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THE AYLESBURY EXPERIMENT. COMPARISON OF MODEL AND FULL-SCALE TESTS

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Summary

The full-scale experiments carried out in the years 1972–1974 by the Building Research Establishment on a specially designed test house in Aylesbury, England, are a unique investigation as regards wind pressures on low-rise buildings. The experiments have been followed up by wind-tunnel investigations all around the world. The wind-tunnel test results are collected at the Building Research Establishment to constitute a comprehensive data base suitable for the comparisons between full-scale and model-scale wind pressures on low-rise buildings, and for the study of differences between the various experimental techniques in current use and the uncertainties inherent in measurement and modelling.

The paper describes the Aylesbury experiment carried out at the Danish Maritime Institute. The simulation of the standard rural terrain and the Aylesbury terrain was achieved by means of the spire-roughness technique. The pressure measurements obtained have been compared both with the full-scale data, and with wind-tunnel data from the University of Oxford in England and the University of Western Ontario in Canada. The comparisons include mean values, standard deviations, 2-s gusts and pressure spectra.

There are some unexplained differences between pressures measured under apparently similar wind conditions in different full-scale runs, which inevitably limit the agreement that can be achieved between full-scale and wind-tunnel tests. The correlation between the results from the above-mentioned three wind-tunnel laboratories is much better than the correlation between the wind-tunnel test results and the results from full-scale measurements.

Nomenclature

C_p	pressure coefficient
F	frequency
L	model length scale
p	pressure on the building
p_0	ambient static pressure
p_m	pressure at the reference pressure manhole
q_{10}	mean velocity pressure at the meteorological mast at 10 m height
S	power spectral density
T	time scale
VAR	variance
z_0	roughness parameter.

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1. Introduction

At present, the only way of examining the reliability of wind-tunnel test results is to compare with full-scale experiments. The full-scale data obtained from the Aylesbury experiment, carried out by the Building Research Establishment, are unique with respect to wind pressures on low-rise buildings.

The Aylesbury experiment was carried out in the years 1972—1974 on a specially designed low-rise experimental building in Aylesbury, England (see ref. 1). Four 1/100 scale models of the building are at present being circulated for testing in wind-tunnel laboratories all around the world (see ref. 2). The wind-tunnel test results are collected at the Building Research Establishment to constitute a comprehensive data base suitable for the comparisons between full-scale and model-scale wind pressures on low-rise buildings. The differences between the various experimental techniques in current use and the uncertainties inherent in measurement and modelling are examined by comparing model-scale results from the wind-tunnel laboratories participating in the experiment. The results from some of the laboratories are given in refs. 3—10.

2. The full-scale measurements

The large number of full-scale data in the Aylesbury experiment are briefly summarized in this section.

2.1. Experimental building and test site

The experimental building and the test site are shown in Fig. 1. The building had a ground plane dimension of 7 × 13.3 m and a height to the eaves of 5 m. The pitch of the roof was adjustable from 5 to 45°.

Based on a description of the test site (see Fig. 2) it is judged that the trees and hedges around the test site had a significant influence on the wind conditions at the experimental building. The most important wind directions in the experiment were in the sector from South to West.

2.2. Wind velocity measurements

Wind velocity measurements at heights of 3, 5 and 10 m above ground level were made using standard cup anemometers mounted on a 10 m high meteorological mast located about 30 m to the southeast of the building (see Fig. 2). The wind direction was measured at the top of the mast.

The results from the full-scale wind velocity measurements are target data for the simulation of the "Aylesbury boundary layer" in the wind tunnel (see Section 4).

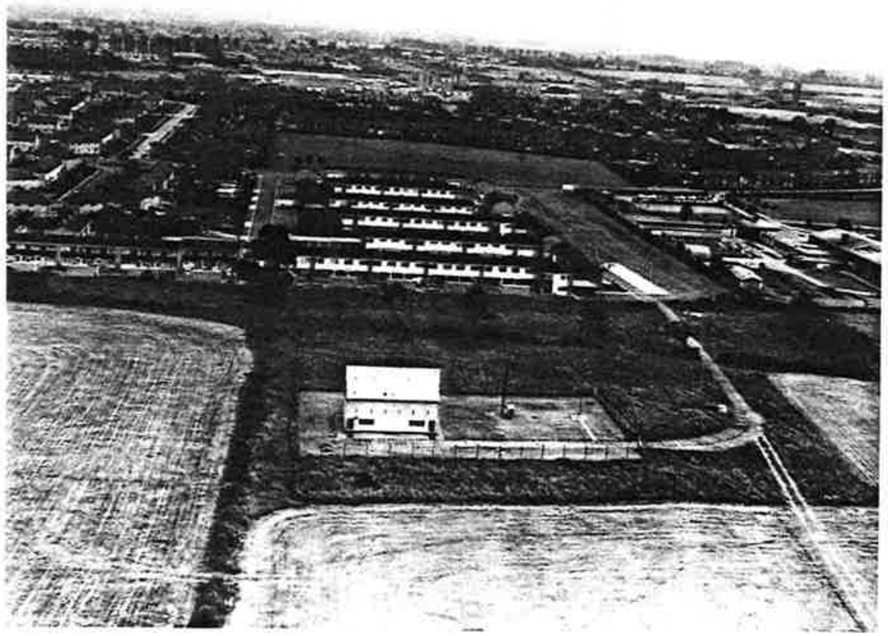


Fig. 1. Aylesbury site looking East.

2.3. Pressure measurements

As indicated by several authors (see refs. 3—10), there are some unexplained differences between pressures measured under similar full-scale conditions. For instance runs A7 and A32, for which the building had a 22.5° roof pitch and a wind direction of 263° relative to the N—S building axis, show considerable scatter when compared (see, e.g., refs. 3, 8 and 9). The mean wind velocities in the two runs were, respectively, 11.9 and 14.3 $m\ s^{-1}$ at 10 m height.

