REVIEW OF AS/NZS1170.2 SECTION 6.3.2

- AWES RESEARCH PROJECT

WD200-13-REV0 REVIEW OF CROSS-WIND

DECEMBER 7, 2018

Prepared for:

Australasian Wind Engineering Society

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DOCUMENT CONTROL

Date	Revision History	Issued Revision	Prepared By
December 5, 2018	Initial Draft	0	Tony Rofail

The work presented in this document was carried out in accordance with the Windtech Consultants Quality Assurance System, which is based on International Standard ISO 9001.

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EXECUTIVE SUMMARY

The main driver behind this study is to investigate the reason for the significant differences often found between the predictions for cross-wind response by AS/NZS 1170.2:2011 and the ISO 4354: 2009. In some cases the AS/NZS 1170.2:2011 tended to underestimate the cross-wind response when compared against the results of wind tunnel model studies, even in cases where interference excitation effects have been ruled out. We agree with the observation by Holmes (2013) that the along-wind response predictions in AS/NZS 1170.2:2011 closely match wind tunnel results, more than other standards, including ASCE 7.

A set of 26 cases were carefully selected to represent towers of aspect ratios *h*:*b*:*d* of 3:1:1, 6:1:1, 6:2:1 and 6:1:2. The cases selected for analysis are those that are not affected by the following exclusion criteria:

- Towers of irregular or substantially curved forms
- Towers likely to be affected by interference excitation for the direction of interest
- Towers that had aspect ratios greater than 2:1 in plan.

With regards to the last exclusion criterion, we found that towers that had plan aspect ratio of 3:1 or more were subject to much more significant cross-wind response than what is estimated from the cases provided in the current standard. Hence we recommend the addition of Clause 6.1(b)(i)(D) for tall buildings with plan aspect ratio of 1:3 or more.

After a thorough comparison between AS/NZS 1170.2:2011 and the ISO 4354: 2009 it was concluded that neither standard is substantially more consistent with the wind tunnel results than the other. It was concluded that it is best to stay with the format of AS/NZS 1170.2:2011 as it reflects more clearly the mechanics of wind-structure interactions. However, we propose that the C_{fs} curves for tower aspect ratios 6:1:1, 6:2:1 and 6:1:2 be modified slightly to provide a reasonable envelope of cross-wind responses from real world cases.

Our wind tunnel results have also shown that apart from the 3:1:1 cases, there is no consistent trend separating the responses of towers that fall within the lower-bound and upper-bound upstream turbulence intensities. Hence we recommend merging of these into a single curve.

References:

AS/NZS 1170.2:2011, "Structural Design Actions, Part 2: Wind Actions", Standards Australia and Standards New Zealand.

ISO 4354: 2009, "Wind actions on structures", International Standard.

Holmes, J., 2013, "Along-wind response of a generic tall building – comparison of consensus wind-tunnel data with codes and standards", The 12th Americas Conference on Wind Engineering, Seattle, Washington, USA June 16-20, 2013.

1 METHODOLOGY

When comparing against the ISO 4354: 2009 the actual base moment was computed for each case of reduced velocity then the equivalent C_{fs} value as defined in AS/NZS1170.2:2011 was calculated. The same approach was adopted for the wind tunnel results.

Wind tunnel results are obtained using either the high-frequency force balance (HFFB) or high frequency pressure integration (HFPI) technique. The accuracy of Windtech's HFFB measurement system has been verified in the benchmark study reported in Holmes and Tse (2012). Also due to Windtech's proprietary pressure measurement system, which allows for a high sampling rate (typically over 1000Hz) and an unbiased response over a frequency range of 0-300Hz. The close match between the HFFB and HFPI techniques has been demonstrated on a complex building by Truong and Rofail (2015). All wind tunnel tests are in compliance with the AWES-QAM-01.

A set of 26 cases were carefully selected to represent towers of aspect ratios *h*:*b*:*d* of 3:1:1, 6:1:1, 6:2:1 and 6:1:2. Multiple angles of incidence each were analyses from each case, each within 10 degrees of the principal axis. The cases selected for analysis are those that are not affected by the following exclusion criteria:

- Towers of irregular or substantially curved forms
- Towers likely to be affected by interference excitation for the direction of interest
- Towers that had aspect ratios greater than 2:1 in plan.

With regards to the last exclusion criterion, we found that towers that had plan aspect ratio of 3:1 or more were subject to much more significant cross-wind response than what is estimated from the cases provided in the current standard. Hence we recommend the addition of Clause 6.1(b)(i)(D) for tall buildings with plan aspect ratio of 1:3 or more.

References:

AWES-QAM-01, "Quality Assurance Manual for Wind Tunnel Testing", Australasian Wind Engineering Society, 2000.

Holmes, J.D. and Tse, T.K.T., 2012, International high-frequency base balance benchmark study", 2012 World Congress on Advances in Civil, Environmental, and Materials Research, 26-29 August 2012, Seoul.

Truong N., Rofail A.W., 2015, "Wind Engineering for a Complex Structure", 14th International Conference on Wind Engineering, Porto Alegre.

2 RESULTS AND RECOMMENDATIONS

The comparative results are presented in Annexures 1 to 5. These annexures present comparative values of the crosswind force spectrum coefficient (C_{fs}) as a function of the reduced velocity (V_n). As can be seen at the end of Annexure 1, interference excitation effects are generally not significant for buildings having a 3:1:1 aspect ratio. Annexure 5 demonstrates that interpolation is appropriate. Excluding a case where there is a significant recess in plan, the C_{fs} curves proposed from this study generally envelope the various cases.

The 3:1:1 cases generally fell within the C_{fs} curves for respective turbulence intensities. These was only one case for each turbulence cases where there was an exceedance at the lower end of the reduced velocity range. This does not give sufficient weight for a revision of the C_{fs} curves for the 3:1:1 case. The AS/NZS 1170.2:2011 also performed significantly better overall than the ISO 4354: 2009 for the 3:1:1 case. For the other cases there was no consistent trend in terms of the effect of the background turbulence intensity. Also there is a consistent pattern of exceedences at the lower range of reduced velocities for the 6:1:1 case; for reduced velocities in the range 4.5 to 7 and above 12 for the 6:2:1 case; and for the entire range particularly are the lower and higher parts of the range of reduced velocities for the 6:1:2 case.

Based on the above it is proposed that the crosswind force spectrum coefficients be modified as follows:

a) For a 3:1:1 square section (*h*:*b*:*d*), where *V*n is in the range 2 to 16:

   (i) For turbulence intensity of 0.12 at 2*h*/3 (no change):

$$\text{Log}_{10}\, C_{fs} = 0.000353V_n^4 - 0.0134V_n^3 + 0.15V_n^2 - 0.345V_n - 3.109 \qquad 6.3(5)$$

   (ii) For turbulence intensity of 0.2 at 2*h*/3 (no change):

$$\text{Log}_{10}\, C_{fs} = 0.00008V_n^4 - 0.0028V_n^3 + 0.199V_n^2 + 0.13V_n - 2.985 \qquad 6.3(6)$$

b) For a 6:1:1 square section (*h*:*b*:*d*), where V_n is in the range 2 to 16:

$$\text{Log}_{10}\, C_{fs} = 0.00037V_n^4 - 0.0145V_n^3 + 0.17V_n^2 - 0.49V_n - 2.5 \qquad 6.3(7)$$

c) For a 6:2:1 square section (*h*:*b*:*d*), where V_n is in the range 2 to 16:

$$\text{Log}_{10}\, C_{fs} = \frac{-0.00045V_n^4 + 0.065V_n^2 - 3.05}{0.00015V_n^4 - 0.018V_n^2 + 1} \qquad 6.3(8)$$

d) For a 6:1:2 square section (*h*:*b*:*d*), where V_n is in the range 2 to 16:

$$\text{Log}_{10}\, C_{fs} = 0.0957V_n - 2.59 \qquad 6.3(9)$$

Given that it is often unclear which way to interpolate, it is recommended that for intermediate values of *h*:*b*, *b*:*d*, the highest C_{fs} value is adopted rather than linear interpolation of $\log_{10} C_{fs}$.

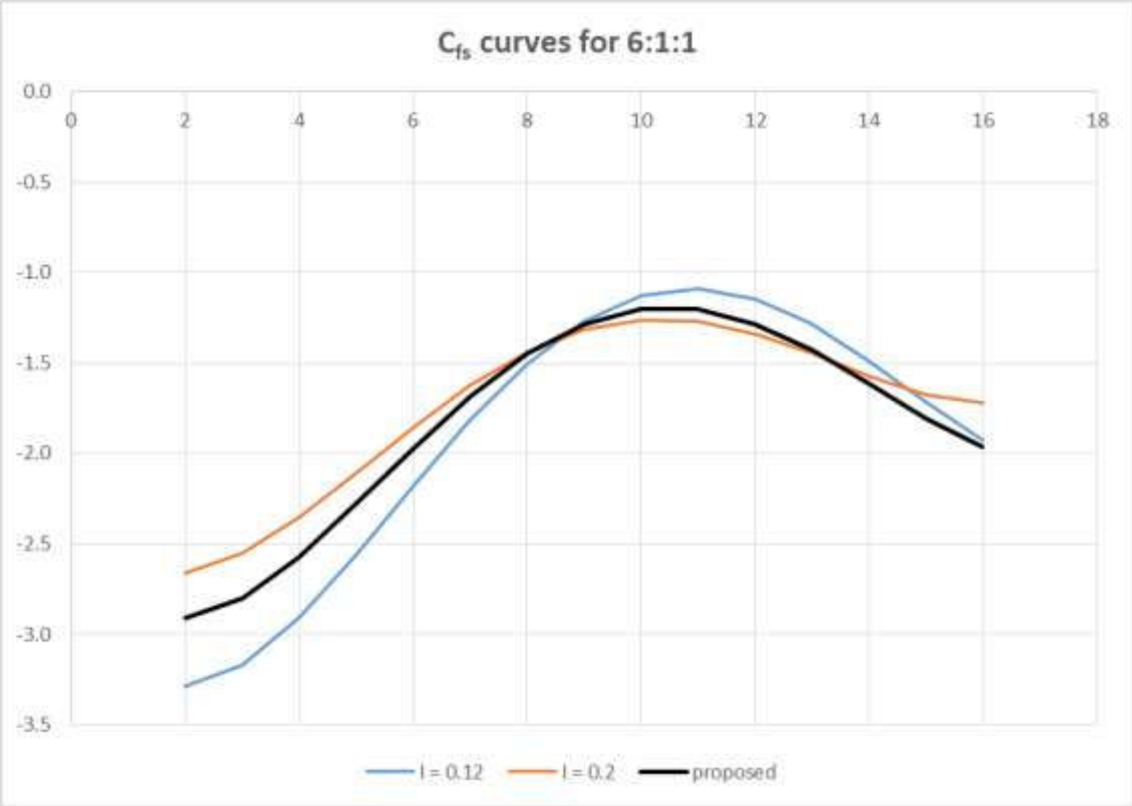


Figure 1a: Proposed C_{fs} curves for tall buildings of aspect ratio 6:1:1

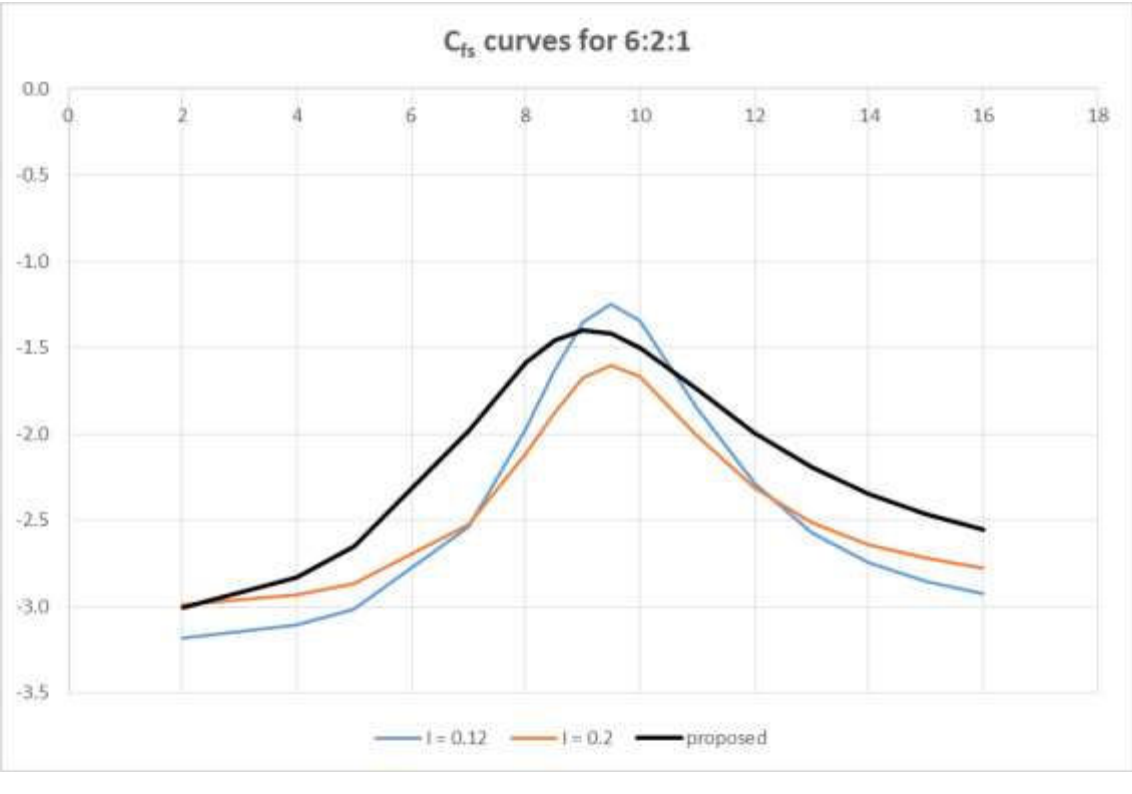


Figure 1b: Proposed C_{fs} curves for tall buildings of aspect ratio 6:2:1

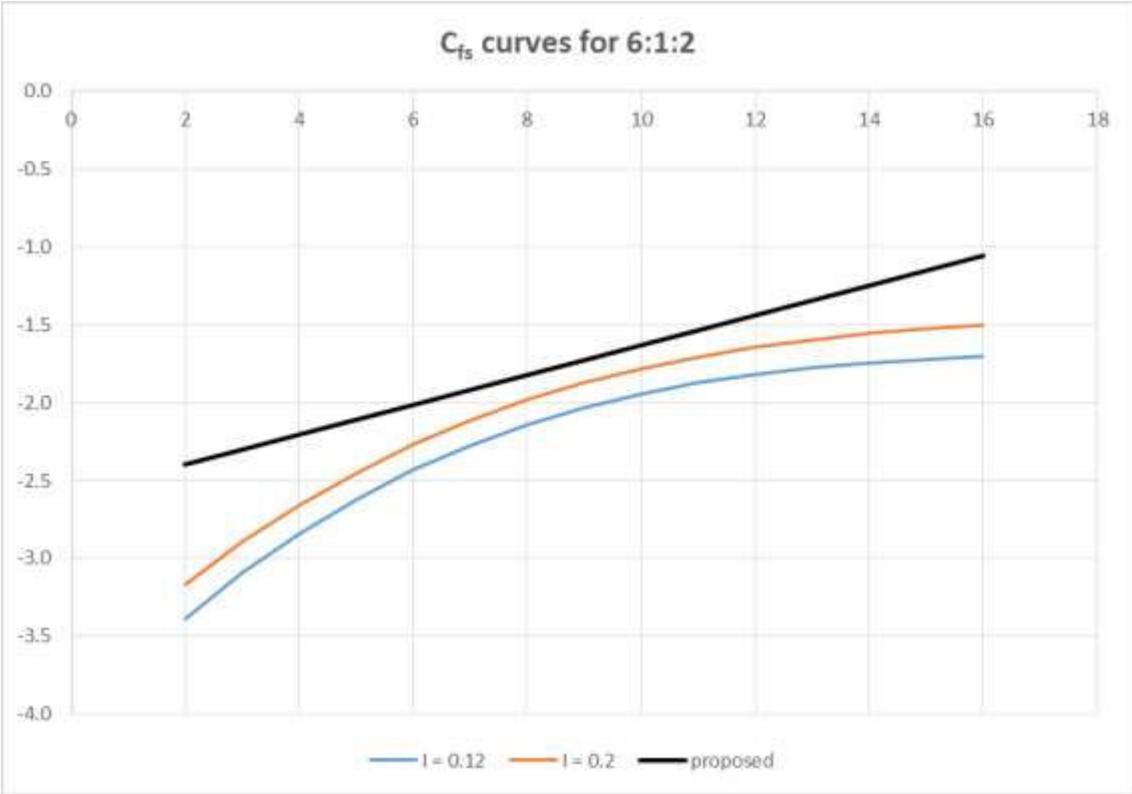


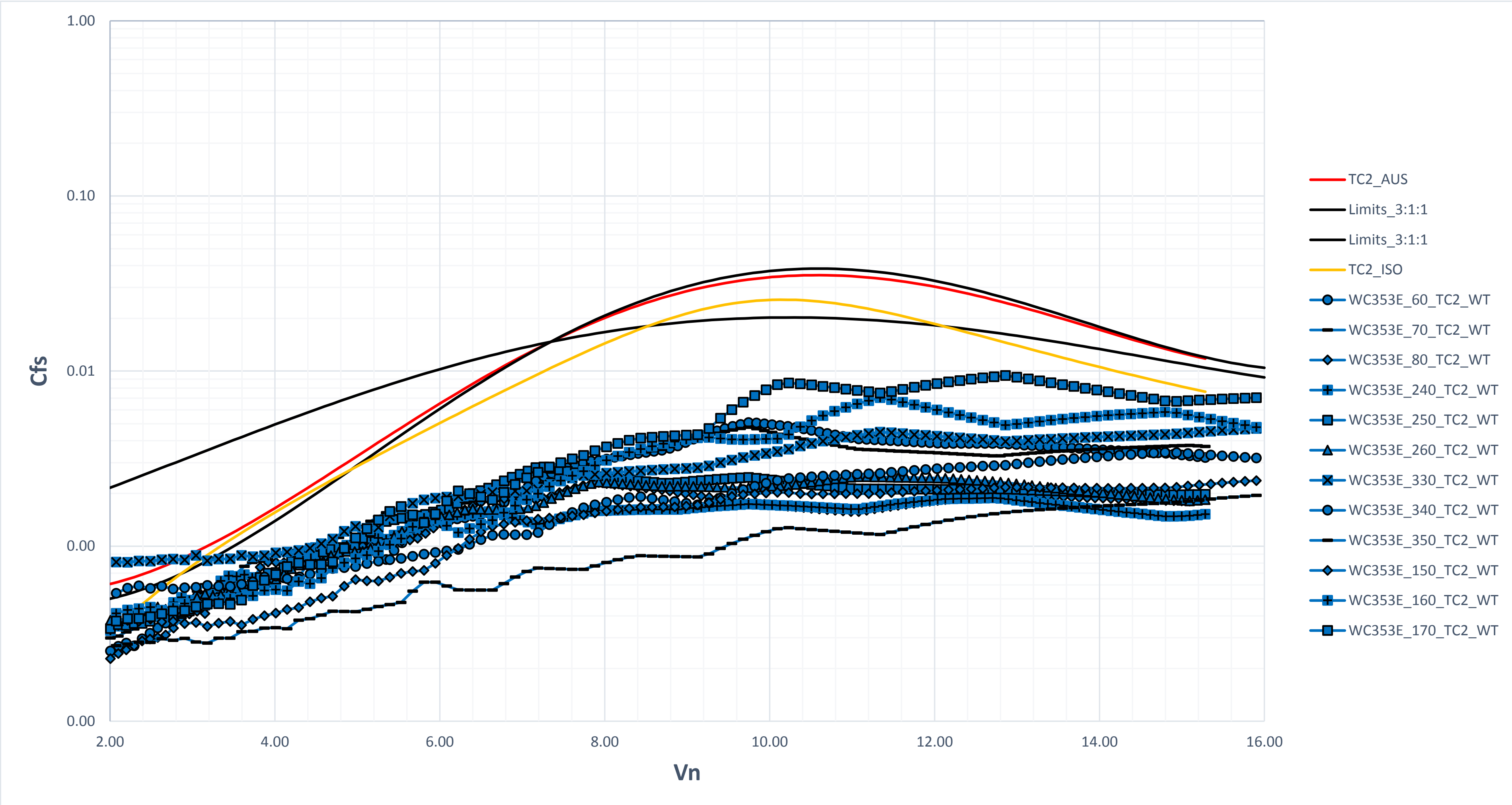
Figure 1c: Proposed C_{fs} curves for tall buildings of aspect ratio 6:1:2

3 ACKNOWLEDGEMENTS

The author wishes to acknowledge the subsidy towards this study, received in February 2018 from the Australasian Wind Engineering Society.

The author wishes to also acknowledge the innumerable hours spent by Todd Davies scouring through hundreds of past projects and running the analyses to compile the C_{fs} data used for this study. Credit also goes to Dr Nicholas Truong for his valuable input into the project.

ANNEXURE 1 – COMPARATIVE RESULTS for *h*:*b*:*d* of 3:1:1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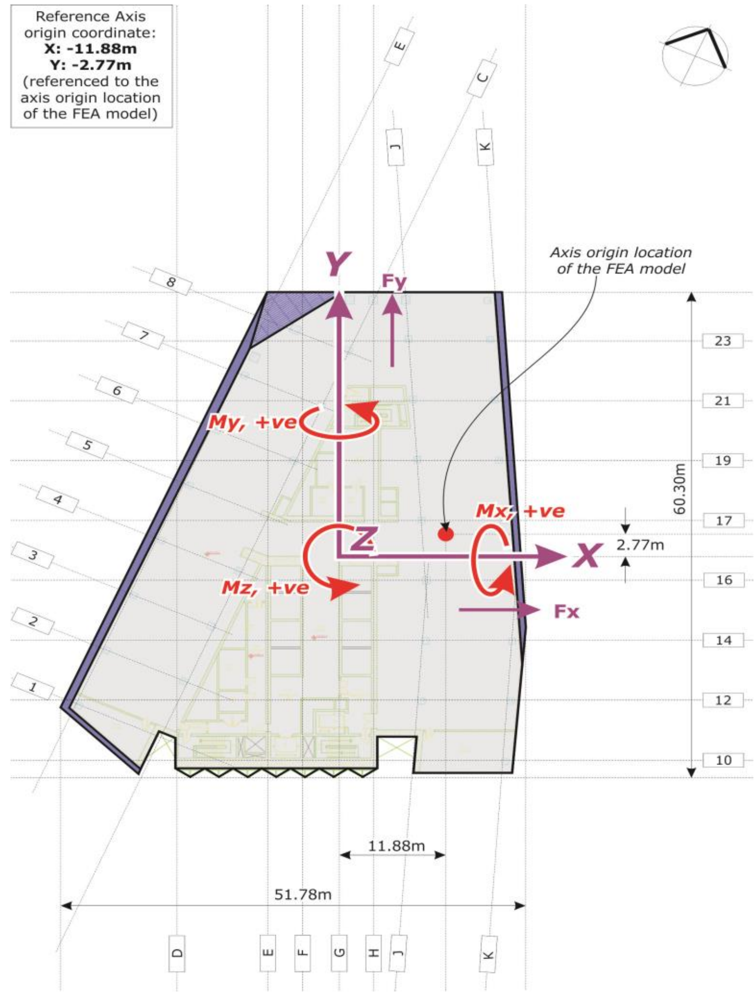
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Axis origin location
of the FEA model
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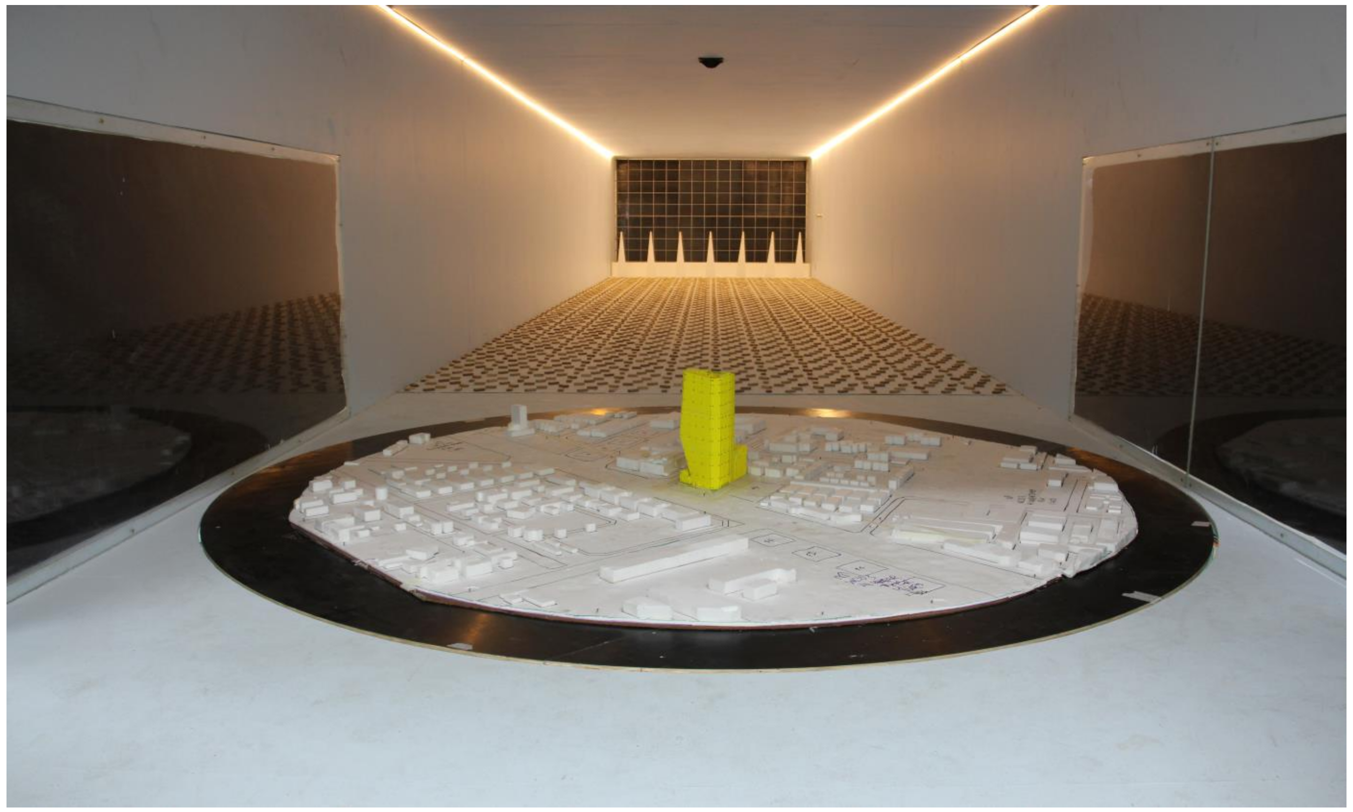

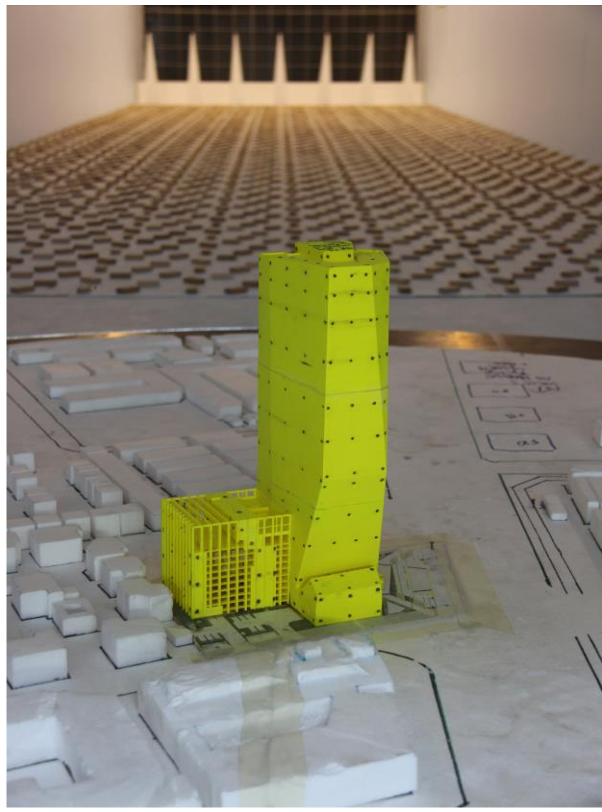

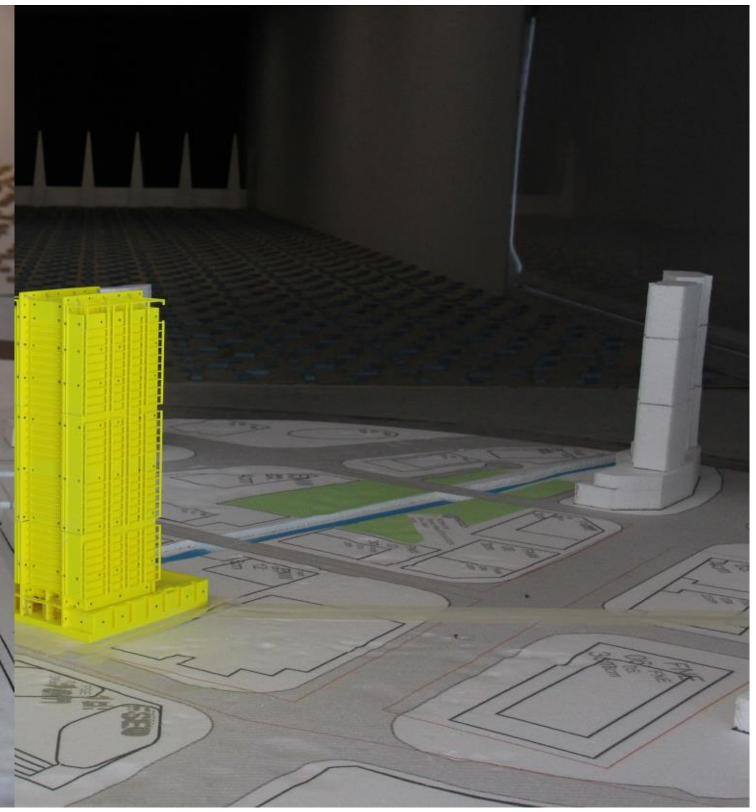

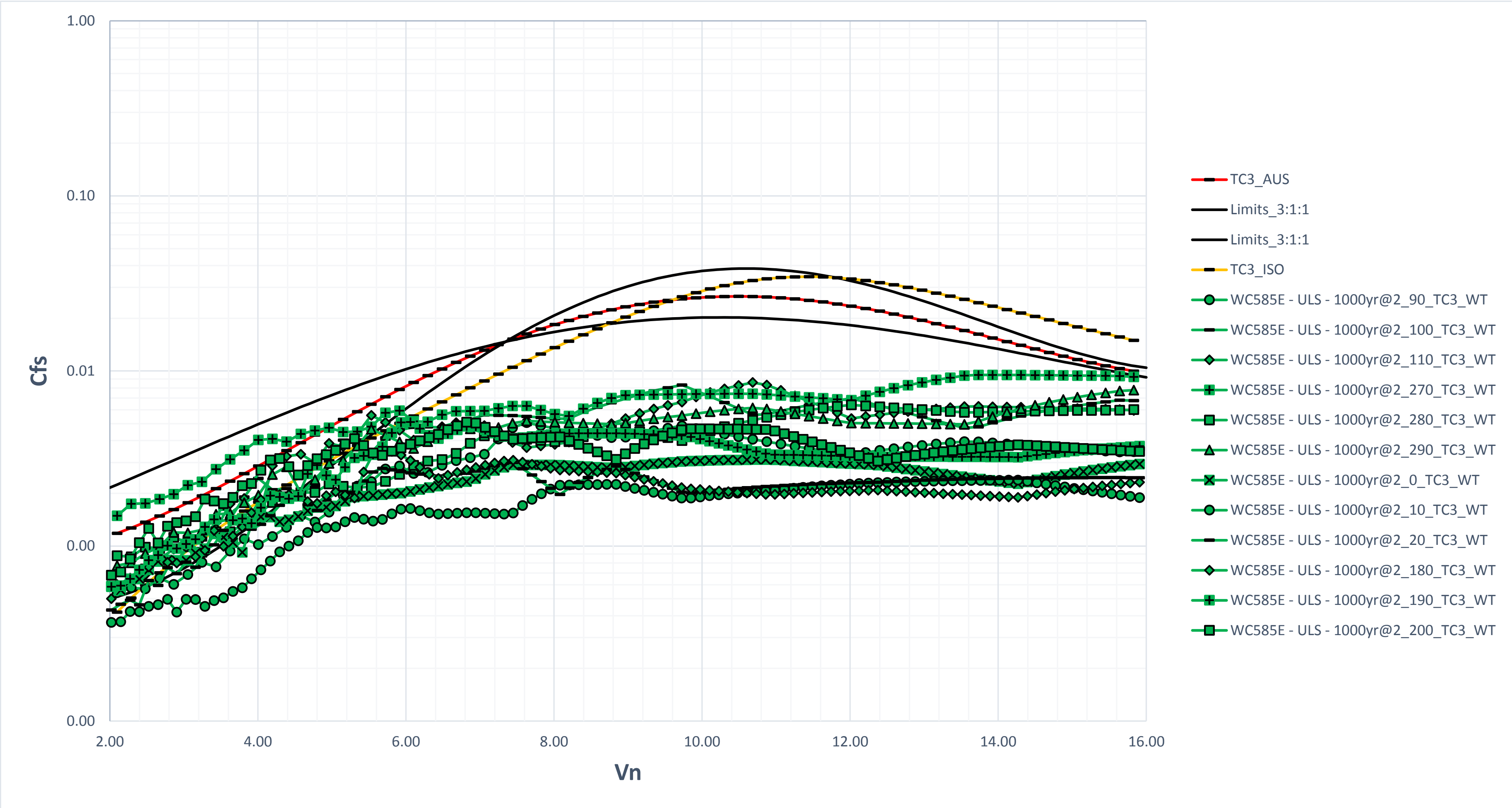
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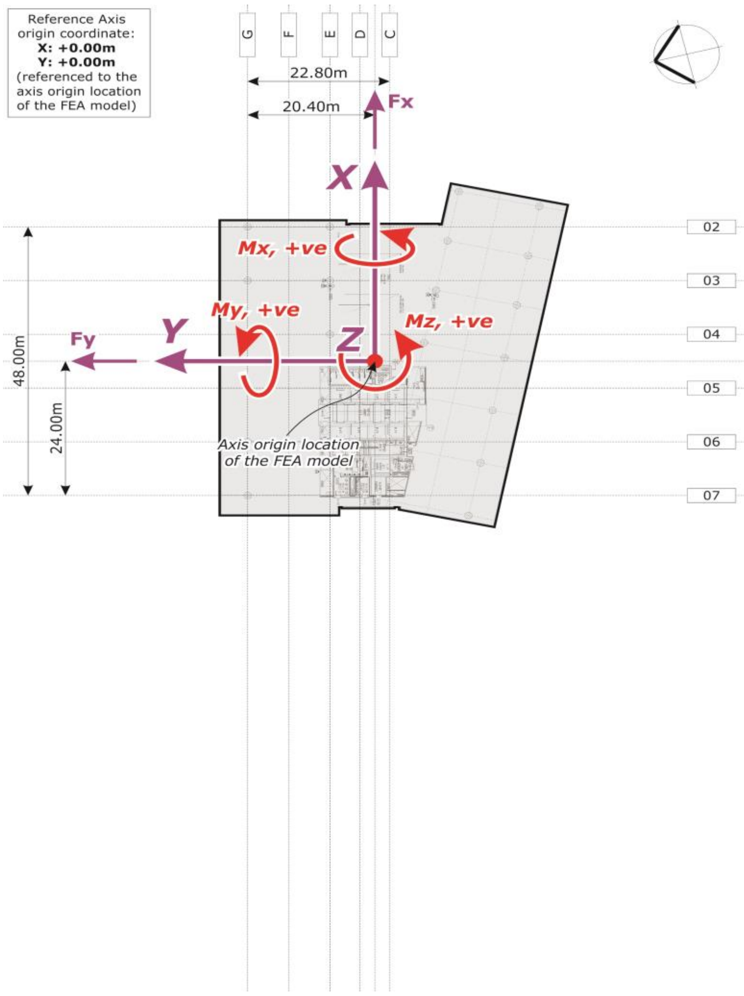
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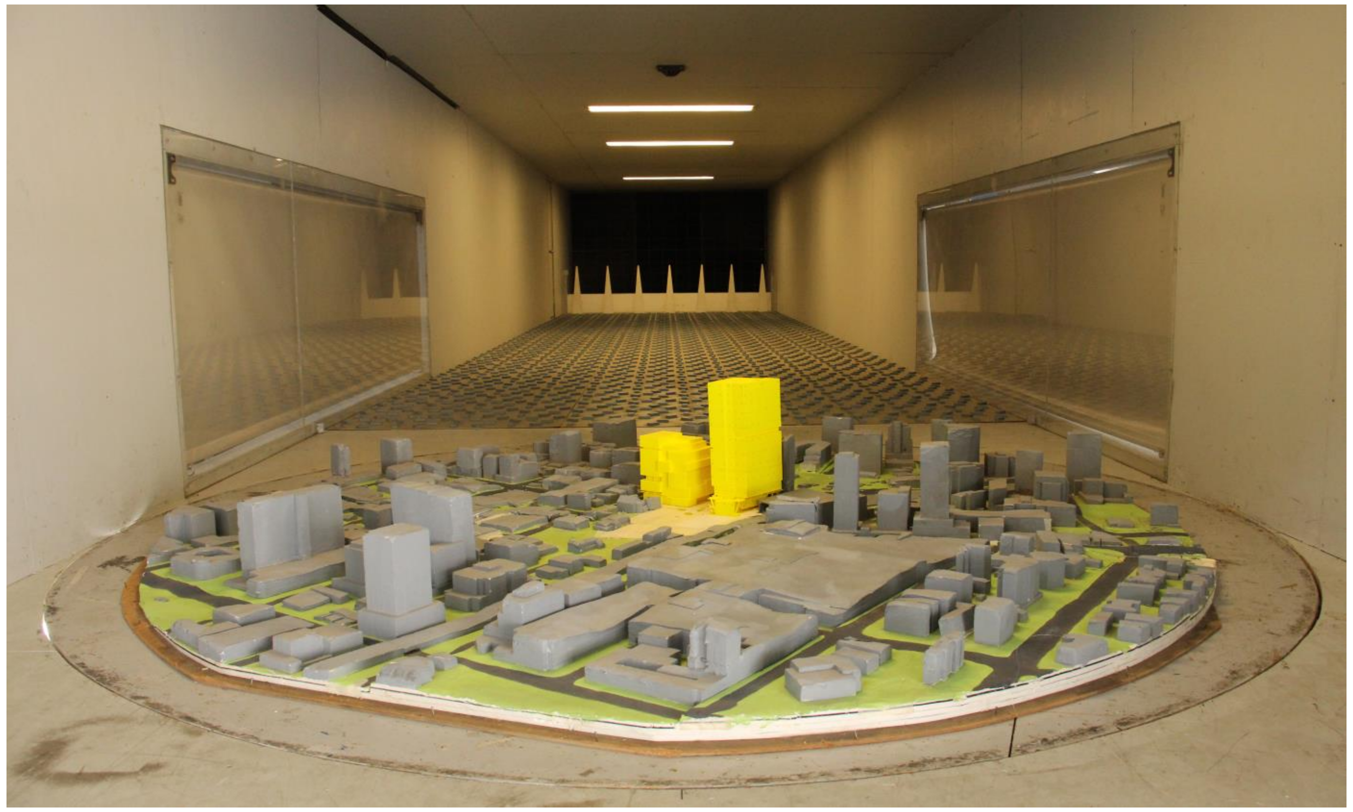

