Wind Engineering Research Field Laboratory Selected Data Sets for Comparison to Model-Scale, Full-Scale and Computational Fluid Dynamics Simulations

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Lubbock, Texas
February 2017

Foreword

An important part of numerical or physical simulation of a physical process, such as wind effects on structures, is validation. In the case of the wind hazard simulation, validation of two components is desirable: (1) validation of the wind flow characteristics (input); and, (2) validation of the measured pressures on the test specimen (output). The validation of these two components of the simulation should, ideally, be made with data collected in the natural environment on identical structures.

Personnel at the Wind Science and Engineering Research Center have collected data on several full-scale buildings and other structures since 1989. Wind and wind-induced pressure data collected in natural winds are available for a full-scale test specimen. This dataset provides the opportunity for comparison with simulation data collected in a physical facility or generated using computational fluid dynamics..

This report provides the time histories and summary statistics for 15-minute duration records with flow direction acting through our 160 ft high meteorological tower and then impinging on the Wind Engineering Research Field Laboratory test structure. In addition, we provide the available drawings for the test structure along with a drawing and a table showing the location of the instrumented pressure taps installed on the test structure.

This research was supported by the National Science Foundation Grants BCS-88-21542 and the CSU/TTU Cooperative Program in Wind Engineering, Grant No. CMS-9411147. and the NIST/TTU Cooperative Agreement, Windstorm Mitigation Initiative.

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1. Introduction

Mitigation of wind-induced damage, such as the roof covering damage shown in Figure 1 that occurred during hurricane Ike, is an overarching goal for wind engineering. The mitigation of damage from wind hazard peril is investigated by the wind engineering community using model-scale simulations in the wind tunnel, full-scale simulations (e.g. those conducted at the Institute of Building and Home Safety, IBHS) and numerical simulations. Regardless of the simulation source, the input (flow characteristics) and the output (flow-induced pressures) should be validated with data collected in the natural environment.

To assist researchers in validating their wind hazard simulations, we identify and provide time histories and summary statistics for 15-minute duration records with flow direction that acted through our 160 ft high meteorological tower and then impinged on the Wind Engineering Research Field Laboratory test structure. In addition, as part of this task, we provide the available drawings for the test structure along with a drawing and a table showing the location of the instrumented pressure taps installed on the test structure.

2. Wind Engineering Research Field Laboratory

The Wind Engineering Research Field Laboratory (WERFL) was constructed in Lubbock, Texas on the campus of Texas Tech University in 1989. Since that point in time it has produced high quality data that is commonly used for validation of wind tunnel [1-4] and computational fluid dynamic results [5-7]. The facility consists of a 160 ft meteorological tower instrumented at 5 heights (8', 13', 33', 70', and 160') and a 30'x45'x13' high test structure. Wind flow from an azimuth angle of approximately 280° flows through the tower and then impacts the test building (see Figure 2). Each component is briefly described below. Additional details about the facility are given in [8, 9].

2.1. Meteorological Tower

The 160 ft high meteorological tower is a guyed lattice structure (see Figure 3) instrumented at 5 heights. Meteorological instrumentation is mounted on a boom arm that extends toward the Northwest, thus wind from this azimuth angle is not influenced by the tower structure. The meteorological instrumentation used on the tower is provided in Table 1. UVW instruments were used at all 5 heights to measure wind speed and wind direction. A three-cup anemometer and a direction vane are mounted on a separate 13 ft high pole between the test structure and the meteorological tower for redundancy. A three-component sonic wind speed instrument is mounted at 19 ft above the geometric center of the flat roof (see Figure 4).

2.2. Test Structure

The flat roof configuration for the test structure is shown in Figure 4. Construction details for the building and the supporting rotation system are given in supporting document.. Omega differential pressure transducers were used to collect the differential pressure data on the surface of the building as well as internal pressures. Table 1 provides additional information on the Omega pressure transducers. Pictures of the instrument organization for roof pressure measurements and wall pressure measurements are given in Figure 5 and Figure 6, respectively.

Construction of the pressure taps has been significantly changed since the procedure reported by [8]. Instead of dimpling the flat stock skin, installing the tap and then using body putty to make the surface smooth again, copper tubing is flared at one end and inserted into a predrilled hole. The tap is held in place by a rubber sleeve that is set flush with the back face of the wall and held in place by a hose clamp. On the exterior surface, the tap projects out from the flat stock sheet approximately 1/32". The new tap configuration is shown in Figure 7.

The effects of the projection beyond the flat stock sheet were established by installing the new tap geometry adjacent to an old tap and data collected for multiple angles of attack. The data from the two taps showed no statistically significant difference using the Kolmogorov-Smirnov (KS) test at the 99% level of significance. Time to install a tap dropped from several hours to about 5 minutes. This made installation of the large number of taps for measurement of overall loads tractable.

Pressure tap locations on the surface of the building are designated using a 5 digit code, sxxyy, where s is the surface number, xx is the nominal dimension in feet from the origin defined for the surface in the x direction and yy is the nominal dimension in feet from the origin defined for the surface in the y direction. Figure 8 provides an exploded view of the WERFL building showing the origin for each building surface and Table 2 provides the nominal tap designations and actual dimensions to each tap for historic as well as for Mode 1001. Angle of attack of wind on the test structure is also defined in Figure 8. Tap designations and angle of attack definitions are the same as originally defined in [8].

3. Data

3.1. Typical Data Characteristics

The sampling rate for all the data, meteorological and pressure, provided is 30 Hz. Each record is 15 minutes in duration, thus each channel has 27000 samples in the record. The records are stored in comma separated value (CSV) format without column headers. The file structure (column headers) for each record is given in Table 3. Each 15-minute duration record in CSV format is approximately 82 MB in size. In Table 3 the local coordinate column refers to the tap designation, sxxyy. As an example, data column 30 has the local coordinate is [1 - 30 - 4] which corresponds with tap designation 13004 which is located on Surface 1 at xx = 30 ft and yy = 4 ft (see Figure 8 and Table 2).

3.2. Data Validation Process

The three step validation procedure described in [8] remains essentially in place. Daily checks are performed and problems with instruments noted and repaired. In general, validation of the data however has taken a slightly different approach. With over 200 pressure transducers alone, the volume of paper and the time involved prevent scrutiny of individual time histories for each 15-minute duration record. Instead plots of summary statistics of pressure coefficients are used to identify anomalies in the pressure coefficients for an individual run. Typical plots for mean and standard deviation pressure coefficients on the building are shown in Figure 9 and Figure 10, respectively. Similar plots for meteorological data are provided for validation as part of the detailed printout of the record. The detailed printout of each record selected for distribution (see Section 3.4 below) is provided in zip format.