Some of the full-scale data are obviously subject to errors originating from reference pressure shifts, gain errors or simply a transducer failure. These failures have been summarized by Vickery [3], where a selection of reliable full-scale data has been made on the basis of comparisons between similar full-scale runs as well as a comparison between full-scale and wind-tunnel test results as regards peak and RMS pressures. According to Vickery [3] the reliable full-scale pressures (mean pressures excluded) are almost identical to the pressures included in the full-scale analysis presented by Eaton and Mayne [1].

These last pressure locations are included in the comparisons throughout this paper. The pressure transducer positions are defined in Fig. 3.

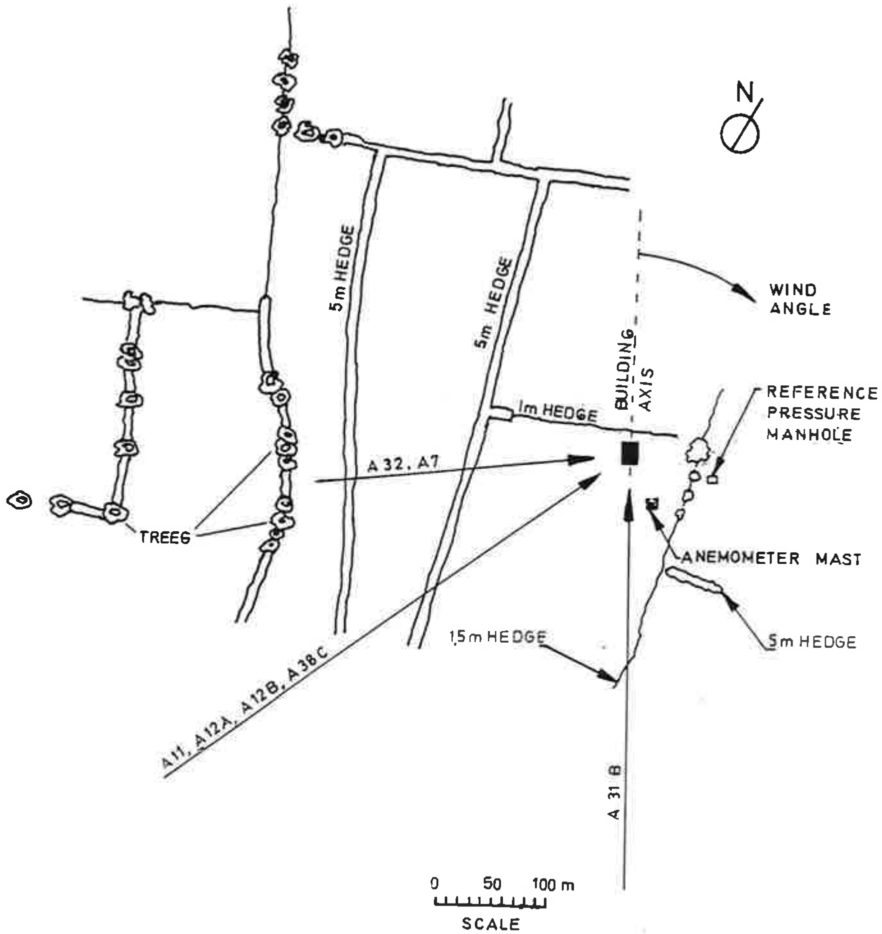


Fig. 2. Plan of Aylesbury site (from refs. 1 and 4).

3. Wind tunnel tests at the Danish Maritime Institute

3.1. Description of the wind tunnel and the instrumentation

The wind tunnel

The wind tunnel has a working section of principal dimensions: length, 20.8 m; width, 2.6 m; height, 1.8 m (adjustable from 1.8 to 2.3 m). Further information concerning the wind tunnel and the instrumentation is included in ref. 11.

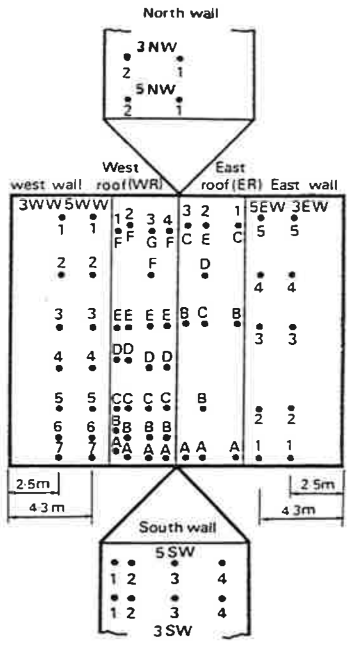


Fig. 3. Aylesbury building pressure transducer positions (from ref. 1).

Pressure measuring equipment

A standard scanivalve system with two Setra transducers (type 237) is used for the pressure measurements on the building. Each pressure tap location is sampled at a scanning rate of 500 Hz by the computer. The signals are low-pass filtered by an analog sixth-order Butterworth filter with the following specifications.

(a) Cut-off frequency (−3 dB), 200 Hz;
(b) Frequency for 99% passage, 140 Hz;
(c) Frequency for 1% passage, 400 Hz.

These filter characteristics seemed suitable in comparison with the applied pressure tubing, which is adequate up to about 200 Hz.

3.2. The Aylesbury 1/100 scale model

One of the four circulating models was used in the investigation. To be able to measure at the 72 pressure locations on the model building without changing tubing connections, the enclosed 50 tubes were supplemented with an extra 22 which were manufactured at the Institute. Each of these tubes was carefully calibrated to ensure that the transfer function was the same as the transfer function of the enclosed tubes.

It should be mentioned that the model and the enclosed tubes had two disadvantages.