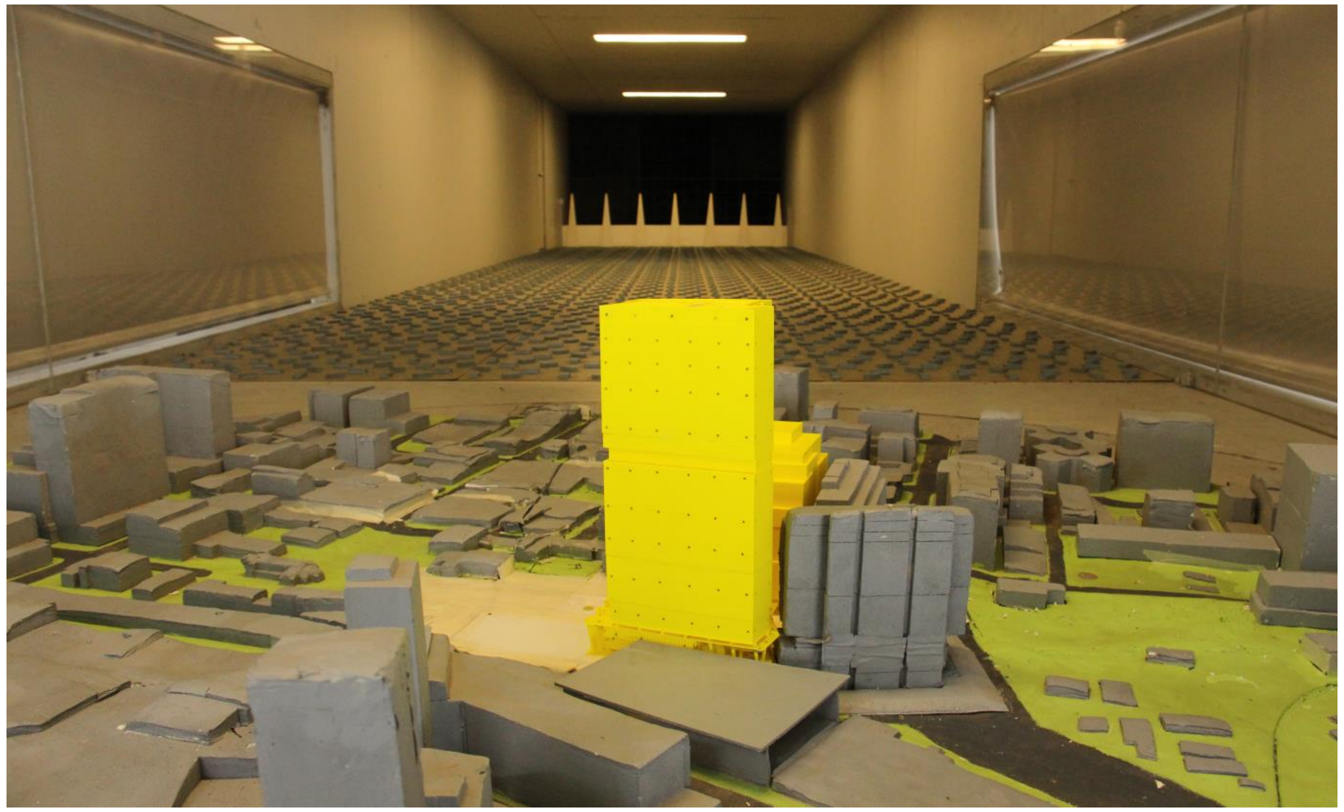

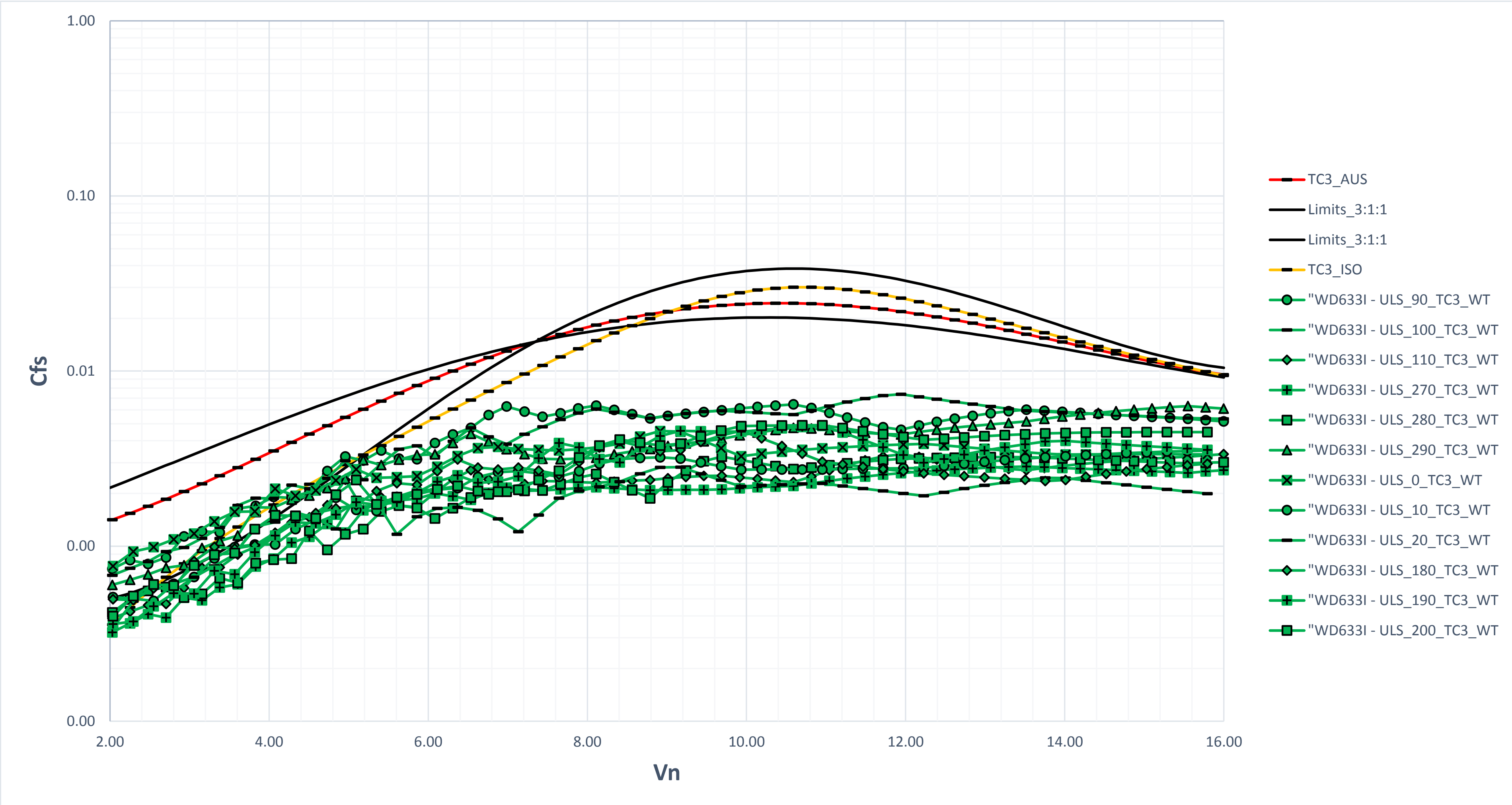

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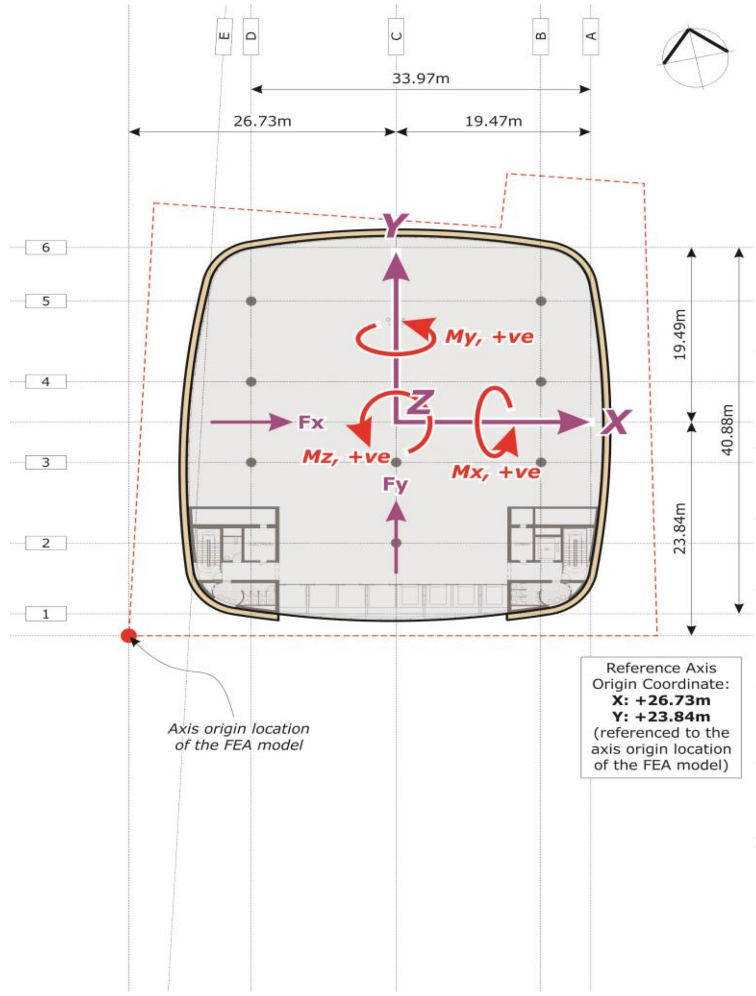

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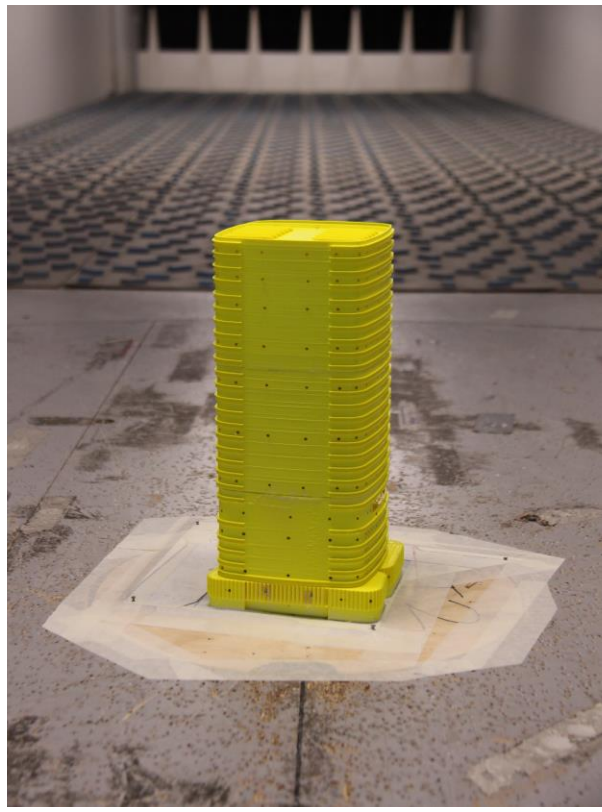

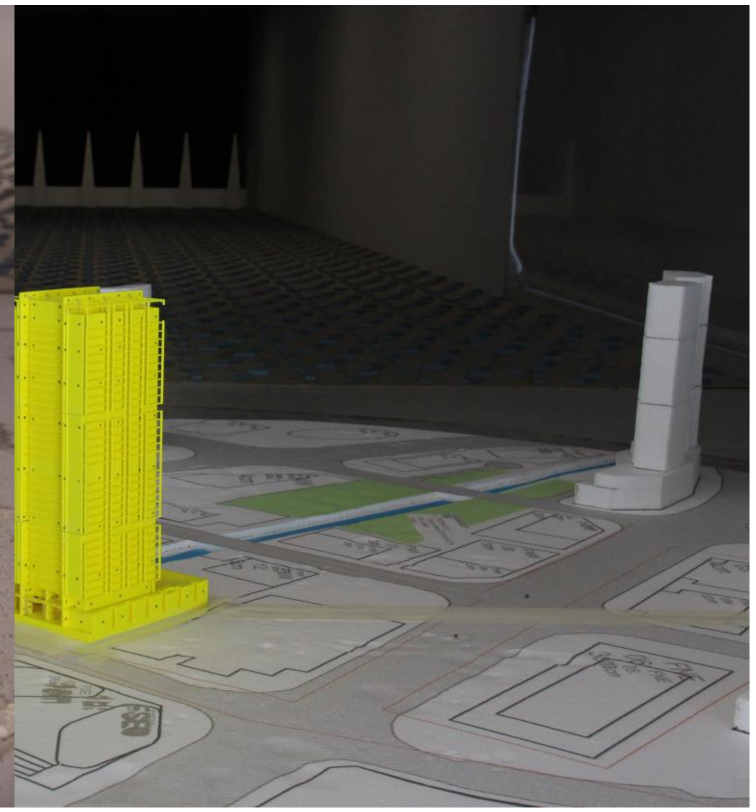

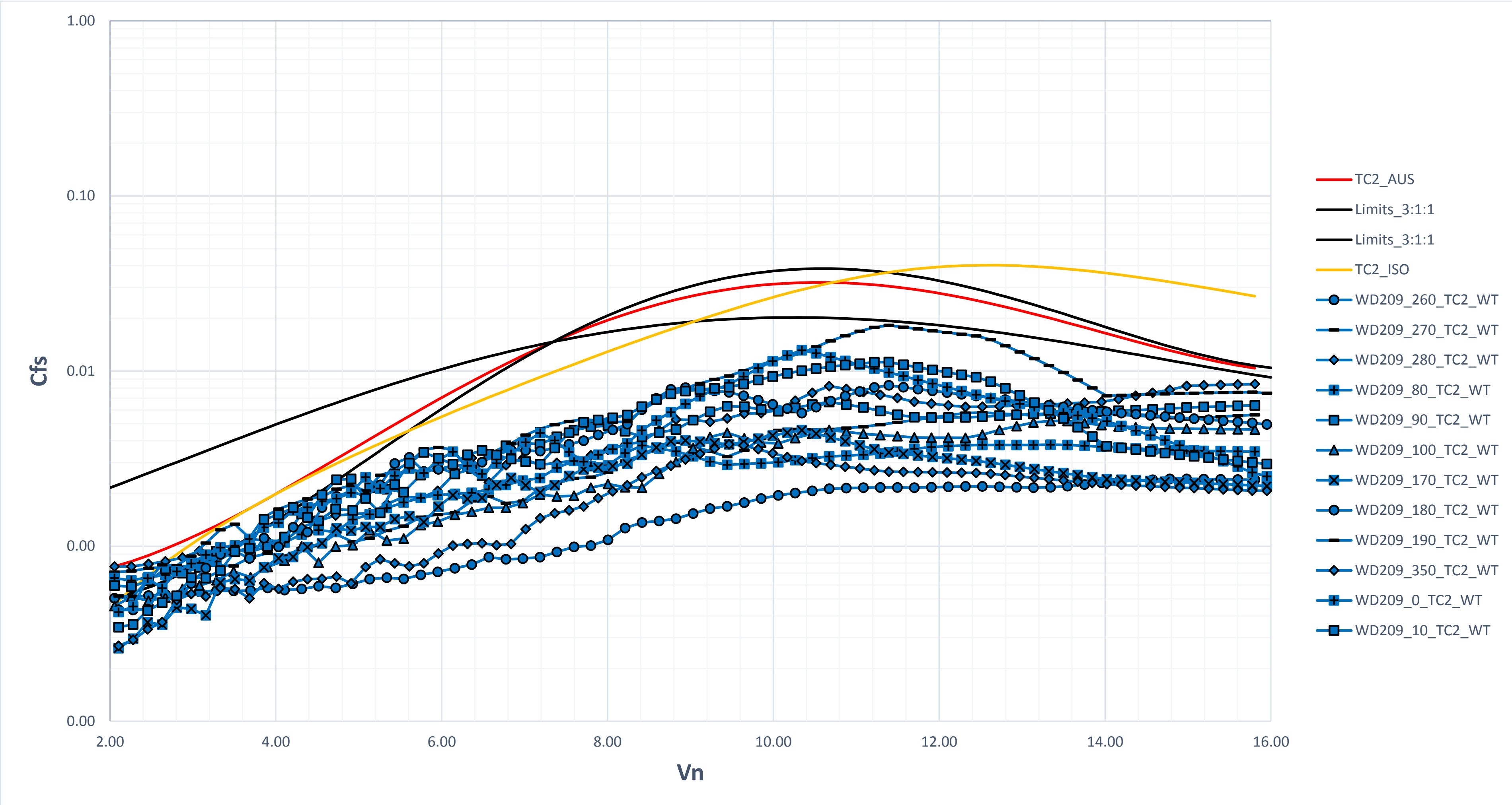
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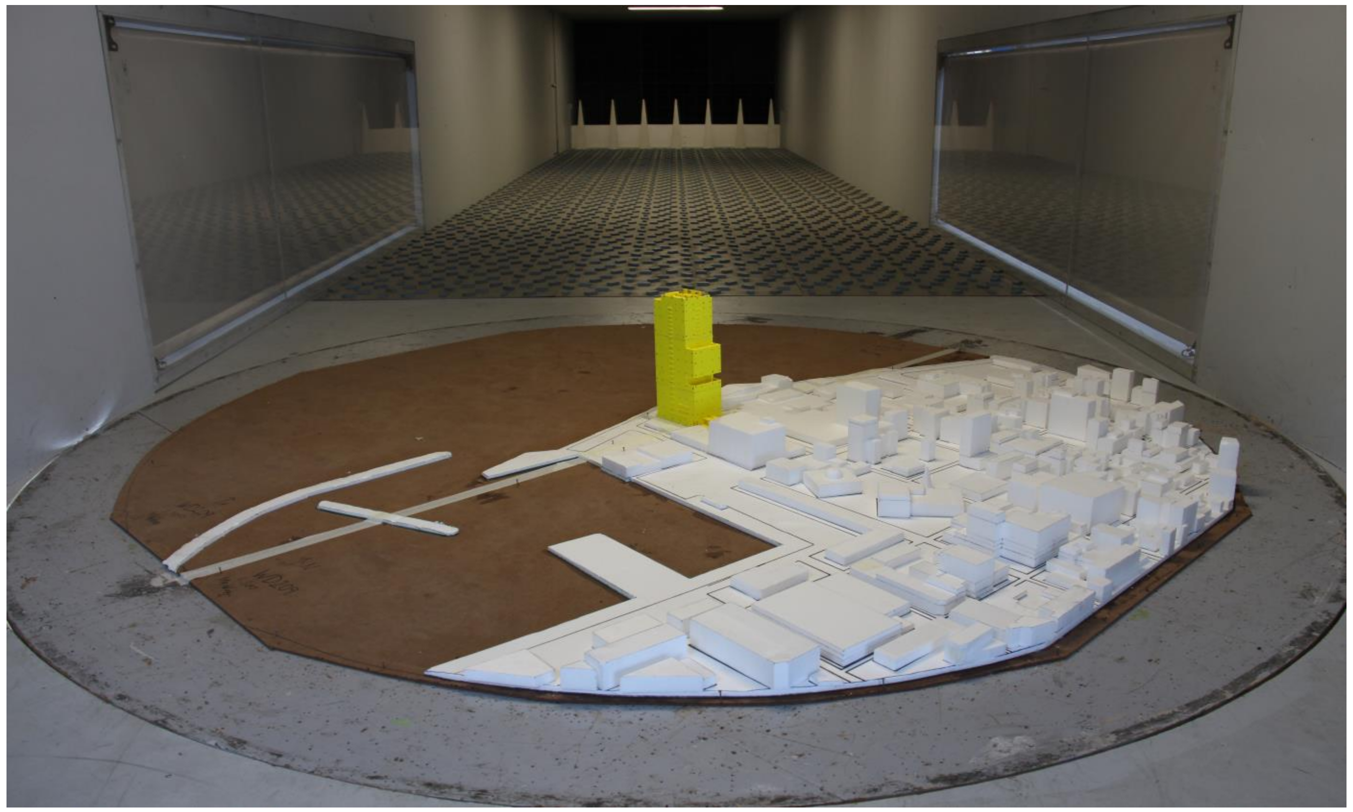

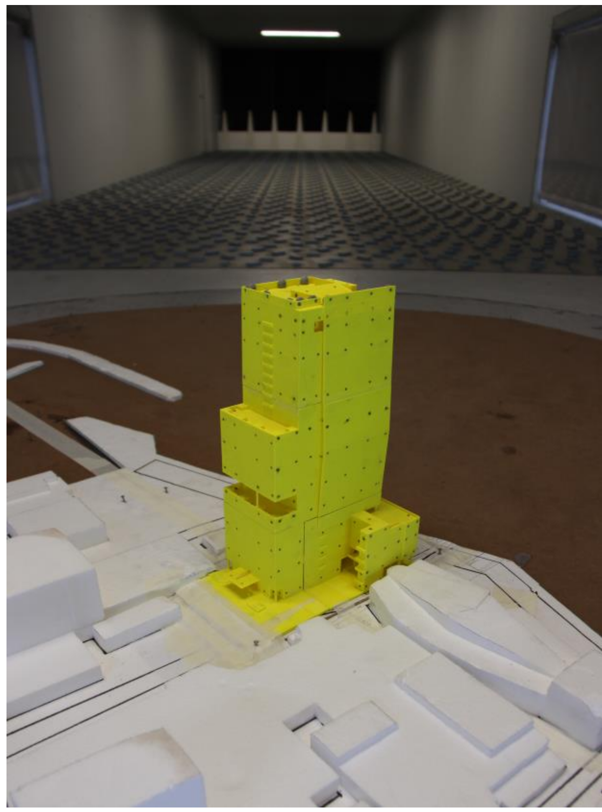

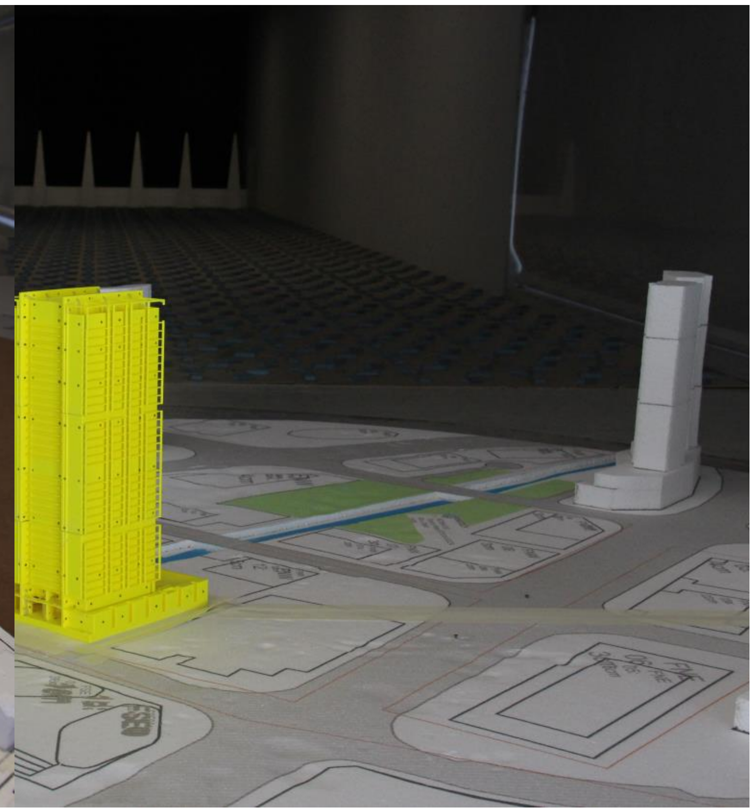

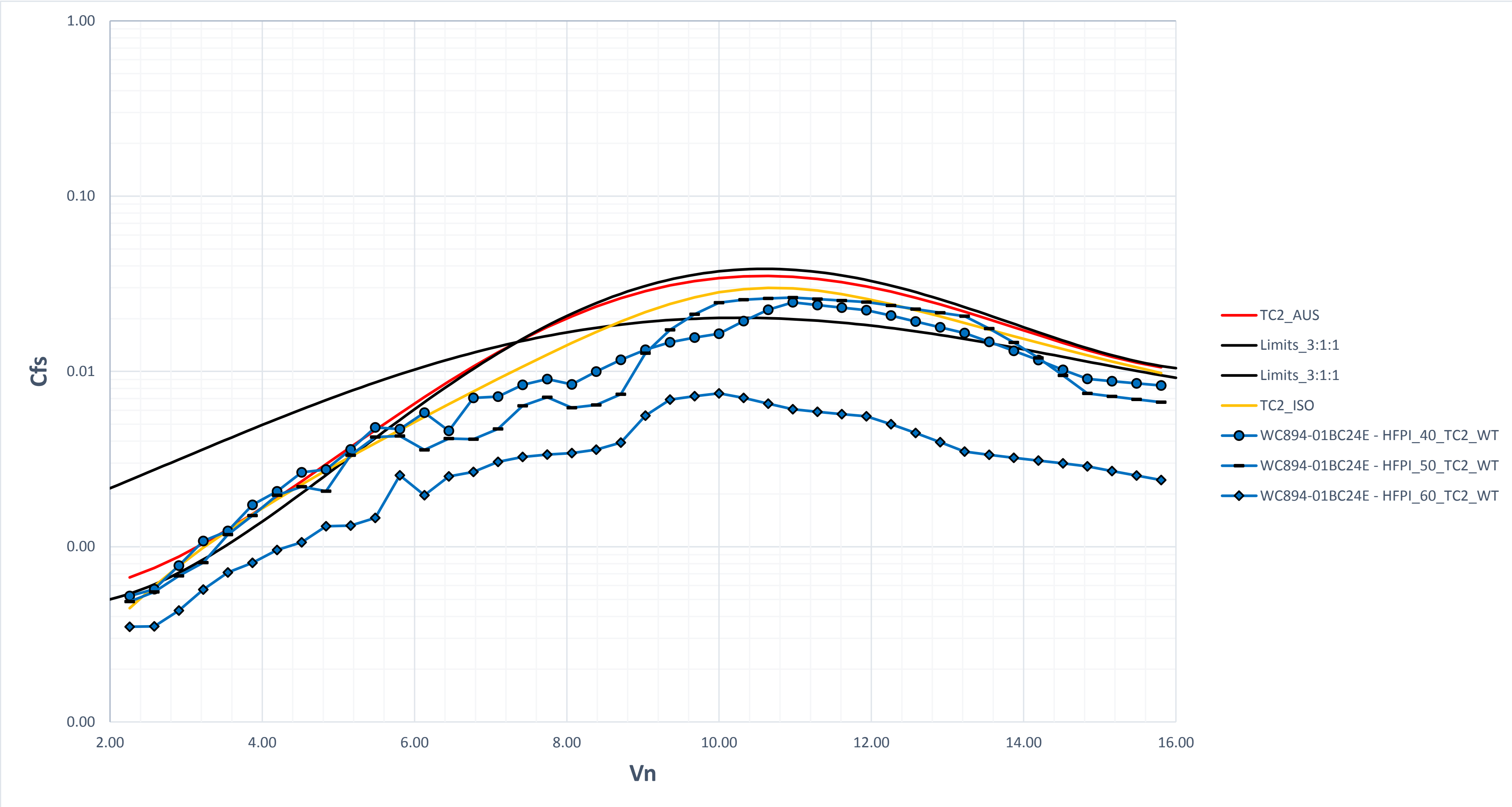
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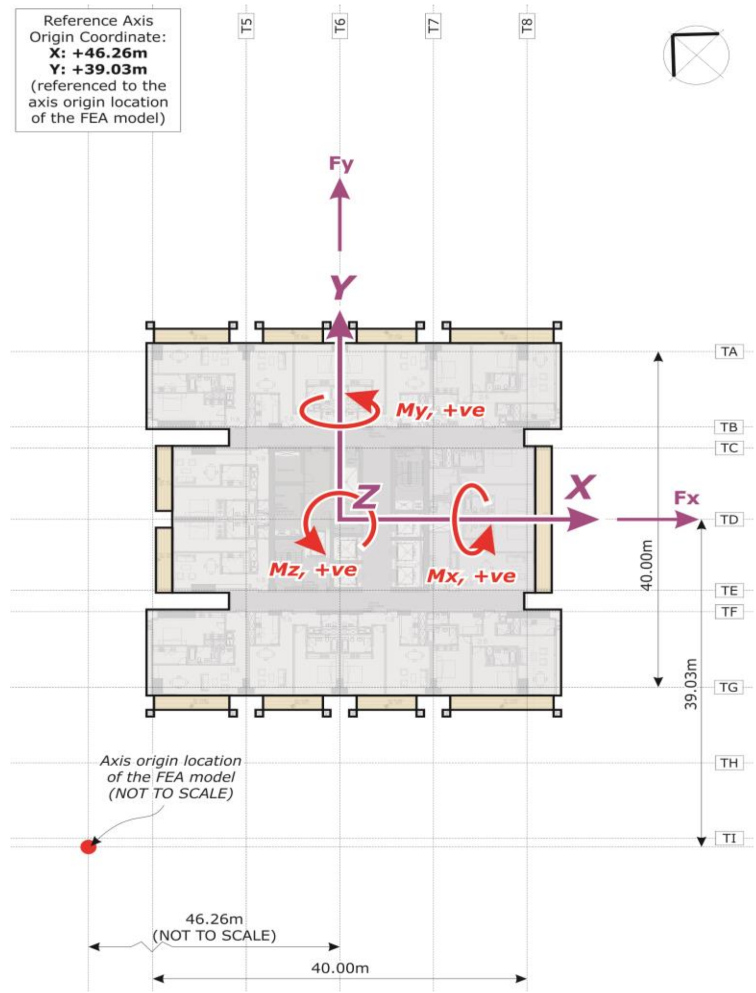
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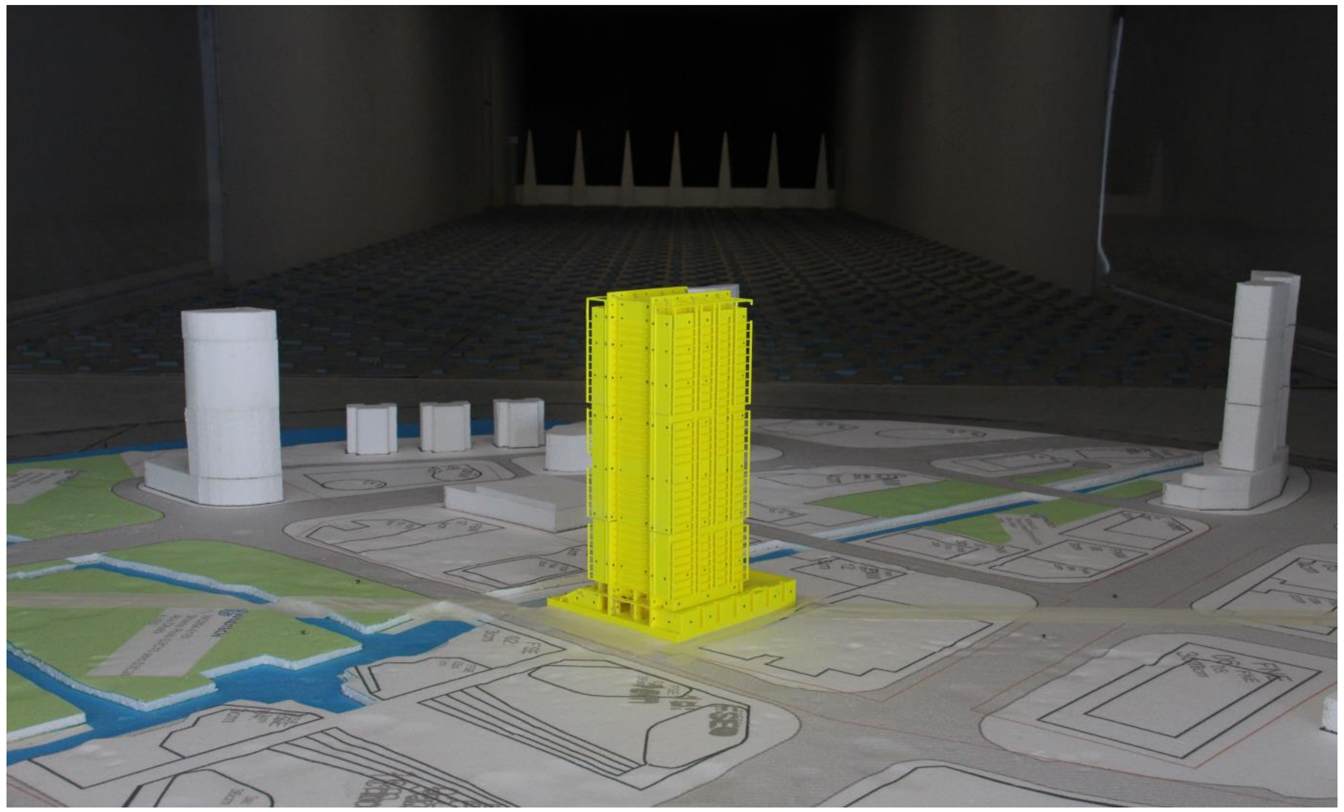

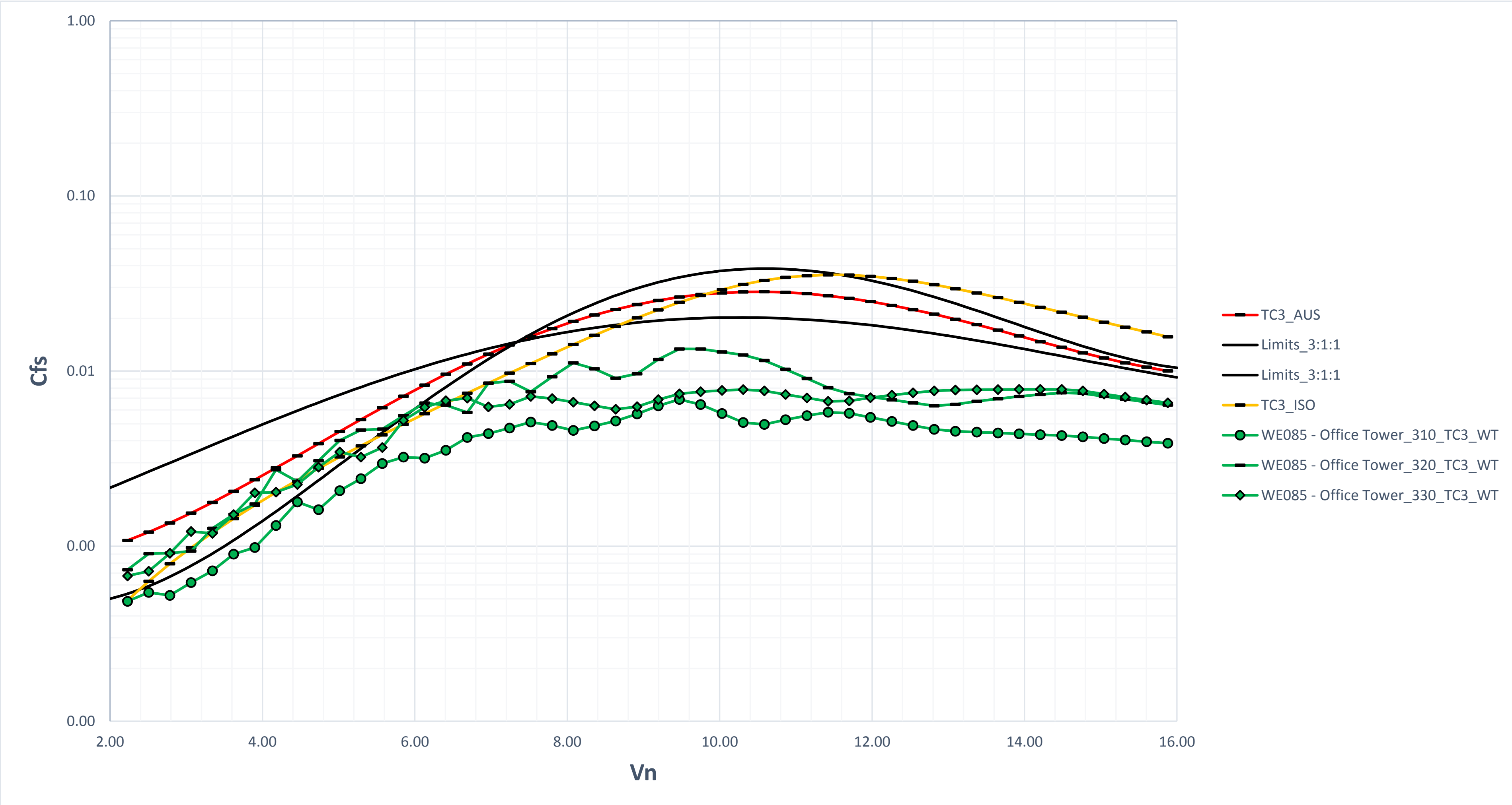
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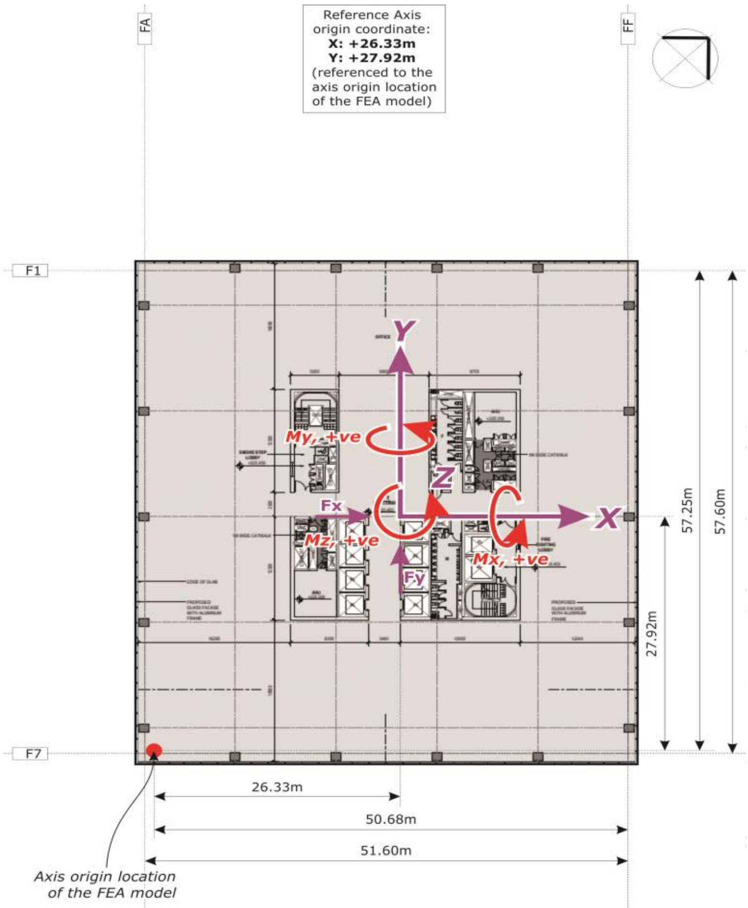
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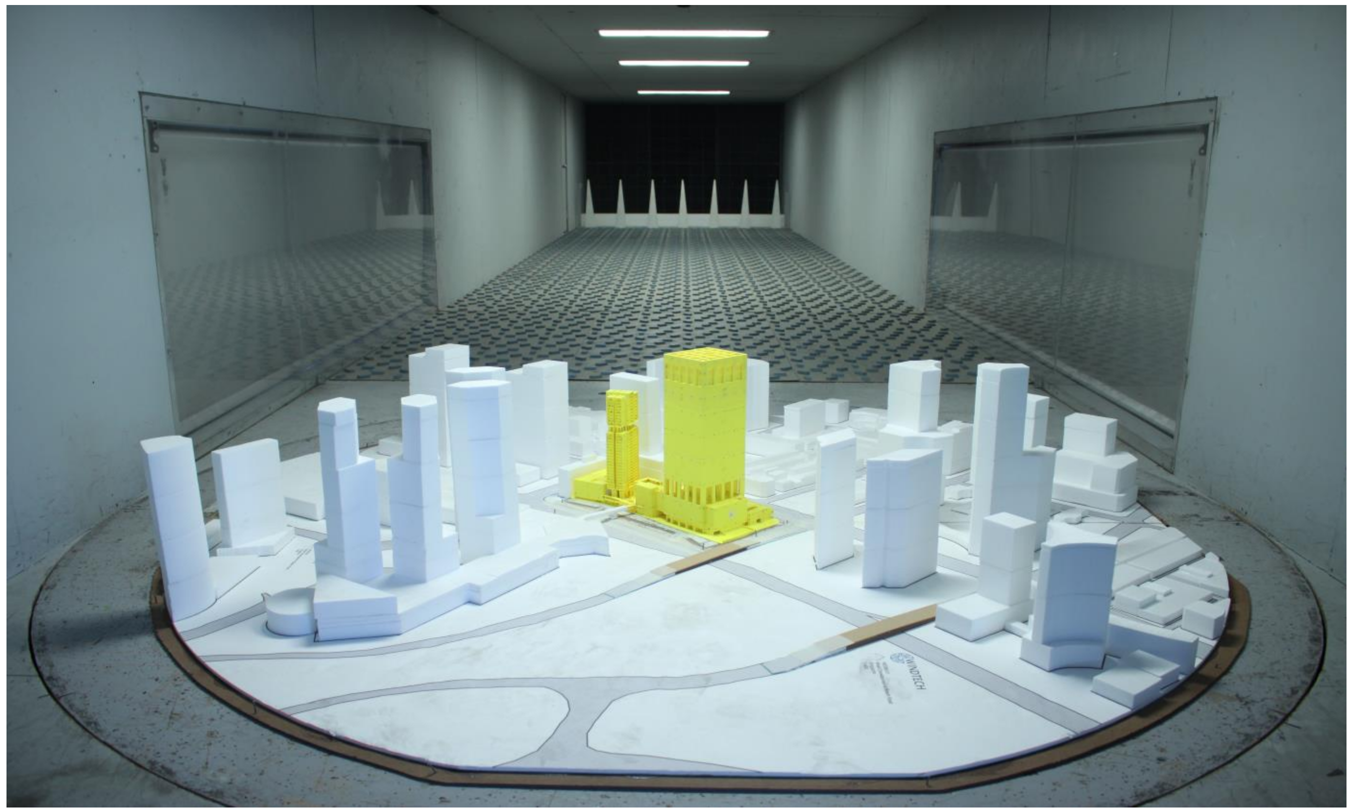