3.3.Data Selection Criteria

To validate simulation data, the flow characteristics directly upwind of the structure (before impinging on the test structure) and the wind induced pressures arising from the flow are required. A wind azimuth angle of 280° meets this requirement. We provide 16 records with an azimuth angle between 275° and 285°. In addition to the azimuth angle requirement, the records are stationary in both speed and direction and have a mean wind speed at 13 ft height greater than 15 mph. The last requirement is imposed to ensure that the turbulence present in the flow is mechanically generated and not due to thermal convection.

3.4. Selected Records

The 16 records selected from Mode 1001 meet the wind azimuth, stationarity criteria, and mean flow speed criteria discussed above. Both summary statistics and time history data are provided for each 15-minute duration record. Table 4 provides a basic summary of the selected records. The time histories and summary statistics given in the detailed printout for each record was reviewed. Table 5 provides information on the instruments that are considered malfunctioning during the run.

4. Conclusion

Wind data from the Wind Engineering Research Field Laboratory (WERFL) is provided to researchers for the purpose of validating simulation results. The data provided includes summary statistics as well as time histories. Details on the locations of the pressure measurements and the construction details for the test structure are also provided.

5. References

1. Bienkiewicz, B. and H.J. Ham, *Wind tunnel modeling of roof pressure and turbulence effects on the TTU test building.* Wind and Structures, An International Journal, 2003. **6**(2): p. 91.
2. Okada, H. and Y.-C. Ha, *Comparison of wind tunnel and full-scale pressure measurement tests on the Texas Tech Building.* Journal of Wind Engineering and Industrial Aerodynamics, 1992. **43**(pt 3): p. 1601.
3. Tieleman, H.W., et al., *Pressures on a surface-mounted rectangular prism under varying incident turbulence.* Journal of Wind Engineering and Industrial Aerodynamics, 2003. **91**(9): p. 1095.
4. Xu, Y.L., *Model- and full-scale comparison of fatigue-related characteristics of wind pressures on the Texas tech building.* Journal of Wind Engineering and Industrial Aerodynamics, 1995. **58**(3): p. 147.
5. Bekele, S.A. and H. Hangan, *A comparative investigation of the TTU pressure envelope. Numerical versus laboratory and full scale results.* Wind and Structures, An International Journal, 2002. **5**(2-4): p. 337.
6. Chang C.-H, M.R.N., *Numerical and physical modeling of bluff body flow and dispersion in urban street canyons.* Journal of Wind Engineering and Industrial Aerodynamics, 2001. **89**(14-15): p. 1325.
7. Qasim, A., T.T. Maxwell, and S. Parameawaran, *Computational predictions of flow over a 2-D building.* Journal of Wind Engineering and Industrial Aerodynamics, 1992. **44**(pt 4): p. 2839.
8. Levitan, M.L. and K.C. Mehta, *Texas Tech field experiments for wind loads part I: building and pressure measuring system.* 1992. **43**(1-3): p. 1565.
9. Levitan, M.L. and K.C. Mehta, *Texas Tech field experiments for wind loads part II: meteorological instrumentation and terrain parameters.* 1992. **43**(1-3): p. 1577.
10. Young, R.M. *UVW Anemometer Model 27005*. 2006 [cited 2006 4/6/2006]; Available from: www.inteltronics.co.za/ products/windsensors/pdf/**27005**.PDF
11. Young, R.M. *Gill MicroVane and 3-cup Anenomenter Model 12002/12005*. 2006 4/11/2006]; Available from: http://www.youngusa.com/.
12. Gill. *Omnidirectional and Asymmetric Research Ultrasonic Anemometer, Doc No. 1210-PS-0002*. 2006 [cited 2006; Available from: www.gill.co.uk.
13. Young, R.M. *Barometric Pressure Sensor Model 61201*. 2006 [cited 2006 4/11/2006]; Available from: www.jsinstruments.com/files/ Model%20**61201**%20Barometric%20Pressure%20Sensor.pdf
14. Young, R. *Relative Humidity/Temperature Probe Model 41372VC/VF*. 2006 [cited 2006 4/11/06].
15. Omega. *Low Pressure Transducer Model PX163-005BD5V*. 2006 [cited 2006 4/11/2006]; Available from: http://www.omega.com/ppt/pptsc.asp?ref=PX160

6. Tables

Table 1 Instrumentation used at the Wind Engineering Research Field Laboratory (WERFL) facility on 4th Street.

Measurement Type	Instrument Type	Manufacturer and Model	Manufacturer Website
Speed and Direction	UVW	R.M. Young Gill UVW Anemometer Model 27005	[10]
	3-cup and vane	R.M. Young Gill Microvane and 3-cup anemometer 12002/12005	[11]
	Ultrasonic UVW	Gill Model R3	[12]
Meteorological	Barometric Pressure	R.M. Young Barometric Pressure Sensor Model 61201	[13]
	Relative Humidity and Temperature	R.M. Young Model 41372VC/VF	[14]
Differential Pressure	Omega	Omega Model PX163-005BD5V	[15]

Table 2 Tap locations on the test structure at the Wind Engineering Research Field Laboratory on 4th Street.

Tap	X ft	X m	Y ft	Y m	Tap	X ft	X m	Y ft	Y m
(Old)					(Old)				
11407	14.17	4.32	6.75	2.06	22304	23.06	7.03	3.5	1.07
(New)					22306	23.06	7.03	6.42	1.96
					22312	23.06	7.03	11.83	3.61
10004	0.25	0.0762	3.88	1.18					
10008	0.25	0.0762	8.4	2.56	(New)				
10013	0.25	0.0762	12.58	3.83					
10404	3.94	1.2	3.88	1.18	20004	0.025	0.008	3.88	1.18
10408	3.94	1.2	8.4	2.56	20008	0.025	0.008	8.4	2.56
10413	3.94	1.2	12.58	3.83	20013	0.025	0.008	12.58	3.83
10804	7.63	2.32	3.88	1.18	20504	5.19	1.58	3.88	1.18
10808	7.63	2.32	8.4	2.56	20508	5.19	1.58	8.4	2.56
10813	7.63	2.32	12.58	3.83	20513	5.19	1.58	12.58	3.83
11104	11.31	3.45	3.88	1.18	21004	10.12	3.08	3.88	1.18
11108	11.31	3.45	8.4	2.56	21008	10.12	3.08	8.4	2.56
11113	11.31	3.45	12.58	3.83	21013	10.12	3.08	12.58	3.83
11504	15	4.57	3.88	1.18	21504	15.06	4.59	3.88	1.18
11508	15	4.57	8.4	2.56	21508	15.06	4.59	8.4	2.56
11513	15	4.57	12.58	3.83	21513	15.06	4.59	12.58	3.83
11904	18.69	5.7	3.88	1.18	22004	20.06	6.11	3.88	1.18
11908	18.69	5.7	8.4	2.56	22008	20.06	6.11	8.4	2.56
11913	18.69	5.7	12.58	3.83	22013	20.06	6.11	12.58	3.83
12304	22.58	6.88	3.88	1.18	22504	24.94	7.6	3.88	1.18
12308	22.39	6.82	8.4	2.56	22508	24.94	7.6	8.4	2.56
12313	22.39	6.82	12.58	3.83	22513	24.94	7.6	12.58	3.83
12604	26.06	7.94	3.88	1.18	23004	29.88	9.11	3.88	1.18
12608	26.06	7.94	8.4	2.56	23008	29.88	9.11	8.4	2.56
12613	26.06	7.94	12.58	3.83	23013	29.88	9.11	12.58	3.83
13004	29.75	9.07	3.88	1.18	23504	34.81	10.61	3.88	1.18
13008	29.75	9.07	8.4	2.56	23508	34.81	10.61	8.4	2.56
13013	29.75	9.07	12.58	3.83	23513	34.81	10.61	12.58	3.83
					24004	39.75	12.12	3.88	1.18
					24008	39.75	12.12	8.4	2.56
					24013	39.75	12.12	12.58	3.83
					24504	44.69	13.62	3.88	1.18
					24508	44.69	13.62	8.4	2.56
					24513	44.69	13.62	12.58	3.83
30207	2.17	0.66	6.75	2.06	30004	0.25	0.0762	3.88	1.18
30210	2.17	0.66	9.75	2.97	30008	0.25	0.0762	8.4	2.56
30211	2.17	0.66	10.75	3.28	30013	0.25	0.0762	12.58	3.83