(a) It was very difficult to get a satisfactory sealed connection between the walls and the roof along the eaves since no screw holes were available for fastening.

(b) Some of the enclosed tubes did not fit the brass tubes on the building sufficiently well to form a seal, probably due to the several changes of tubing connections at the participating wind-tunnel laboratories.

However, it is judged that these shortcomings do not significantly reduce the overall usefulness of the experiment, but the results from a few of the pressure measuring positions have had to be left out of the analysis.

Scaling

The linear scaling of the model is L = 1:100. Since the velocity scale was chosen as unity, the time scale is T = 1:100, making a 1024 s full-scale observation period equal to 10.24 s in model scale. This scaling is recommended in the experiment, since the pressures measured automatically equal the full-scale pressures provided the density of the air is the same.

3.3. Experimental programme and analysis

The Institute did not have sufficient funding to carry out the entire experimental programme according to ref. 2. However, in agreement with the European Coordinator, Dr. N.J. Cook, Building Research Establishment, the shortened experimental programme shown in Table 1 was accomplished.

TABLE 1

Experimental programme. R7 standard rural simulation, the remainder runs Aylesbury simulation

Run code	Direction of true North (deg.)	Direction of North axis of building (deg.)	Roof slope (deg.)	Mean wind speed at mast, 10 m height, full-scale experiment ($m\ s^{-1}$)
R7	235	263	22.5	11.9
A7	235	263	22.5	11.9
A11	205	233	22.5	9.42
A12A (A38B)	205	233	10	8.44
A12B (A38A)	205	233	15	8.37
A38C	205	233	5	11.13
A31B	150	178	22.5	13.28

Pressure analysis

As suggested in IAWE Aylesbury Collaborative Experiment 4th draft [2], Advanced Measurements, the following on-line analysis was performed (same numbering as in ref. 2).

(F) Mean, RMS, maximum and minimum pressures from 16 observation periods equivalent to 1024 s full-scale were determined before as well as after running block-averaging was performed over 1, 2, 4, 8, 16 and 32 s periods full-scale.

The above analysis was done by a specially designed assembler program reducing the time of calculation by a factor of approximately 5 in comparison to an ordinary program written in FORTRAN code.

The tunnel time required for one run was by this means reduced from 25 to 12 h.

(G) The probability distribution function of pressures before and after running block-averaging over the periods given in item F was estimated for the tappings WR1A, WR1E, WR1F, WR3A, WR4A, ER1A, ER1B, ER2A, ER2B, 3EW1, 3EW3, 3SW1, 3SW4, 3WW3, 3WW7, 5WW3 and 5WW7 (cf. Fig. 3).

(H) Pressure spectra were determined for a total of 36 tappings, i.e., half of the total amount of 72 tappings on the building. The tappings were as mentioned in item G above plus WR1B, WR1C, WR1D, WR2A, WR2B, WR2C, WR2D, WR2E, WR2F, 3EW2, 3EW4, 3EW5, 5EW1, 5EW2, 5EW3, 5EW4, 5EW5, 3SW2 and 3SW3 (cf. Fig. 3).

The pressure spectra were calculated by a Nicolet Scientific Corporation 660A FFT analyser, which was completely controlled by the computer used for data acquisition. The resultant spectra were transmitted to the computer for storage.

The resolution in the FFT analyser made it possible to determine the pressure spectra between 0.0025 and 2 Hz in full scale.

4. Wind velocity characteristics

The spire-roughness technique has been used to simulate the incoming wind to the scale of 1:100. Spires in the flow processing section were combined with 1 in. blocks evenly distributed in the working section (see Fig. 4). Additionally, a few relatively large roughness elements were placed randomly, but with decreasing density in the flow direction. The turbulent length scale of the boundary-layer flow was thereby considerably improved.

4.1. Standard rural simulation

No hedges are included in the standard rural simulation. Table 2 compares the roughness parameter, z_0, as well as the longitudinal turbulence intensity in full and model scales, respectively. The spectral distribution of the wind velocity at 10 m is illustrated in Fig. 5. It is concluded that a satisfactory simulation of standard rural terrain of scale 1:100 was achieved in the wind tunnel.

4.2. Aylesbury simulation

The 1 and 5 m high hedges at Aylesbury were simulated by means of bent metal screens (see Fig. 4). The porosity of the screens was 42%.

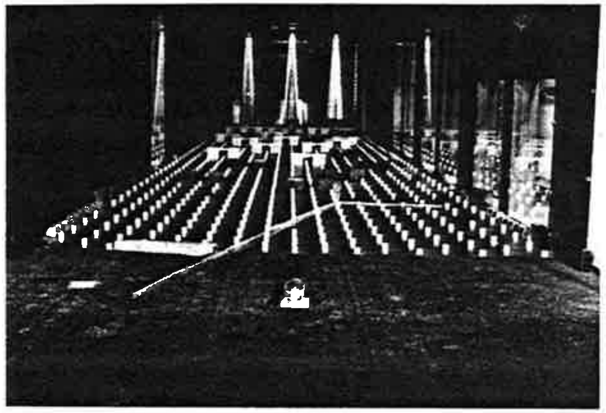


Fig. 4. Aylesbury simulation in the wind tunnel (run A31B).