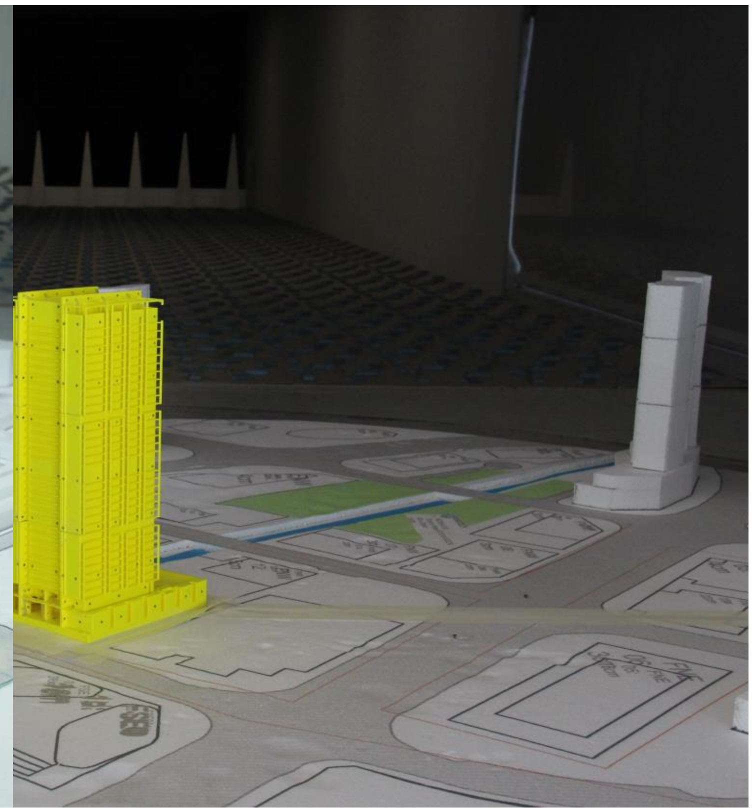

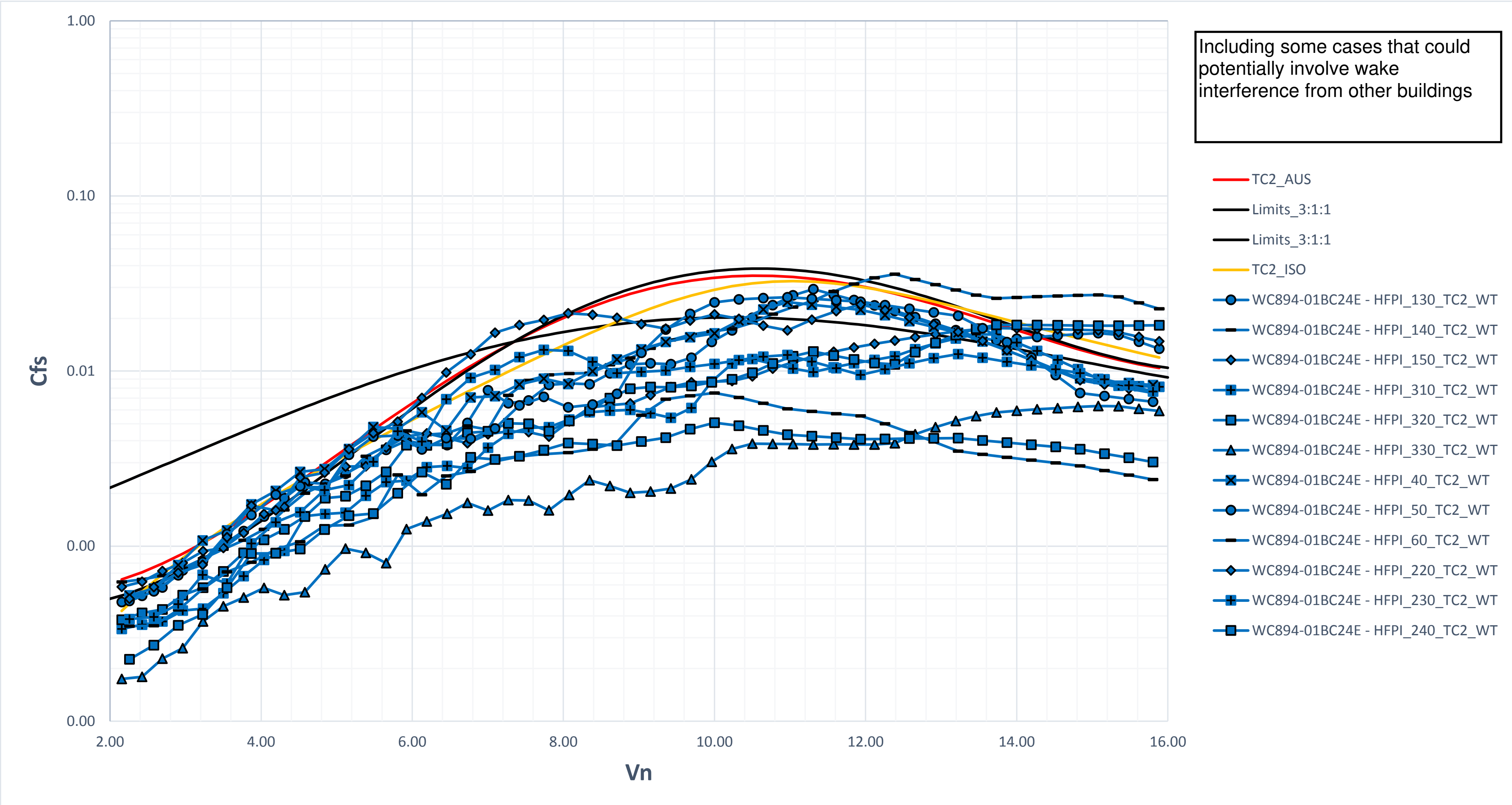
Including some cases that could potentially involve wake interference from other buildings
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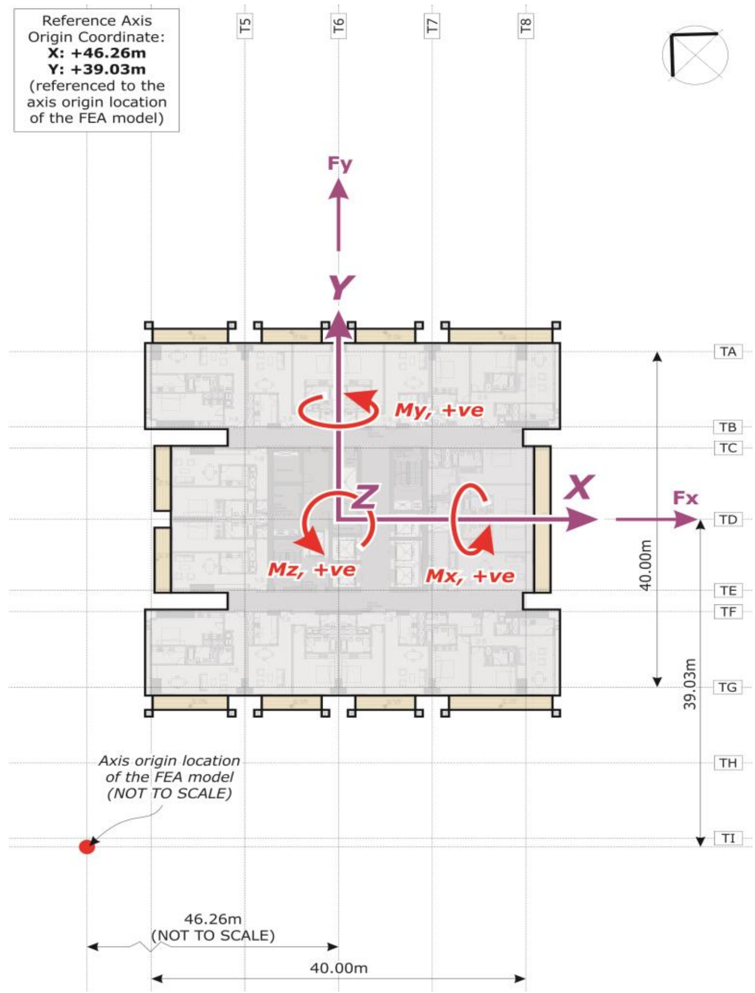
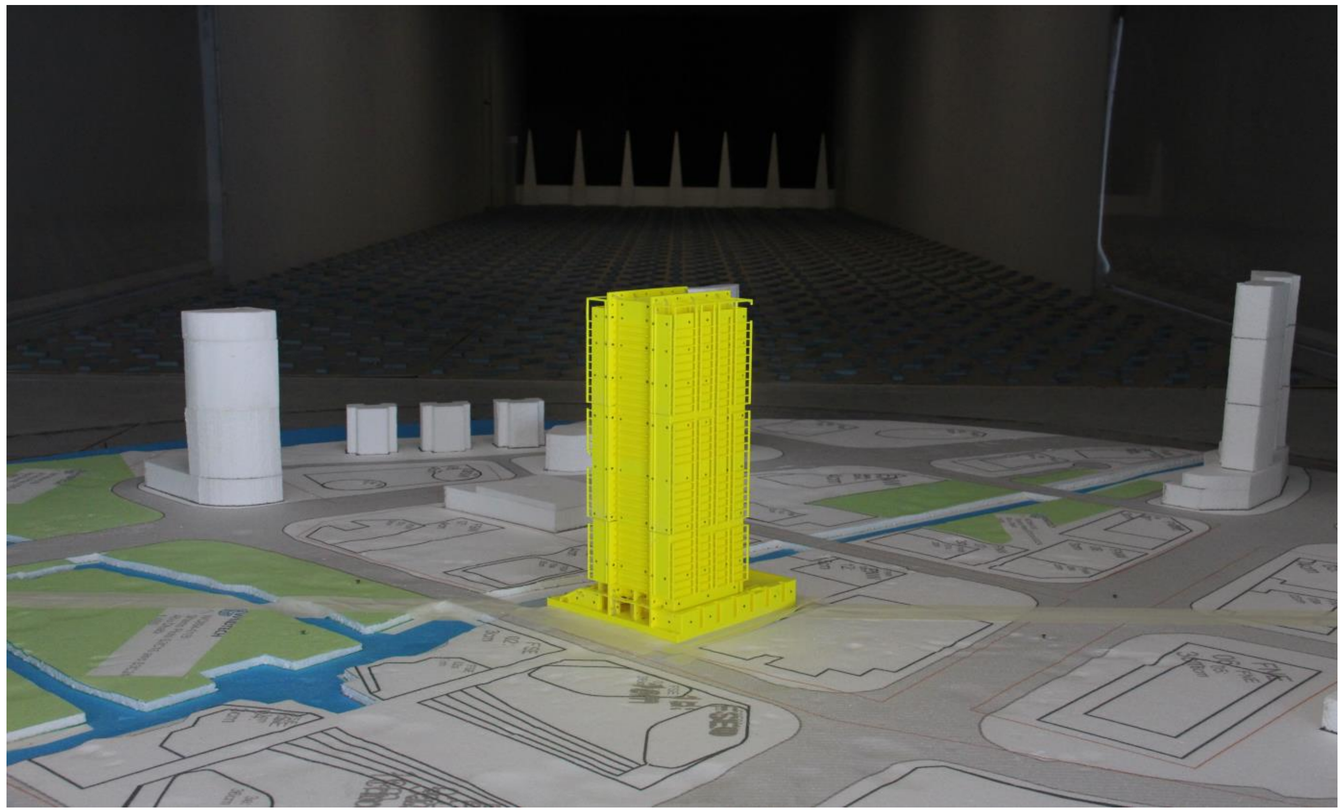
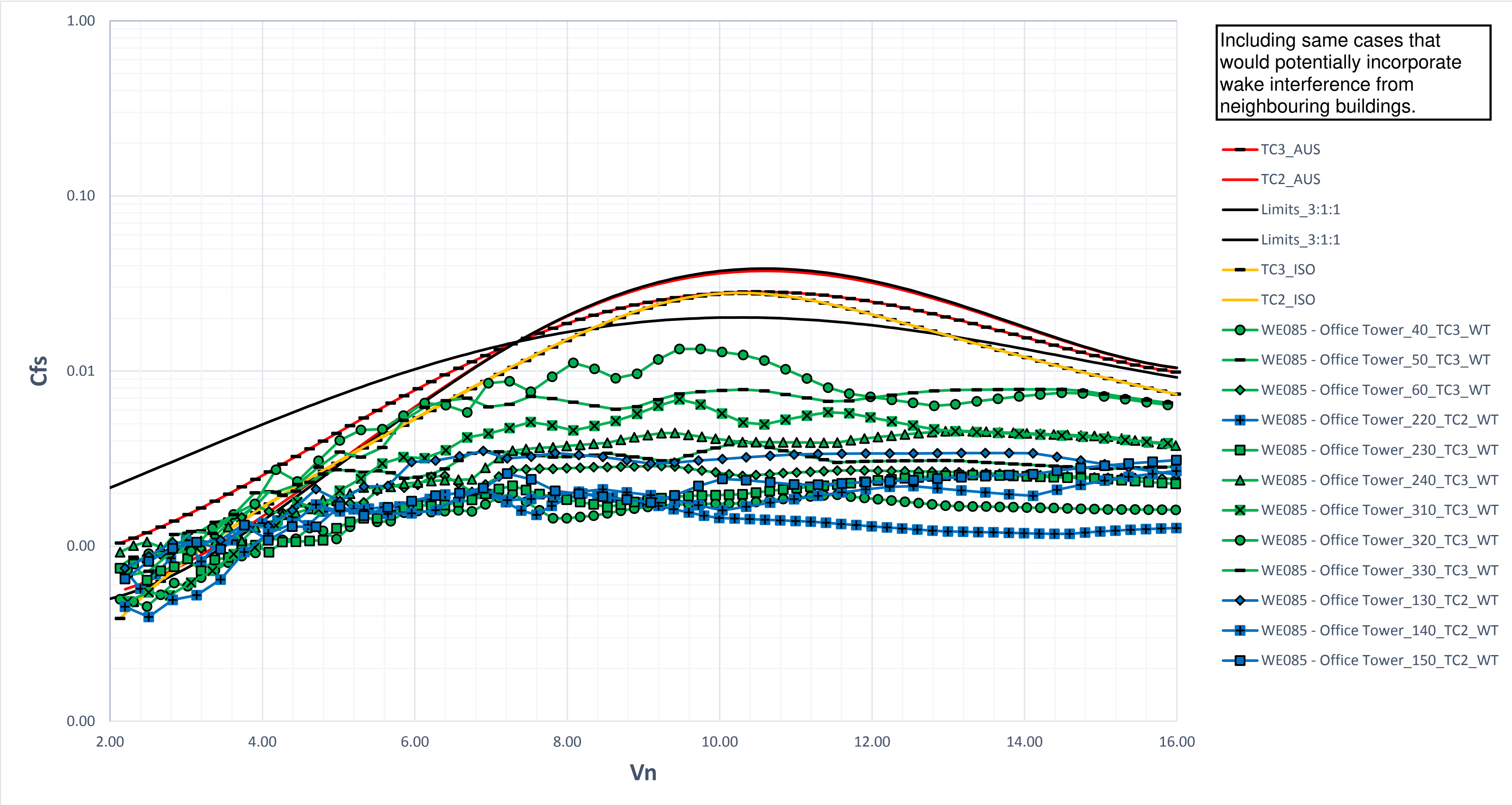
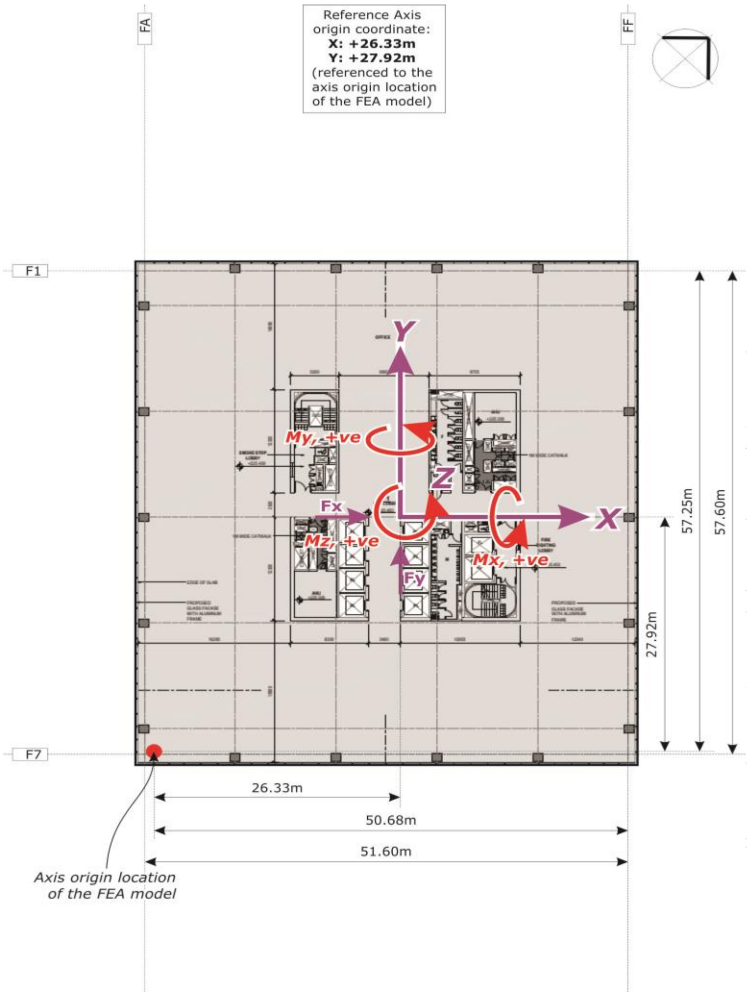
WC894-01BC24E - HFPI_230_TC2_WT
WC894-01BC24E - HFPI_240_TC2_WT

Reference Axis Origin Coordinate:
X: +46.26m
Y: +39.03m
(referenced to the axis origin location of the FEA model)
T5
T6
T7
T8
Fy
Y
My, +ve
X
Fx
Z
Mz, +ve
Mx, +ve
TA
TB
TC
TD
TE
TF
TG
TH
TI
40.00m
39.03m
Axis origin location of the FEA model (NOT TO SCALE)
46.26m (NOT TO SCALE)
40.00m

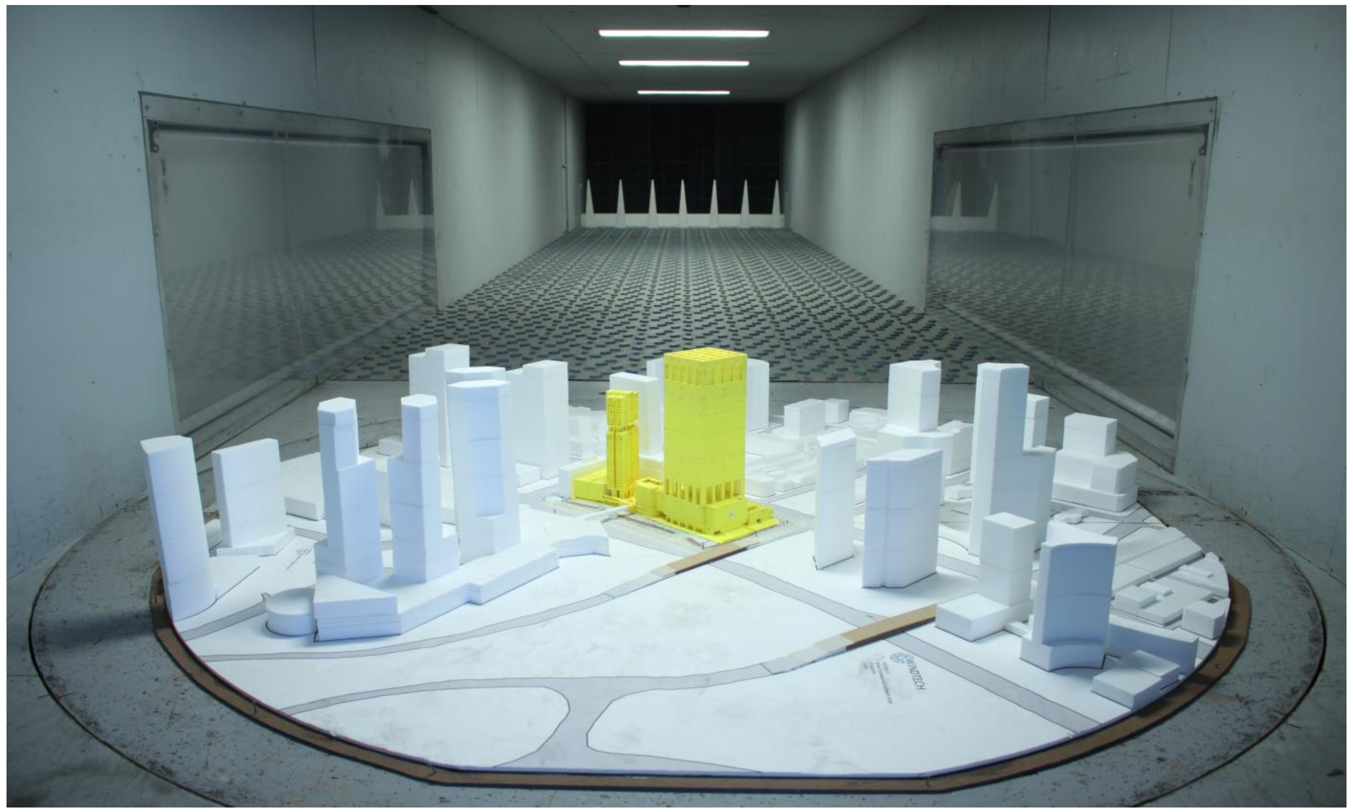


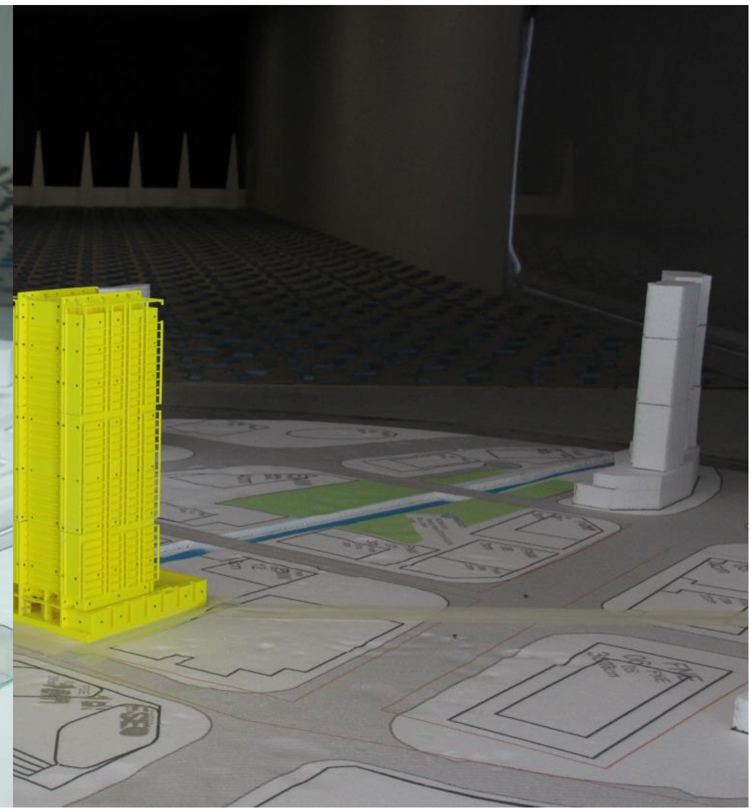


Including same cases that would potentially incorporate wake interference from neighbouring buildings.
Cfs
Vn
1.00
0.10
0.01
0.00
0.00
2.00
4.00
6.00
8.00
10.00
12.00
14.00
16.00
TC3_AUS
TC2_AUS
Limits_3:1:1
Limits_3:1:1
TC3_ISO
TC2_ISO
WE085 - Office Tower_40_TC3_WT
WE085 - Office Tower_50_TC3_WT
WE085 - Office Tower_60_TC3_WT
WE085 - Office Tower_220_TC2_WT
WE085 - Office Tower_230_TC3_WT
WE085 - Office Tower_240_TC3_WT
WE085 - Office Tower_310_TC3_WT
WE085 - Office Tower_320_TC3_WT
WE085 - Office Tower_330_TC3_WT
WE085 - Office Tower_130_TC2_WT
WE085 - Office Tower_140_TC2_WT
WE085 - Office Tower_150_TC2_WT

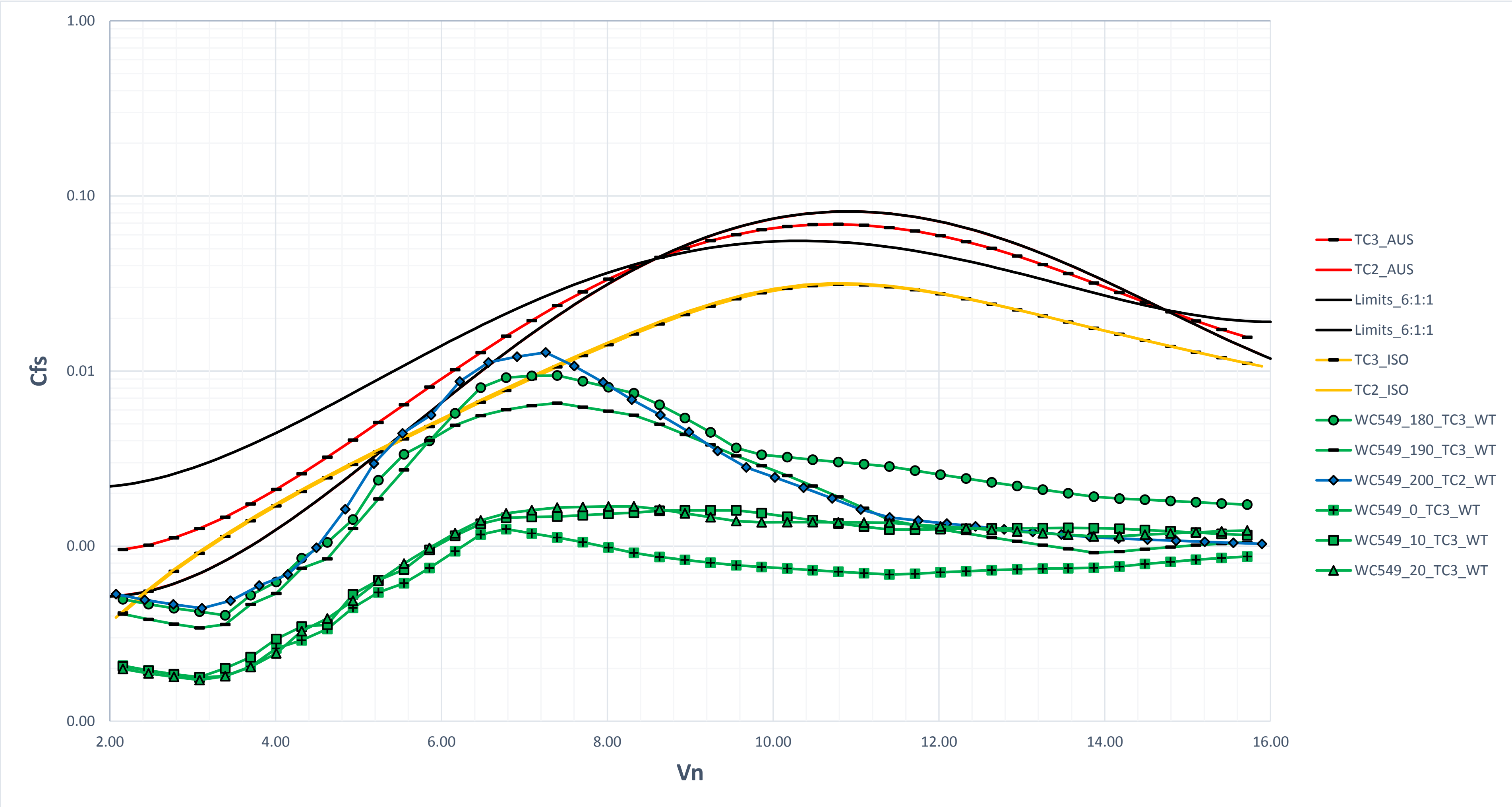


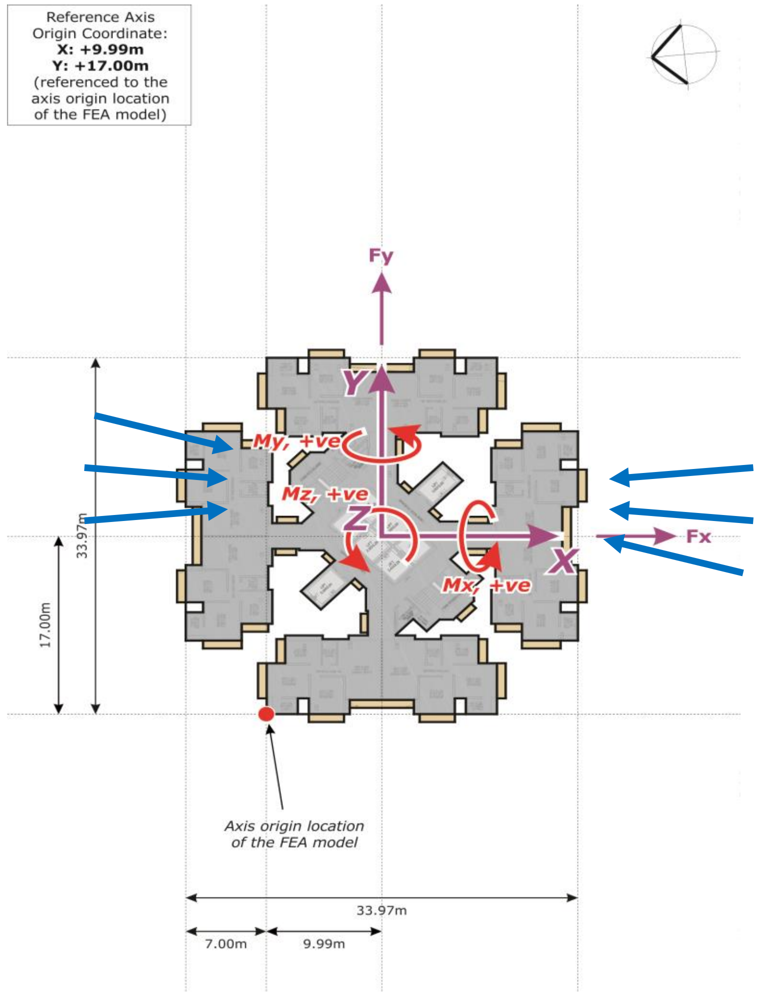
Reference Axis origin coordinate:
X: +26.33m
Y: +27.92m
(referenced to the axis origin location of the FEA model)
FA
FF
F1
F7
Y
X
Z
My, +ve
Mz, +ve
Mx, +ve
Fx
Fy
57.25m
57.60m
27.92m
26.33m
50.68m
51.60m
Axis origin location of the FEA model

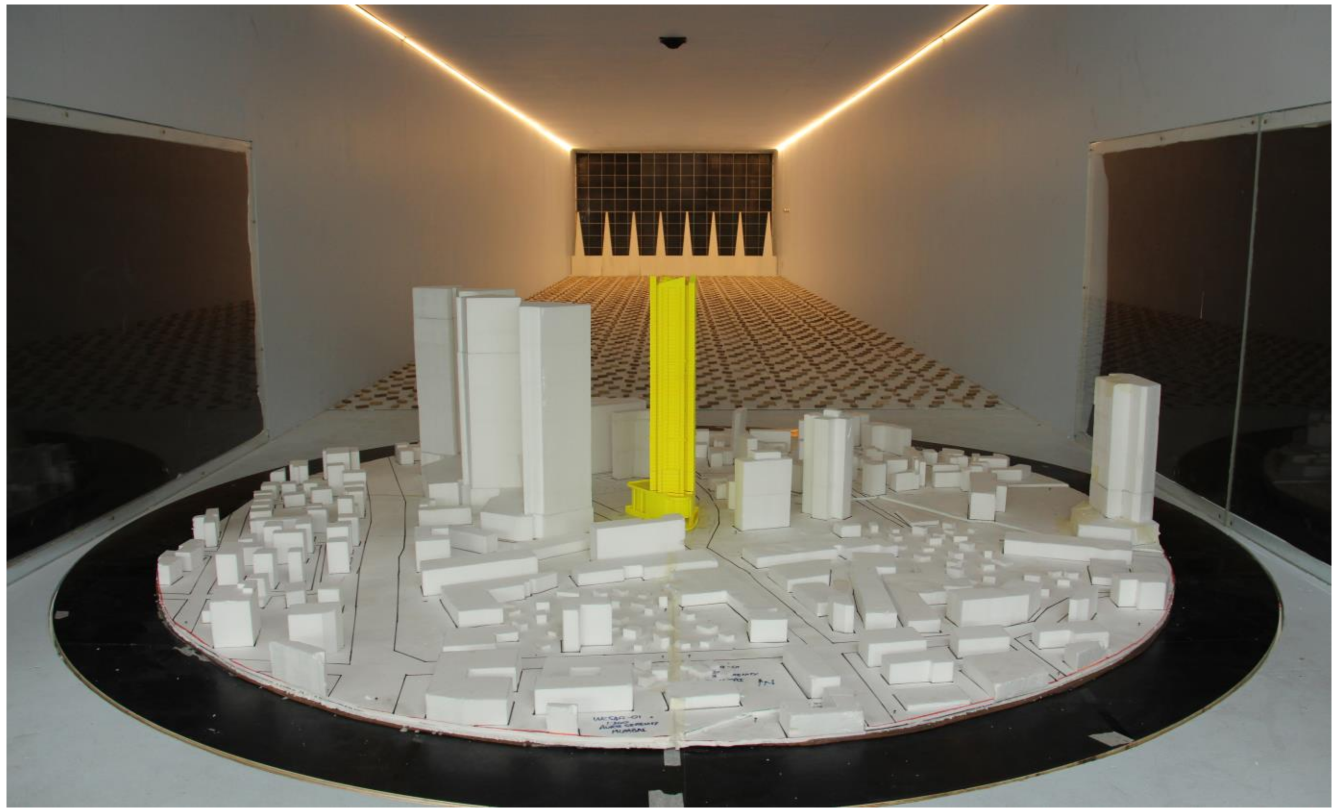


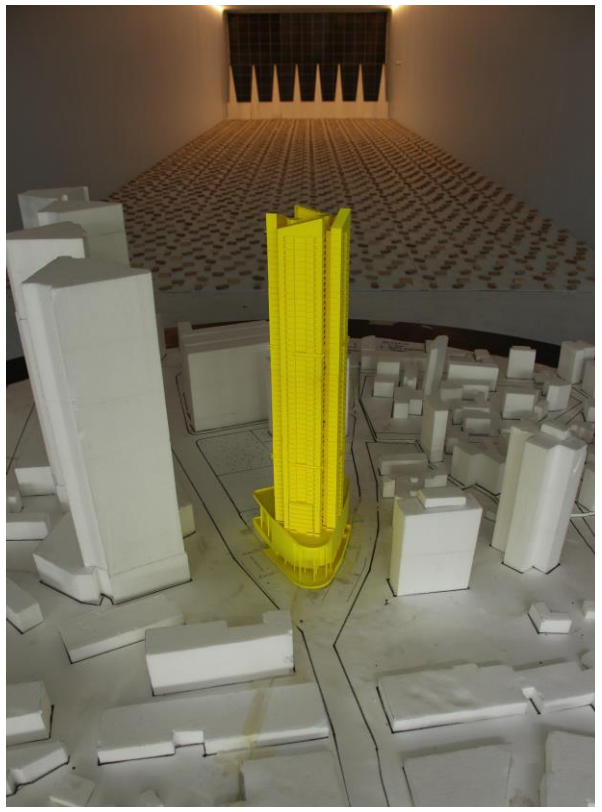


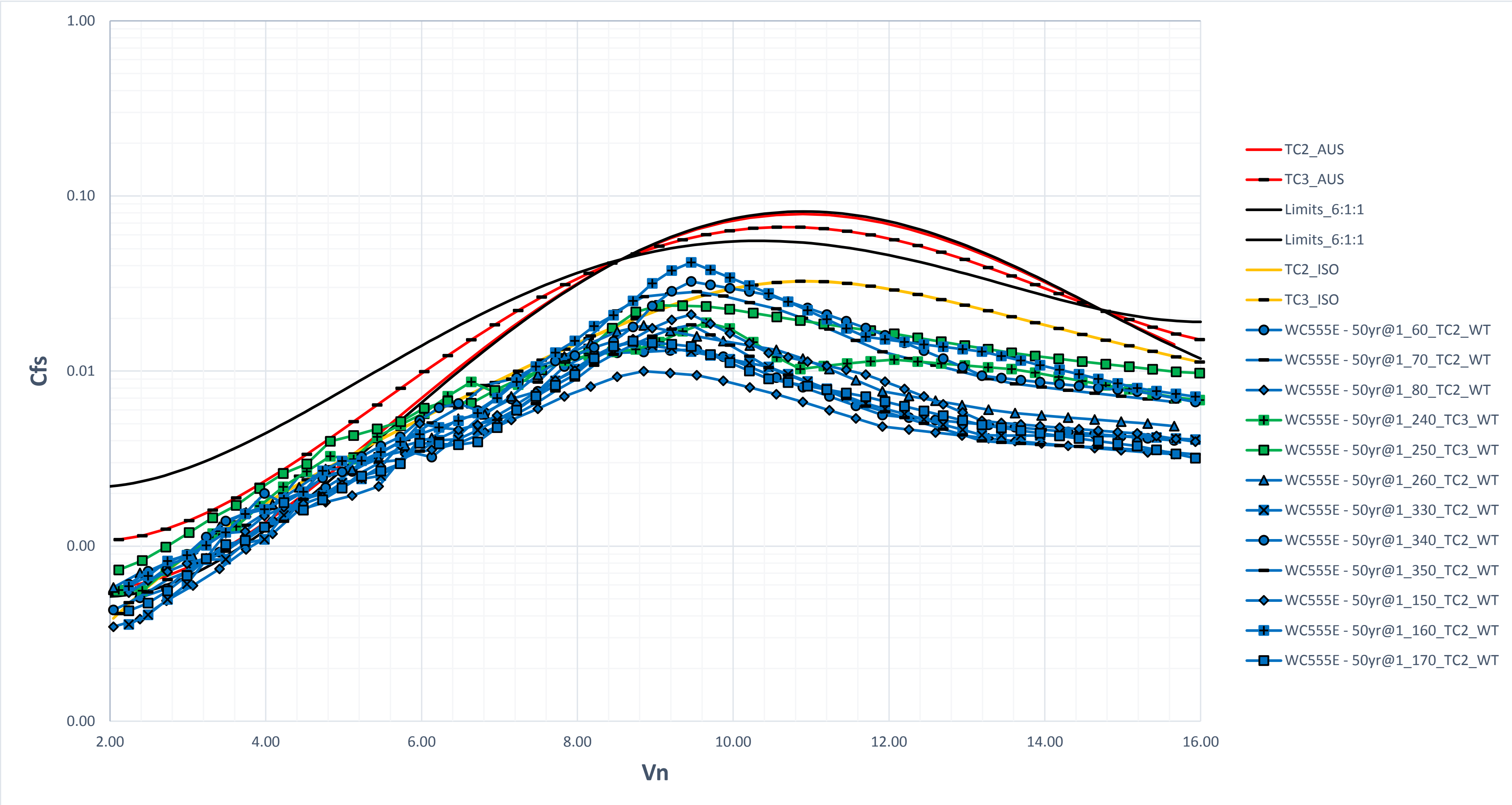
ANNEXURE 2 – COMPARATIVE RESULTS for *h*:*b*:*d* of 6:1:1