30212	2.17	0.66	11.75	3.58	30404	3.94	1.2	3.88	1.18
30307	3.17	0.97	6.75	2.06	30408	3.94	1.2	8.4	2.56
30310	3.17	0.97	9.75	2.97	30413	3.94	1.2	12.58	3.83
30311	3.17	0.97	10.75	3.28	30804	7.63	2.32	3.88	1.18
30407	4.17	1.27	6.75	2.06	30808	7.63	2.32	8.4	2.56
30410	4.17	1.27	9.75	2.97	30813	7.63	2.32	12.58	3.83
30411	4.17	1.27	10.75	3.28	31104	11.31	3.45	3.88	1.18
30412	4.17	1.27	11.75	3.58	31108	11.31	3.45	8.4	2.56
30607	6.17	1.88	6.75	2.06	31113	11.31	3.45	12.58	3.83
30610	6.17	1.88	9.75	2.97	31504	15	4.57	3.88	1.18
30611	6.17	1.88	10.75	3.28	31508	15	4.57	8.4	2.56
30612	6.17	1.88	11.75	3.58	31513	15	4.57	12.58	3.83
30807	8.17	2.49	6.75	2.06	31904	18.69	5.7	3.88	1.18
30810	8.17	2.49	9.75	2.97	31908	18.69	5.7	8.4	2.56
30811	8.17	2.49	10.75	3.28	31913	18.69	5.7	12.58	3.83
30812	8.17	2.49	11.75	3.58	32304	22.39	6.88	3.88	1.18
31407	14.17	4.32	6.75	2.06	32308	22.39	6.82	8.4	2.56
31410	14.17	4.32	9.75	2.97	32313	22.39	6.82	12.58	3.83
31411	14.17	4.32	10.75	3.28	32604	26.06	7.94	3.88	1.18
31412	14.17	4.32	11.75	3.58	32608	26.06	7.94	8.4	2.56
					32613	26.06	7.94	12.58	3.83
					33004	29.75	9.07	3.88	1.18
					33008	29.75	9.07	8.4	2.56
					33013	29.75	9.07	12.58	3.83

42204	22.17	6.76	3.5	1.07	40004	0.025	0.008	3.88	1.18
42206	22.17	6.76	6.42	1.96	40008	0.025	0.008	8.4	2.56
42212	22.17	6.76	11.83	3.61	40013	0.025	0.008	12.58	3.83
42306	23.17	7.06	6.42	1.96	40504	5.19	1.58	3.88	1.18
43607	36.08	11	6.92	2.11	40508	5.19	1.58	8.4	2.56
43610	36.08	11	9.92	3.02	40513	5.19	1.58	12.58	3.83
43611	36.08	11	10.92	3.33	41004	10.12	3.08	3.88	1.18
43612	36.08	11	11.83	3.61	41008	10.12	3.08	8.4	2.56
43807	38.08	11.61	6.92	2.11	41013	10.12	3.08	12.58	3.83
43810	38.08	11.61	9.92	3.02	41504	15.06	4.59	3.88	1.18
43811	38.08	11.61	10.92	3.33	41508	15.06	4.59	8.4	2.56
43812	38.08	11.61	11.83	3.61	41513	15.06	4.59	12.58	3.83
44007	40.08	12.22	6.92	2.11	42504	20.06	6.11	3.88	1.18
44010	40.08	12.22	9.92	3.02	42508	24.94	7.6	8.4	2.56
44011	40.08	12.22	10.91	3.33	42513	24.94	7.6	12.58	3.83
44012	40.08	12.22	11.83	3.61	43004	29.88	9.11	3.88	1.18
44207	42.08	12.83	6.92	2.11	43008	29.88	9.11	8.4	2.56
44210	42.08	12.83	9.92	3.02	43013	29.88	9.11	12.58	3.83
44211	42.08	12.83	10.91	3.33	43504	34.81	10.61	3.88	1.18
44212	42.08	12.83	11.83	3.61	43508	34.81	10.61	8.4	2.56
44307	43.08	13.13	6.92	2.11	43513	34.81	10.61	12.58	3.83
44310	43.08	13.13	9.92	3.02	44004	39.75	12.12	3.88	1.18
44311	43.08	13.13	10.92	3.33	44008	39.75	12.12	8.4	2.56

44312	43.08	13.13	11.83	3.61	44013	39.75	12.12	12.58	3.83
44407	44.08	13.43	6.92	2.11	44504	44.69	13.62	3.88	1.18
44410	44.08	13.43	9.92	3.02	44508	44.69	13.62	8.4	2.56
44411	44.08	13.43	10.92	3.33	44513	44.69	13.62	12.58	3.83
44412	44.08	13.43	11.83	3.61					