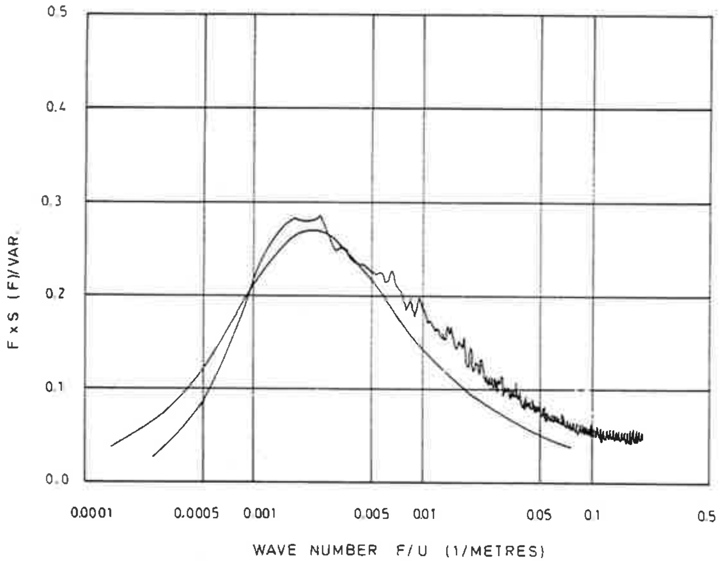


Fig. 5. Wind velocity spectrum at 10 m in standard rural simulation. Curve is target spectrum.

TABLE 2

Main characteristics (full-scale values) — standard rural simulation

	Target	Wind tunnel
Roughness parameter, z_0	0.05 m	0.03 m
Longitudinal turbulence intensity at 10 m	0.21	0.17

Obtaining an exact correspondence to full-scale velocities at 3, 5 and 10 m height is an extremely extensive task. It was decided to include the hedges in the simulation, and subsequently accept the wind characteristics obtained at the meteorological mast. The characteristics achieved could have been slightly improved by modifying the terrain roughness in the neighbourhood of the mast and building. However, the agreement between the model- and full-scale velocity characteristics shown in Tables 3 and 4 is judged to be satisfactory in order to justify a comparison of pressures on the building.

The spectra of the along-wind velocity component at 10 m in the Aylesbury simulations are approximately similar to the spectrum for standard rural simulation given in Fig. 5. This indicates a considerably lower length scale of the simulated longitudinal turbulence compared to the full-scale data as given in ref. 2. In fact, when large geometric scales, e.g., 1:100 are used in a boundary-layer wind tunnel with principal dimensions the same as those at DMI, it is difficult to obtain satisfactory length scales in the simulated wind. However, the importance of the length scale distortion has yet to be clarified.

TABLE 3

Mean wind velocity characteristics — Aylesbury simulation (m s^{-1})

Run code	10 m height		5 m height		3 m height	
	Full scale	Model scale	Full scale	Model scale	Full scale	Model scale
A7	11.9	11.9	9.7	11.0	8.1	9.5
A11	9.4	9.4	—	8.7	8.3	7.8
A12A	8.4	8.4	—	7.8	7.4	7.0
A12B	8.4	8.4	—	7.8	7.3	7.0
A38C	11.1	11.1	9.4	10.2	8.2	9.2
A31B	13.3	13.3	11.8	11.7	10.8	10.3

TABLE 4

Turbulence intensities — Aylesbury simulation

Run code	10 m height		5 m height		3 m height	
	Full scale	Model scale	Full scale	Model scale	Full scale	Model scale
A7	0.22	0.22	0.31	0.23	0.24	0.25
A11	0.19	0.19	—	0.20	0.22	0.23
A12A	0.19	0.19	—	0.20	0.27	0.23
A12B	0.19	0.19	—	0.20	0.24	0.23
A38C	0.19	0.19	0.27	0.20	0.30	0.23
A31B	0.19	0.19	0.22	0.21	0.23	0.24

5. Comparative studies of the pressure measurements

Up to the present, the Aylesbury experiment has been carried out at several wind-tunnel laboratories all around the world. However, the test programs have not been equally comprehensive.

The results obtained at the Danish Maritime Institute have been compared with the full-scale data, as well as with wind-tunnel data from the University of Oxford [4—6] and the University of Western Ontario [3]. These laboratories were selected, since the experimental data were the only available at DMI.

The geometric scaling ratio in the tests at the three laboratories is listed in Table 5.

TABLE 5

Geometric scaling ratio in the selected experimental tests used for comparative studies

Laboratory	Geometric scaling ratio
University of Oxford [4—6][a]	1/75
University of Western Ontario [3]	1/100
Danish Maritime Institute	1/100

[a]This model was not one of the four circulating ones.

5.1. Definitions — reference pressures

The pressures, p, measured during the experiment at DMI were referenced to the ambient static pressure, p_0, at the wind tunnel wall 0.9 m above the floor in the same cross-section as that where the model was positioned. The pressures were converted to coefficient form, C_p, by normalizing with the mean velocity pressure, q_{10}, at the meteorological mast at 10 m height

$$C_p = (p - p_0)/q_{10}$$

Meteorological mast

The mean velocity pressure, q_{10}, as well as the static pressure, p_s, at the meteorological mast at 10 m height were measured by means of a pitot tube. The difference between the static pressure, p_s, and the ambient static pressure, p_0, is listed below in Table 6. It is about −0.13 times the velocity pressure, q_{10}.

Pressure manhole

It should be noted, that the full-scale pressures were referenced to the static pressure at the manhole shown in Fig. 2. The difference in the wind-tunnel test between the ambient static pressure, p_0, and the pressure at the manhole, p_m, has been determined to be between −0.15 and −0.23 times the velocity pressure, q_{10}, at the meteorological mast (see Table 6). The

TABLE 6

Wind tunnel test results: difference between the ambient static pressure and the static pressures at the reference manhole, p_m, and at the meteorological mast, p_s, respectively

Run code	$(p_m - p_0)/q_{10}$	$(p_s - p_0)/q_{10}$
R7	−0.23	—
A7	−0.18	—
A11	−0.18	−0.14
A12A (A38B)	−0.16	−0.12
A12B (A38A)	−0.15	−0.12
A38C	−0.15	−0.13
A31B	0.34	−0.15

great deviation from this value in run A31B is due to the nearby upstream position of 5 m high trees.

