.

It is important to note that our study is not based on a specific scenario event and only focuses on earthquake-prone buildings within urban areas. Therefore, any direct comparison should be approached with caution. Additionally, in the Christchurch event, most fatalities were concentrated in just two buildings, whereas our study still overpredicts deaths compared to what occurred.

The Christchurch 2011 earthquake in New Zealand reported a death toll equivalent to 0.05% of the city's population. This is somewhat comparable to our study's findings for the "% death of city population – no upgrade" values, which are 0.02% in the "Low Model" and 0.04% in the "Mean Model" under Christchurch APoE (Annual Probability of Exceedance) 1:500 conditions.

Despite these limitations, this high-level comparison suggests that the final settings of our Low-Mean Model (30th percentile) are reasonably aligned with observed outcomes, though we acknowledge the inherent challenges in making direct comparisons.

Hazard uniform Hazard Spectrum - spectral acceleration at 0.4 sec

assuming Vs30=275m/s, T1=0.4sec

0.89g Christchurch Feb 2011,
average record of top 30 stations. Close match to APoE 1:500 Christchurch NSHM2022

(Source: https://nshm.gns.cri.nz/Hazardcurves)

MEAN MODEL (50%til Consequence model)

APoE **	Location	SA(T1)	CS5 totals			EPB population *	total population	CS5 % of EPB population			CS5 % of city population		
		[g]	no upgrade	*34%NBS*	*67%NBS*			no upgrade	*34%NBS*	*67%NBS*	no upgrade	*34%NBS*	*67%NBS*
1:500	Wellington	1.8				34,074	213,100	3%	2%	0.4%	0.5%	0.3%	0.06%
	Feilding	1.5				4,578	17,550	2%	1%	0.2%	0.5%	0.2%	0.05%
	Christchurch	0.95				36,949	389,300	2%	0%	0.1%	0.2%	0.0%	0.01%
	Whanganui	1.10				1,959	40,000	12%	4%	0.8%	0.6%	0.2%	0.04%
	Dunedin	0.59				14,378	130,400	5%	2%	0.3%	0.5%	0.2%	0.03%
	Auckland	0.31				104,843	1,775,900	0%	0.1%	0.00%	0.0%	0.00%	0.000%
1:1000	Wellington	2.3				34,074	213,100	4%	3%	0.8%	0.7%	0.4%	0.12%
	Feilding	2				4,578	17,550	2%	1%	0.3%	0.6%	0.3%	0.09%
	Christchurch	1.3				36,949	389,300	2%	1%	0.1%	0.2%	0.1%	0.01%
	Whanganui	1.4				1,959	40,000	14%	7%	1.6%	0.7%	0.3%	0.08%
	Dunedin	0.82				14,378	130,400	6%	3%	0.7%	0.7%	0.3%	0.08%
	Auckland	0.44				104,843	1,775,900	1%	0%	0.0%	0.1%	0.0%	0.001%
1:2500	Wellington	3.2				34,074	213,100	5%	4%	1.4%	0.8%	0.6%	0.23%
	Feilding	2.7				4,578	17,550	3%	2%	0.7%	0.7%	0.5%	0.18%
	Christchurch	1.6				36,949	389,300	3%	1%	0.3%	0.3%	0.1%	0.03%
	Whanganui	1.9				1,959	40,000	16%	10%	3.4%	0.8%	0.5%	0.17%
	Dunedin	1.2				14,378	130,400	8%	5%	1.6%	0.9%	0.5%	0.17%
	Auckland	0.67				104,843	1,775,900	2%	1%	0.1%	0.1%	0.0%	0.01%

Real Earthquakes	toll
Hawke's Bay, NZ 1931	1.60%
Long Beach, USA, 1933	0.05%
Mexico City, 1986	0.06%
Loma Prieta, USA, 1989	0.10%
Kobe, Japan, 1995	0.43%
Northridge , USA, 1994	0.05%
Haiti, 2010	5.14%
Tōhoku, Japan 2011	0.21%
Christchurch, NZ 2011	0.05%
Turkey & Syria, 2023	1.55%