50101	1.17	0.36	1.17	0.36	50001	0.29	0.09	0.54	0.17
50123	1	0.3	23.17	7.06	50005	0.29	0.09	4.94	1.51
50202	1.67	0.51	2.17	0.66	50010	0.29	0.09	9.88	3.01
50203	1.67	0.51	3.17	0.97	50015	0.29	0.09	14.82	4.52
50205	1.5	0.46	5.17	1.58	50020	0.29	0.09	19.76	6.02
50207	1.67	0.51	7.17	2.18	50025	0.29	0.09	24.7	7.53
50209	1.83	0.56	9.17	2.79	50030	0.29	0.09	29.64	9.03
50213	1.83	0.56	13.17	4.01	50035	0.29	0.09	34.58	10.54
50218	1.83	0.56	18.17	5.54	50040	0.29	0.09	39.52	12.05
50223	1.67	0.51	23.17	7.06	50044	0.29	0.09	44.46	13.55
50401	3.67	1.12	1.17	0.36	50301	2.79	0.85	0.54	0.17
50402	3.67	1.12	2.17	0.66	50305	2.79	0.85	4.94	1.51
50403	3.67	1.12	3.17	0.97	50310	2.79	0.85	9.88	3.01
50405	3.5	1.07	5.17	1.58	50315	2.79	0.85	14.82	4.52
50407	3.58	1.09	7.17	2.18	50320	2.79	0.85	19.76	6.02
50409	3.83	1.17	9.17	2.79	50325	2.79	0.85	24.7	7.53
50501	4.67	1.42	1.17	0.36	50330	2.79	0.85	29.64	9.03
50502	4.67	1.42	2.17	0.66	50335	2.79	0.85	34.58	10.54
50503	4.67	1.42	3.17	0.97	50340	2.79	0.85	44.46	12.05
50505	4.5	1.37	5.17	1.58	50344	2.79	0.85	4.94	13.55
50507	4.58	1.4	7.17	2.18	50501	5.29	1.61	0.54	0.17
50509	4.83	1.47	9.17	2.79	50505	5.29	1.61	9.88	1.51
50513	4.67	1.42	13.17	4.01	50510	5.29	1.61	14.82	3.01
50518	4.67	1.42	18.17	5.54	50515	5.29	1.61	19.76	4.52
50523	4.67	1.42	23.17	7.06	50520	5.29	1.61	24.7	6.02
50701	6.67	2.03	1.17	0.36	50525	5.29	1.61	29.64	7.53
50702	6.67	2.03	2.17	0.66	50530	5.29	1.61	34.58	9.03
50703	6.75	2.06	3.17	0.97	50535	5.29	1.61	39.52	10.54
50705	6.58	2.01	5.17	1.58	50540	5.29	1.61	44.46	12.05
50707	6.58	2.01	7.17	2.18	50544	5.29	1.61	44.46	13.55
50709	6.83	2.08	9.17	2.79	51001	10.29	3.14	0.54	0.17
50823	7.58	2.31	23.17	7.06	51005	10.29	3.14	4.94	1.51
50833	8.25	2.51	33.17	10.11	51010	10.29	3.14	9.88	3.01
50900	8.67	2.64	0.5	0.15	51015	10.29	3.14	14.82	4.52
50901	8.67	2.64	1.17	0.36	51020	10.29	3.14	19.76	6.02
50902	8.67	2.64	2.17	0.66	51025	10.29	3.14	24.7	7.53
50903	8.75	2.67	3.17	0.97	51030	10.29	3.14	29.64	9.03
50904	8.67	2.64	4.17	1.27	51035	10.29	3.14	34.58	10.54
50905	8.67	2.64	5.17	1.58	51040	10.29	3.14	39.52	12.05
50907	8.83	2.69	7.17	2.18	51044	10.29	3.14	44.46	13.55
50909	8.83	2.69	9.17	2.79	51501	15.29	4.66	0.54	0.17
50913	8.67	2.64	13.17	4.01	51505	15.29	4.66	4.94	1.51

50918	8.87	2.64	18.17	5.54
50923	8.67	2.64	23.17	7.06
50927	9.17	2.79	27.17	8.28
50944	9.17	2.79	44.17	13.46
51123	11.17	3.4	23.17	7.06
51138	11.17	3.4	38.17	11.63
51232	12.25	3.73	32.17	9.8
51423	14.08	4.29	23.17	7.06
51501	14.67	4.47	1.17	0.36
51502	14.67	4.47	2.17	0.66
51503	14.75	4.5	3.17	0.97
51505	14.75	4.5	5.17	1.58
51507	14.75	4.5	7.17	2.18
51509	14.75	4.5	9.17	2.79
52323	22.58	6.88	23.17	7.06
52923	29.25	8.91	23.17	7.06

51510	15.29	4.66	9.88	3.01
51515	15.29	4.66	14.82	4.52
51520	15.29	4.66	19.76	6.02
51525	15.29	4.66	24.7	7.53
51530	15.29	4.66	29.64	9.03
51535	15.29	4.66	34.58	10.54
51540	15.29	4.66	39.52	12.05
51544	15.29	4.66	44.46	13.55
52001	20.29	6.18	0.54	0.17
52005	20.29	6.18	4.94	1.51
52010	20.29	6.18	9.88	3.01
52015	20.29	6.18	14.82	4.52
52020	20.29	6.18	19.76	6.02
52025	20.29	6.18	24.7	7.53
52030	20.29	6.18	29.64	9.03
52035	20.29	6.18	34.58	10.54
52040	20.29	6.18	39.52	12.05
52044	20.29	6.18	44.46	13.55
52501	25.29	7.71	0.54	0.17
52505	25.29	7.71	4.94	1.51
52510	25.29	7.71	9.88	3.01
52515	25.29	7.71	14.82	4.52
52520	25.29	7.71	19.76	6.02
52525	25.29	7.71	24.7	7.53
52530	25.29	7.71	29.64	9.03
52535	25.29	7.71	34.58	10.54
52540	25.29	7.71	39.52	12.05
52544	25.29	7.71	44.46	13.55
52801	27.79	8.47	0.54	0.17
52805	27.79	8.47	4.94	1.51
52810	27.79	8.47	9.88	3.01
52815	27.79	8.47	14.82	4.52
52820	27.79	8.47	19.76	6.02
52825	27.79	8.47	24.7	7.53
52830	27.79	8.47	29.64	9.03
52835	27.79	8.47	34.58	10.54
52840	27.79	8.47	39.52	12.05
52844	27.79	8.47	44.46	13.55
53001	29.71	9.06	0.54	0.17
53005	29.71	9.06	4.94	1.51
53010	29.71	9.06	9.88	3.01
53015	29.71	9.06	14.82	4.52
53020	29.71	9.06	19.76	6.02
53025	29.71	9.06	24.7	7.53
53030	29.71	9.06	29.64	9.03
53035	29.71	9.06	34.58	10.54
53040	29.71	9.06	39.52	12.05
53044	29.71	9.06	44.46	13.55

Table 3 File structure for time histories of data collected at the Wind Engineering Research Field Laboratory (WERFL) on 4th Street

Column #	Name	Local Coordinates
1	Internal 1	
2	Internal 2	
3	Calibration Check	
4	13 ft 3 Cup (Master)	
5	Internal Power	
6	Cal Check Power	
7	8 ft North	
8	8 ft West	
9	8 ft Vertical	
10	13 ft North	
11	13 ft West	
12	13 ft Vertical	
13	33 ft North	
14	33 ft West	
15	33 ft Vertical	
16	70 ft North	
17	70 ft West	
18	70 ft Vertical	
19	160 ft North	
20	160 ft West	
21	160 ft Vertical	
22	13 ft Temp	
23	13 ft Rel. Humidity	
24	13 ft Bar	
25	13 ft 3-Cup	
26	13 ft Vane	
27	30 ft Building North	
28	30 ft Building West	
29	30 ft Building Vertical	
30	A_01_G001	[1 - 30 - 4]
31	A_01_G002	[1 - 30 - 8]
32	A_01_G003	[1 - 30 - 13]
33	A_02_G004	[1 - 26 - 4]
34	A_02_G005	[1 - 26 - 8]
35	A_02_G006	[1 - 26 - 13]
36	A_03_G007	[1 - 23 - 4]
37	A_03_G008	[1 - 23 - 8]
38	A_04_G009	[1 - 23 - 13]
39	A_04_G010	[1 - 19 - 4]