The static pressure at the manhole is slightly below the static pressure at the meteorological mast. The difference is found to be between 0.02 and 0.04 times the velocity pressure, q_{10}. This is in reasonable agreement with the full-scale value of 0.08 mentioned in ref. 1.

It is quite important to take the differences in static pressures in a full/model scale correlation into account. However, the model-scale pressure coefficients listed in this paper are referenced to the ambient static pressure, p_0, since the influence on that reference from the experimental building, the hedges, etc., is insignificant. Also, this is the normal procedure at the Institute when measuring pressures on buildings.

5.2. Comparative studies — full/model scale

Most of the comparative studies made concern the mean pressures as well as the fluctuating pressures described by the standard deviation and the 2-s gust. The spectral distribution of the pressures has been considered at some selected locations.

Mean, standard deviation and 2-s gusts

Figures 6—9 show a comparison of the mean values and standard deviations of pressures on the building in full-scale runs A7 and A32. Both runs are equivalent to wind-tunnel run A7. However, since the full-scale wind velocities in the two runs are different (see Section 2.3) a comparison concerning the 2-s gusts is only relevant for run A7. This has been done in Fig. 10.

It should be emphasized that the full-scale 2-s gust values listed by Eaton and Mayne [1] use the 2-s velocity pressure at the meteorological mast as reference. For comparison, they have been modified to a reference of the mean velocity pressure, q_{10}, at the meteorological mast at 10 m height.

The linear regression line based upon a least-squares fit with the wind-tunnel test results as the dependent variable is shown in the figures. Table

7 summarizes the slope, the intercept (cf. Section 5.3, item B) and the correlation coefficient of the regression lines for all the runs analysed. They are compared with values estimated at the University of Oxford [4–6] and at the University of Western Ontario [3].

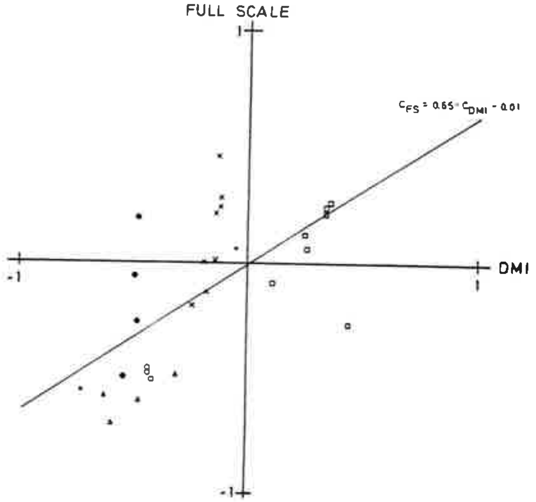


Fig. 6. Comparison of mean pressure coefficients, C_p, in run A7. (□) West wall, (○) East wall, (△) South wall, (+) North wall, (×) West roof, (•) East roof.

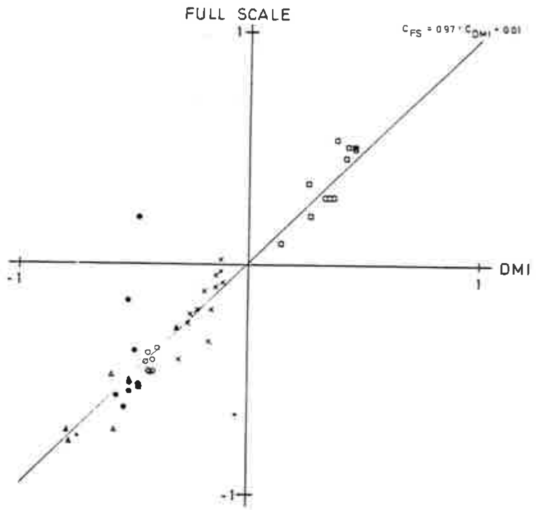
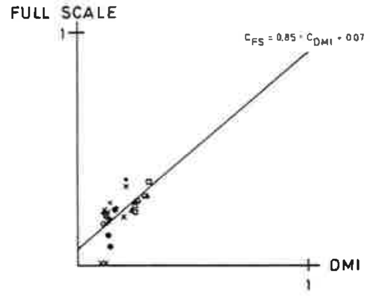


Fig. 7. Comparison of mean pressure coefficients, C_p, in run A32. For symbols, see Fig. 6.



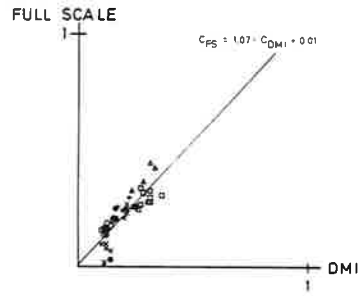


Fig. 8. Comparison of coefficients of standard deviations in run A7. For symbols, see Fig. 6.

Fig. 9. Comparison of coefficients of standard deviations in run A32. For symbols, see Fig. 6.