Mean model appears conservative, high quantities of CS5 when compared to real earthquake data

LOW MODEL (10%til Consequence model)

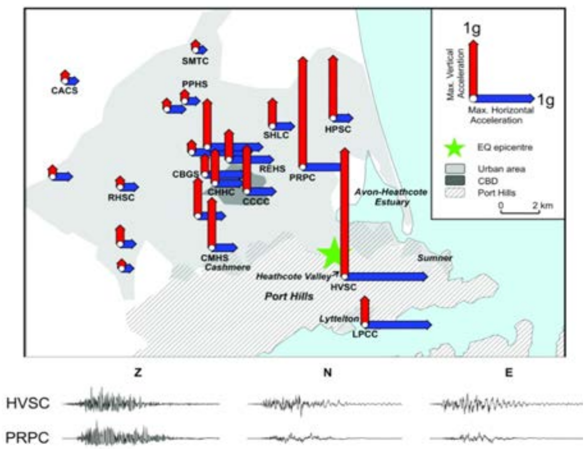
APoE **	Location	SA(T1)	CS5 totals			EPB population *	total population	CS5 % of EPB population			CS5 % of city population		
		[g]	no upgrade	*34%NBS*	*67%NBS*			no upgrade	*34%NBS*	*67%NBS*	no upgrade	*34%NBS*	*67%NBS*
1:500		1.8				34,074	213,100	1%	0%	0.2%	0.2%	0.0%	0.03%
		1.5				4,578	17,550	1%	0%	0.1%	0.2%	0.1%	0.02%
		0.95				36,949	389,300	1%	0%	0.0%	0.1%	0.0%	0.00%
		1.10				1,959	40,000	5%	2%	0.4%	0.3%	0.1%	0.02%
		0.59				14,378	130,400	2%	1%	0.1%	0.2%	0.1%	0.02%
		0.31				104,843	1,775,900	0%	0.0%	0.00%	0.0%	0.00%	0.0001%
1:1000		2.3				34,074	213,100	2%	1%	0.3%	0.3%	0.1%	0.05%
		2				4,578	17,550	1%	1%	0.2%	0.3%	0.1%	0.04%
		1.3				36,949	389,300	1%	0%	0.1%	0.1%	0.0%	0.01%
		1.4				1,959	40,000	6%	2%	0.8%	0.3%	0.1%	0.04%
		0.82				14,378	130,400	3%	1%	0.3%	0.3%	0.1%	0.03%
		0.44				104,843	1,775,900	0%	0%	0.0%	0.0%	0.0%	0.000%
1:2500		3.2				34,074	213,100	2%	1%	0.6%	0.3%	0.2%	0.10%
		2.7				4,578	17,550	1%	1%	0.3%	0.3%	0.2%	0.07%
		1.6				36,949	389,300	1%	1%	0.1%	0.1%	0.1%	0.01%
		1.9				1,959	40,000	7%	5%	1.5%	0.4%	0.2%	0.08%
		1.2				14,378	130,400	4%	2%	0.7%	0.4%	0.2%	0.08%
		0.67				104,843	1,775,900	1%	0%	0.0%	0.1%	0.0%	0.00%

Real Earthquakes	toll
Hawke's Bay, NZ 1931	1.60%
Long Beach, USA, 1933	0.05%
Mexico City, 1986	0.06%
Loma Prieta, USA, 1989	0.10%
Kobe, Japan, 1995	0.43%
Northridge , USA, 1994	0.05%
Haiti, 2010	5.14%
Tōhoku, Japan 2011	0.21%
Christchurch, NZ 2011	0.05%
Turkey & Syria, 2023	1.55%