40	A_04_G011	[1 - 19 - 8]
41	A_04_G012	[1 - 19 - 13]
42	Board 1 Power	
43	Board 2 Power	
44	Board 3 Power	
45	Board 4 Power	
46	B_05_G013	[1 - 15 - 4]
47	B_05_G014	[1 - 15 - 8]
48	B_05_G015	[1 - 15 - 13]
49	B_06_G016	[1 - 11 - 4]
50	B_06_G017	[1 - 11 - 8]
51	B_06_G018	[1 - 11 - 13]
52	B_07_G019	[1 - 8 - 4]
53	B_07_G020	[1 - 8 - 8]
54	B_07_G021	[1 - 8 - 13]
55	B_08_G022	[1 - 4 - 4]
56	B_08_G023	[1 - 4 - 13]
57	B_08_G024	[1 - 4 - 8]
58	B_09_G025	[1 - 0 - 4]
59	B_09_G026	[1 - 0 - 8]
60	B_09_G027	[1 - 0 - 13]
61	Board 5 Power	
62	Board 6 Power	
63	Board 7 Power	
64	Board 8 Power	
65	Board 9 Power	
66	C_10_G028	[2 - 45 - 4]
67	C_10_G029	[2 - 45 - 8]
68	C_10_G030	[2 - 45 - 13]
69	C_11_G031	[2 - 40 - 4]
70	C_11_G032	[2 - 40 - 8]
71	C_11_G033	[2 - 40 - 13]
72	C_12_G034	[2 - 35 - 4]
73	C_12_G035	[2 - 35 - 8]
74	C_12_G036	[2 - 35 - 13]
75	C_13_G037	[2 - 30 - 4]
76	C_13_G038	[2 - 30 - 8]
77	C_13_G039	[2 - 30 - 13]
78	C_14_G040	[2 - 25 - 4]
79	C_14_G041	[2 - 25 - 8]
80	C_14_G042	[2 - 25 - 13]
81	Board 10 Power	
82	Board 11 Power	

83	Board 12 Power	
84	Board 13 Power	
85	Board 14 Power	
86	D_15_G043	[2 - 20 - 4]
87	D_15_G044	[2 - 20 - 8]
88	D_15_G045	[2 - 20 - 13]
89	D_16_G046	[2 - 15 - 4]
90	D_16_G047	[2 - 15 - 8]
91	D_16_G048	[2 - 15 - 13]
92	D_17_G049	[2 - 10 - 4]
93	D_17_G050	[2 - 10 - 8]
94	D_17_G051	[2 - 10 - 13]
95	D_18_G052	[2 - 5 - 4]
96	D_18_G053	[2 - 5 - 8]
97	D_18_G054	[2 - 5 - 13]
98	D_19_G055	[2 - 0 - 4]
99	D_19_G056	[2 - 0 - 8]
100	D_19_G057	[2 - 0 - 13]
101	Board 15 Power	
102	Board 16 Power	
103	Board 17 Power	
104	Board 18 Power	
105	Board 19 Power	
106	E_20_G058	[3 - 30 - 4]
107	E_20_G059	[3 - 30 - 8]
108	E_20_G060	[3 - 30 - 13]
109	E_21_G061	[3 - 26 - 4]
110	E_21_G062	[3 - 26 - 8]
111	E_21_G063	[3 - 26 - 13]
112	E_22_G064	[3 - 23 - 4]
113	E_22_G065	[3 - 23 - 8]
114	E_22_G066	[3 - 23 - 13]
115	E_23_G067	[3 - 19 - 4]
116	E_23_G068	[3 - 19 - 8]
117	E_23_G069	[3 - 19 - 13]
118	Board 20 Power	
119	Board 21 Power	
120	Board 22 Power	
121	Board 23 Power	
122	F_24_G070	[3 - 15 - 4]
123	F_24_G071	[3 - 15 - 8]
124	F_24_G072	[3 - 15 - 13]
125	F_25_G073	[3 - 11 - 4]

126	F_25_G074	[3 - 11 - 8]
127	F_25_G075	[3 - 11 - 13]
128	F_26_G076	[3 - 8 - 4]
129	F_26_G077	[3 - 8 - 8]
130	F_26_G078	[3 - 8 - 13]
131	F_27_G079	[3 - 4 - 4]
132	F_27_G080	[3 - 4 - 8]
133	F_27_G081	[3 - 4 - 13]
134	F_28_G082	[3 - 0 - 4]
135	F_28_G083	[3 - 0 - 8]
136	F_28_G084	[3 - 0 - 13]
137	Board 24 Power	
138	Board 25 Power	
139	Board 26 Power	
140	Board 27 Power	
141	Board 28 Power	
142	G_29_085	[4 - 45 - 4]
143	G_29_086	[4 - 45 - 8]
144	G_29_087	[4 - 45 - 13]
145	G_30_088	[4 - 40 - 4]
146	G_30_089	[4 - 40 - 8]
147	G_30_090	[4 - 40 - 13]
148	G_31_091	[4 - 35 - 4]
149	G_31_092	[4 - 35 - 8]
150	G_31_093	[4 - 35 - 13]
151	G_32_094	[4 - 30 - 4]
152	G_32_095	[4 - 30 - 8]
153	G_32_096	[4 - 30 - 13]
154	G_33_097	[4 - 25 - 4]
155	G_33_098	[4 - 25 - 8]
156	G_33_099	[4 - 25 - 13]
157	Board 29 Power	
158	Board 30 Power	
159	Board 31 Power	
160	Board 32 Power	
161	Board 33 Power	
162	H_34_G100	[4 - 20 - 4]
163	H_34_G101	[4 - 20 - 8]
164	H_34_G102	[4 - 20 - 13]
165	H_35_G103	[4 - 15 - 4]
166	H_35_G104	[4 - 15 - 8]
167	H_35_G105	[4 - 15 - 13]
168	H_36_G106	[4 - 10 - 4]