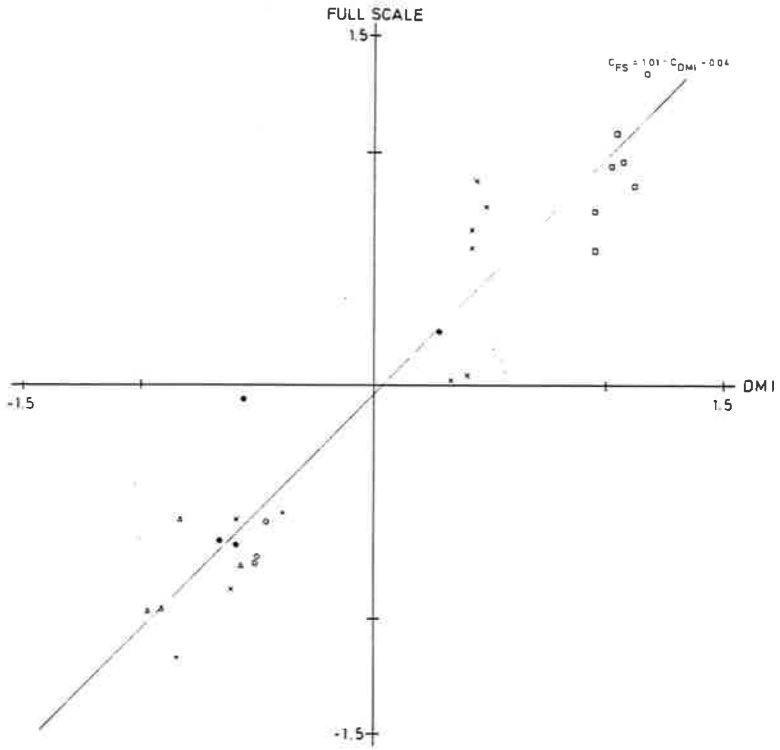


Fig. 10. Comparison of coefficients of 2-s gusts in run A7. For symbols, see Fig. 6.

TABLE 7

Comparisons of regression lines for correlations of full/model scale. UWO (University of Western Ontario) results from ref. 3. UOX (University of Oxford) results from refs. 4—6

Run		Mean			Standard deviation			2-s gust		
		Slope	Intercept	Correlation coefficient	Slope	Intercept	Correlation coefficient	Slope	Intercept	Correlation coefficient
A7	UWO	0.61	−0.12	0.61	0.92	0.02	0.67	0.91	0.00	0.96
	DMI	0.65	−0.01	0.65	0.85	0.07	0.66	1.01	−0.04	0.95
A11	UWO	1.37	−0.33	0.93	1.60	−0.02	0.63	1.63	−0.14	0.93
	DMI	1.15	−0.08	0.95	1.35	0.04	0.70	1.59	−0.17	0.90
A12A	DMI	1.14	−0.08	0.85	1.02	0.13	0.55	1.39	−0.04	0.93
A12B	DMI	1.01	−0.08	0.87	1.15	0.08	0.67	1.25	0.05	0.90
A31B	UWO	0.67	0.10	0.76	0.43	0.10	0.36	—	—	—
	DMI	0.56	0.19	0.72	0.49	0.09	0.46	0.94	0.08	0.86
A32	UOX	0.83	0.03	0.89	0.88	0.00	0.75	—	—	—
	UWO	1.07	−0.16	0.91	1.32	−0.08	0.88	—	—	—
	DMI[b]	0.97	0.01	0.91	1.07	0.01	0.83	—	—	—
A38A[a]	UOX	0.68	0.11	0.76	1.10	0.00	0.80	—	—	—
	DMI[c]	0.60	0.06	0.72	1.24	0.06	0.82	—	—	—
A38B[a]	UOX	0.68	0.16	0.78	1.14	0.00	0.83	—	—	—
	DMI[d]	0.70	0.12	0.77	1.41	0.04	0.84	—	—	—
A38C[a]	UOX	0.74	0.18	0.79	1.10	0.04	0.67	—	—	—
	UWO	0.67	0.02	0.79	1.17	−0.01	0.89	—	—	—
	DMI	0.72	0.13	0.77	1.37	0.05	0.88	—	—	—

[a]The full-scale results are listed in ref. 5.
[b]Wind-tunnel run A7.
[c]Wind-tunnel run A12B.
[d]Wind-tunnel run A12A.

The main differences between full-scale measurements and the experimental results from the three wind-tunnel laboratories are evident when looking at Figs. 11—13 illustrating the estimates of regression slopes in the runs compared.

The following conclusions can be drawn.

(A) There is a considerable scatter between similar (identical roof pitch and wind direction) full-scale runs: A7/A32, A12A/A38B and A12B/A38A. See Section 2.3 for further discussion.

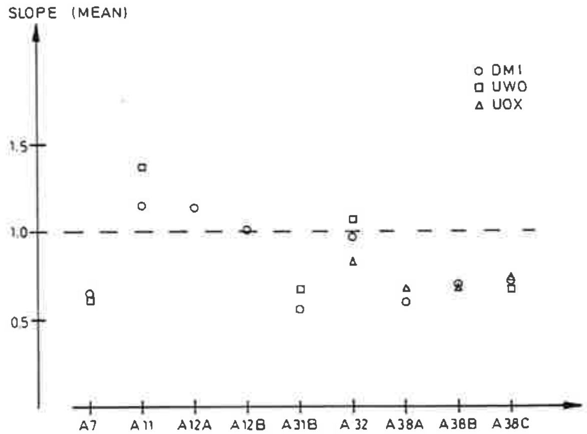


Fig. 11. Regression slope estimates for mean pressure coefficients.

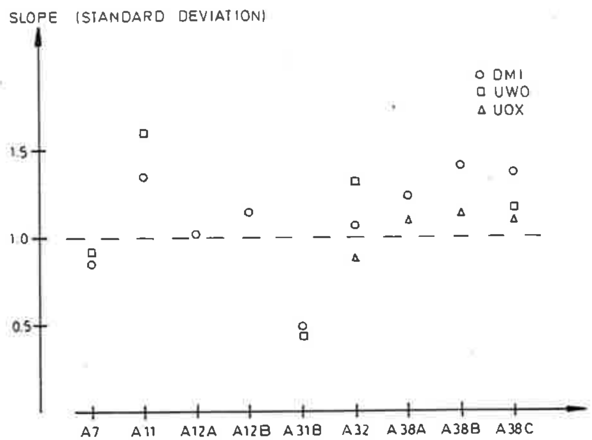


Fig. 12. Regression slope estimates for coefficients of standard deviations.