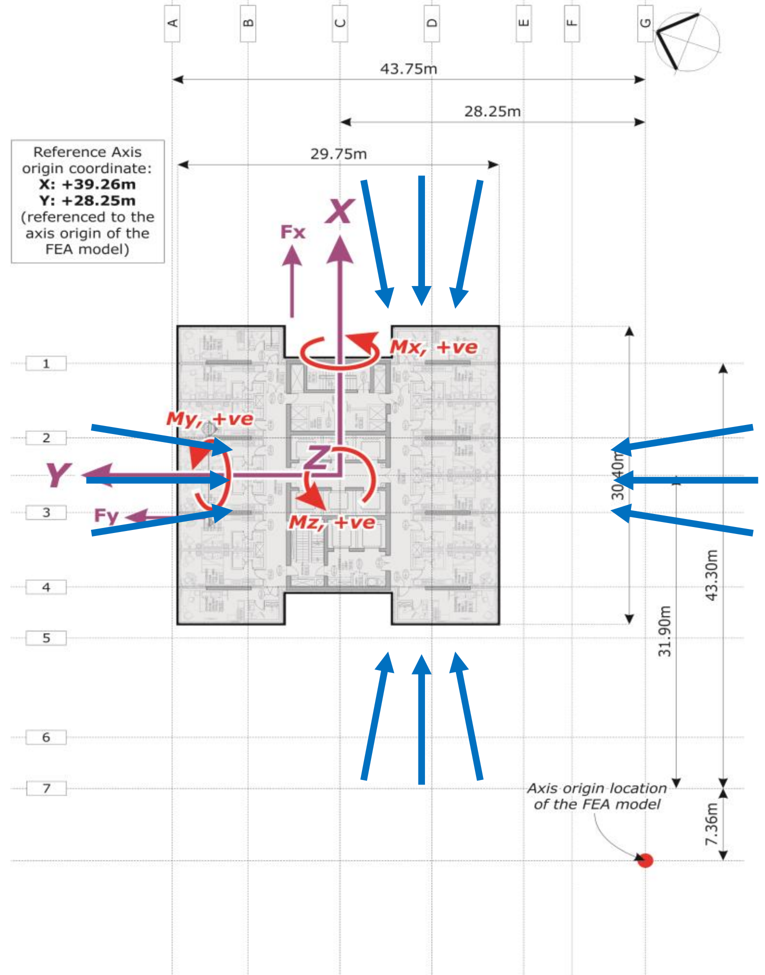

1.00
0.10
0.01
0.00
0.00
0.00
Cfs
2.00
4.00
6.00
8.00
10.00
12.00
14.00
16.00
Vn
TC3_AUS
TC2_AUS
Limits_6:1:1
Limits_6:1:1
TC3_ISO
TC2_ISO
WC549_180_TC3_WT
WC549_190_TC3_WT
WC549_200_TC2_WT
WC549_0_TC3_WT
WC549_10_TC3_WT
WC549_20_TC3_WT

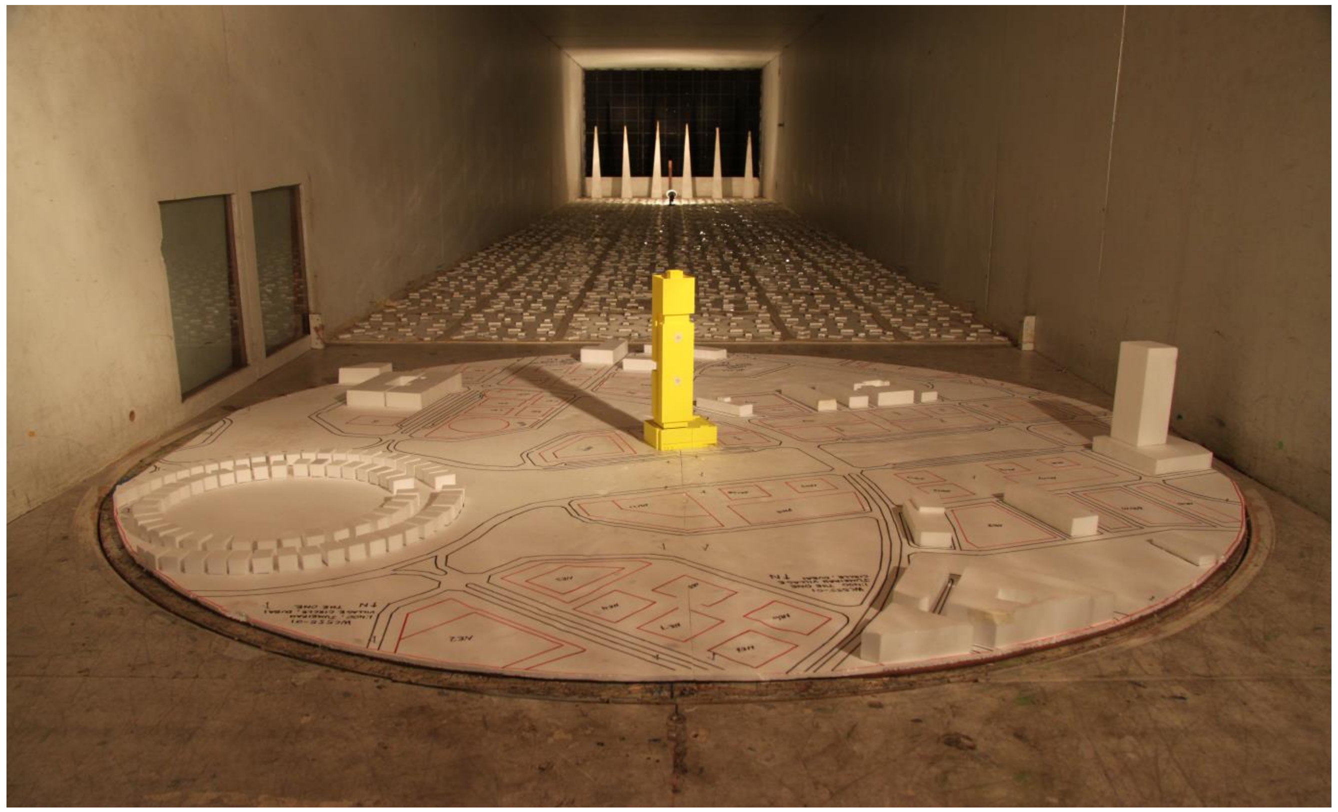

Reference Axis
Origin Coordinate:
X: +9.99m
Y: +17.00m
(referenced to the
axis origin location
of the FEA model)
Fy
Y
My, +ve
Mz, +ve
Z
X
Fx
Mx, +ve
33.97m
17.00m
Axis origin location
of the FEA model
33.97m
7.00m
9.99m

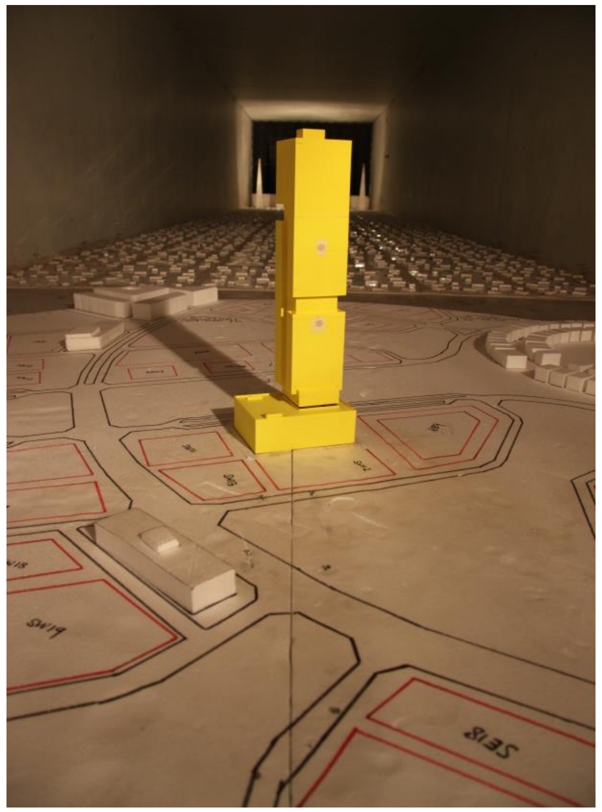


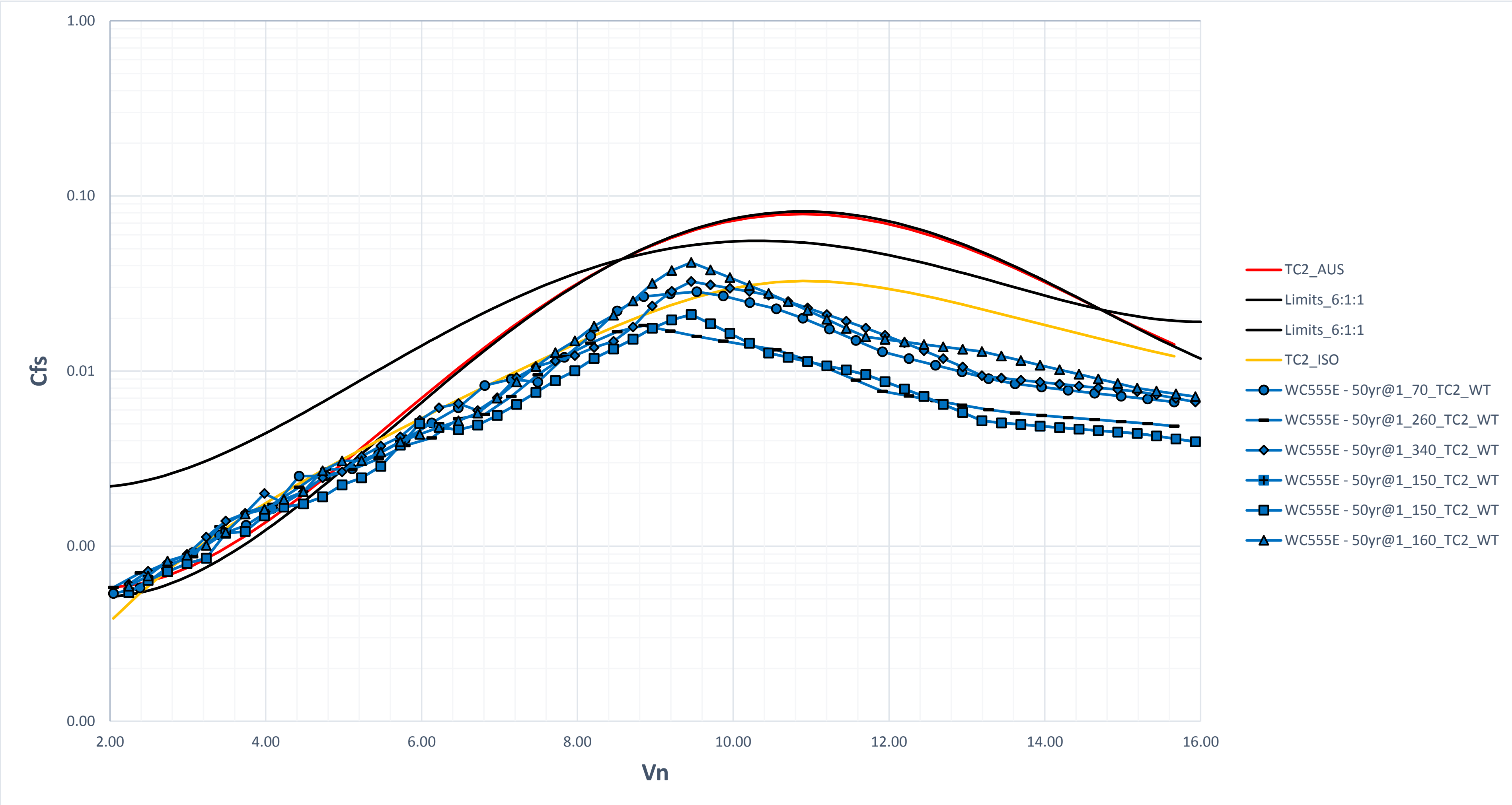


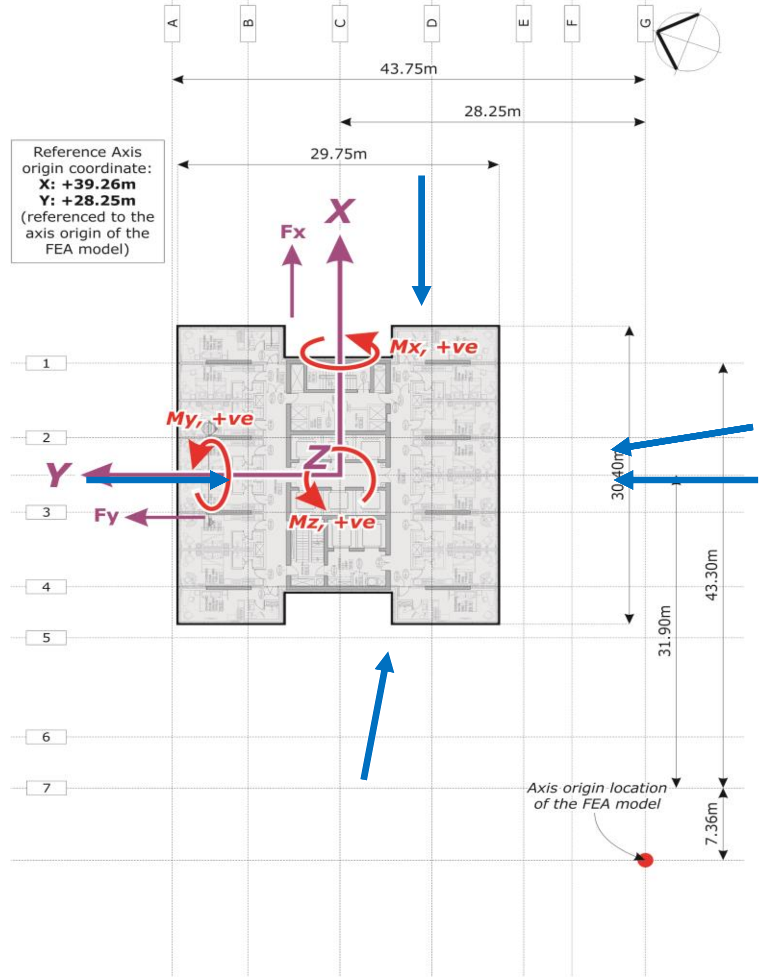

Cfs
Vn
1.00
0.10
0.01
0.00
0.00
2.00
4.00
6.00
8.00
10.00
12.00
14.00
16.00
TC2_AUS
TC3_AUS
Limits_6:1:1
Limits_6:1:1
TC2_ISO
TC3_ISO
WC555E - 50yr@1_60_TC2_WT
WC555E - 50yr@1_70_TC2_WT
WC555E - 50yr@1_80_TC2_WT
WC555E - 50yr@1_240_TC3_WT
WC555E - 50yr@1_250_TC3_WT
WC555E - 50yr@1_260_TC2_WT
WC555E - 50yr@1_330_TC2_WT
WC555E - 50yr@1_340_TC2_WT
WC555E - 50yr@1_350_TC2_WT
WC555E - 50yr@1_150_TC2_WT
WC555E - 50yr@1_160_TC2_WT
WC555E - 50yr@1_170_TC2_WT

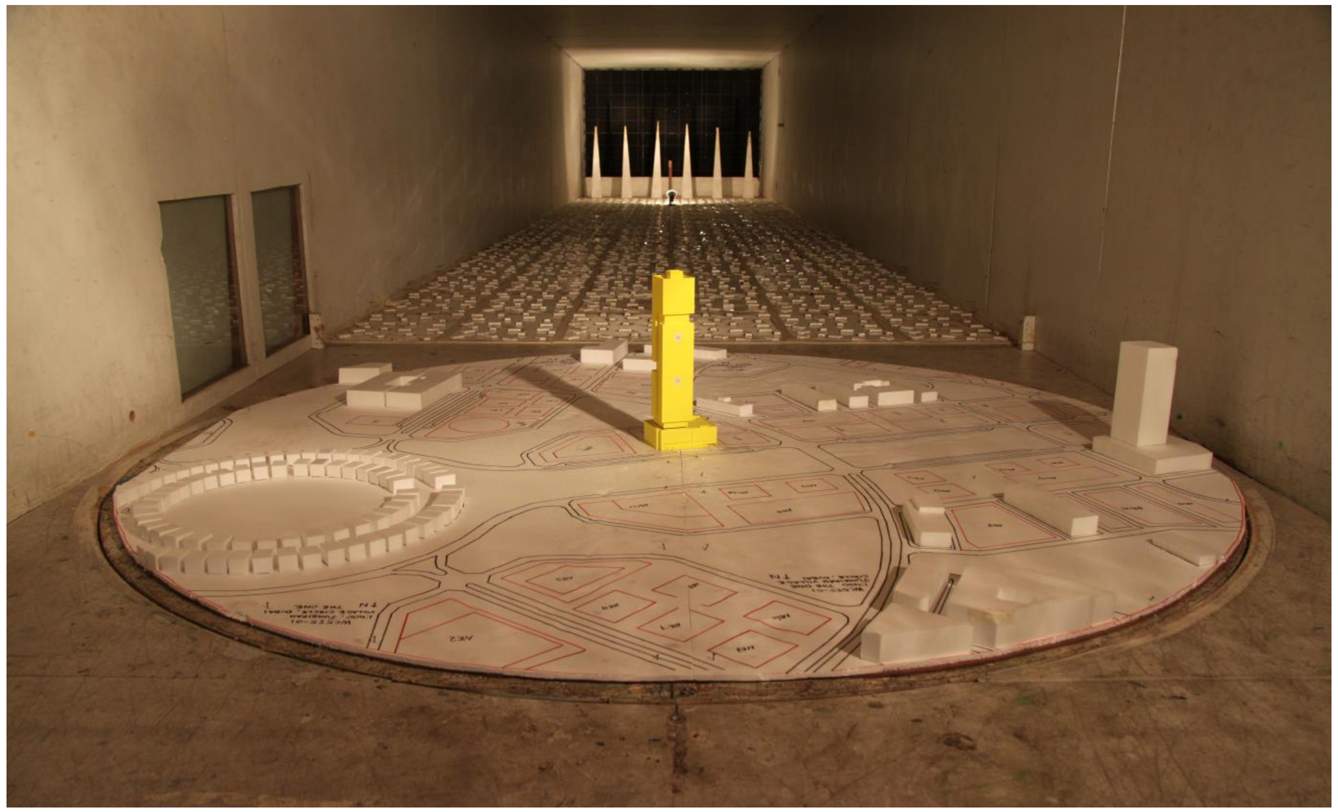

A
B
C
D
E
F
G
43.75m
28.25m
29.75m
Reference Axis
origin coordinate:
X: +39.26m
Y: +28.25m
(referenced to the
axis origin of the
FEA model)
Fx
X
Mx, +ve
My, +ve
Y
Fy
Z
Mz, +ve
1
2
3
4
5
6
7
30.40m
43.30m
31.90m
7.36m
Axis origin location
of the FEA model

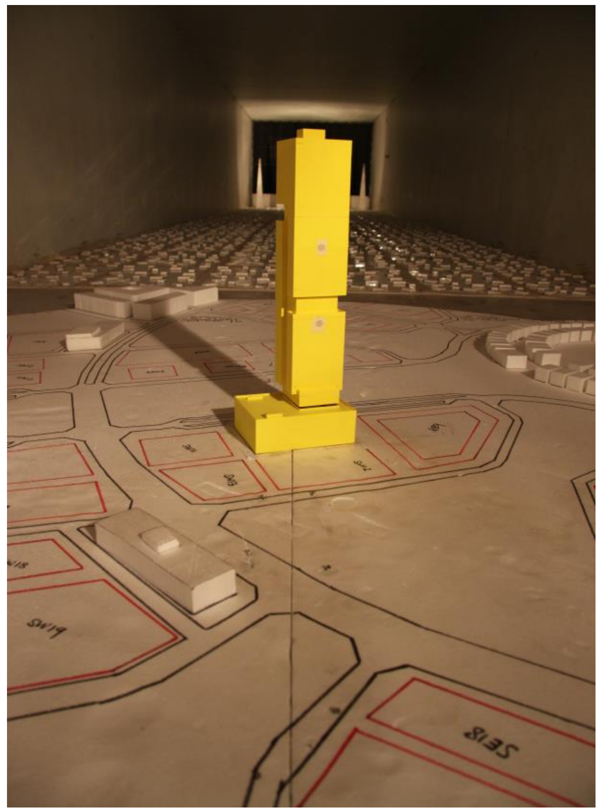


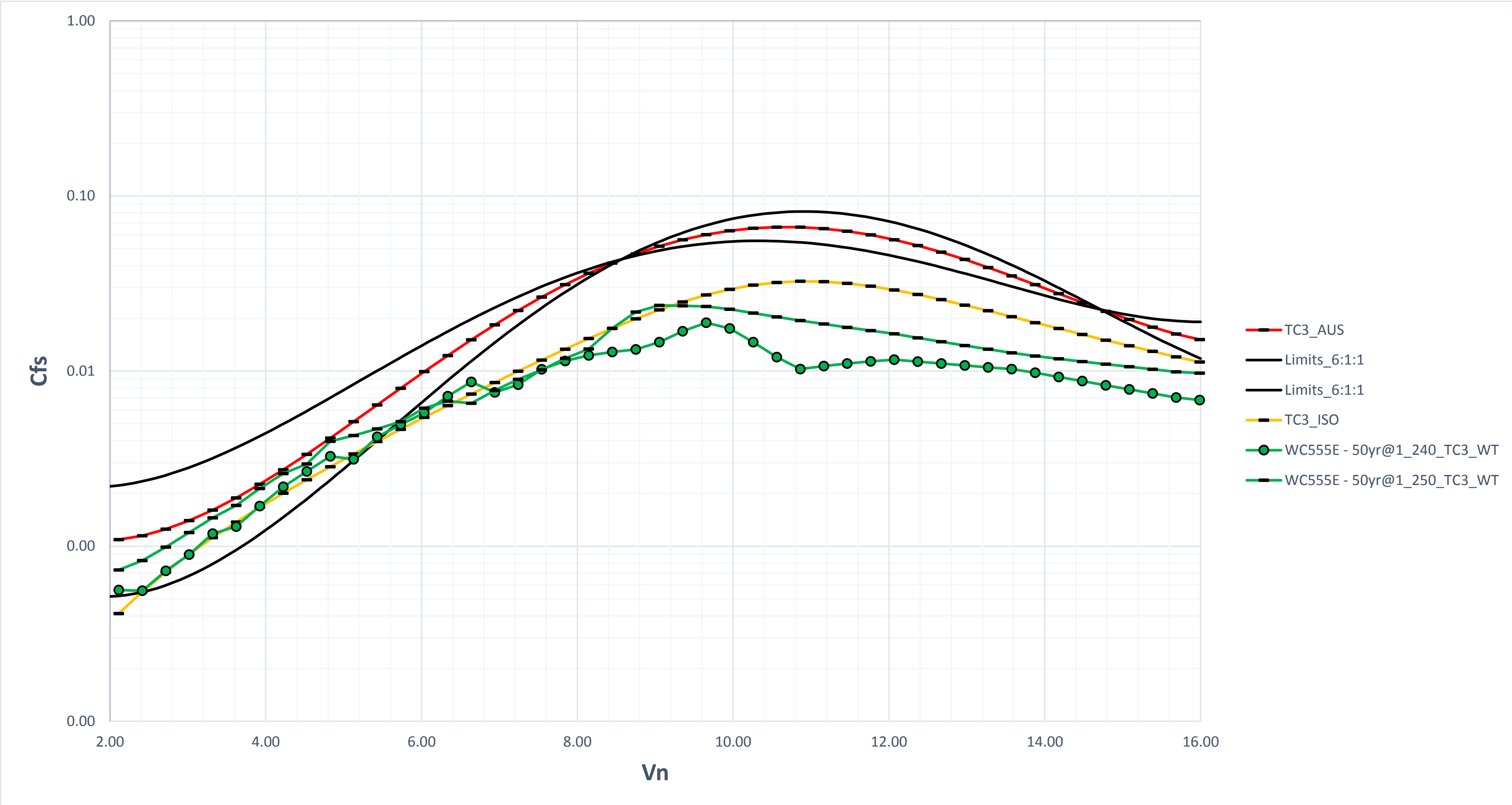



1.00
0.10
0.01
0.00
0.00
Cfs
2.00
4.00
6.00
8.00
10.00
12.00
14.00
16.00
Vn
TC2_AUS
Limits_6:1:1
Limits_6:1:1
TC2_ISO
WC555E - 50yr@1_70_TC2_WT
WC555E - 50yr@1_260_TC2_WT
WC555E - 50yr@1_340_TC2_WT
WC555E - 50yr@1_150_TC2_WT
WC555E - 50yr@1_150_TC2_WT
WC555E - 50yr@1_160_TC2_WT

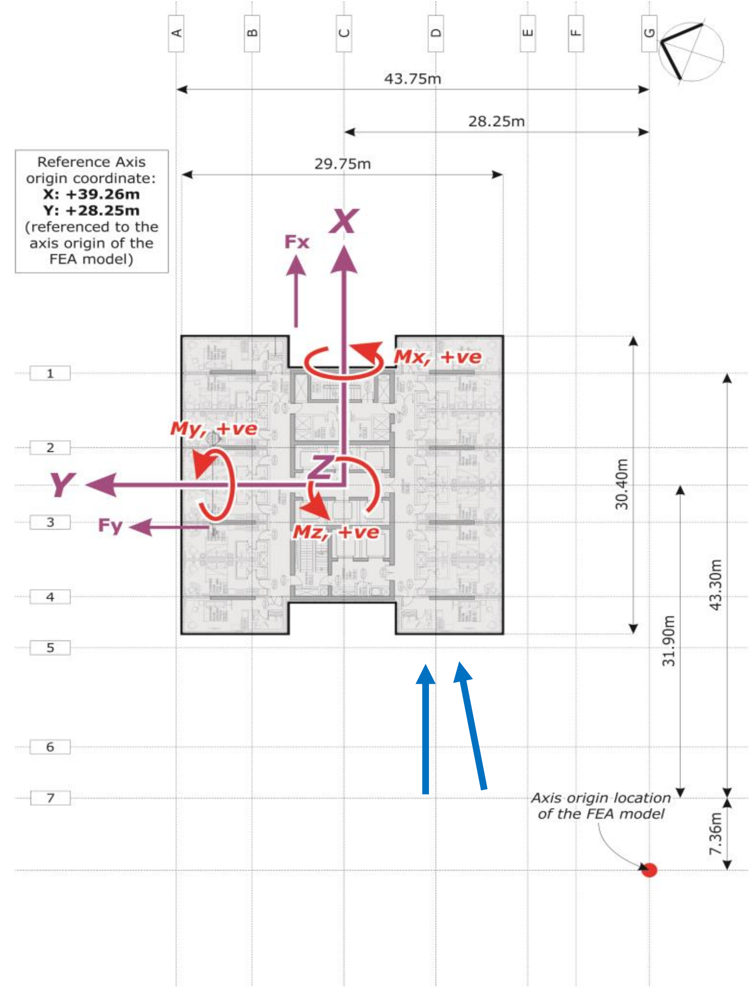

A
B
C
D
E
F
G
43.75m
28.25m
29.75m
Reference Axis origin coordinate:
X: +39.26m
Y: +28.25m
(referenced to the axis origin of the FEA model)
Fx
X
Mx, +ve
My, +ve
Y
Z
Fy
Mz, +ve
1
2
3
4
5
6
7
30.40m
31.90m
43.30m
7.36m
Axis origin location of the FEA model



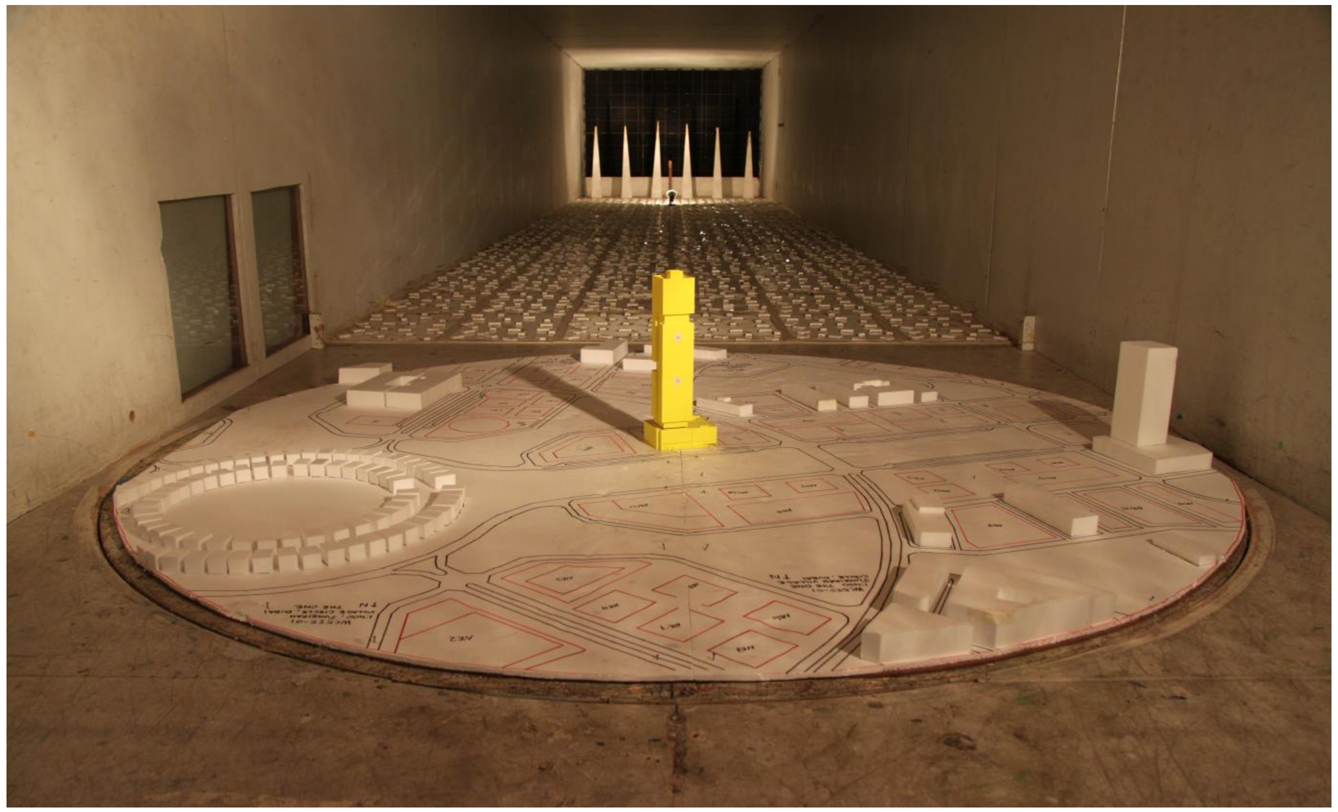


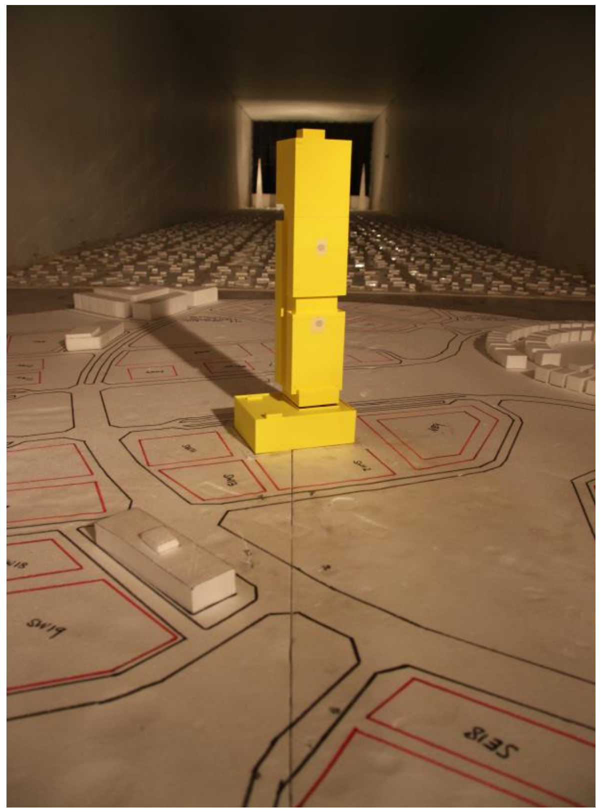


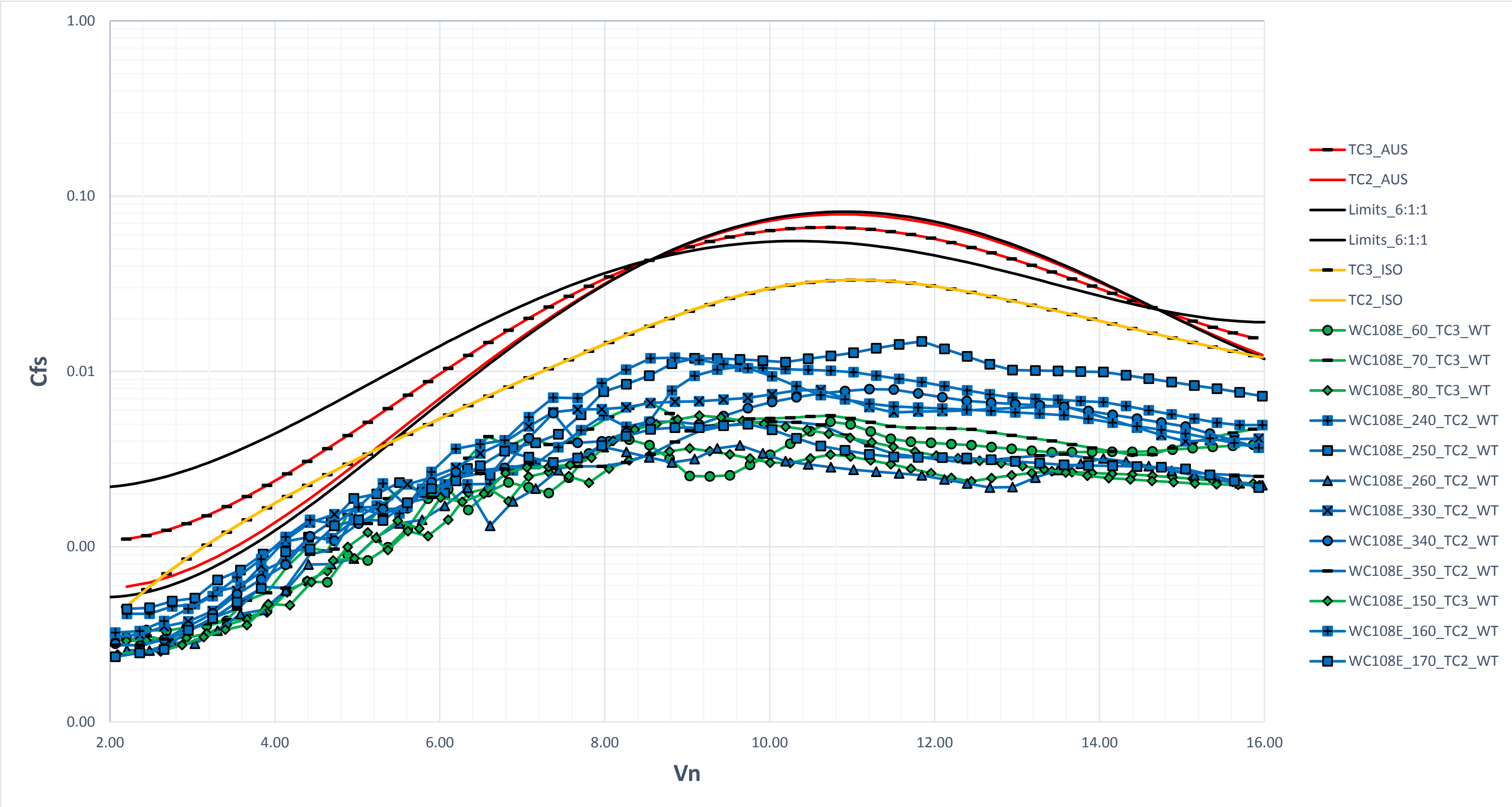
1.00
0.10
0.01
0.00
0.00
Cfs
2.00
4.00
6.00
8.00
10.00
12.00
14.00
16.00
Vn
TC3_AUS
Limits_6:1:1
Limits_6:1:1
TC3_ISO
WC555E - 50yr@1_240_TC3_WT
WC555E - 50yr@1_250_TC3_WT



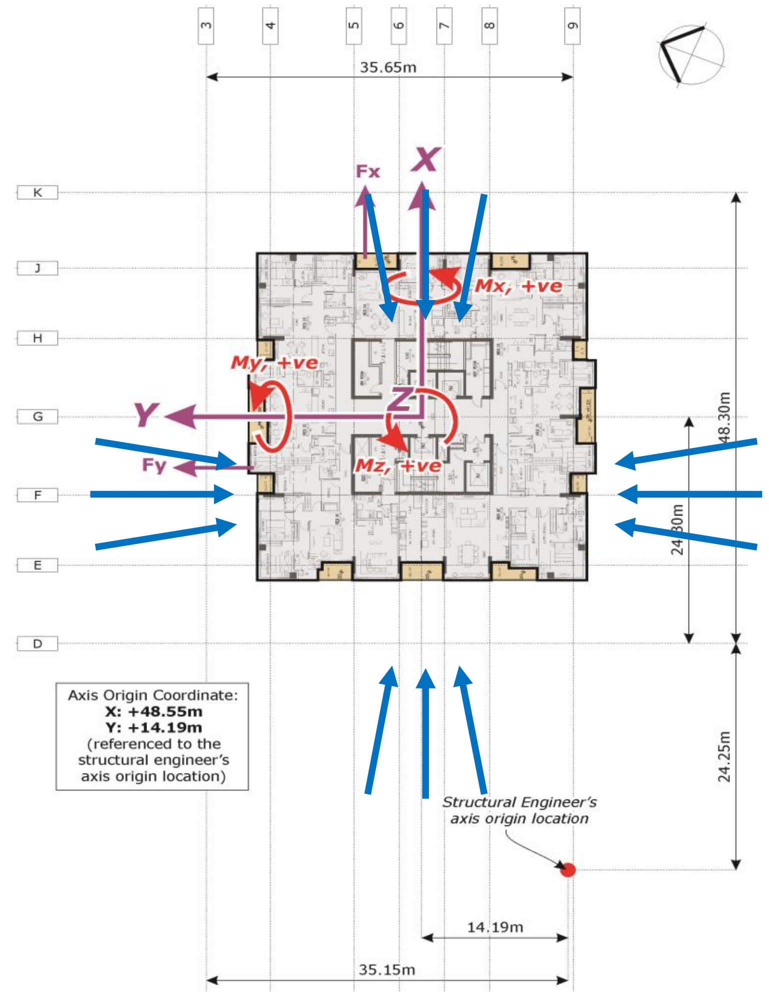
A
B
C
D
E
F
G
43.75m
28.25m
29.75m
Reference Axis origin coordinate:
X: +39.26m
Y: +28.25m
(referenced to the axis origin of the FEA model)
Fx
X
Mx, +ve
My, +ve
Y
Fy
Z
Mz, +ve
1
2
3
4
5
6
7
30.40m
31.90m
43.30m
7.36m
Axis origin location of the FEA model