169	H_36_G107	[4 - 10 - 8]
170	H_36_G108	[4 - 10 - 13]
171	H_37_G109	[4 - 5 - 4]
172	H_37_G110	[4 - 5 - 8]
173	H_37_G111	[4 - 5 - 13]
174	H_38_G112	[4 - 0 - 4]
175	H_38_G113	[4 - 0 - 8]
176	H_38_G114	[4 - 0 - 13]
177	Board 34 Power	
178	Board 35 Power	
179	Board 36 Power	
180	Board 37 Power	
181	Board 38 Power	
182	I_39_G115	[5 - 0 - 45]
183	I_39_G116	[5 - 3 - 45]
184	I_39_G117	[5 - 5 - 45]
185	I_39_G118	[5 - 10 - 45]
186	I_41_G124	[5 - 0 - 40]
187	I_41_G125	[5 - 3 - 40]
188	I_41_G126	[5 - 5 - 40]
189	I_41_G127	[5 - 10 - 40]
190	I_43_G133	[5 - 0 - 35]
191	I_43_G134	[5 - 3 - 35]
192	I_43_G135	[5 - 5 - 35]
193	I_43_G136	[5 - 10 - 35]
194	I_45_G142	[5 - 0 - 30]
195	I_45_G143	[5 - 3 - 30]
196	I_45_G144	[5 - 5 - 30]
197	I_45_G145	[5 - 10 - 30]
198	I_47_G151	[5 - 0 - 25]
199	I_47_G152	[5 - 3 - 25]
200	I_47_G153	[5 - 5 - 25]
201	I_47_G154	[5 - 10 - 25]
202	Board 39 Power	
203	Board 41 Power	
204	Board 43 Power	
205	Board 45 Power	
206	Board 47 Power	
207	J_40_G119	[5 - 15 - 45]
208	J_40_G120	[5 - 20 - 45]
209	J_40_G121	[5 - 25 - 45]
210	J_40_G122	[5 - 28 - 45]
211	J_40_G123	[5 - 30 - 45]

212	J_42_G128	[5 - 15 - 40]
213	J_42_G129	[5 - 20 - 40]
214	J_42_G130	[5 - 25 - 40]
215	J_42_G131	[5 - 28 - 40]
216	J_42_G132	[5 - 30 - 40]
217	J_44_G137	[5 - 15 - 35]
218	J_44_G138	[5 - 20 - 35]
219	J_44_G139	[5 - 25 - 35]
220	J_44_G140	[5 - 28 - 35]
221	J_44_G141	[5 - 30 - 35]
222	J_46_G146	[5 - 15 - 30]
223	J_46_G147	[5 - 20 - 30]
224	J_46_G148	[5 - 25 - 30]
225	J_46_G149	[5 - 28 - 30]
226	J_46_G150	[5 - 30 - 30]
227	J_48_G155	[5 - 15 - 25]
228	J_48_G156	[5 - 20 - 25]
229	J_48_G157	[5 - 25 - 25]
230	J_48_G158	[5 - 28 - 25]
231	J_48_G159	[5 - 30 - 25]
232	Board 40 Power	
233	Board 42 Power	
234	Board 44 Power	
235	Board 46 Power	
236	Board 48 Power	
237	K_50_G164	[5 - 15 - 20]
238	K_50_G165	[5 - 20 - 20]
239	K_50_G166	[5 - 25 - 20]
240	K_50_G167	[5 - 28 - 20]
241	K_50_G168	[5 - 30 - 20]
242	K_52_G173	[5 - 15 - 15]
243	K_52_G174	[5 - 20 - 15]
244	K_52_G175	[5 - 25 - 15]
245	K_52_G176	[5 - 28 - 15]
246	K_52_G177	[5 - 30 - 15]
247	K_54_G182	[5 - 15 - 10]
248	K_54_G183	[5 - 20 - 10]
249	K_54_G184	[5 - 25 - 10]
250	K_54_G185	[5 - 28 - 10]
251	K_54_G186	[5 - 30 - 10]
252	K_56_G191	[5 - 15 - 5]
253	K_56_G192	[5 - 20 - 5]
254	K_56_G193	[5 - 25 - 5]

255	K_56_G194	[5 - 28 - 5]
256	K_56_G195	[5 - 30 - 5]
257	K_58_G200	[5 - 15 - 0]
258	K_58_G201	[5 - 20 - 0]
259	K_58_G202	[5 - 25 - 0]
260	K_58_G203	[5 - 28 - 0]
261	K_58_G204	[5 - 30 - 0]
262	Board 50 Power	
263	Board 52 Power	
264	Board 54 Power	
265	Board 56 Power	
266	Board 58 Power	
267	L_49_G160	[5 - 0 - 20]
268	L_49_G161	[5 - 3 - 20]
269	L_49_G162	[5 - 5 - 20]
270	L_49_G163	[5 - 10 - 20]
271	L_51_G169	[5 - 0 - 15]
272	L_51_G170	[5 - 3 - 15]
273	L_51_G171	[5 - 5 - 15]
274	L_51_G172	[5 - 10 - 15]
275	L_53_G178	[5 - 0 - 10]
276	L_53_G179	[5 - 3 - 10]
277	L_53_G180	[5 - 5 - 10]
278	L_53_G181	[5 - 10 - 10]
279	L_55_G187	[5 - 0 - 5]
280	L_55_G188	[5 - 3 - 5]
281	L_55_G189	[5 - 5 - 5]
282	L_57_G190	[5 - 10 - 5]
283	L_57_G196	[5 - 0 - 0]
284	L_57_G197	[5 - 3 - 0]
285	L_57_G198	[5 - 5 - 0]
286	L_57_G199	[5 - 10 - 0]
287	Board 49 Power	
288	Board 51 Power	
289	Board 53 Power	
290	Board 55 Power	
291	Board 57 Power	
292	8 ft Wind Speed	
293	8 ft Wind Direction	
294	8 ft Along Wind Comp.	
295	8 ft Cross Wind Comp.	
296	13 ft Wind Speed	
297	13 ft Wind Direction	

298	13 ft Along Wind Comp.
299	13 ft Cross Wind Comp.
300	33 ft Wind Speed
301	33 ft Wind Direction
302	33 ft Along Wind Comp.
303	33 ft Cross Wind Comp.
304	70 ft Wind Speed
305	70 ft Wind Direction
306	70 ft Along Wind Comp.
307	70 ft Cross Wind Comp.
308	160 ft Wind Speed
309	160 ft Wind Direction
310	160 ft Along Wind Comp.
311	160 ft Cross Wind Comp.
312	13 ft (3cup/Vane) Along Wind Component
313	13 ft (3cup/Vane) Cross Wind Component
314	30 ft (Sonic) Wind Speed
315	30 ft (Sonic) Wind Direction
316	30 ft (Sonic) Along Wind Component
317	30 ft (Sonic) Cross Wind Component

Table 4 Summary statistics of wind flow characteristics for selected records from WERFL.