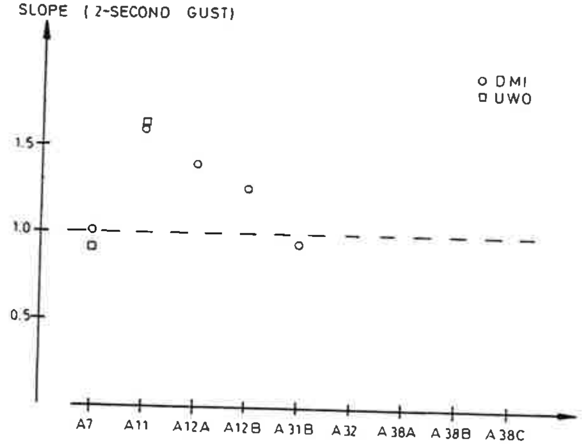


Fig. 13. Regression slope estimates for coefficients of 2-s gusts.

(B) In general, the wind-tunnel test results show a reasonable agreement with the full-scale data. However, the correlation between the different wind-tunnel test results seems to be much better than the correlation between full and model scale. This is confirmed in Section 5.3 where a direct comparison between model tests is presented.

Spectral distribution of pressures

The spectral distribution of pressures was determined at 36 pressure locations on the building (see Section 3.3, item H).

Figures 14—18 concerning full-scale run A32 (wind-tunnel run A7) show the power spectral densities at five selected locations where full- and model-scale spectra were available. The frequency scaling takes into account differences in wind velocities between runs A7 and A32. It is concluded that the model spectra are in overall agreement with the full-scale results. This conclusion is similar to the conclusion drawn by Vickery [3].

The peaked nature of the full-scale spectra compared to the quite smooth appearance of the model-scale spectra could be due to larger statistical uncertainties in the full-scale estimates. Furthermore, it should be pointed out that the high frequency part of the model- and the full-scale spectra at pressure location WR3A for some reason is considerably deviant in nature (see Fig. 16). Hopefully, the International Aylesbury Comparative Study will throw some light on this point.

Probability density functions

The probability density function of pressures was determined before and after performing running block-averaging over 1, 2, 4, 8, 16 and 32 s full scale periods. Seventeen pressure locations were investigated as mentioned in Section 3.3, item G.

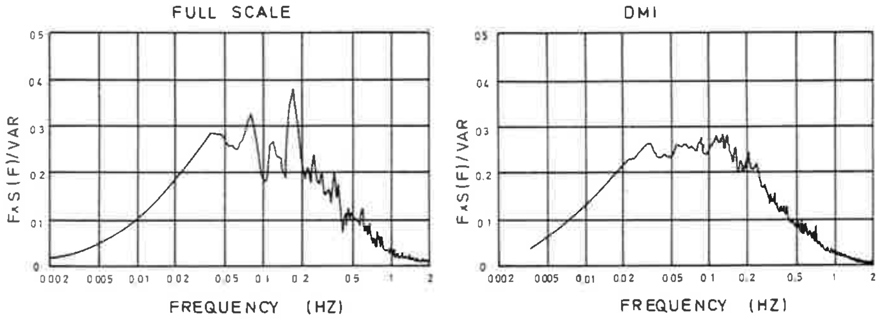


Fig. 14. Spectrum comparison for pressure location 3WW3 in run A32 (wind-tunnel run A7).

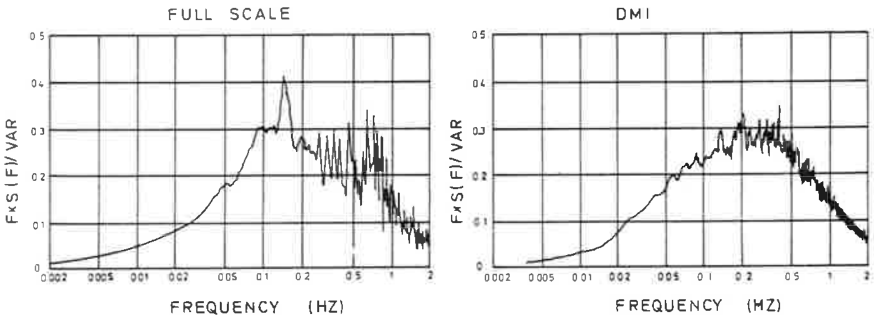


Fig. 15. Spectrum comparison for pressure location WR1D in run A32 (wind-tunnel run A7).

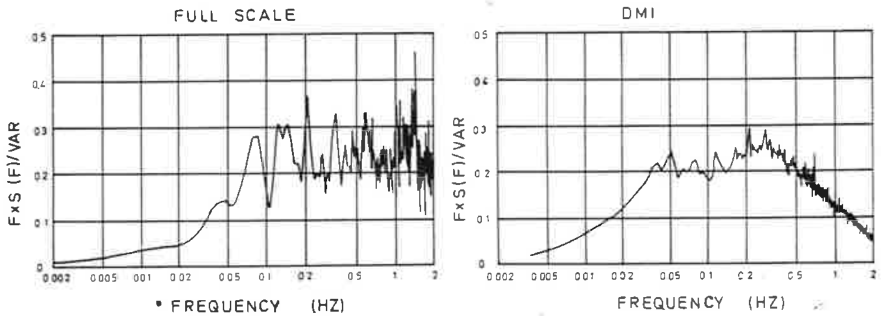


Fig. 16. Spectrum comparison for pressure location WR3A in run A32 (wind-tunnel run A7).