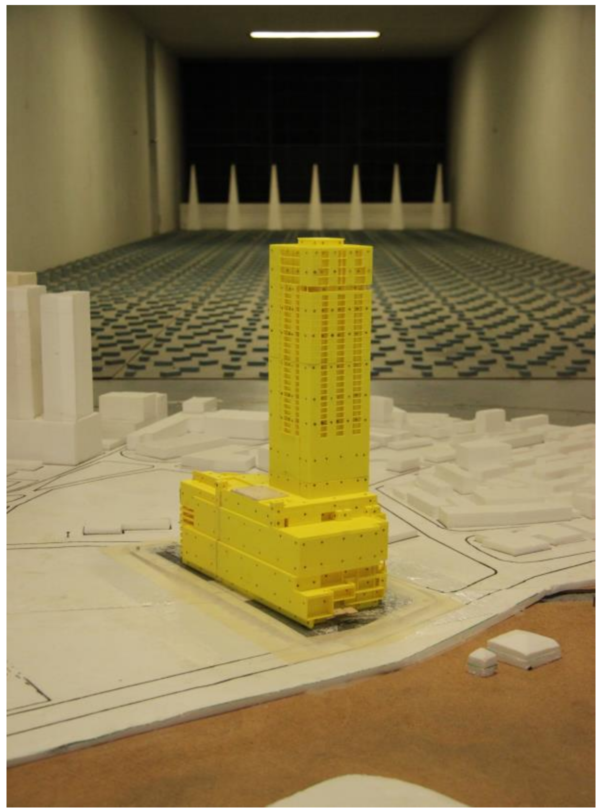


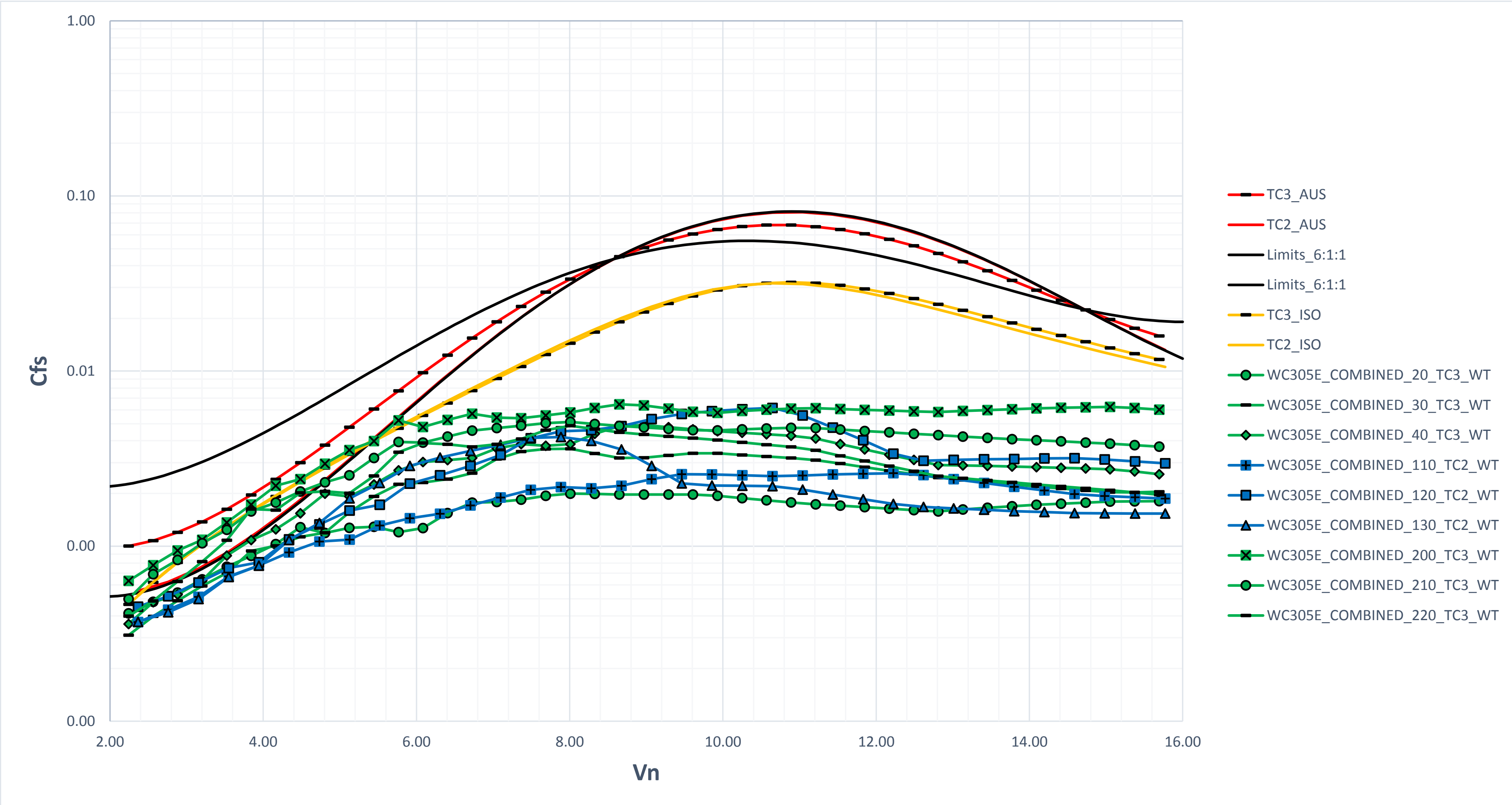


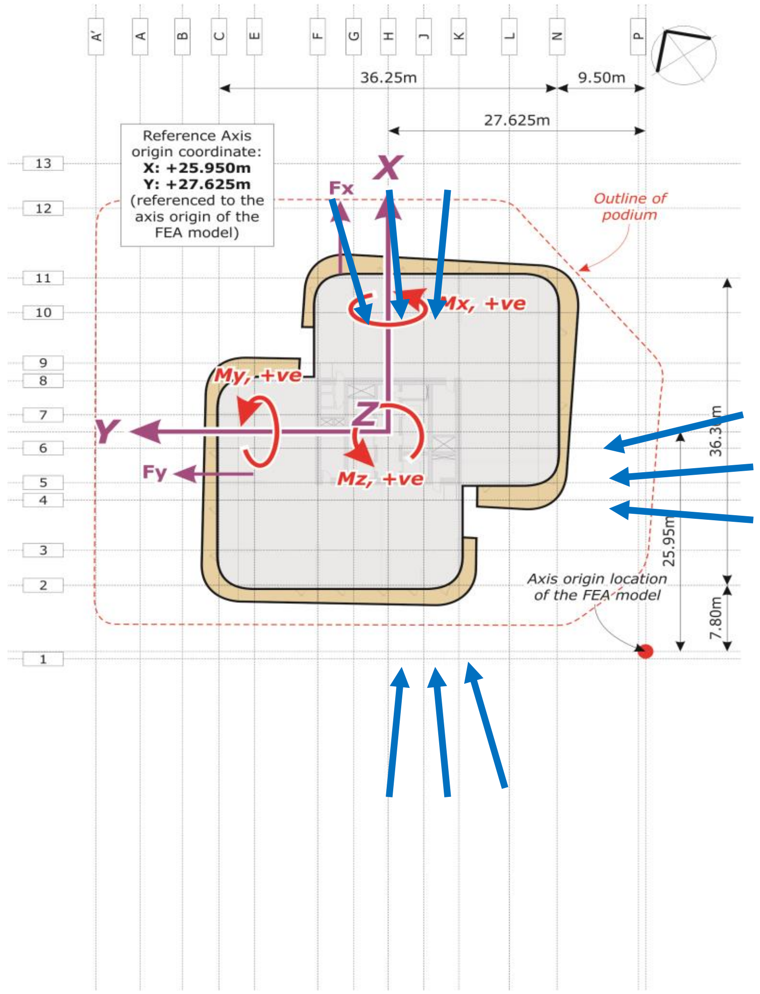
1.00
0.10
0.01
0.00
0.00
Cfs
2.00
4.00
6.00
8.00
10.00
12.00
14.00
16.00
Vn
TC3_AUS
TC2_AUS
Limits_6:1:1
Limits_6:1:1
TC3_ISO
TC2_ISO
WC108E_60_TC3_WT
WC108E_70_TC3_WT
WC108E_80_TC3_WT
WC108E_240_TC2_WT
WC108E_250_TC2_WT
WC108E_260_TC2_WT
WC108E_330_TC2_WT
WC108E_340_TC2_WT
WC108E_350_TC2_WT
WC108E_150_TC3_WT
WC108E_160_TC2_WT
WC108E_170_TC2_WT

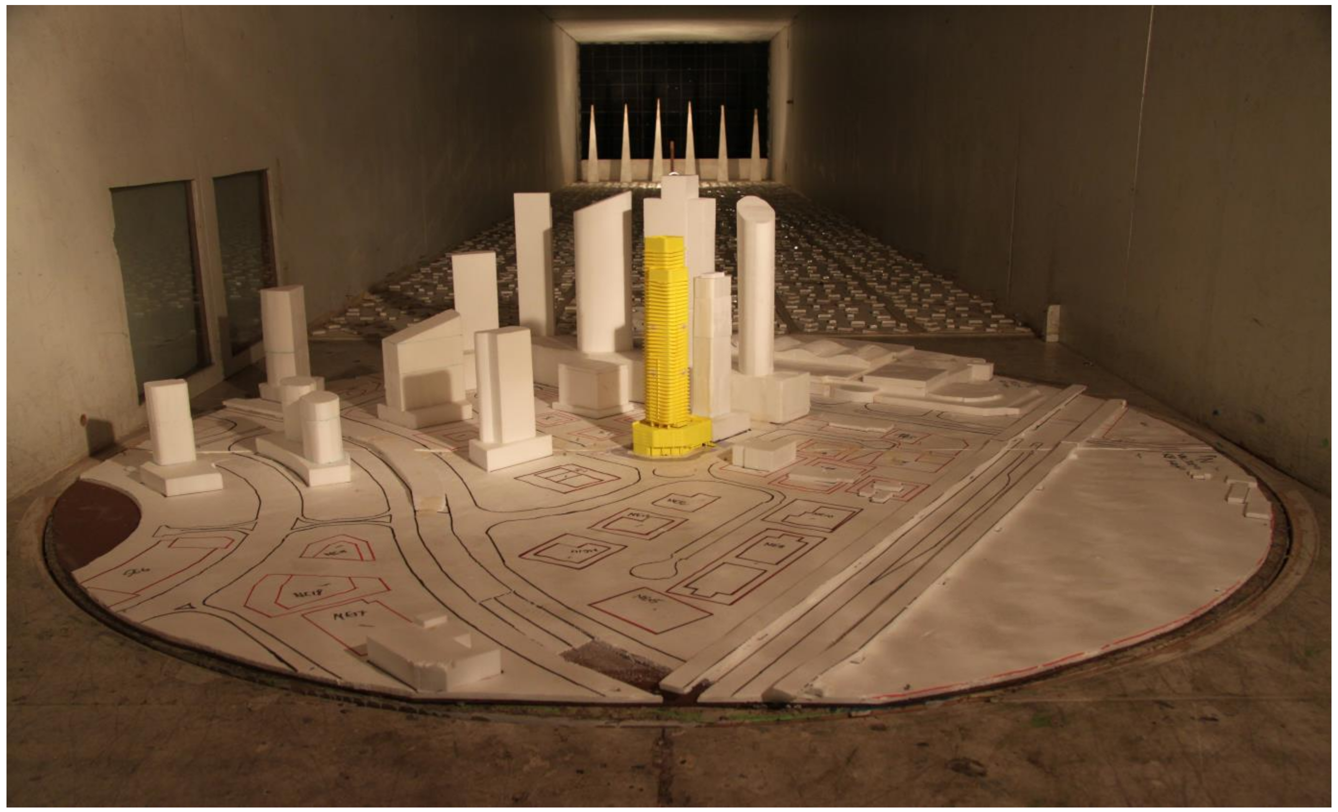


35.65m
Fx
X
Mx, +ve
My, +ve
Y
Z
Fy
Mz, +ve
48.30m
24.30m
24.25m
Axis Origin Coordinate:
X: +48.55m
Y: +14.19m
(referenced to the structural engineer's axis origin location)
Structural Engineer's axis origin location
14.19m
35.15m

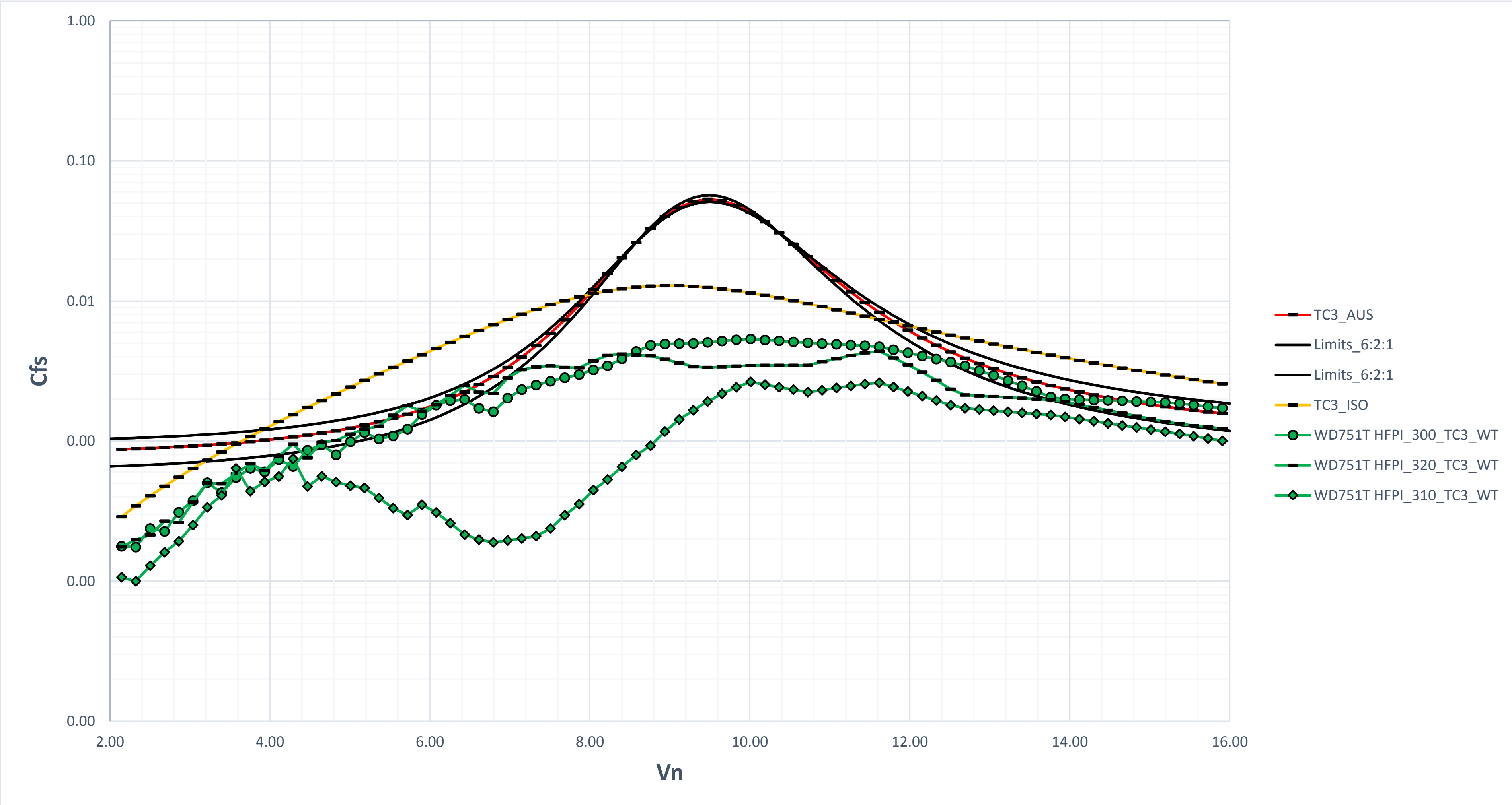


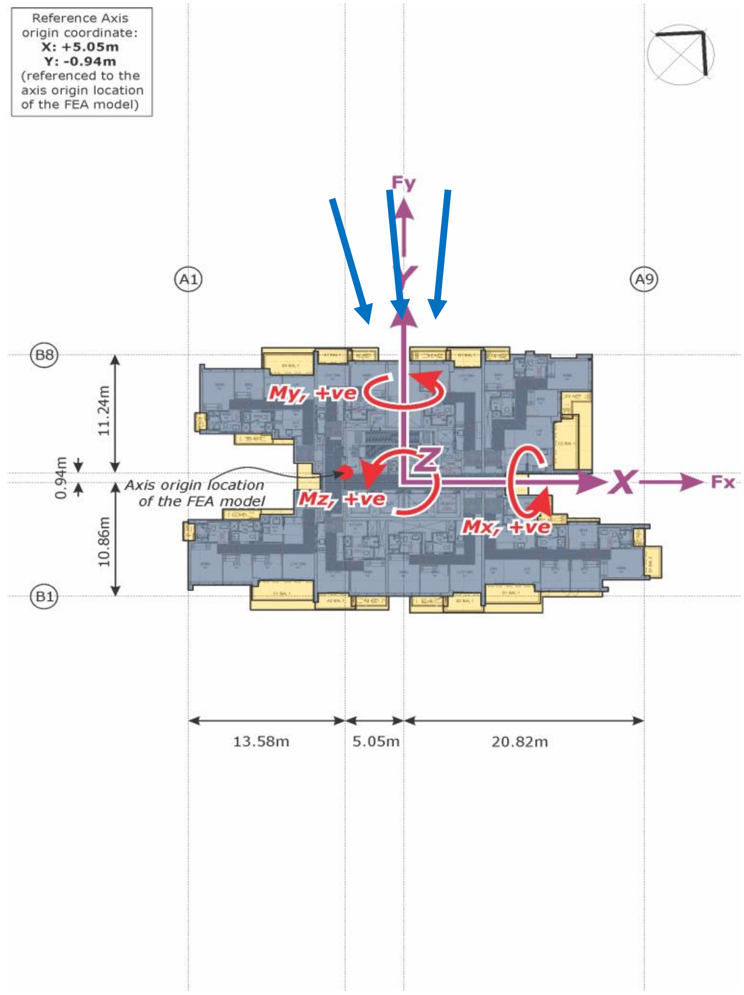

Cfs
1.00
0.10
0.01
0.00
0.00
2.00
4.00
6.00
8.00
10.00
12.00
14.00
16.00
Vn
TC3_AUS
TC2_AUS
Limits_6:1:1
Limits_6:1:1
TC3_ISO
TC2_ISO
WC305E_COMBINED_20_TC3_WT
WC305E_COMBINED_30_TC3_WT
WC305E_COMBINED_40_TC3_WT
WC305E_COMBINED_110_TC2_WT
WC305E_COMBINED_120_TC2_WT
WC305E_COMBINED_130_TC2_WT
WC305E_COMBINED_200_TC3_WT
WC305E_COMBINED_210_TC3_WT
WC305E_COMBINED_220_TC3_WT

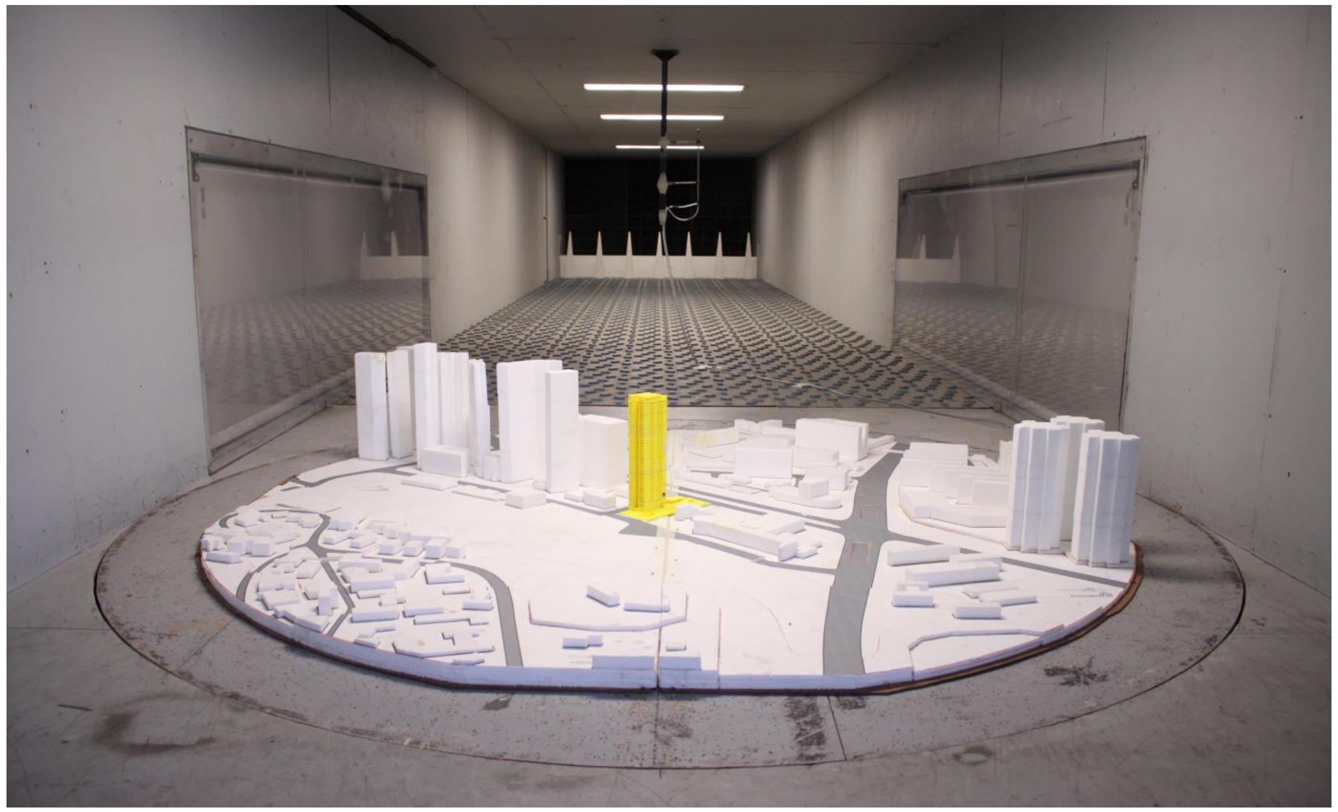

36.25m
9.50m
27.625m
Reference Axis
origin coordinate:
X: +25.950m
Y: +27.625m
(referenced to the
axis origin of the
FEA model)
X
Fx
Mx, +ve
My, +ve
Y
Z
Fy
Mz, +ve
Outline of
podium
Axis origin location
of the FEA model
25.95m
7.80m

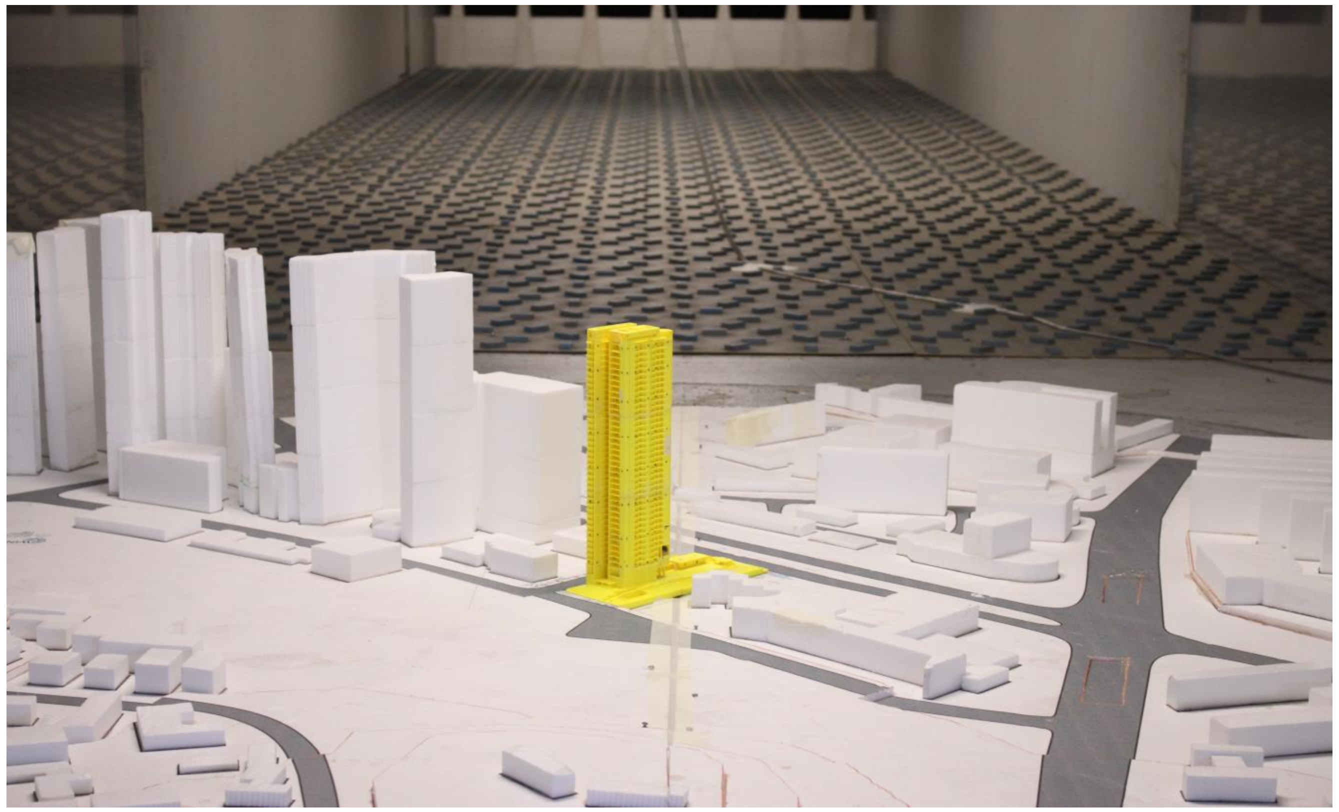


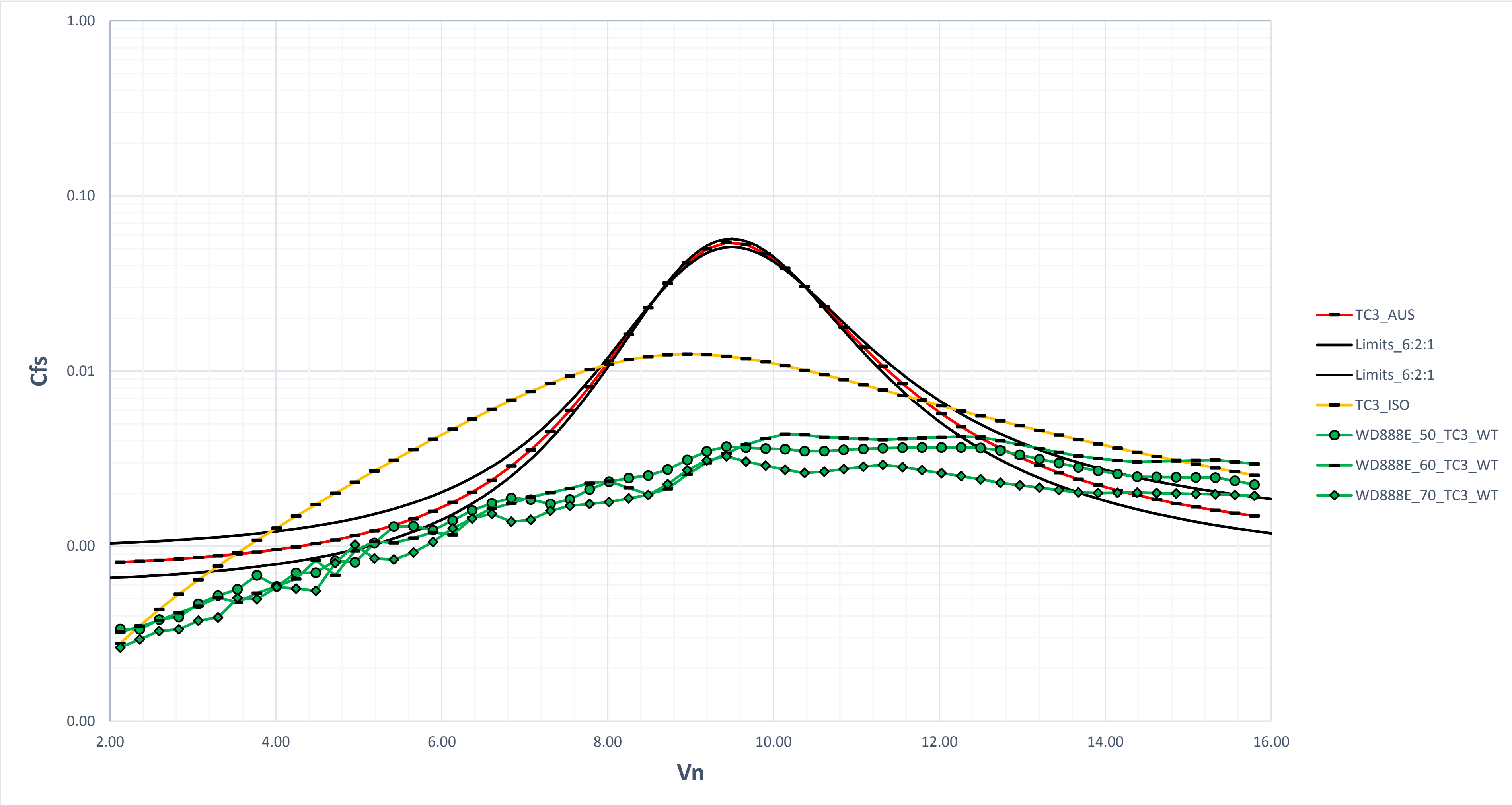
ANNEXURE 3 – COMPARATIVE RESULTS for *h*:*b*:*d* of 6:2:1

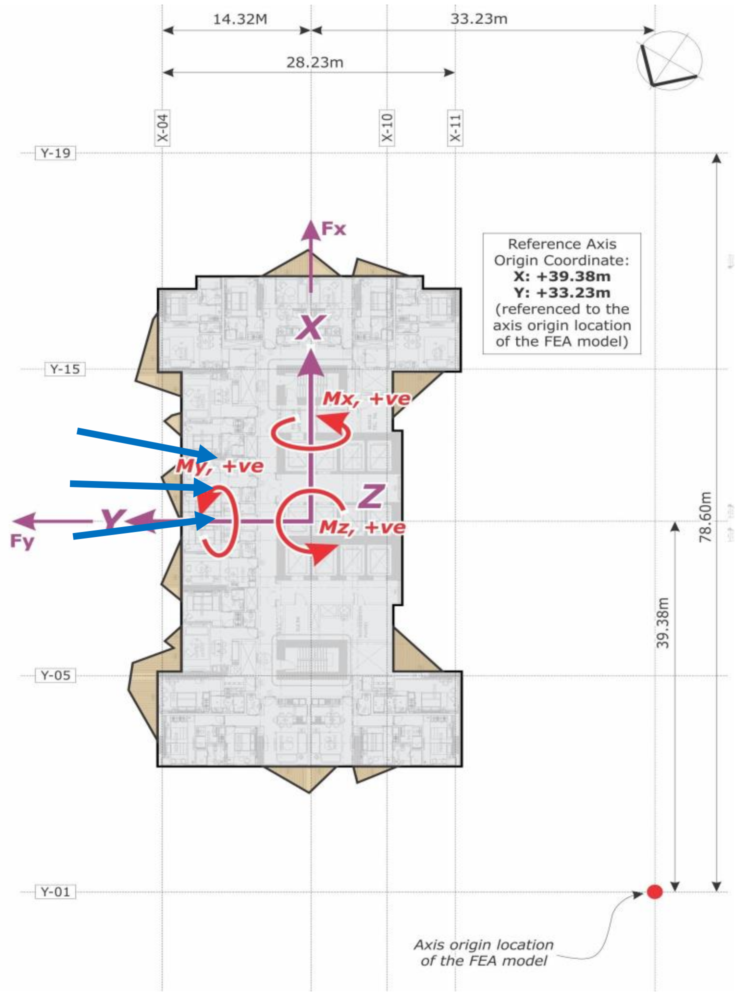

1.00
0.10
0.01
0.00
0.00
0.00
0.00
Cfs
2.00
4.00
6.00
8.00
10.00
12.00
14.00
16.00
Vn
TC3_AUS
Limits_6:2:1
Limits_6:2:1
TC3_ISO
WD751T HFPI_300_TC3_WT
WD751T HFPI_320_TC3_WT
WD751T HFPI_310_TC3_WT

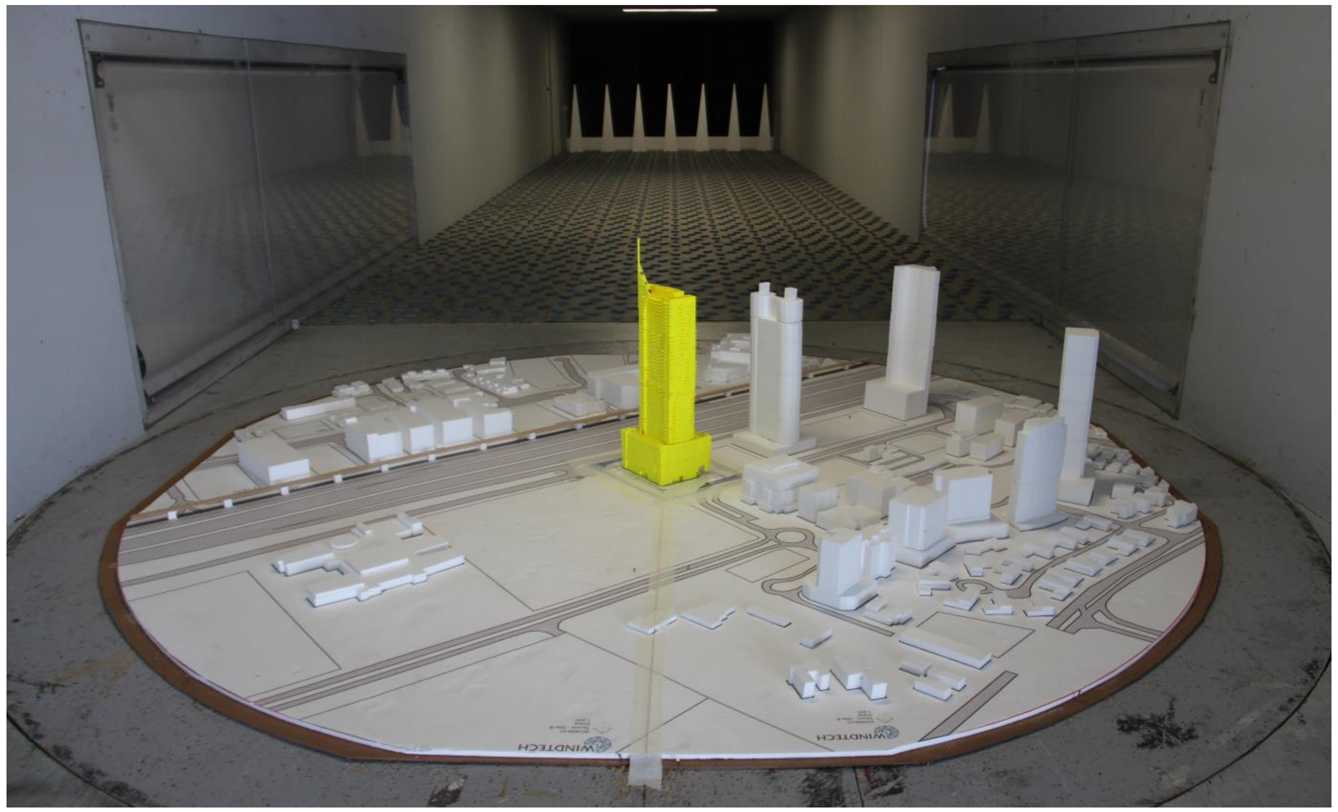

Reference Axis
origin coordinate:
X: +5.05m
Y: -0.94m
(referenced to the
axis origin location
of the FEA model)
Fy
A1
A9
B8
B1
My, +ve
Mz, +ve
Mx, +ve
Z
X
Fx
Axis origin location
of the FEA model
11.24m
0.94m
10.86m
13.58m
5.05m
20.82m

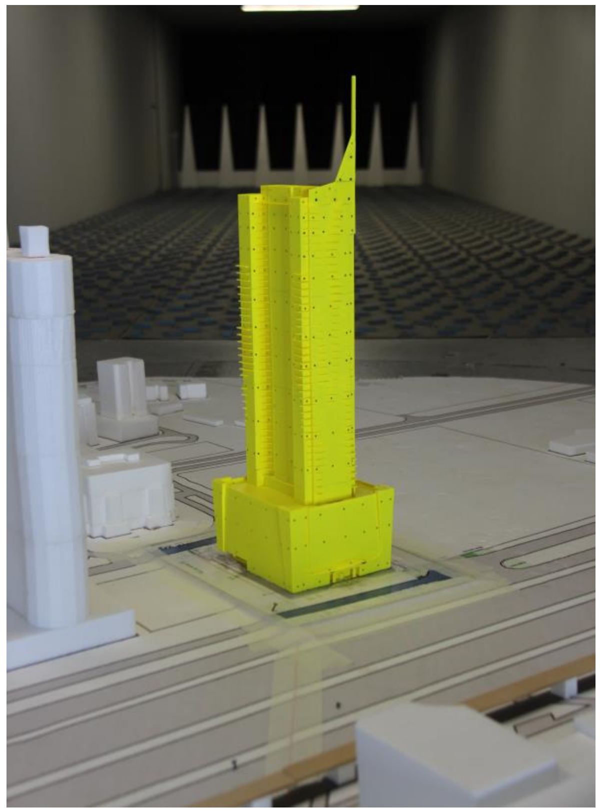


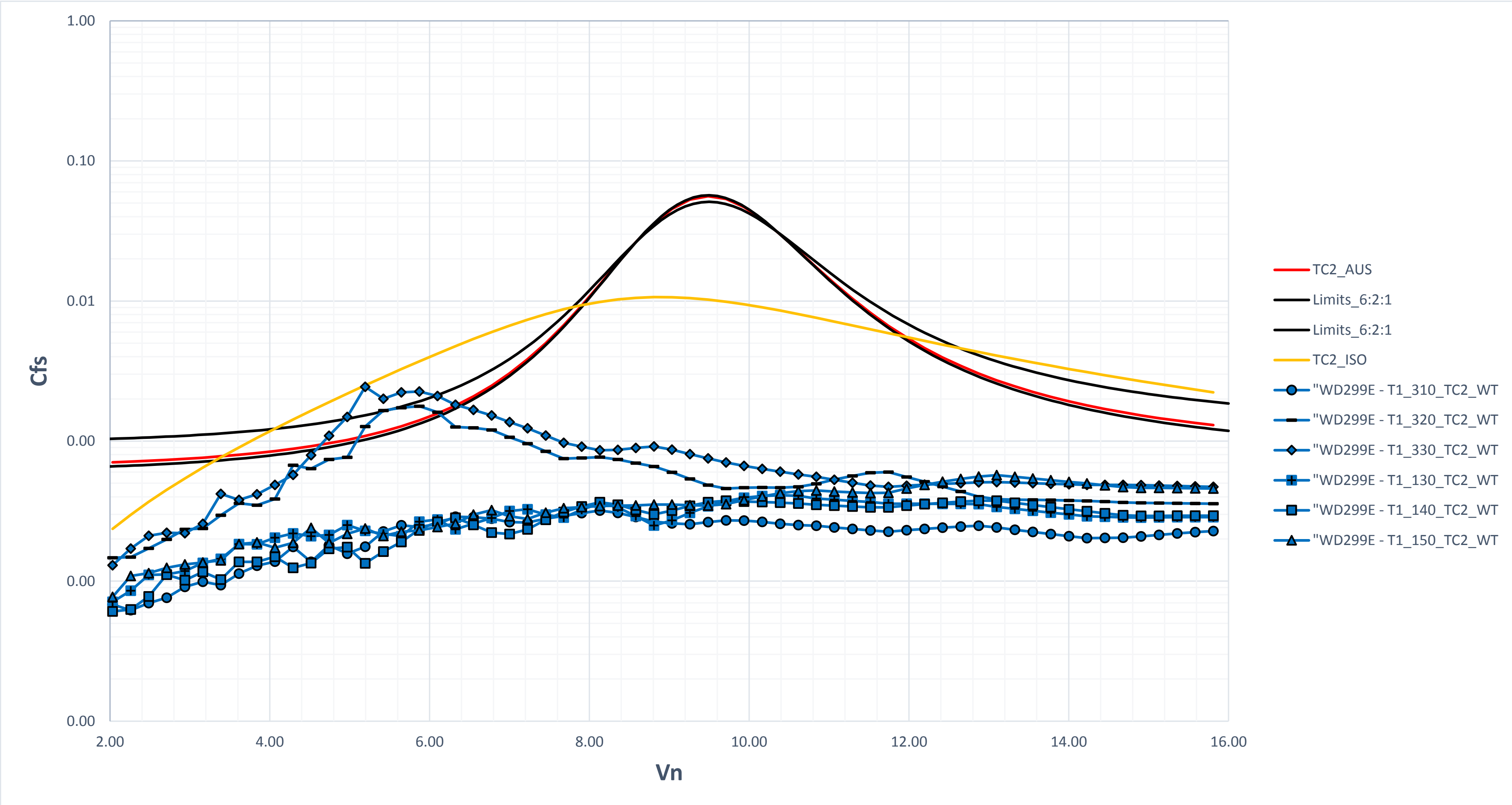


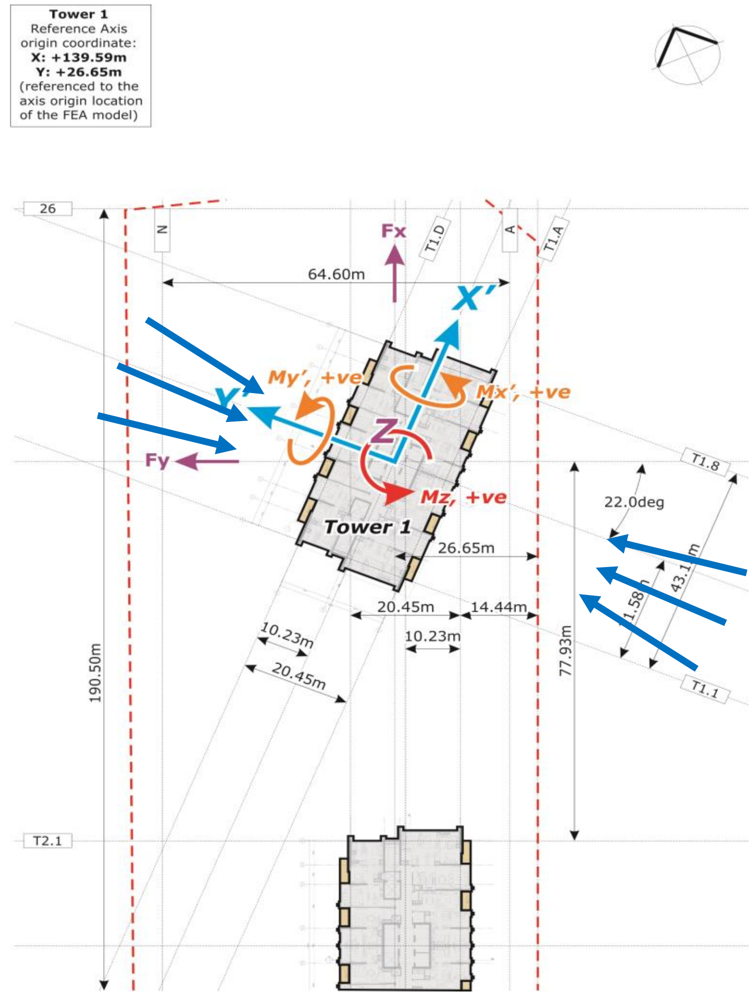

1.00
0.10
0.01
0.00
0.00
Cfs
2.00
4.00
6.00
8.00
10.00
12.00
14.00
16.00
Vn
TC3_AUS
Limits_6:2:1
Limits_6:2:1
TC3_ISO
WD888E_50_TC3_WT
WD888E_60_TC3_WT
WD888E_70_TC3_WT