Mode Number	Run Name	Run Date	Building position	Angle of Attack	Wind Azimuth Angle	Mean Wind Speed, mph
1001.01a	276	1/9/2003	270	7.7731018	277.7731	18.28
1001.01a	277	1/9/2003	270	6.3760991	276.3761	19.46
1001.01a	279	1/9/2003	270	9.6672058	279.66721	18.13
1001.02a	620	2/9/2003	270	6.2192988	276.2193	25.18
1001.02a	623	2/9/2003	270	6.3705139	276.37051	25.4
1001.02a	958	2/27/2003	270	7.0049129	277.00491	21.8
1001.02a	966	2/27/2003	270	6.6520081	276.65201	17.97
1001.02a	1851	4/4/2003	285	352.65479	277.65479	16.74
1001.02a	1912	4/6/2003	285	351.7236	276.7236	19.97
1001.02a	1920	4/6/2003	285	354.81601	279.81601	21.04
1001.02a	1926	4/6/2003	285	352.8945	277.8945	15.37
1001.02a	2071	4/16/2003	285	354.77051	279.77051	29.93
1001.02a	2072	4/16/2003	285	352.74301	277.74301	28.56
1001.02a	2190	4/19/2003	285	352.16959	277.16959	19.02
1001.02a	2292	4/24/2003	195	81.648277	276.64828	16.71
1001.02a	2637	5/10/2003	195	83.331207	278.33121	15.99

Table 5 Malfunctioning instruments for each run.

Mode	Record	Malfunctioning instrument
1001.01	276	
	277	
	279	Tap 52000
1001.02	620	70’ WS & Dir
	623	
	958	70’ WS & Dir Tap 42004, 42008, 42013, 41504,41508, 41513,41004, 41008, 41013, 40504, 4-508, 40513, 40004, 40008, 40013
	966	70’ WS & Dir Tap 42004, 42008, 42013, 41504,41508, 41513,41004, 41008, 41013, 40504, 4-508, 40513, 40004, 40008, 40013
	1851	
	1912	70’ WS & Dir
	1920	70’ WS & Dir
	1926	
	2071	
	2072	70’ WS & Dir
	2190	70’ WS & Dir
	2292	70’ WS & Dir
	2637	70’ WS & Dir

7. Figures

Figure 1 Roof damage from Hurricane Ike

Figure 2 Orientation of meteorological tower and the test building (North is towards the top of figure and the 160 ft tower has an azimuth angle of approximately 280° relative to the center of the WERFL building location).

Figure 3 Meteorological tower located at the Wind Engineering Research Field Laboratory (WERFL) on 4th Street.

Figure 4 Flat roof configuration of test structure corresponding to the data provided.

Figure 5 Organization of instruments and tubing for roof pressure measurements on the test structure.

Figure 6 Organization of instruments and tubing for wall pressure measurements on the test structure.

Figure 7 New pressure tap installation used for Mode 1001 data.

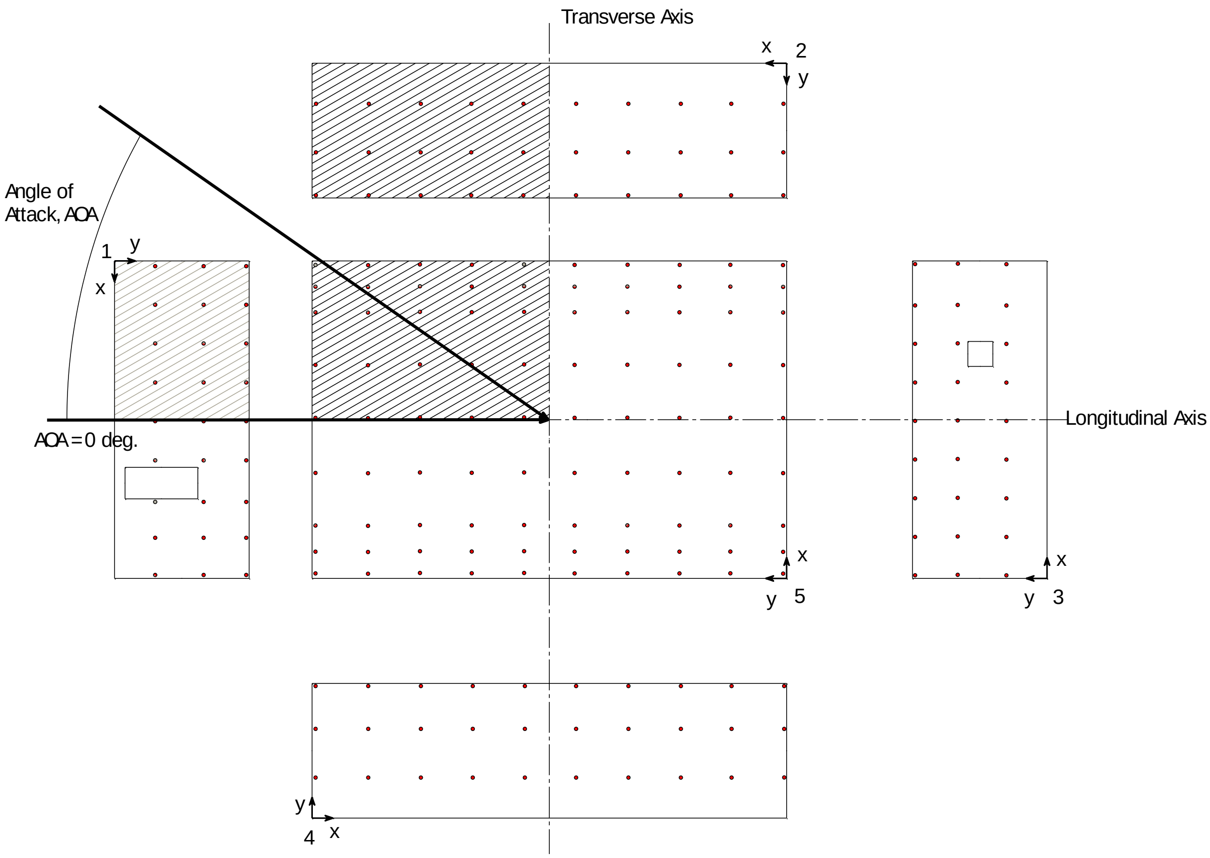

Figure 8 Tap locations on the test structure.