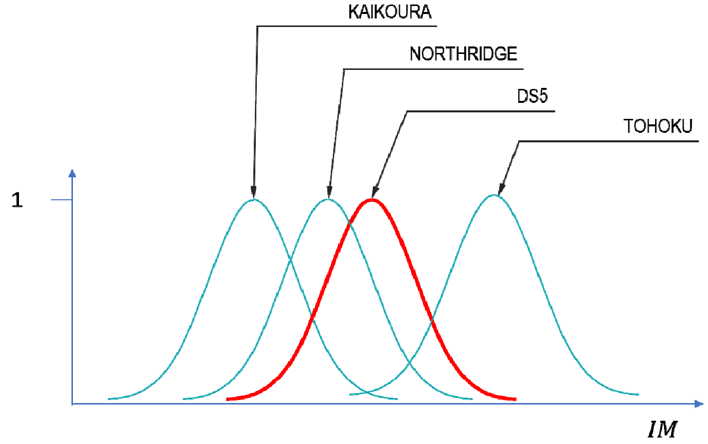
Lower model CS5 quantities closer to real earthquake data

	Earthquake	Year	Death toll DS5 total	Population (estimate only)	Magnitude	Distance	Depth	% of population
international earthquakes	Haiyuan, China	1920	180,000	3,000,000	M 8.3	~10km from Haiyuan County	~15km	6%
	Kanto, Japan	1923	143,000	4,500,000	M 7.9	Epicenter near the Sagami Bay (~80km from Tokyo)	~23km	3%
	Nanchang, China (1927)	1927	200,000	3,000,000	M 7.6	No info		7%
	Ashgabat, Turkmenistan	1948	110,000	1,000,000	M 7.3	Near Ashgabat (~10km)	~25km	11%
	Tangshan, China	1976	242,000–650,000	2,000,000	M 7.5	Directly under Tangshan (~0 km)	~12km	10%
	Sumatra, Indonesia	2004	227,898	2,600,000	M 9.1	Offshore (~250km from Banda Aceh)	~30km	8.8%
	Haiti	2010	100,000–316,000	2,100,000	M 7.0	Epicenter near Léogâne (~25km from Port-au-Prince)	~13km	5.1%
	Sichuan, China	2008	87,587	11,000,000	M 7.9	Epicenter in Wenchuan County (~80km from Chengdu)	~19km	0.8%
	Muzaffarabad, Pakistan	2005	73,338	650,000	M 7.6	Not well-documented		11%
	Mexico City	1985	10,000	18,000,000	M8 .1	Michoacán (~350km from Mexico City)	~15km	0.06%
	Kobe Earthquake, Japan	1995	6,434	1,500,000	M6 .9	~20km from Kobe	~16km	0.43%
	Tōhoku Earthquake and Tsunami	2011	18,500	9,000,000	M9 .0	(~70km east of Sendai)	~29km	0.21%
	Long Beach Earthquake, USA	1933	120	250,000	M6 .4	Newport-Inglewood Fault Line near Long Beach		0.05%
	Loma Prieta Earthquake	1989	63 deaths, 3,757 injuries	62,956 Santa Cruz		peak accelration 0.65 g (at epicenter), MMI IX		0.10%
	Northridge Earthquake, USA	1994	57	9,000,000	M 6.7	~30km northwest of downtown Los Angeles	~18km	0.001%
	Puebla-Morelos, Mexico	2017	370	18,000,000	M7 .1	~120km from Mexico City	~51km	0.00%
	Turkey & Syria	2023	62,013	4,000,000	M 7.8			1.55%
New Zealand	Napier-Hawke's Bay, New Zealand	1931	256	16,000	M 7.8			1.60%
	Christchurch, New Zealand	Feb-11	185	376,700	M 6.3	~10km from Christchurch	~5km	0.05%
	Christchurch, New Zealand	Sep-10	0	376,700	M7 .1	~40km west of Christchurch	10km	0%
	Kaikōura Earthquake	2016	2 deaths and 618 injuries	212,000 (Wellington) 2,080 (Kaikoura)	M 7.8	~60km from Kaikōura, ~300km from Wellington	15km	0.001%

Shaking level distribution Christchurch event:



Create a distribution of intensity measures for each earthquake and relate them to current fragility distribution



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