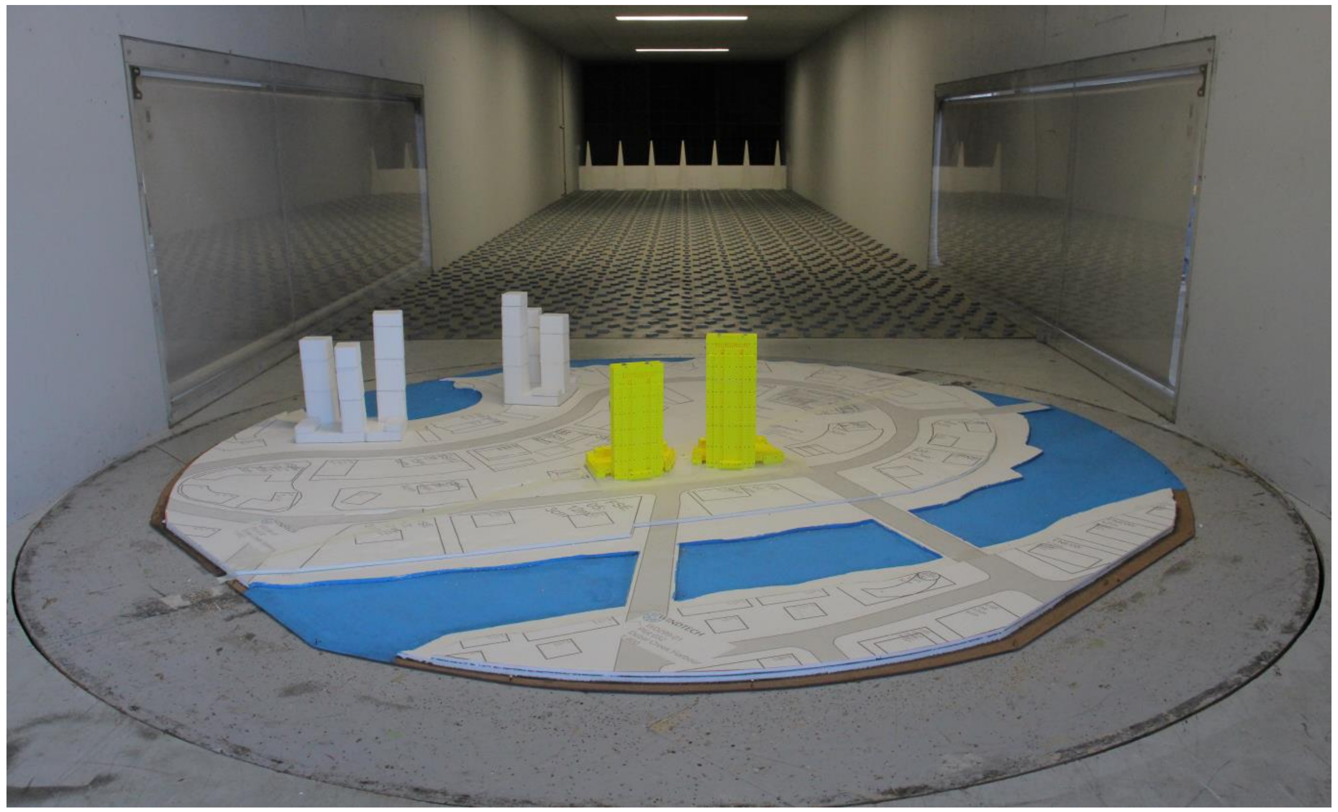

14.32M
33.23m
28.23m
X-04
X-10
X-11
Y-19
Y-15
Y-05
Y-01
Fx
X
Reference Axis Origin Coordinate:
X: +39.38m
Y: +33.23m
(referenced to the axis origin location of the FEA model)
Mx, +ve
My, +ve
Y
Z
Mz, +ve
Fy
78.60m
39.38m
Axis origin location of the FEA model

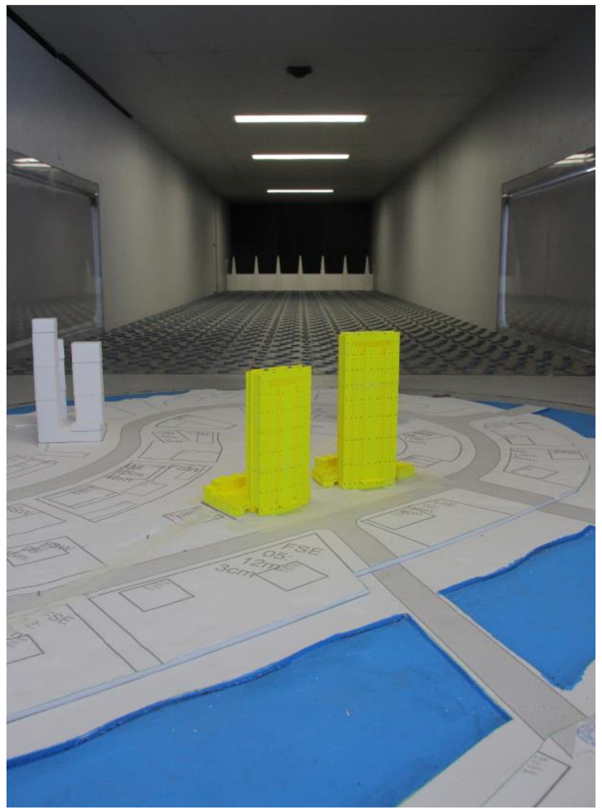


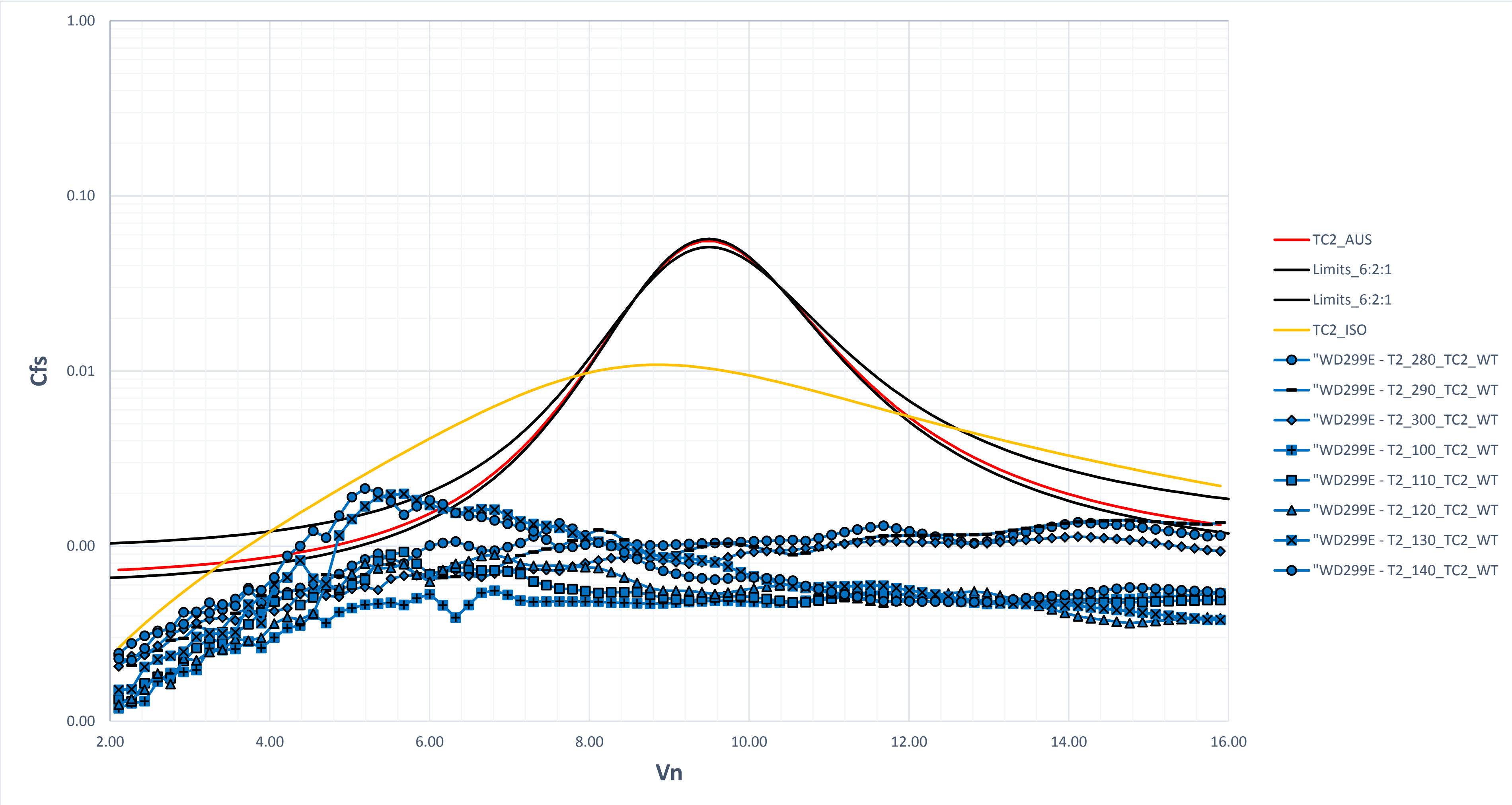


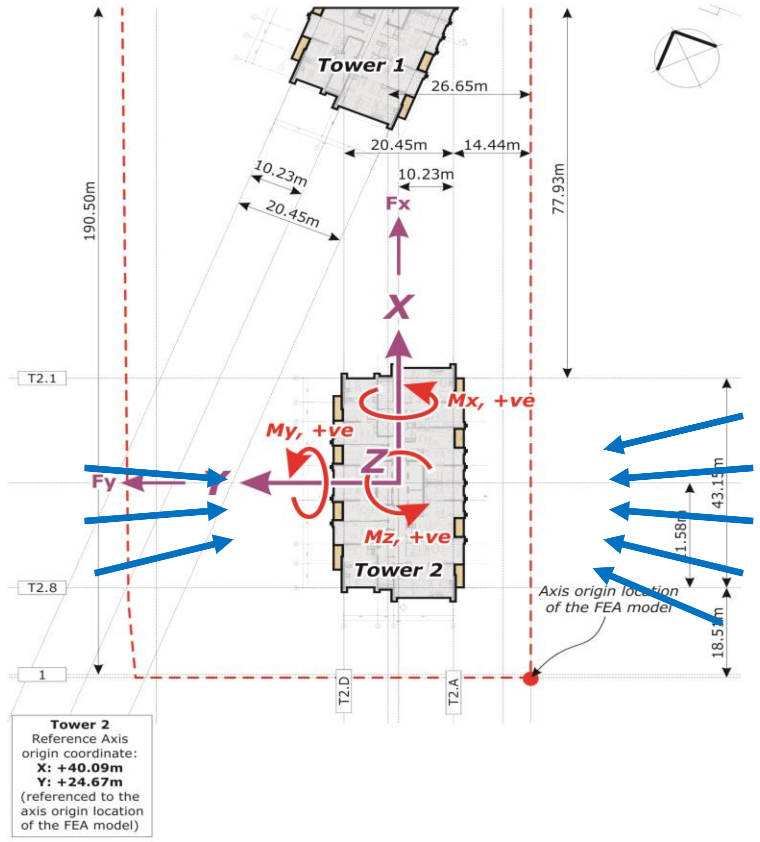

1.00
0.10
0.01
0.00
0.00
0.00
0.00
Cfs
2.00
4.00
6.00
8.00
10.00
12.00
14.00
16.00
Vn
TC2_AUS
Limits_6:2:1
Limits_6:2:1
TC2_ISO
"WD299E - T1_310_TC2_WT
"WD299E - T1_320_TC2_WT
"WD299E - T1_330_TC2_WT
"WD299E - T1_130_TC2_WT
"WD299E - T1_140_TC2_WT
"WD299E - T1_150_TC2_WT

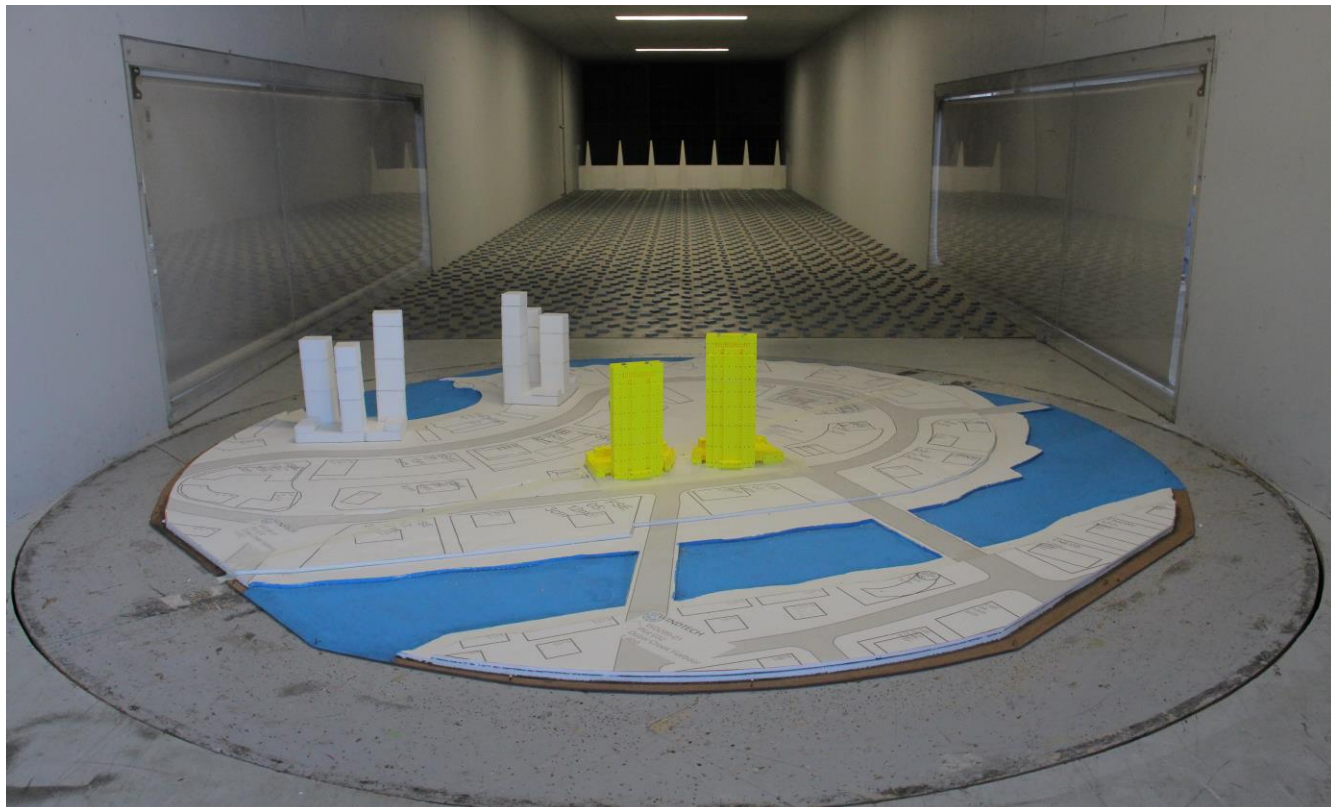

Tower 1
Reference Axis
origin coordinate:
X: +139.59m
Y: +26.65m
(referenced to the
axis origin location
of the FEA model)
26
T2.1
Fx
Fy
X'
Y'
Z
My', +ve
Mx', +ve
Mz, +ve
Tower 1
64.60m
26.65m
20.45m
14.44m
10.23m
10.23m
20.45m
190.50m
77.93m
22.0deg

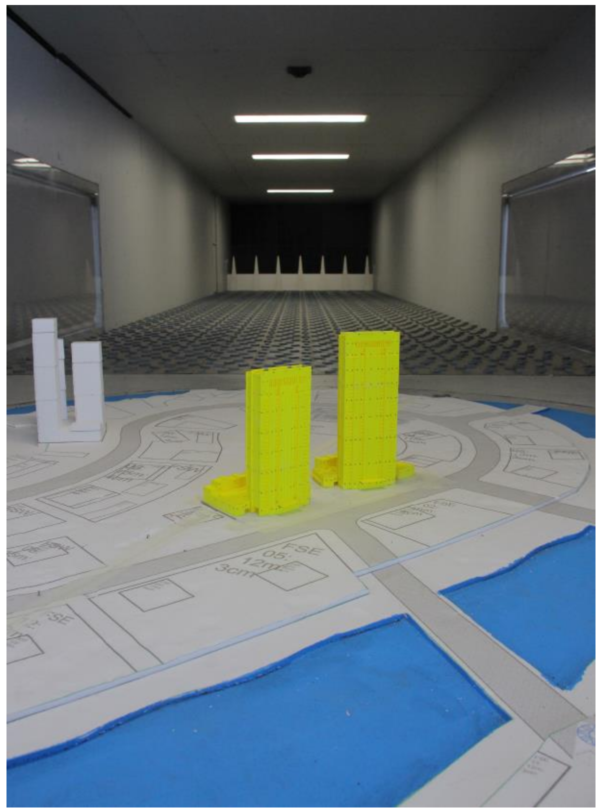




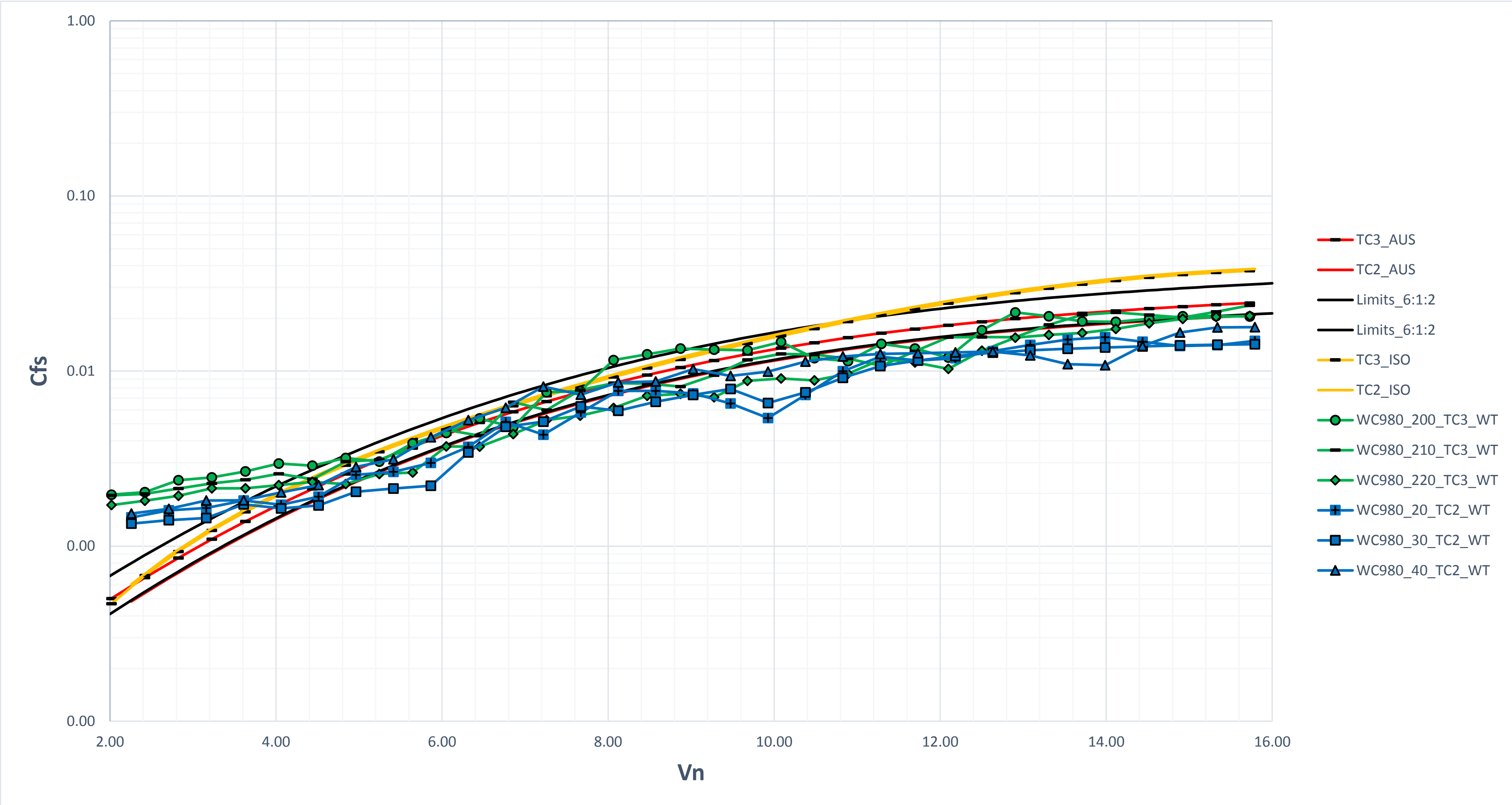

1.00
0.10
0.01
0.00
0.00
Cfs
2.00
4.00
6.00
8.00
10.00
12.00
14.00
16.00
Vn
TC2_AUS
Limits_6:2:1
Limits_6:2:1
TC2_ISO
"WD299E - T2_280_TC2_WT
"WD299E - T2_290_TC2_WT
"WD299E - T2_300_TC2_WT
"WD299E - T2_100_TC2_WT
"WD299E - T2_110_TC2_WT
"WD299E - T2_120_TC2_WT
"WD299E - T2_130_TC2_WT
"WD299E - T2_140_TC2_WT


Tower 1
26.65m
20.45m
14.44m
10.23m
10.23m
20.45m
190.50m
77.93m
Fx
X
T2.1
Mx, +ve
My, +ve
Z
Fy
Y
Mz, +ve
Tower 2
T2.8
Axis origin location of the FEA model
43.15m
18.51m
1
T2.D
T2.A
Tower 2
Reference Axis
origin coordinate:
X: +40.09m
Y: +24.67m
(referenced to the
axis origin location
of the FEA model)

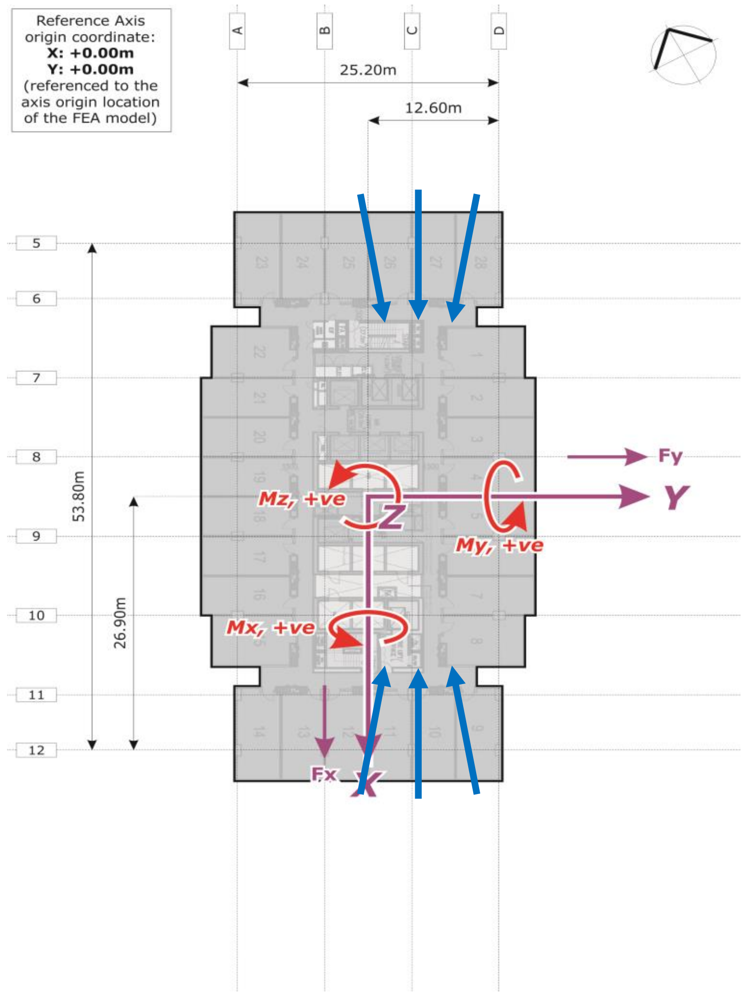




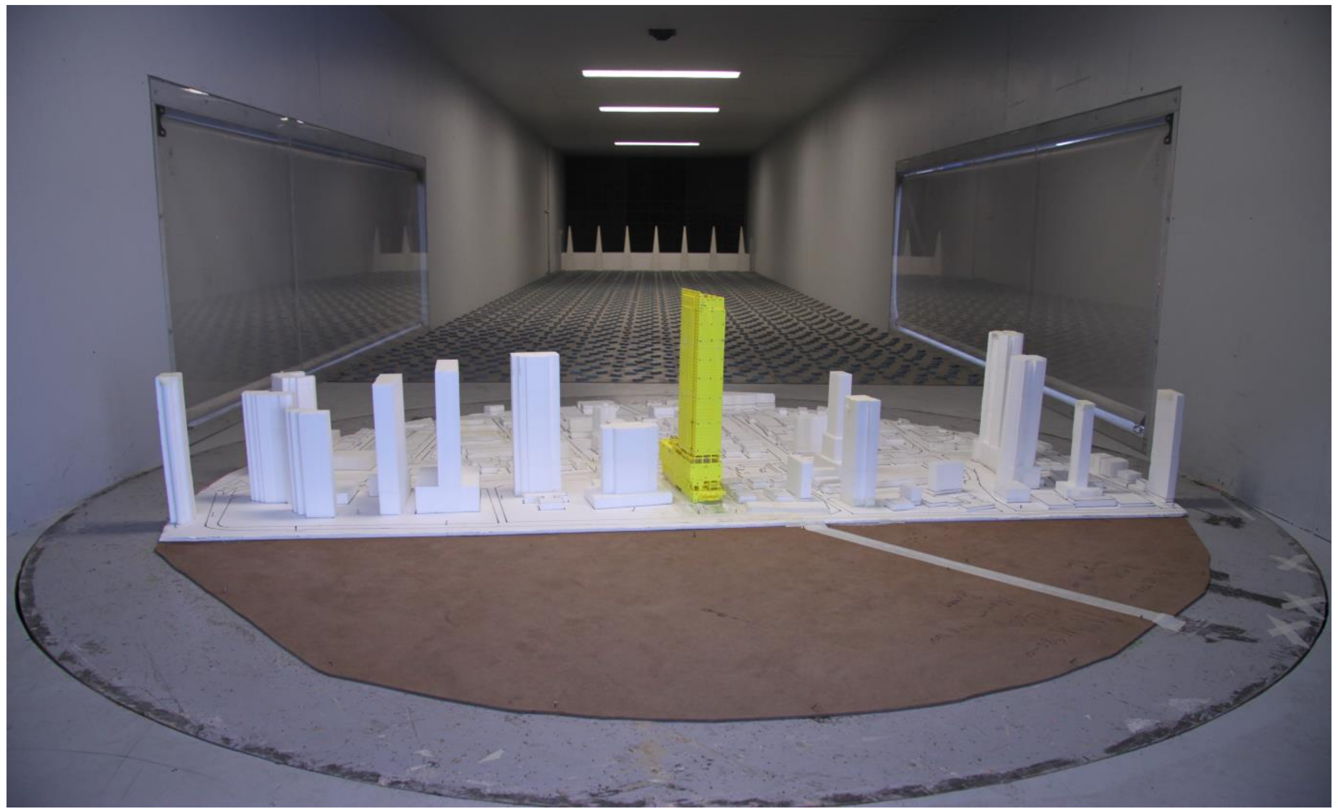
ANNEXURE 4 – COMPARATIVE RESULTS for *h*:*b*:*d* of 6:1:2

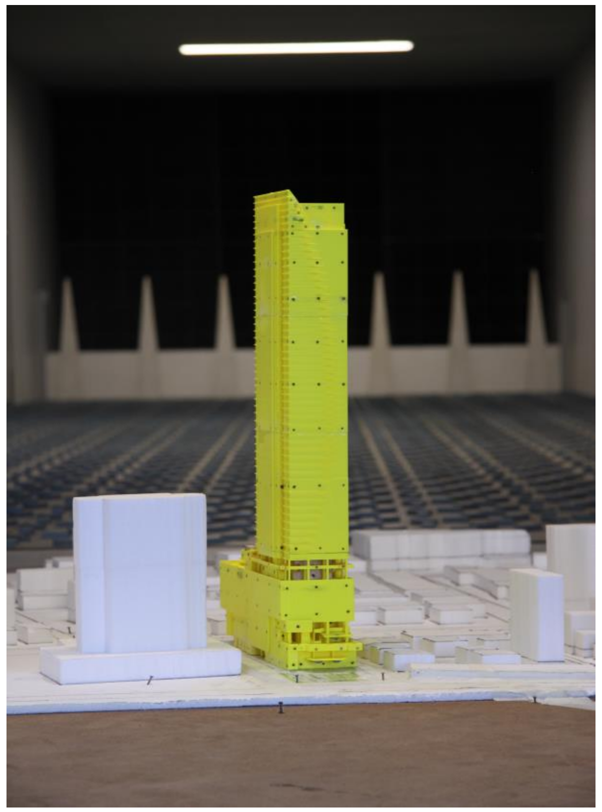


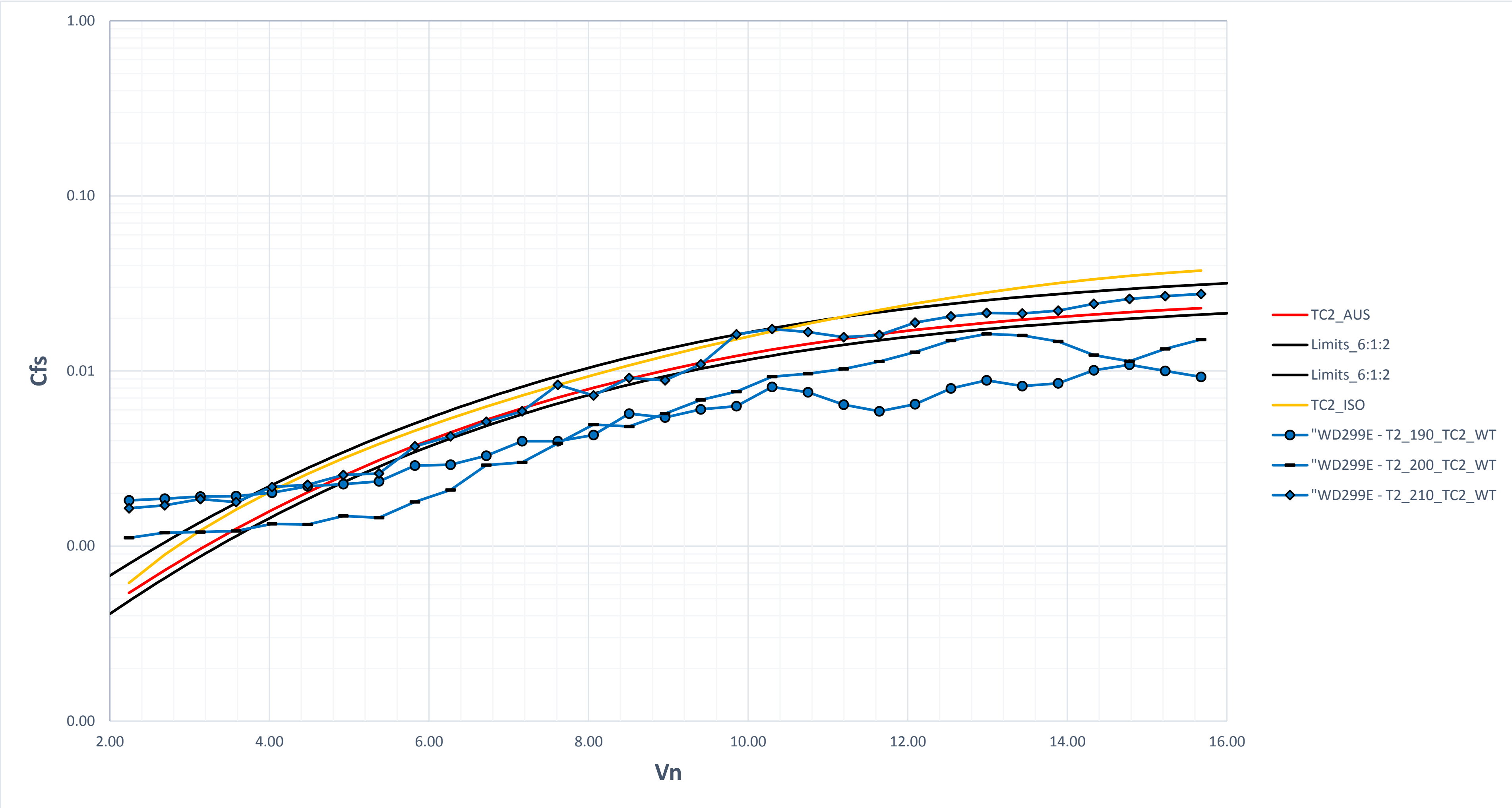
1.00
0.10
0.01
0.00
0.00
Cfs
2.00
4.00
6.00
8.00
10.00
12.00
14.00
16.00
Vn
TC3_AUS
TC2_AUS
Limits_6:1:2
Limits_6:1:2
TC3_ISO
TC2_ISO
WC980_200_TC3_WT
WC980_210_TC3_WT
WC980_220_TC3_WT
WC980_20_TC2_WT
WC980_30_TC2_WT
WC980_40_TC2_WT

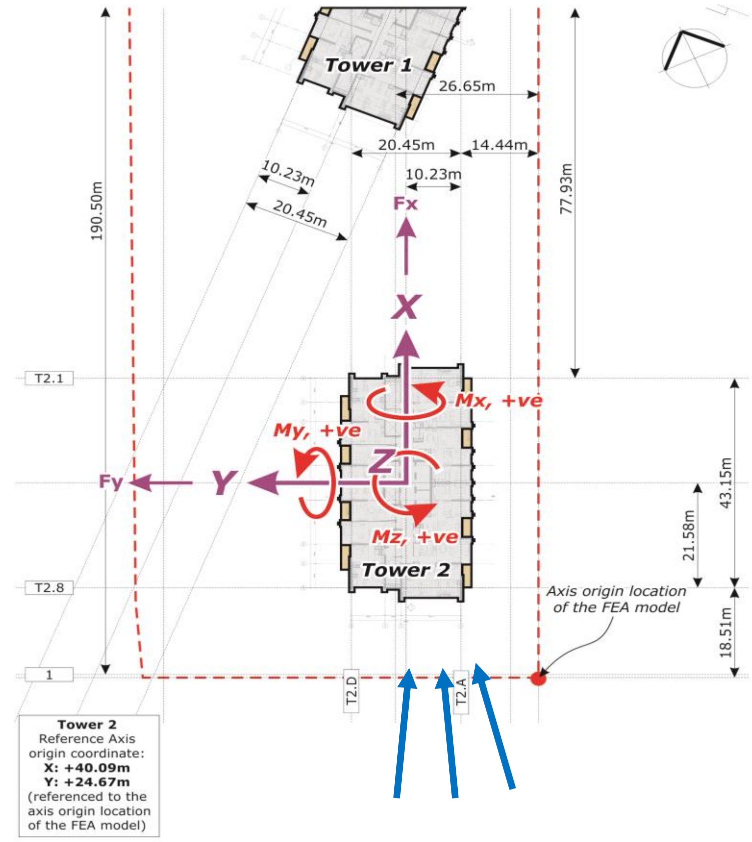


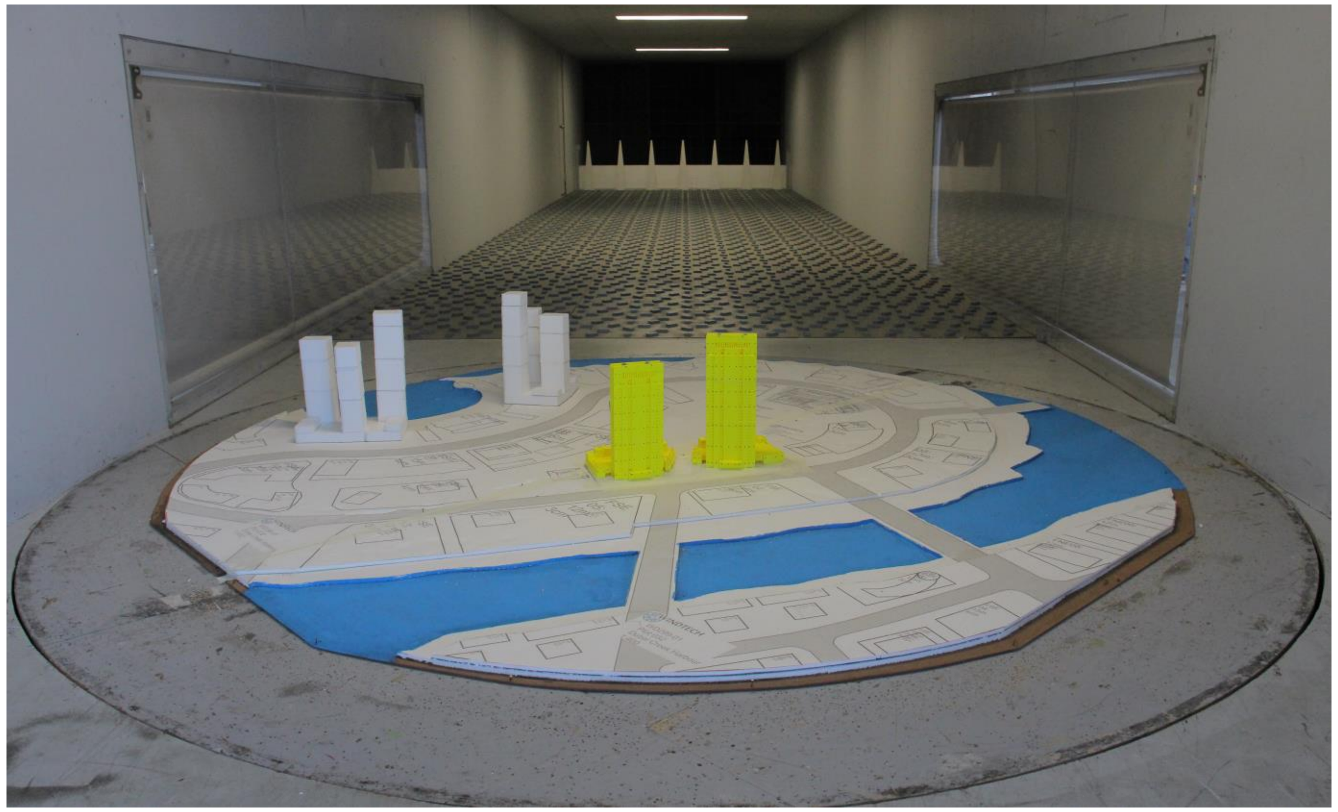
Reference Axis origin coordinate:
X: +0.00m
Y: +0.00m
(referenced to the axis origin location of the FEA model)
A
B
C
D
25.20m
12.60m
5
6
7
8
9
10
11
12
53.80m
26.90m
Fy
Y
Mz, +ve
Z
My, +ve
Mx, +ve
Fx
X