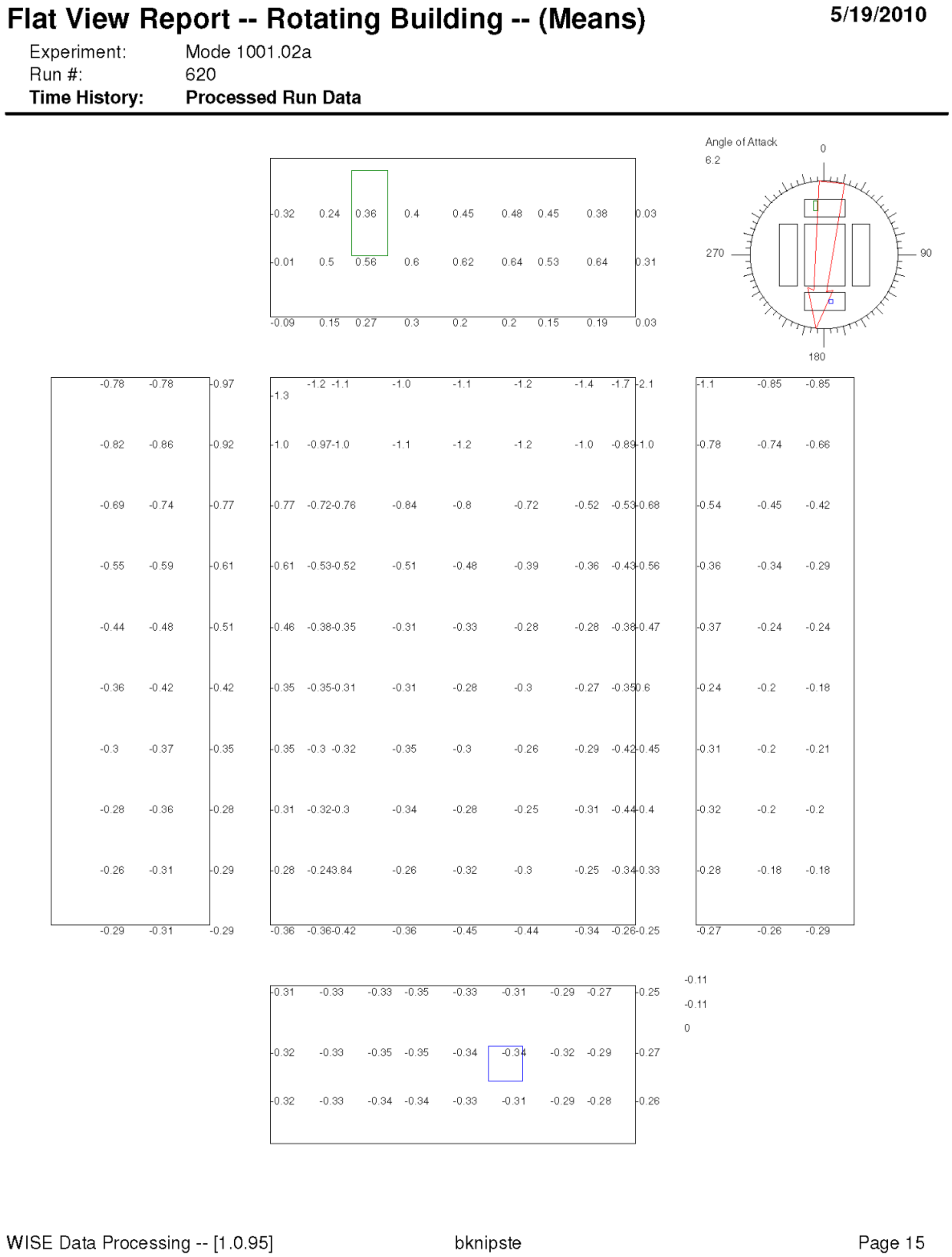

Figure 9 Plot of mean Pressure coefficients for record 620.

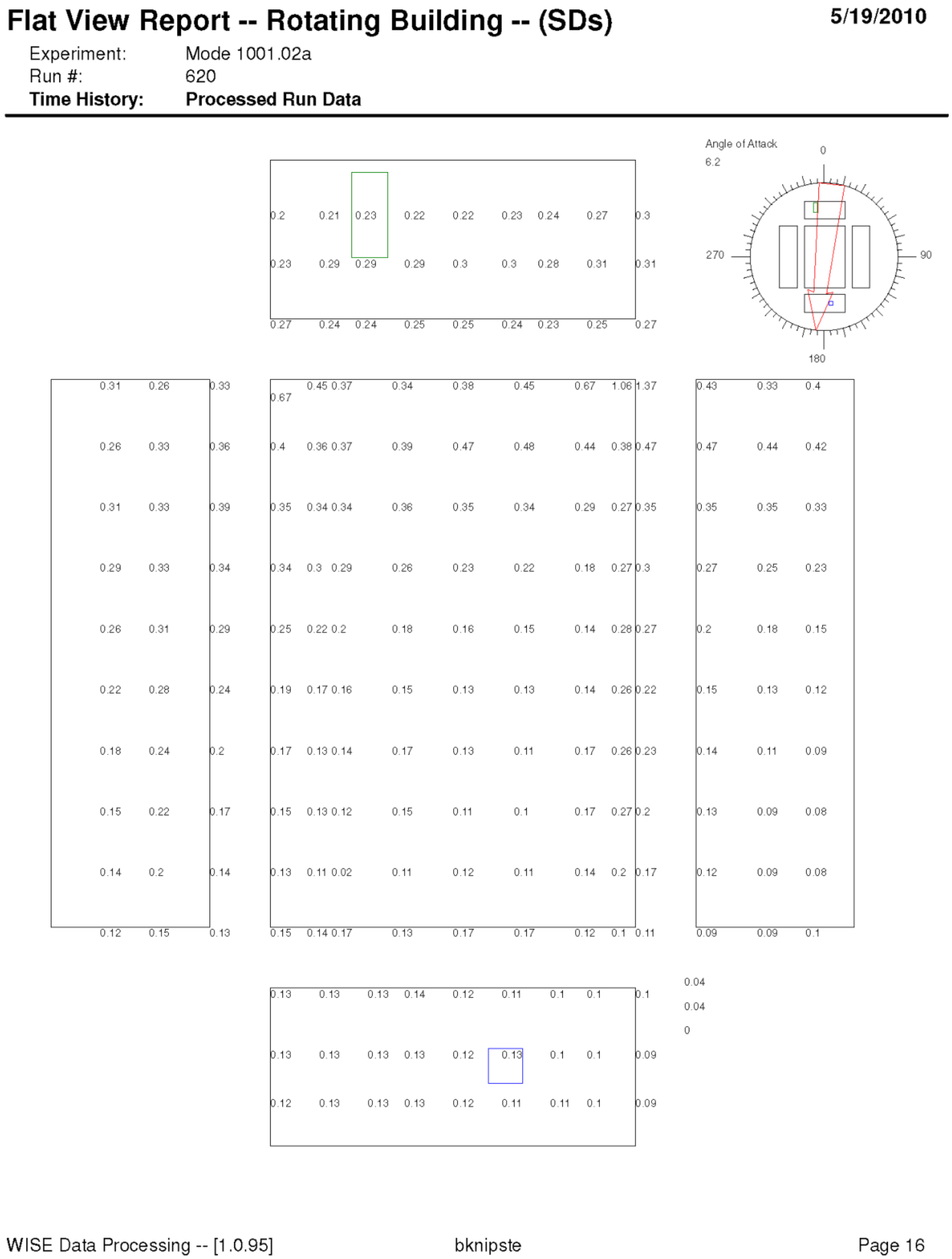

Figure 10 Plot of standard deviation pressure coefficients for record 620.