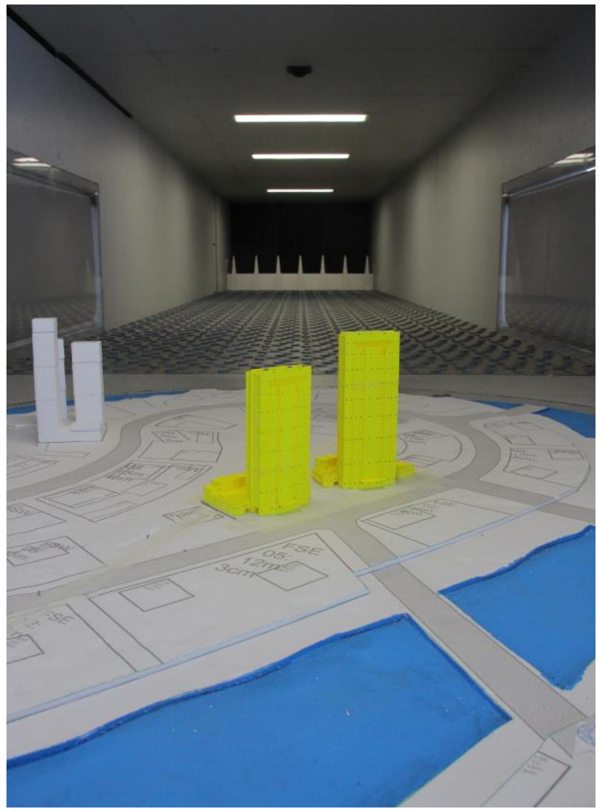


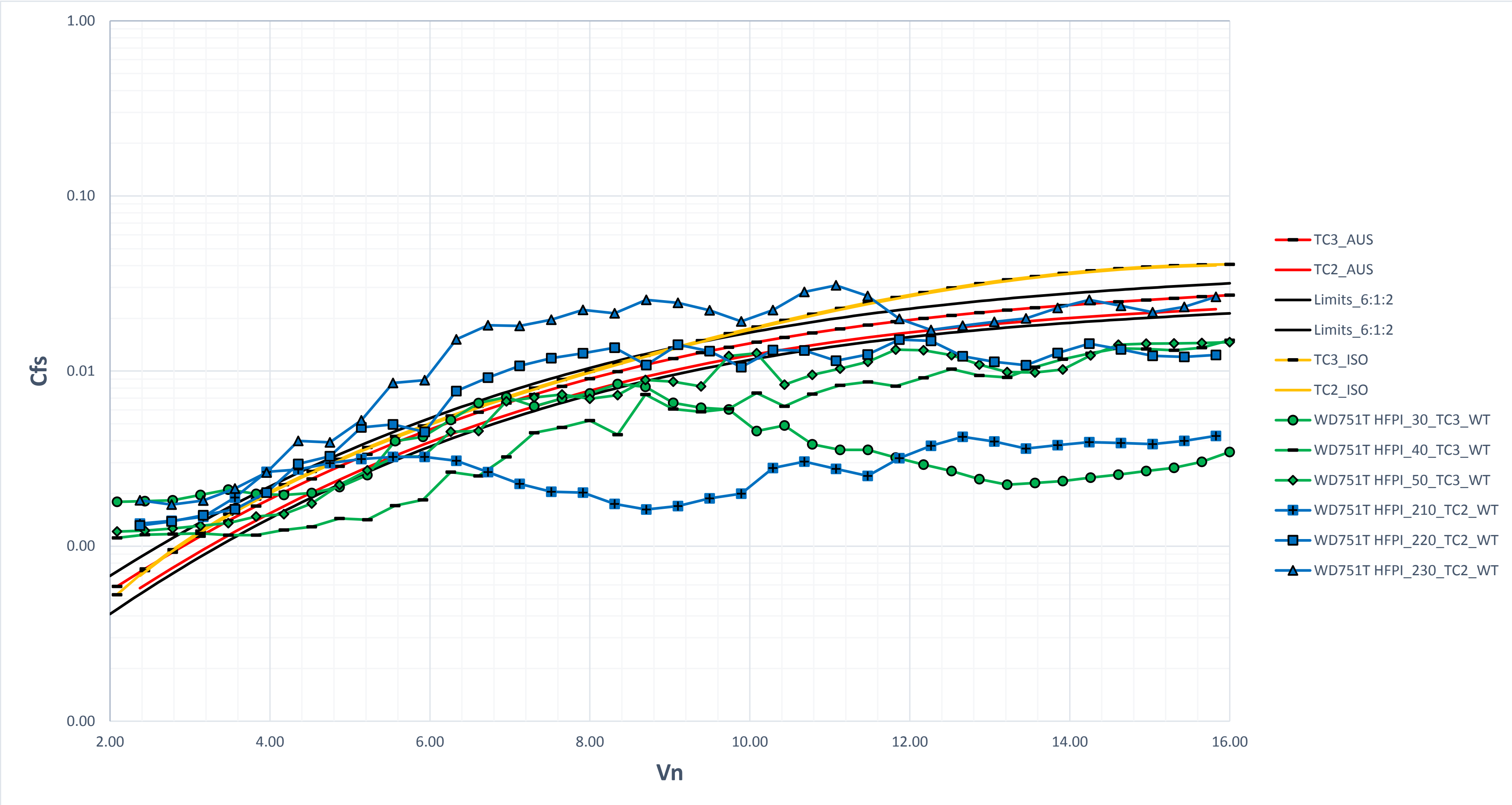


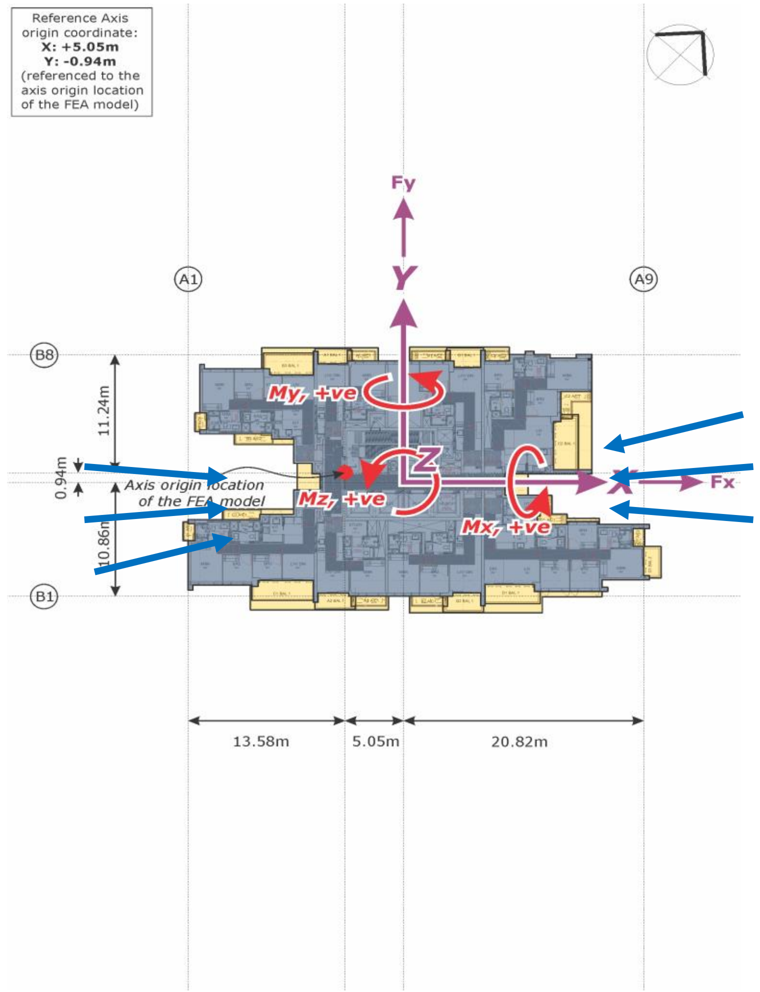

1.00
0.10
0.01
0.00
0.00
Cfs
2.00
4.00
6.00
8.00
10.00
12.00
14.00
16.00
Vn
TC2_AUS
Limits_6:1:2
Limits_6:1:2
TC2_ISO
"WD299E - T2_190_TC2_WT
"WD299E - T2_200_TC2_WT
"WD299E - T2_210_TC2_WT

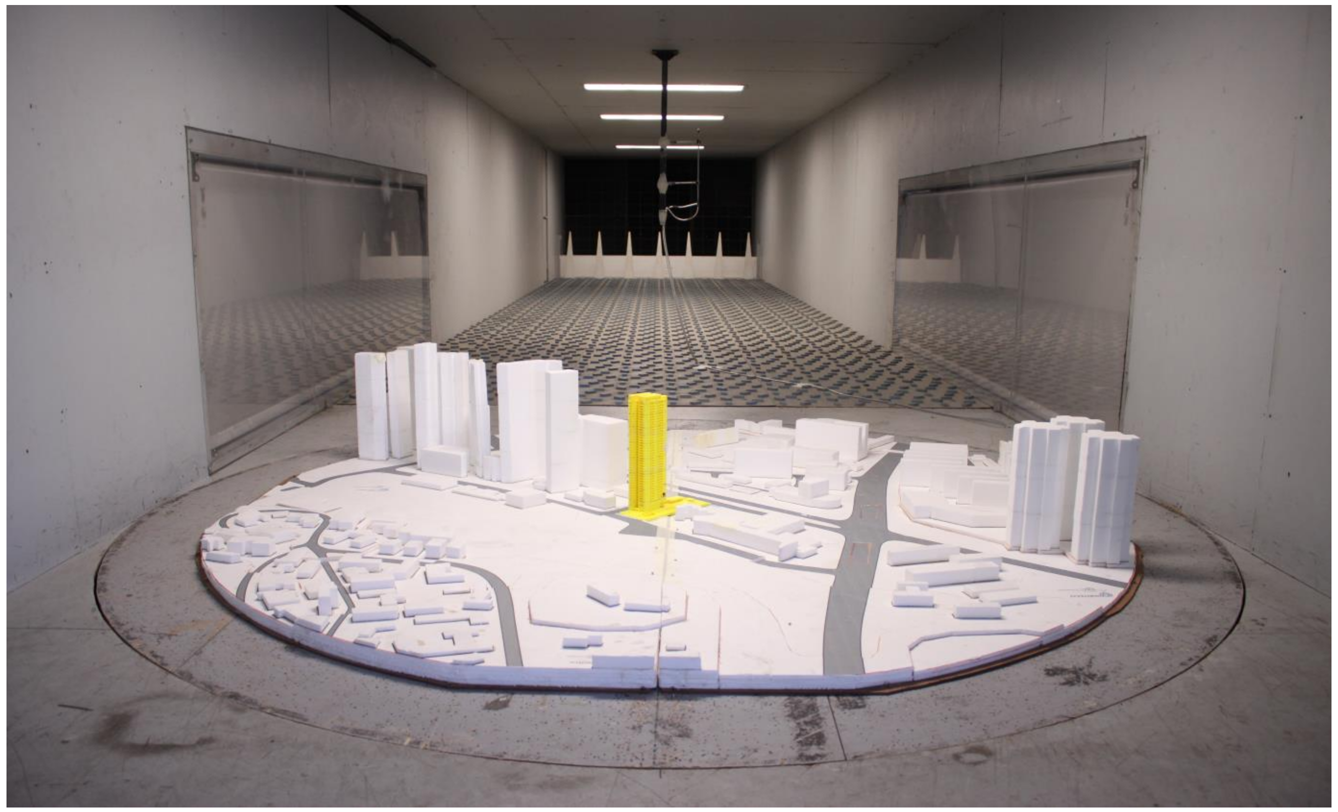

Tower 1
26.65m
20.45m
14.44m
10.23m
10.23m
20.45m
190.50m
77.93m
Fx
X
T2.1
Mx, +ve
My, +ve
Z
Fy
Y
Mz, +ve
Tower 2
43.15m
21.58m
T2.8
Axis origin location
of the FEA model
18.51m
1
T2.D
T2.A
Tower 2
Reference Axis
origin coordinate:
X: +40.09m
Y: +24.67m
(referenced to the
axis origin location
of the FEA model)

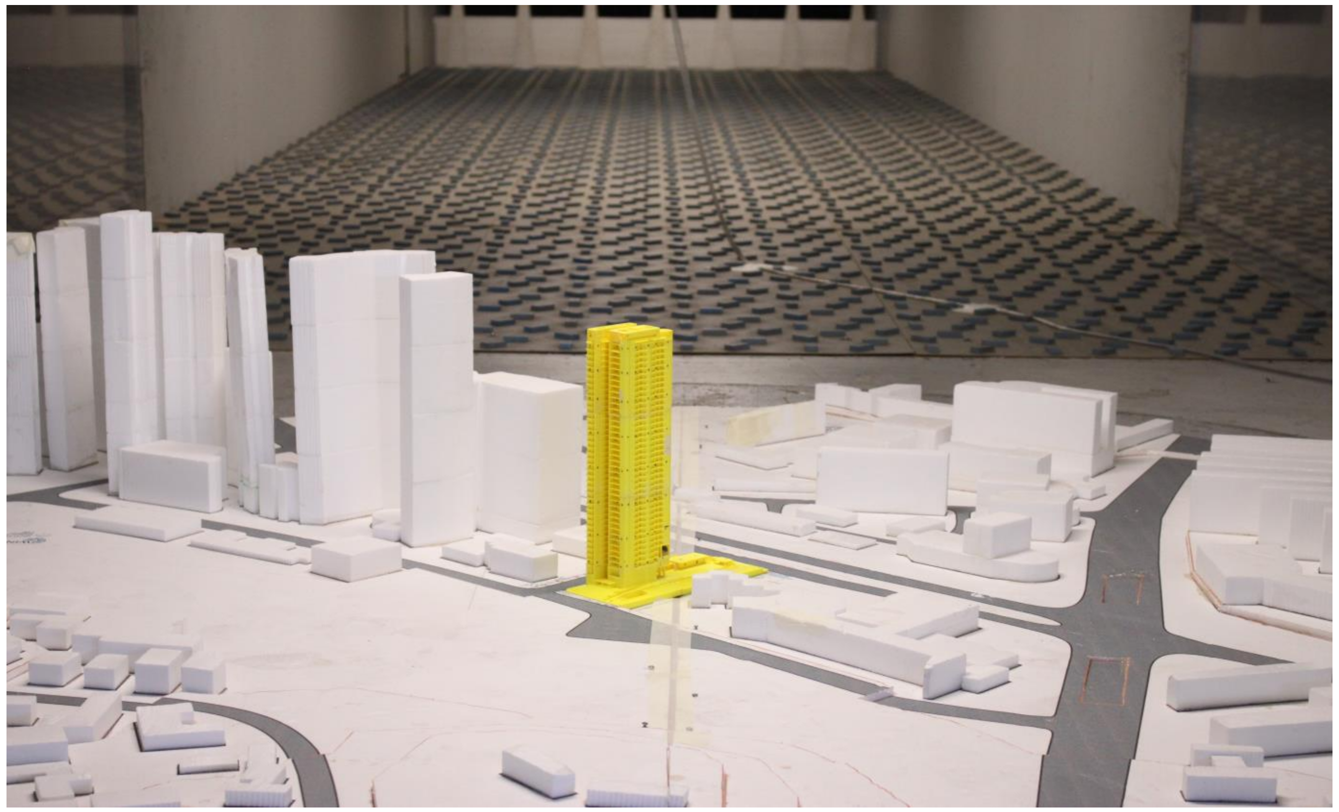


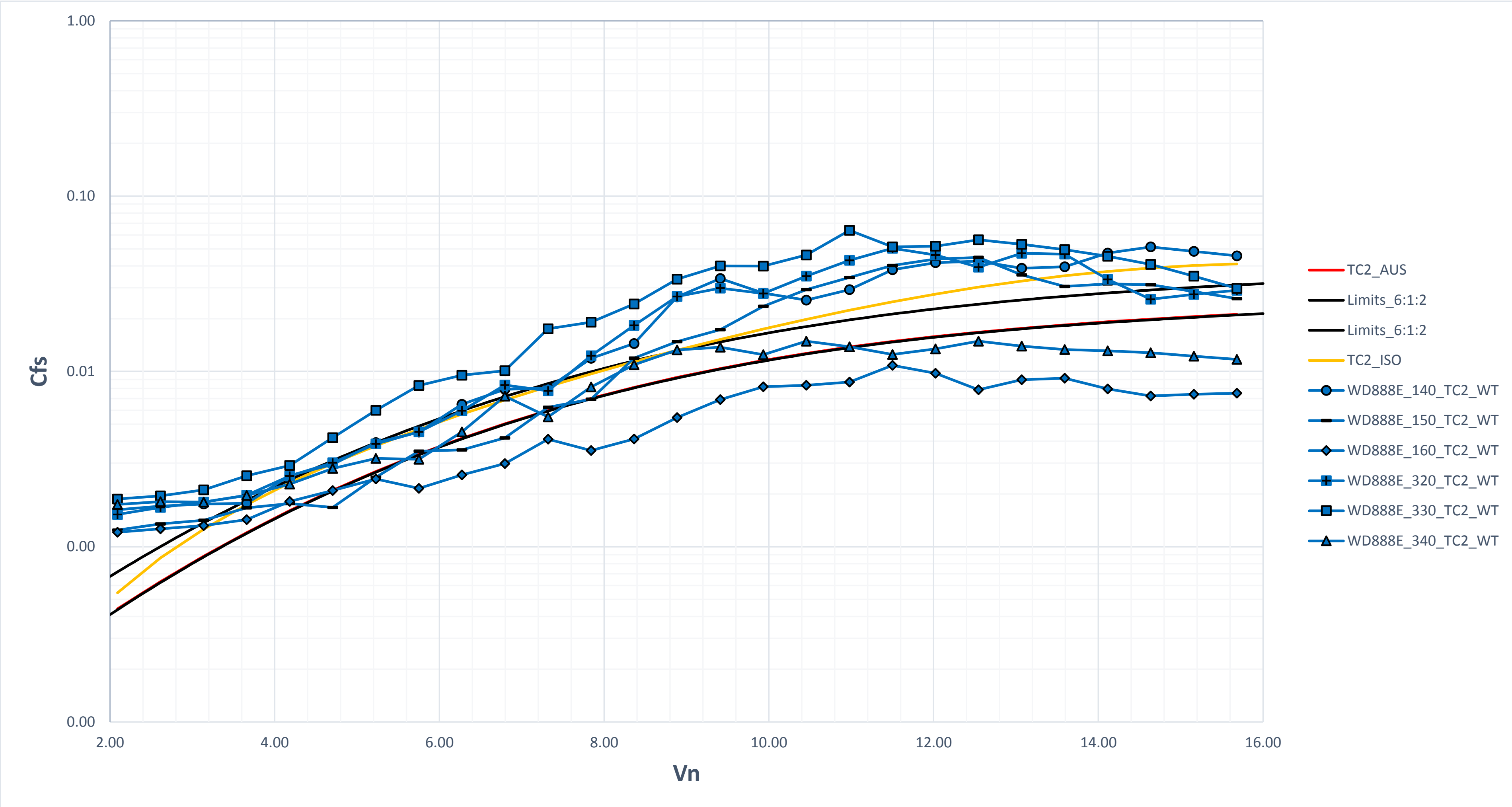



1.00
0.10
0.01
0.00
0.00
Cfs
2.00
4.00
6.00
8.00
10.00
12.00
14.00
16.00
Vn
TC3_AUS
TC2_AUS
Limits_6:1:2
Limits_6:1:2
TC3_ISO
TC2_ISO
WD751T HFPI_30_TC3_WT
WD751T HFPI_40_TC3_WT
WD751T HFPI_50_TC3_WT
WD751T HFPI_210_TC2_WT
WD751T HFPI_220_TC2_WT
WD751T HFPI_230_TC2_WT

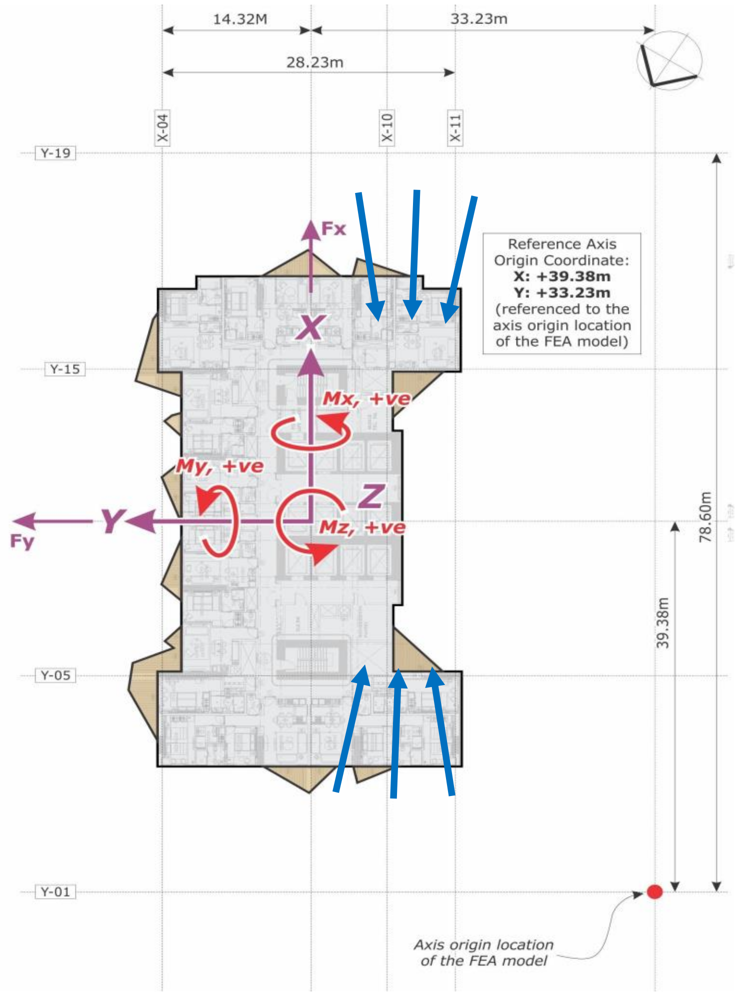

Reference Axis origin coordinate:
X: +5.05m
Y: -0.94m
(referenced to the axis origin location of the FEA model)
Fy
Y
A1
A9
B8
B1
11.24m
0.94m
10.86m
My, +ve
Mz, +ve
Mx, +ve
Z
X
Fx
Axis origin location of the FEA model
13.58m
5.05m
20.82m



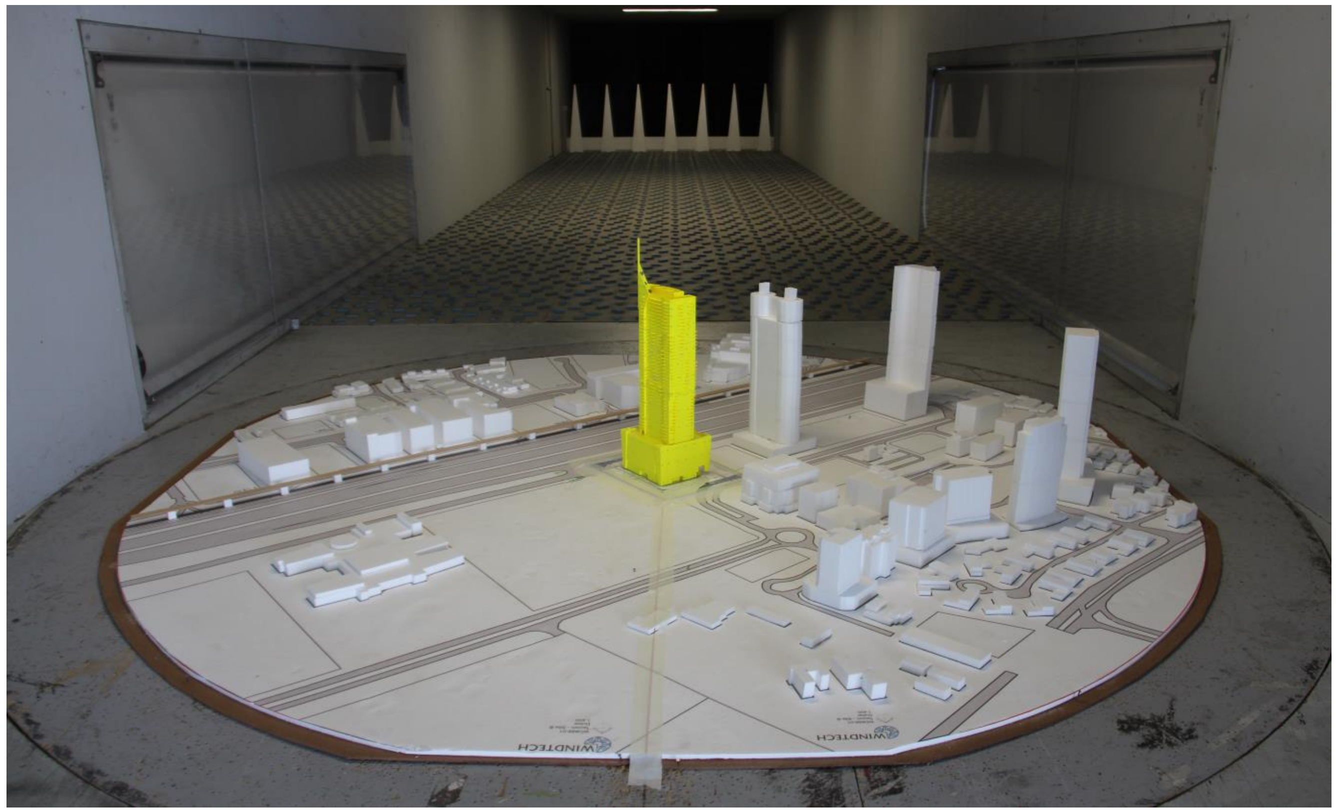


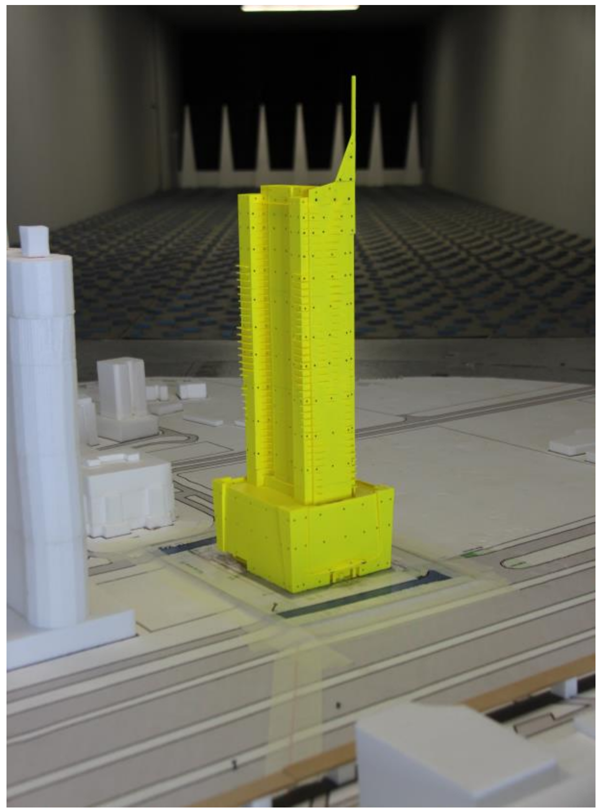


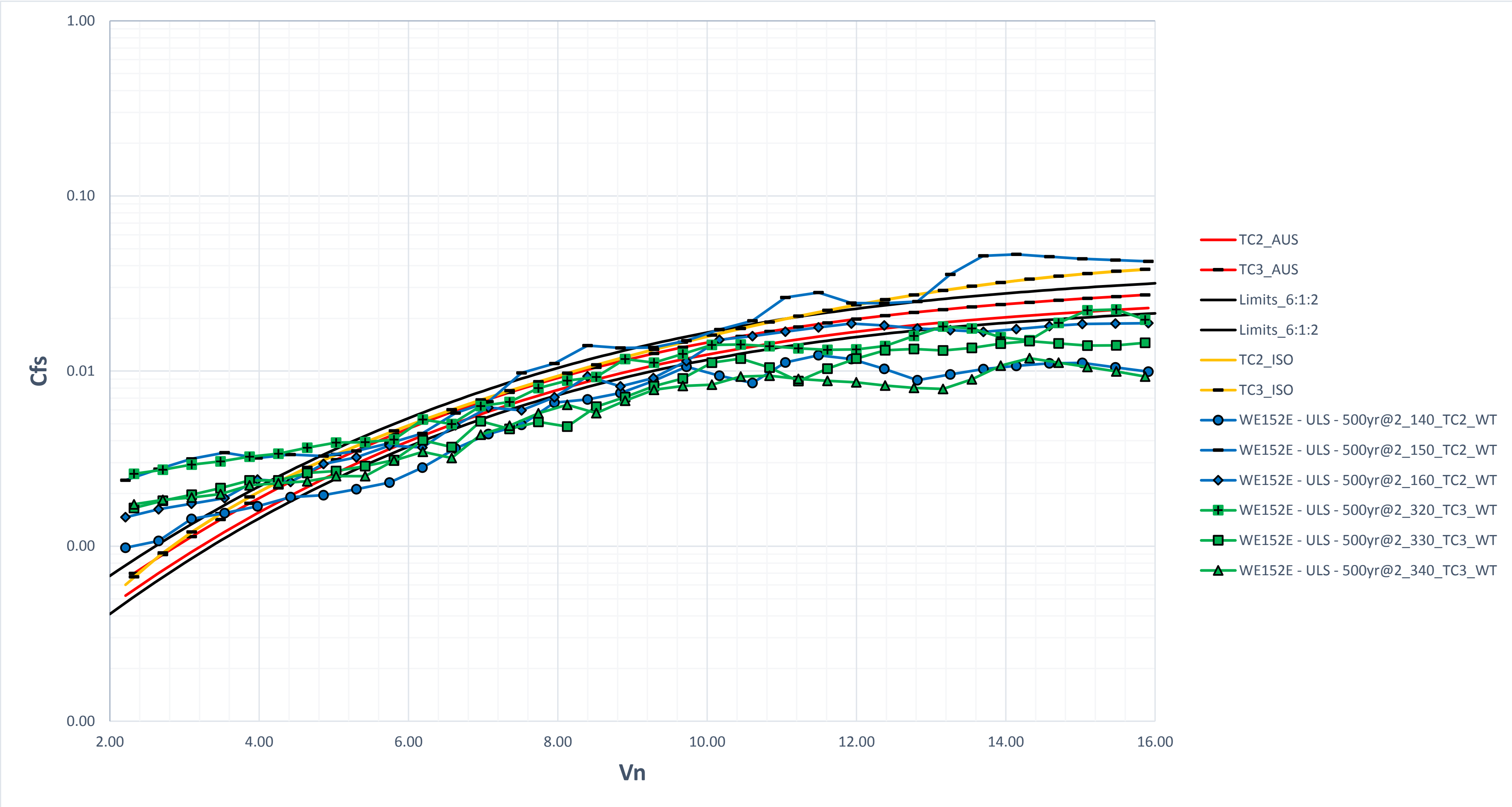
1.00
0.10
0.01
0.00
0.00
Cfs
2.00
4.00
6.00
8.00
10.00
12.00
14.00
16.00
Vn
TC2_AUS
Limits_6:1:2
Limits_6:1:2
TC2_ISO
WD888E_140_TC2_WT
WD888E_150_TC2_WT
WD888E_160_TC2_WT
WD888E_320_TC2_WT
WD888E_330_TC2_WT
WD888E_340_TC2_WT



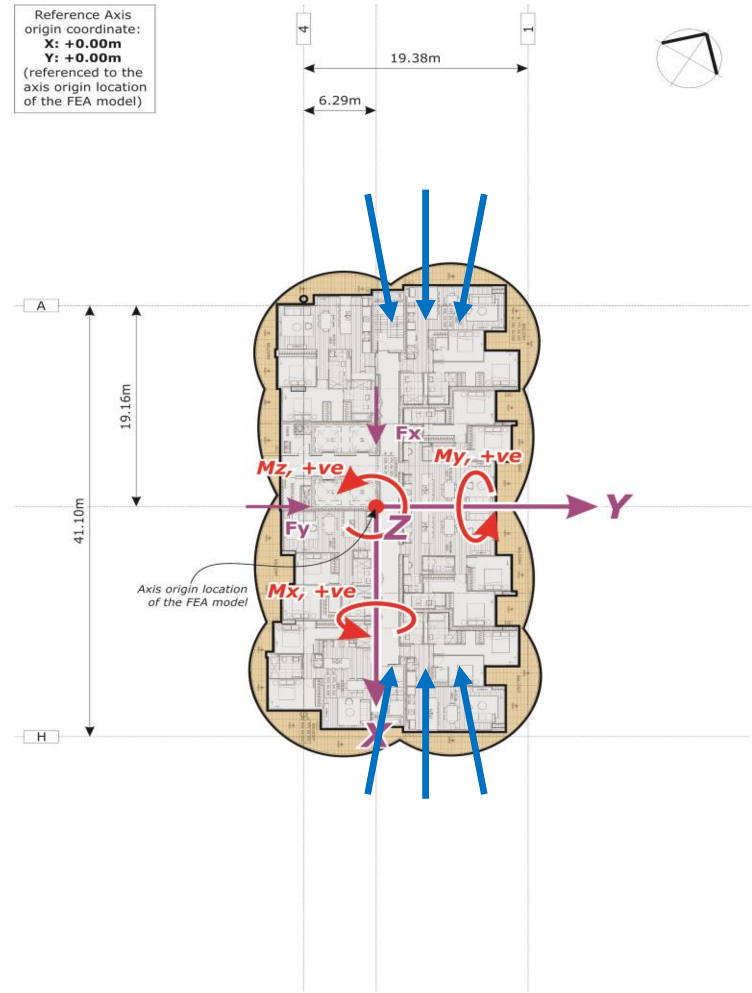
14.32M
33.23m
28.23m
X-04
X-10
X-11
Y-19
Y-15
Y-05
Y-01
Fx
X
Mx, +ve
My, +ve
Y
Fy
Z
Mz, +ve
Reference Axis
Origin Coordinate:
X: +39.38m
Y: +33.23m
(referenced to the
axis origin location
of the FEA model)
78.60m
39.38m
Axis origin location
of the FEA model



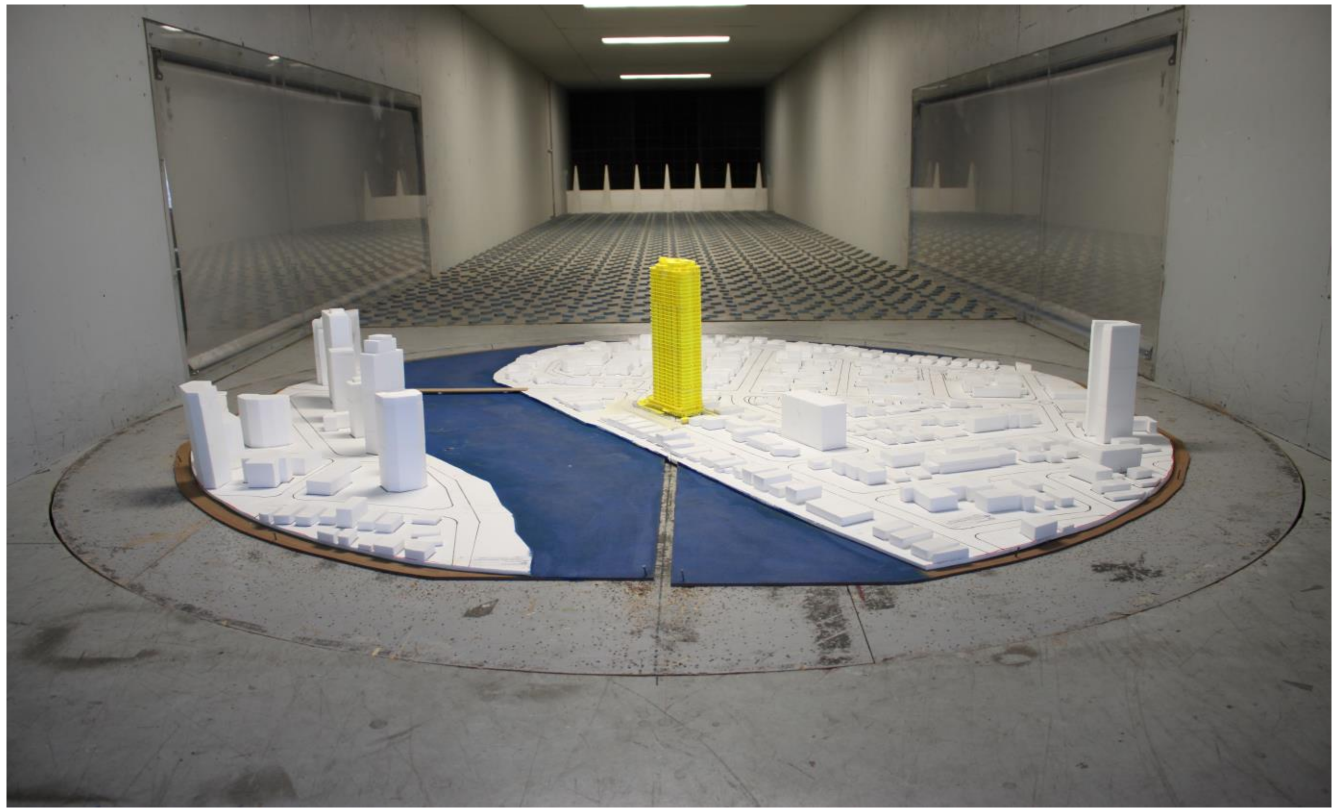


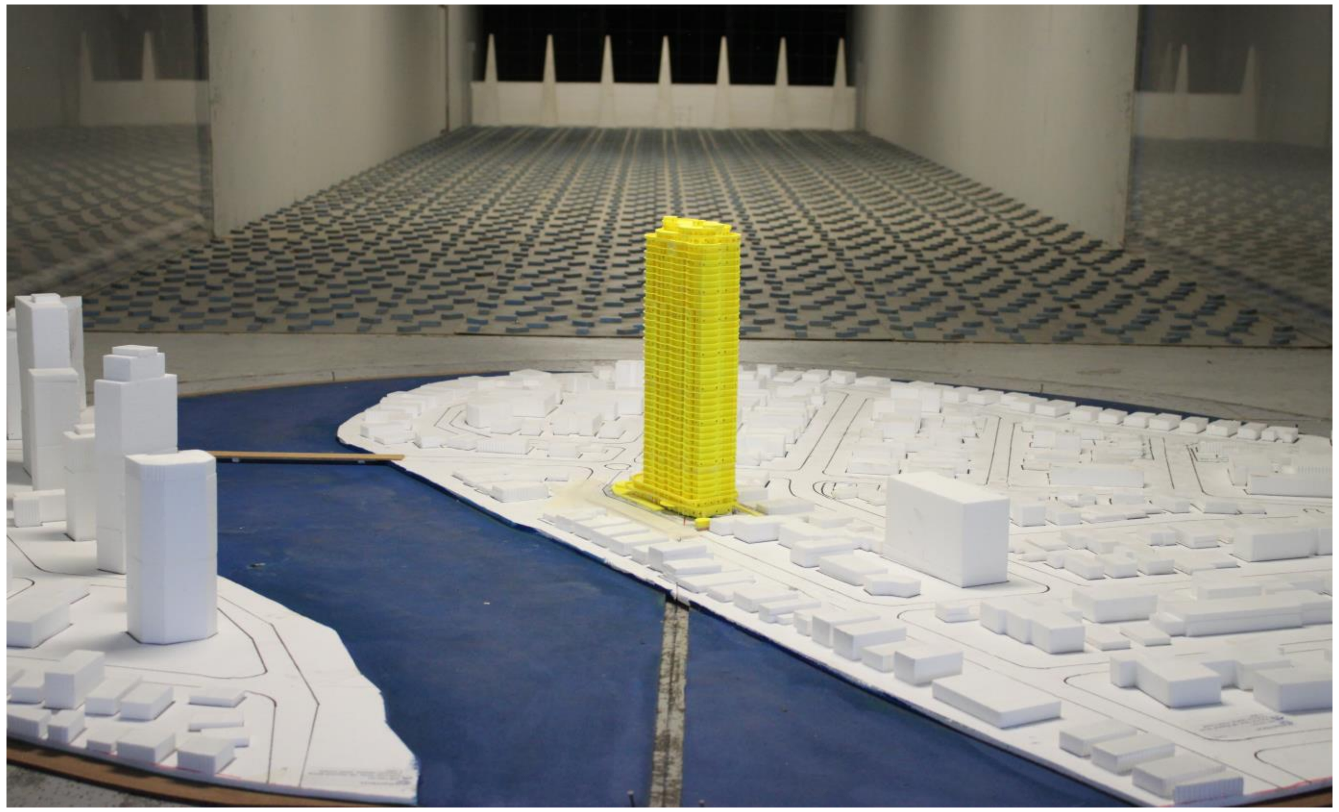


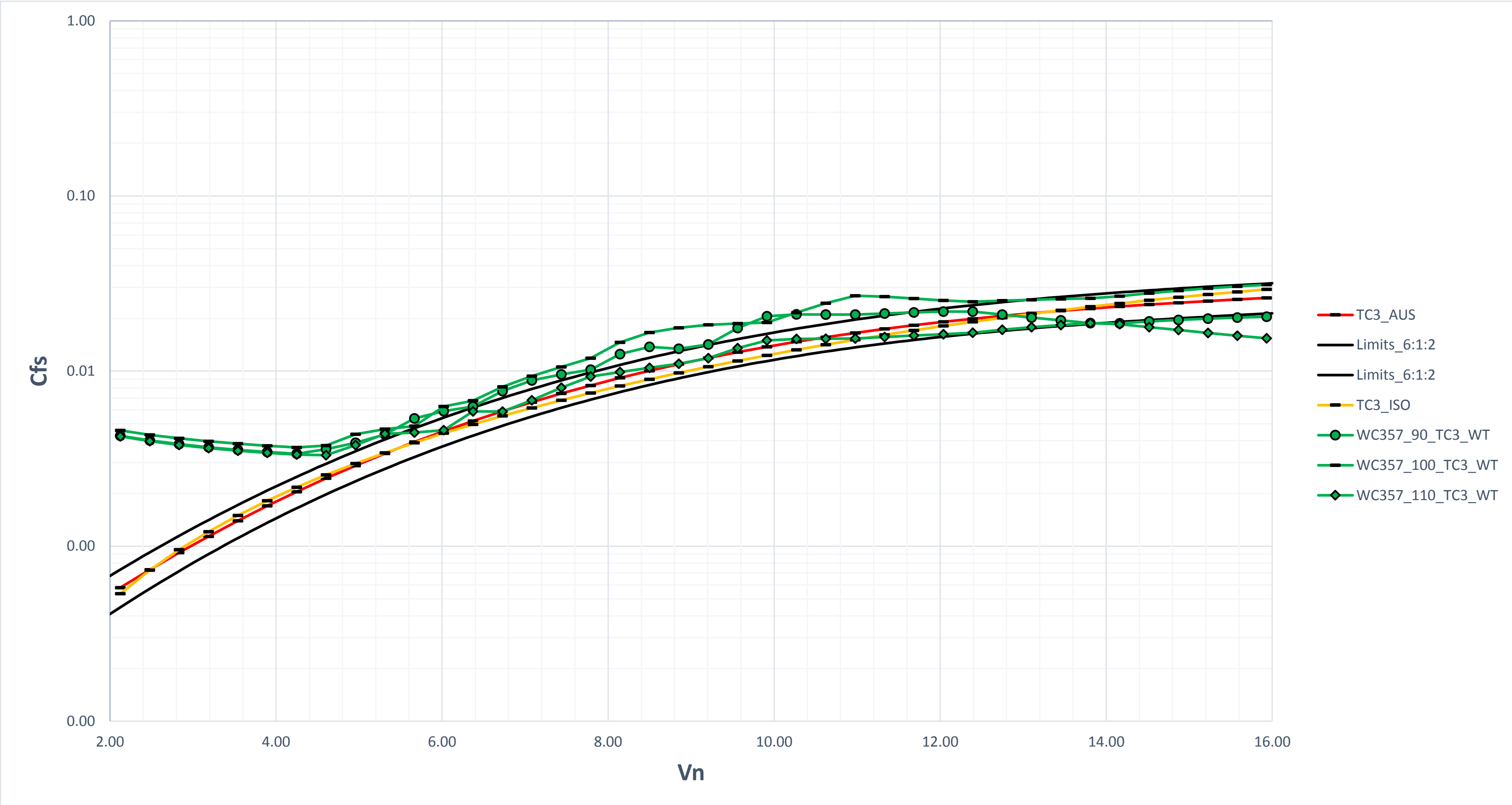
1.00
0.10
0.01
0.00
0.00
Cfs
2.00
4.00
6.00
8.00
10.00
12.00
14.00
16.00
Vn
TC2_AUS
TC3_AUS
Limits_6:1:2
Limits_6:1:2
TC2_ISO
TC3_ISO
WE152E - ULS - 500yr@2_140_TC2_WT
WE152E - ULS - 500yr@2_150_TC2_WT
WE152E - ULS - 500yr@2_160_TC2_WT
WE152E - ULS - 500yr@2_320_TC3_WT
WE152E - ULS - 500yr@2_330_TC3_WT
WE152E - ULS - 500yr@2_340_TC3_WT

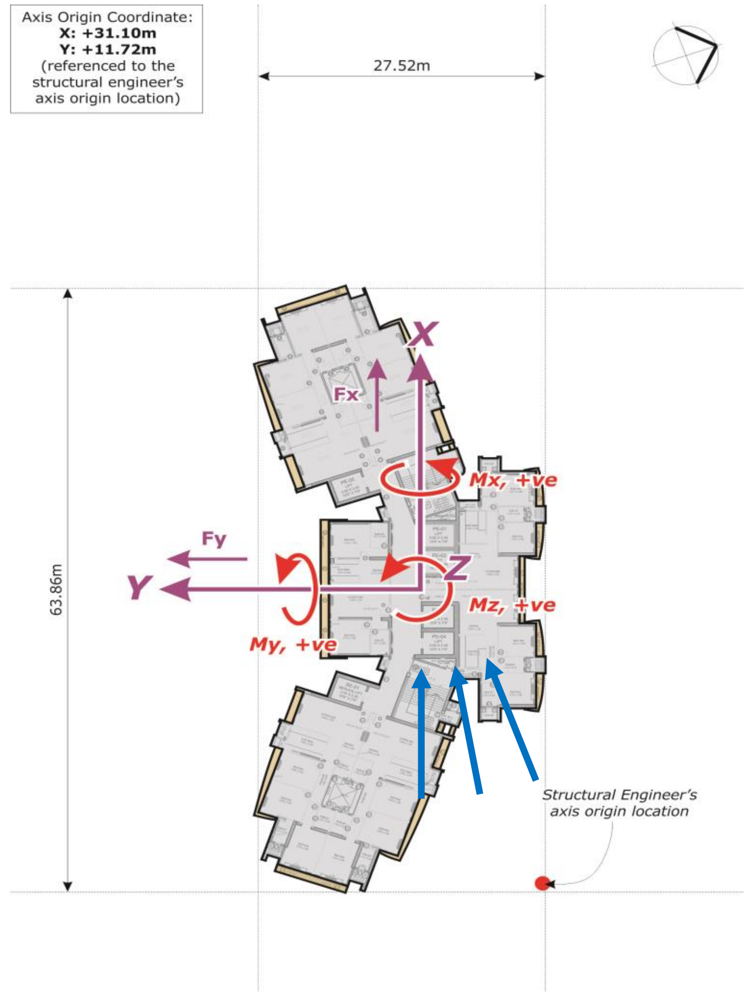


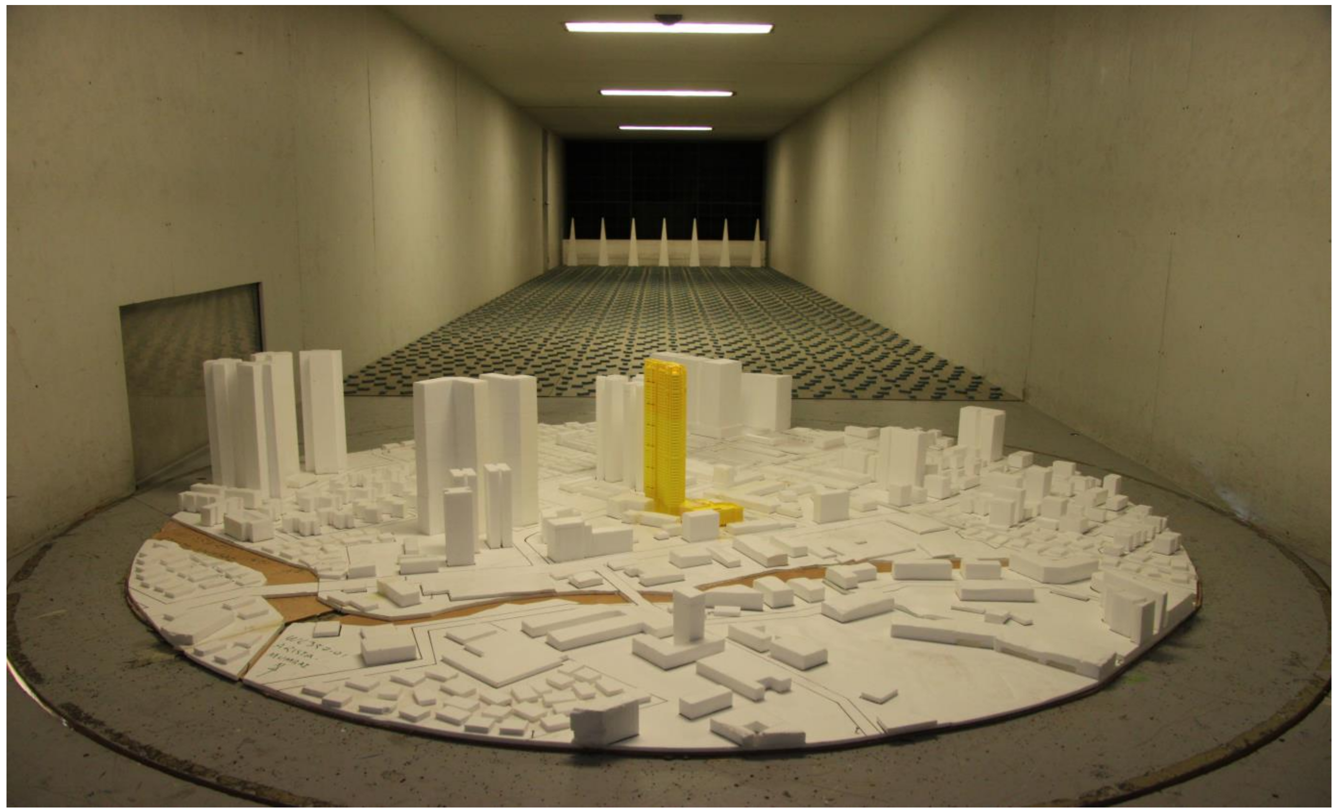
Reference Axis
origin coordinate:
X: +0.00m
Y: +0.00m
(referenced to the
axis origin location
of the FEA model)
4
1
19.38m
6.29m
A
H
19.16m
41.10m
Fx
Fy
Mz, +ve
My, +ve
Mx, +ve
Axis origin location
of the FEA model
Y
Z
X

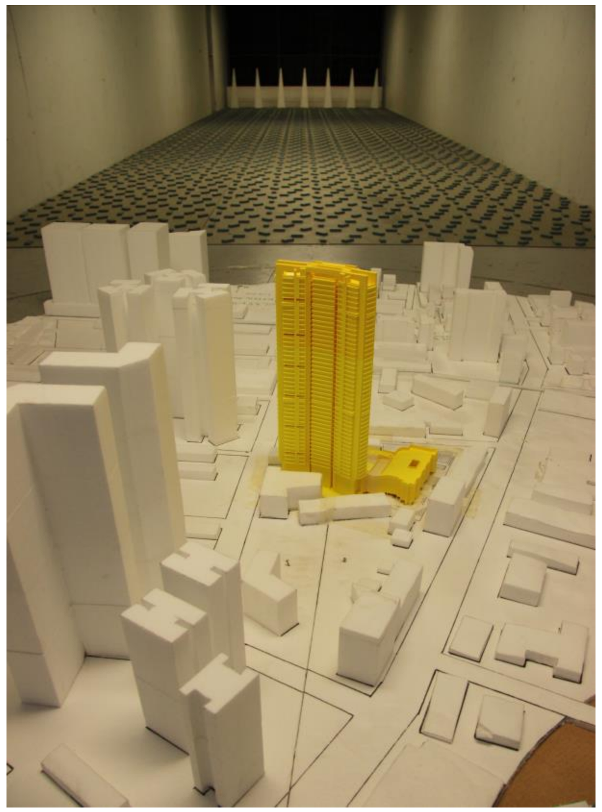


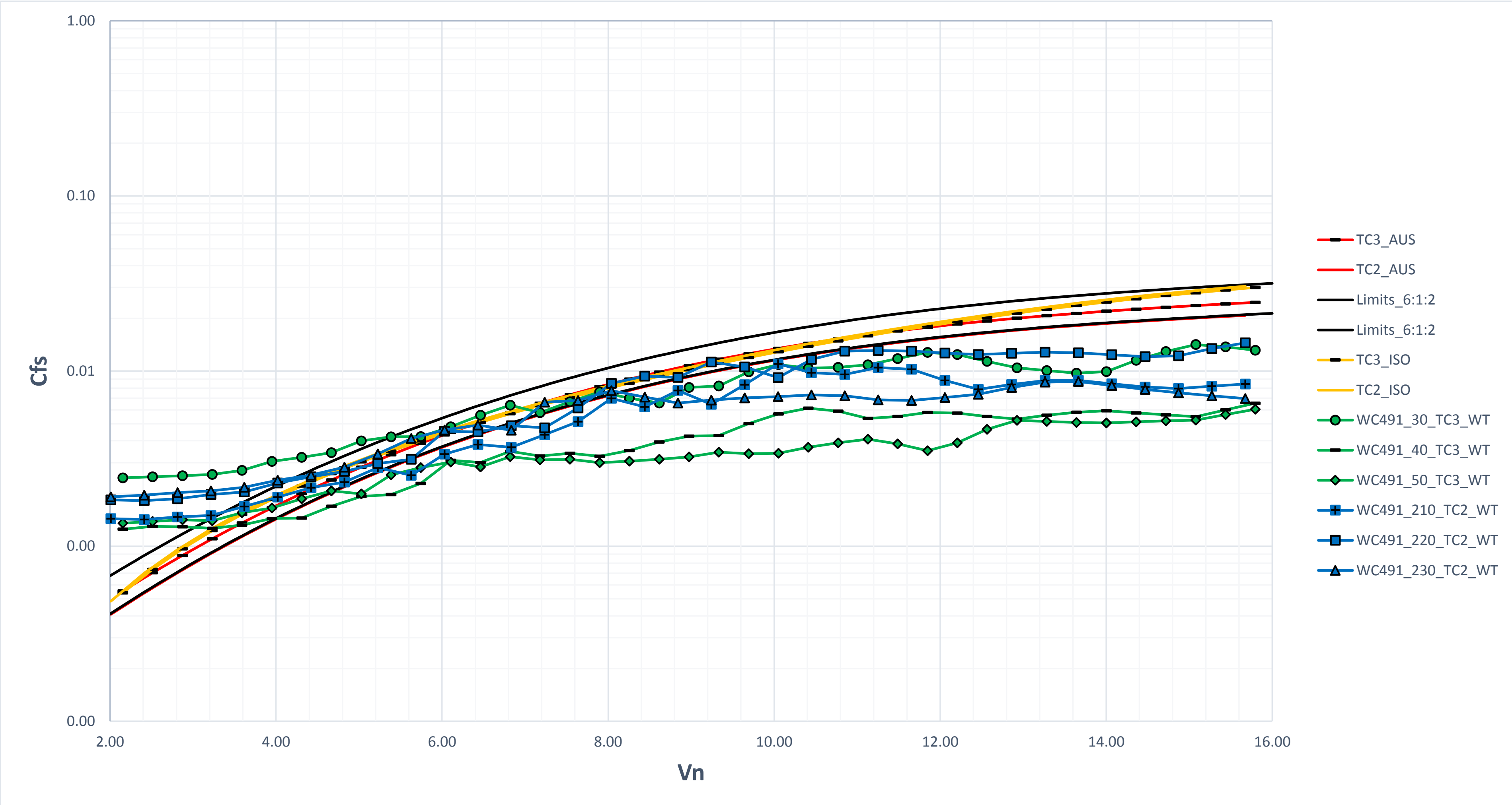



1.00
0.10
0.01
0.00
0.00
Cfs
2.00
4.00
6.00
8.00
10.00
12.00
14.00
16.00
Vn
TC3_AUS
Limits_6:1:2
Limits_6:1:2
TC3_ISO
WC357_90_TC3_WT
WC357_100_TC3_WT
WC357_110_TC3_WT

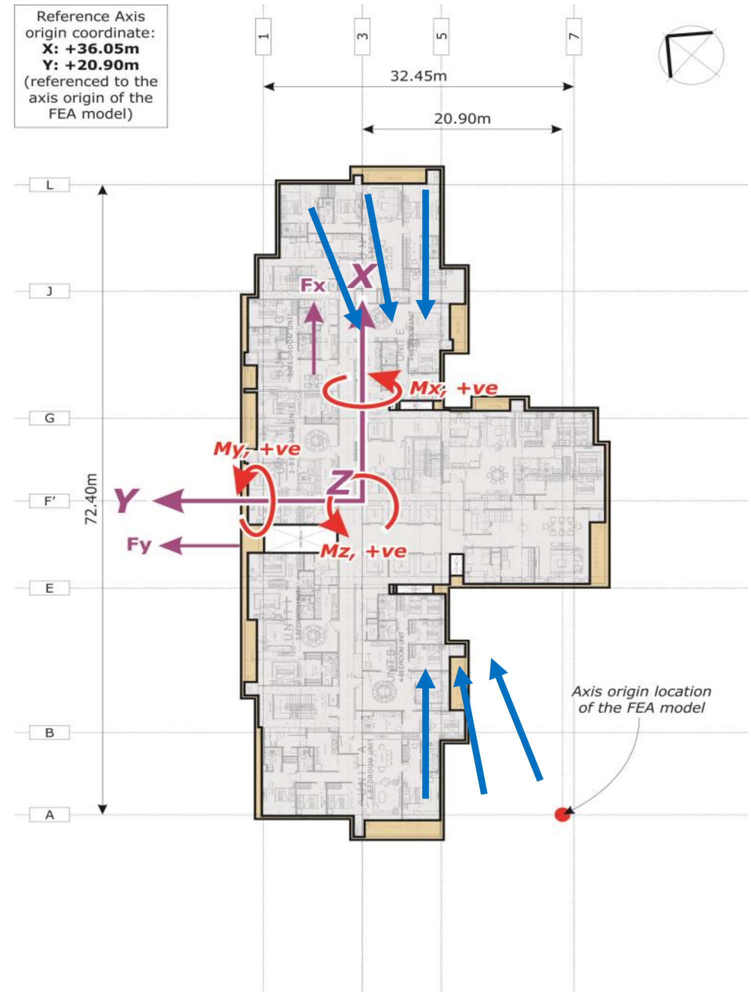

Axis Origin Coordinate:
X: +31.10m
Y: +11.72m
(referenced to the structural engineer's axis origin location)
27.52m
63.86m
X
Fx
Mx, +ve
Fy
Y
Z
Mz, +ve
My, +ve
Structural Engineer's axis origin location



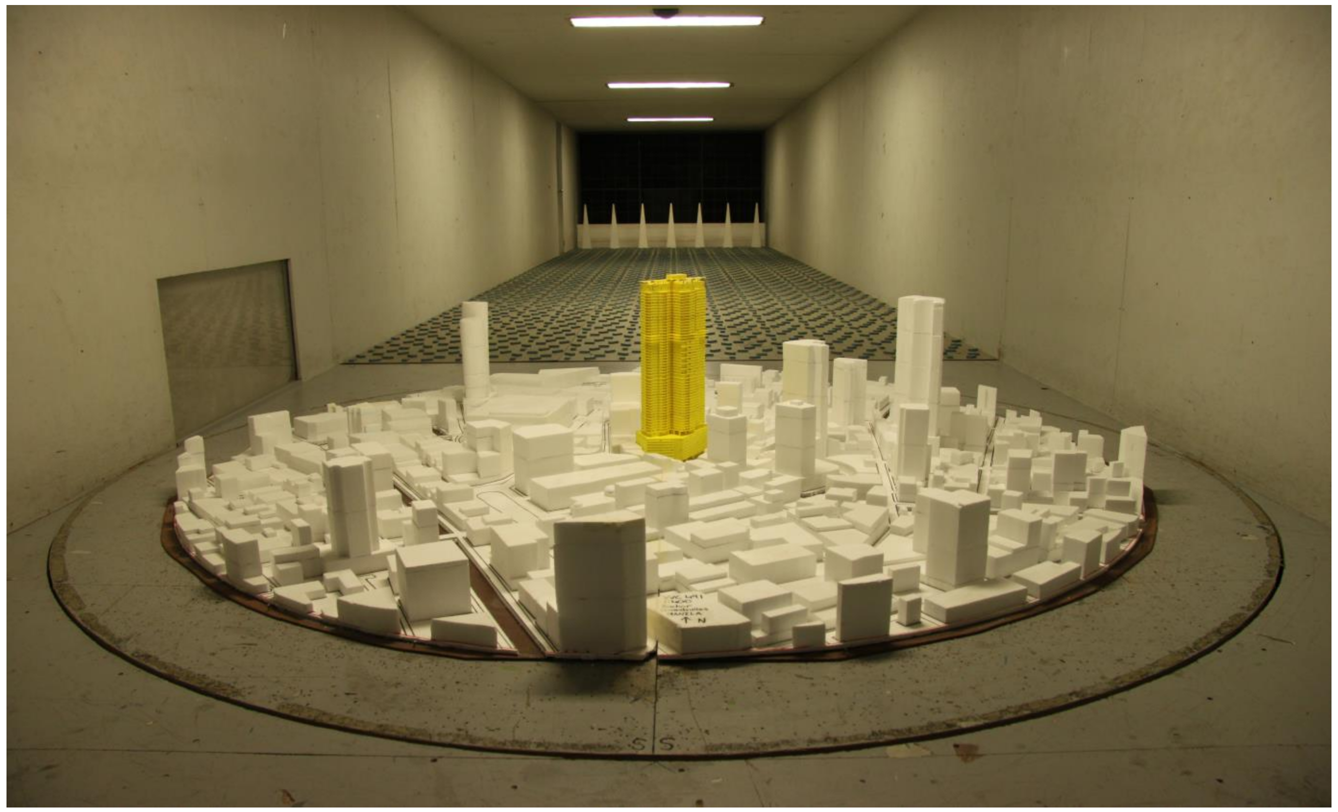


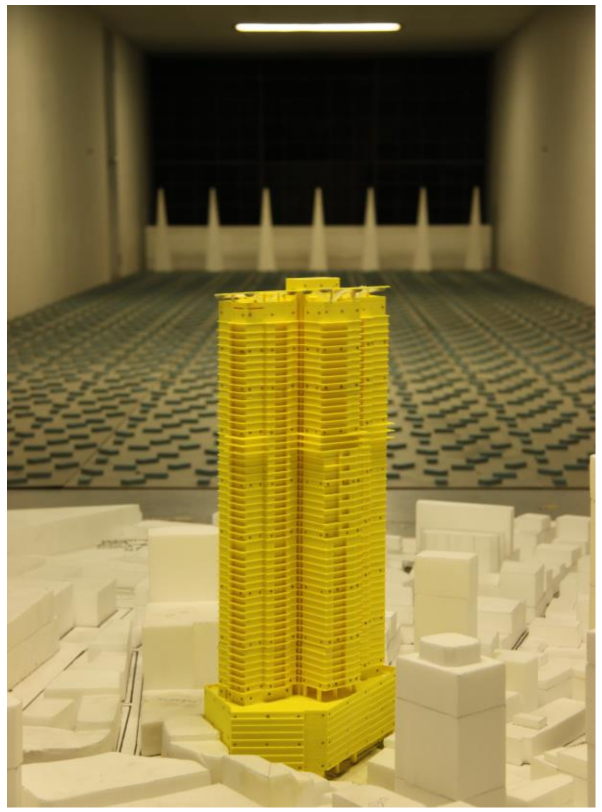


1.00
0.10
0.01
0.00
0.00
2.00
4.00
6.00
8.00
10.00
12.00
14.00
16.00
Cfs
Vn
TC3_AUS
TC2_AUS
Limits_6:1:2
Limits_6:1:2
TC3_ISO
TC2_ISO
WC491_30_TC3_WT
WC491_40_TC3_WT
WC491_50_TC3_WT
WC491_210_TC2_WT
WC491_220_TC2_WT
WC491_230_TC2_WT

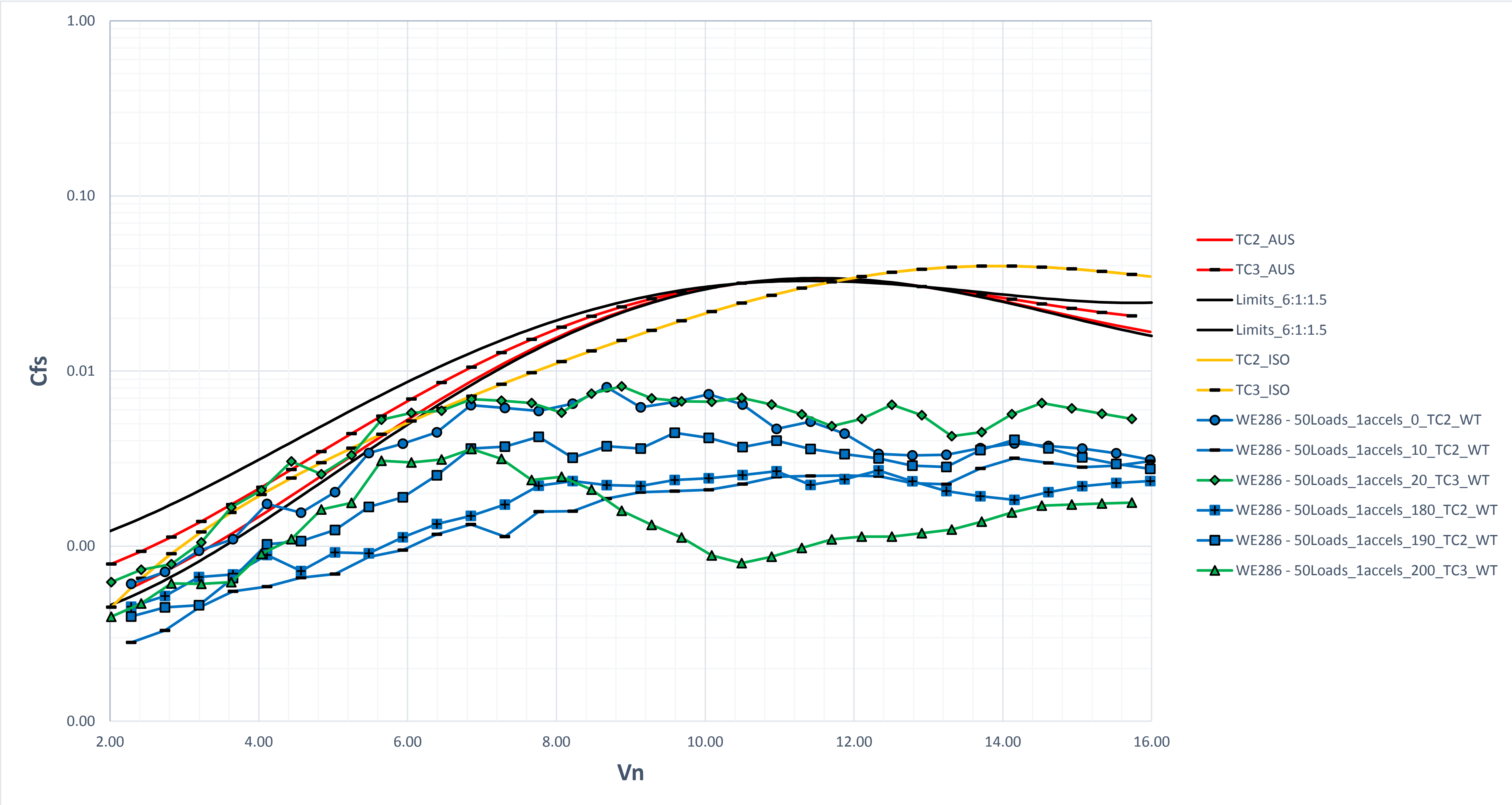


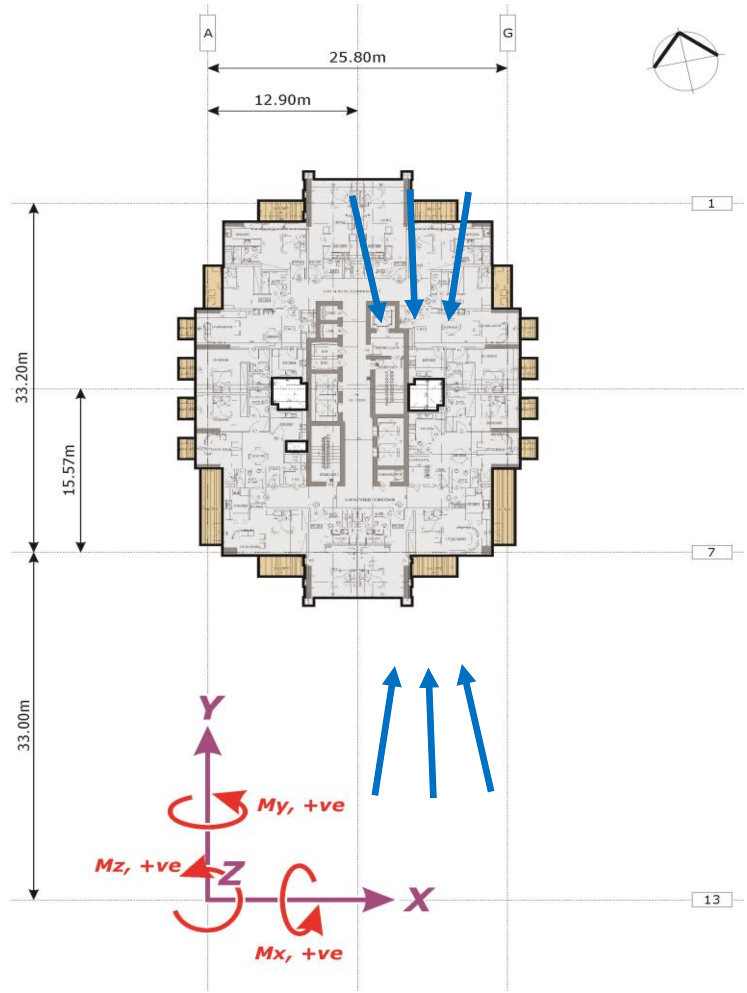
Reference Axis origin coordinate:
X: +36.05m
Y: +20.90m
(referenced to the axis origin of the FEA model)
1
3
5
7
32.45m
20.90m
L
J
G
F'
E
B
A
72.40m
Fx
X
Mx, +ve
My, +ve
Y
Z
Fy
Mz, +ve
Axis origin location of the FEA model

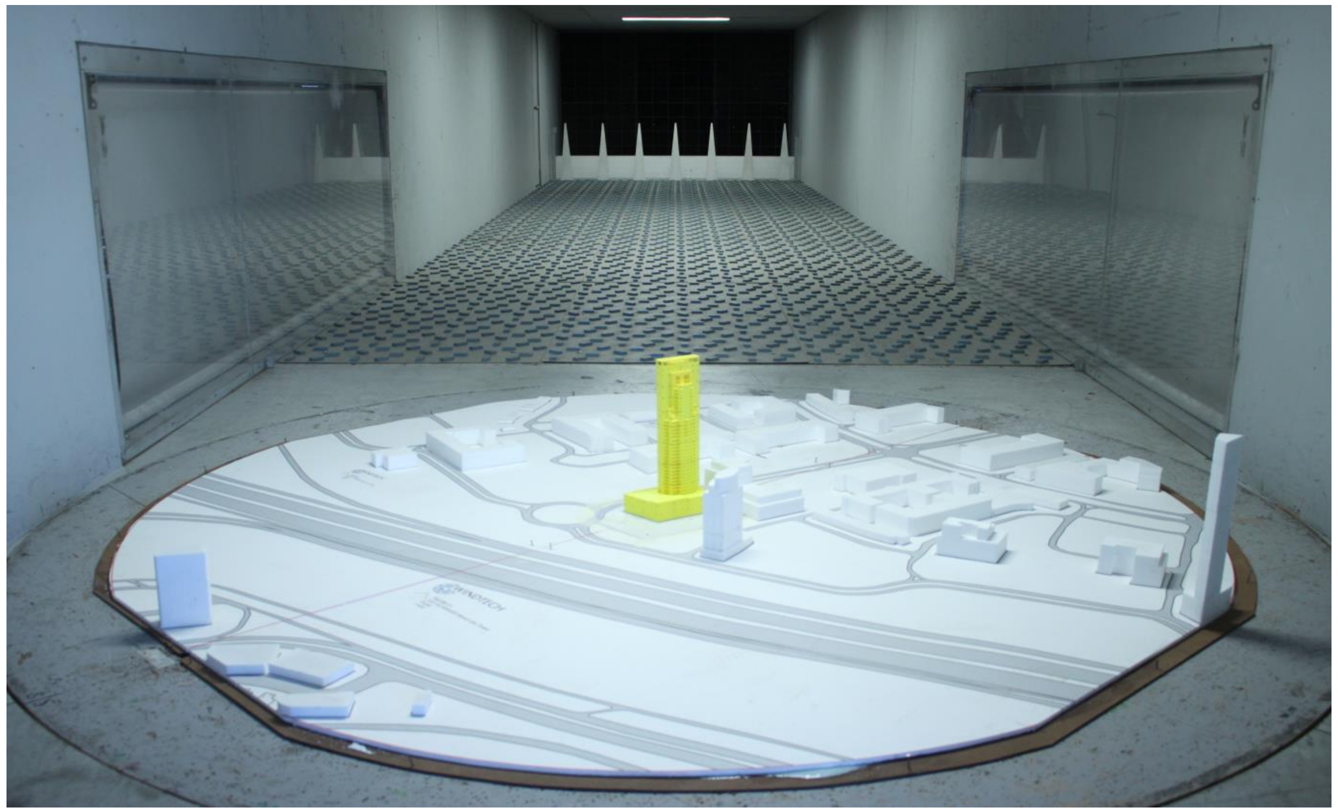


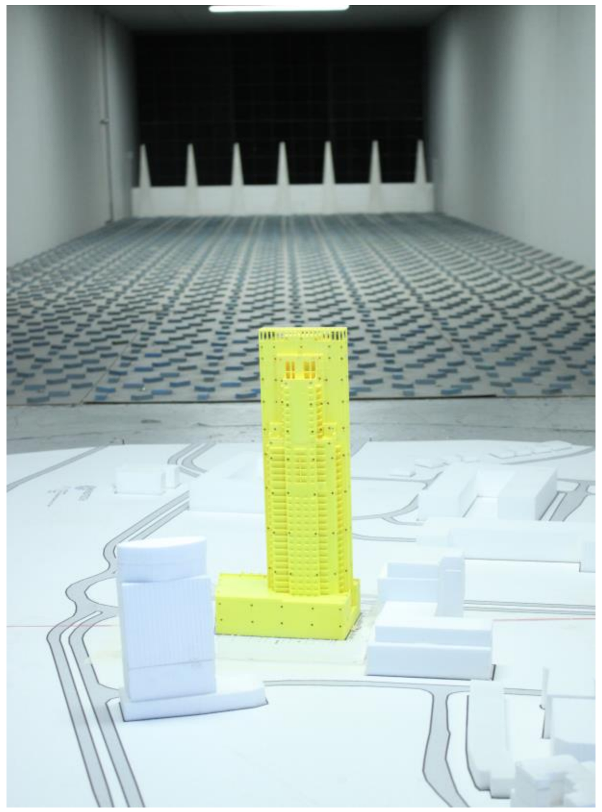


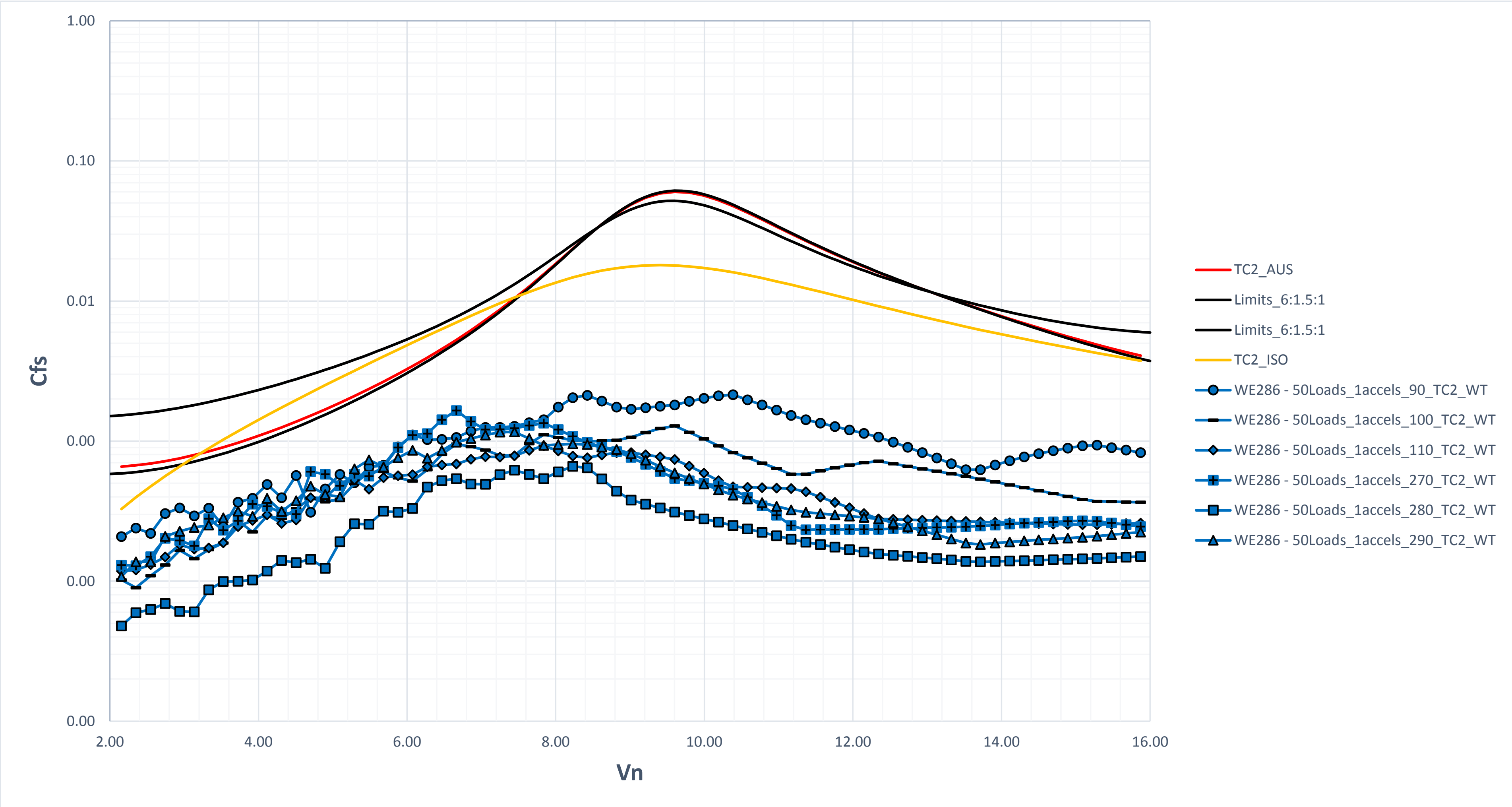
ANNEXURE 5 – COMPARATIVE RESULTS for *h*:*b*:*d* of 6:1.5:1 & 6:1:1.5


1.00
0.10
0.01
0.00
0.00
0.00
Cfs
2.00
4.00
6.00
8.00
10.00
12.00
14.00
16.00
Vn
TC2_AUS
TC3_AUS
Limits_6:1:1.5
Limits_6:1:1.5
TC2_ISO
TC3_ISO
WE286 - 50Loads_1accels_0_TC2_WT
WE286 - 50Loads_1accels_10_TC2_WT
WE286 - 50Loads_1accels_20_TC3_WT
WE286 - 50Loads_1accels_180_TC2_WT
WE286 - 50Loads_1accels_190_TC2_WT
WE286 - 50Loads_1accels_200_TC3_WT

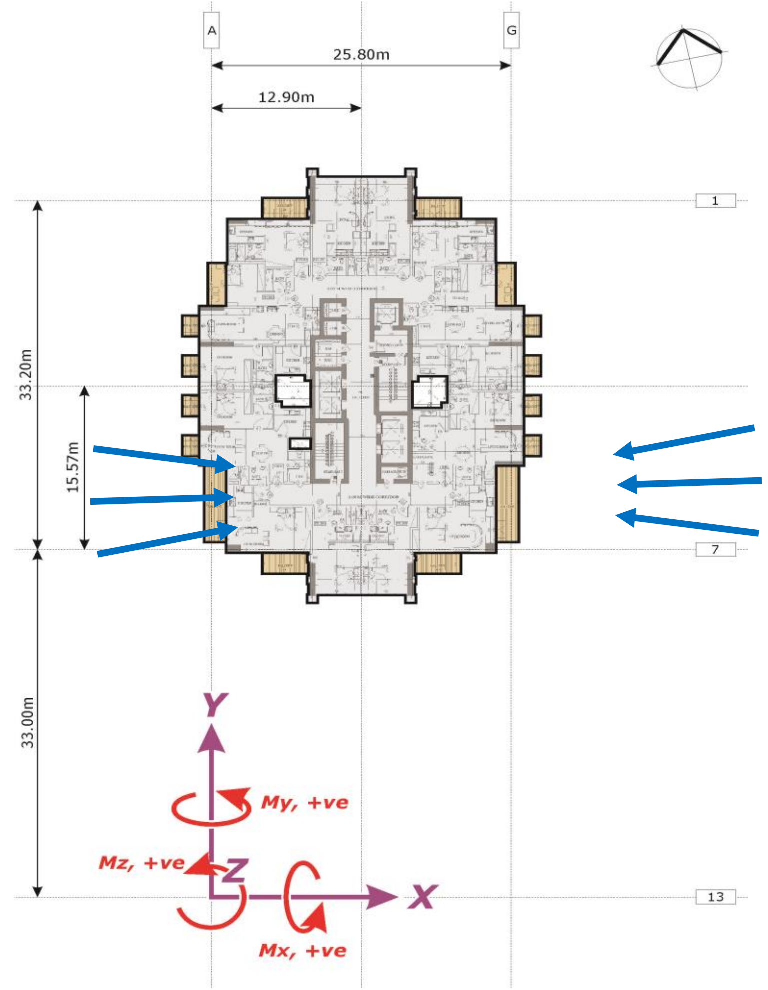

A
G
25.80m
12.90m
1
7
13
33.20m
15.57m
33.00m
Y
My, +ve
Mz, +ve
Z
X
Mx, +ve







1.00
0.10
0.01
0.00
0.00
0.00
0.00
Cfs
2.00
4.00
6.00
8.00
10.00
12.00
14.00
16.00
Vn
TC2_AUS
Limits_6:1.5:1
Limits_6:1.5:1
TC2_ISO
WE286 - 50Loads_1accels_90_TC2_WT
WE286 - 50Loads_1accels_100_TC2_WT
WE286 - 50Loads_1accels_110_TC2_WT
WE286 - 50Loads_1accels_270_TC2_WT
WE286 - 50Loads_1accels_280_TC2_WT
WE286 - 50Loads_1accels_290_TC2_WT



A
G
25.80m
12.90m
33.20m
15.57m
33.00m
Y
My, +ve
Mz, +ve
Z
X
Mx, +ve