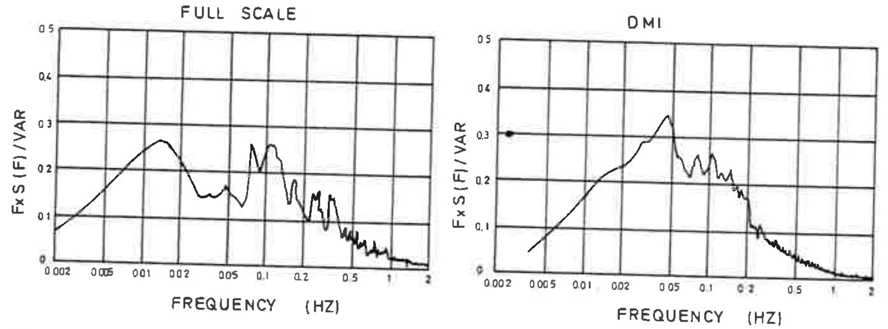


Fig. 17. Spectrum comparison for pressure location 3EW4 in run A32 (wind-tunnel run A7).

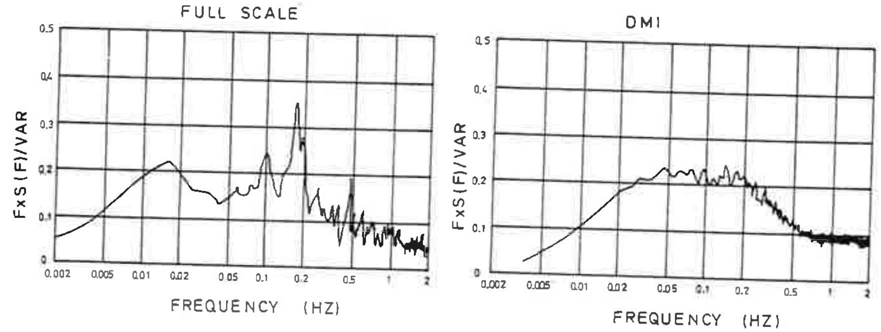


Fig. 18. Spectrum comparison for pressure location 3SW2 in run A32 (wind-tunnel run A7).

Figures 19—23 concerning run A7 show the probability density function at five locations situated on different characteristic parts of the building. Curves with 1, 8 and 32 s block-averaging are included in the figures. Unfortunately, no full-scale probability density functions are available at the Institute for comparison.

The following conclusions can be drawn.

(A) As expected, the probability density function becomes narrower when the averaging time is increased.

(B) The skewness of the function is dependent on the location and it seems to be minimum on the East wall of the building. This is to be expected, since the East wall is positioned to the leeward side of the building for the actual wind direction.

5.3. *Comparative studies — model/model scale*

A direct comparison between model scale results obtained at the University of Oxford and the Danish Maritime Institute has been made in

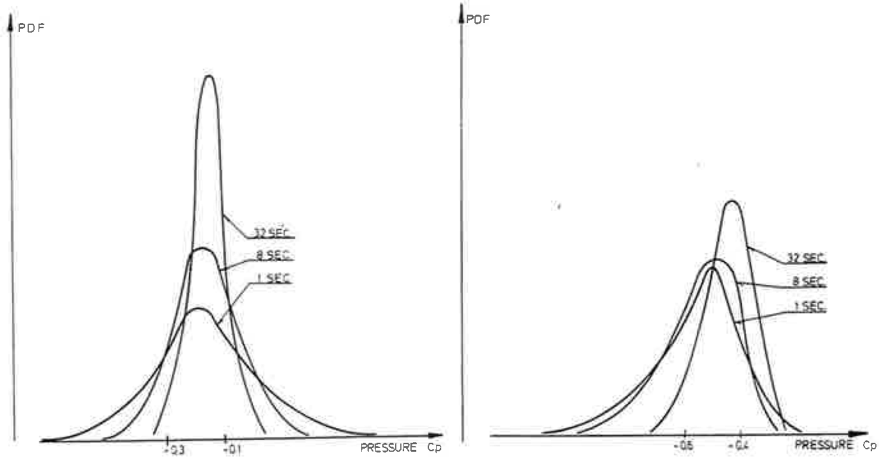


Fig. 19. Measured probability density function at location WR1A in run A7.

Fig. 20. Measured probability density function at location ER1B in run A7.

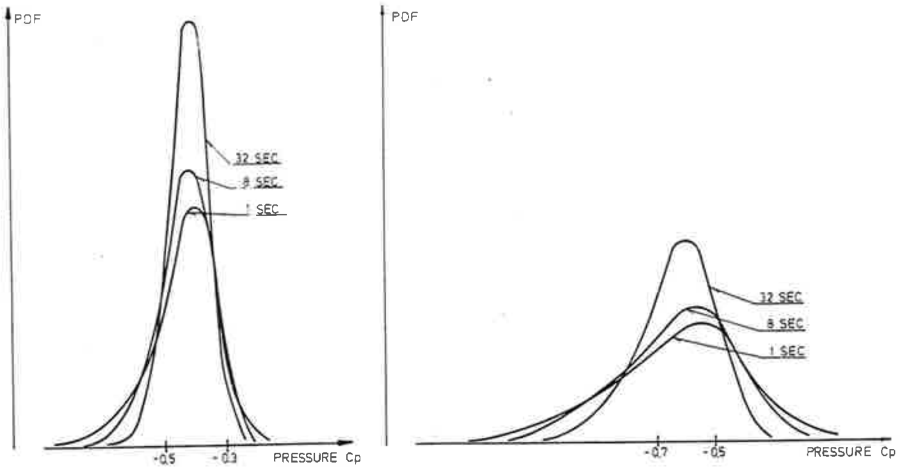


Fig. 21. Measured probability density function at location 3EW3 in run A7.

Fig. 22. Measured probability density function at location 3SW1 in run A7.

two selected runs (A32 and A38A) concerning mean pressures on the building (see Table 8 and Fig. 24). It should be emphasized that the full/model scale correlations in runs A32 and A38A are quite good and relatively poor, respectively (see Table 7).

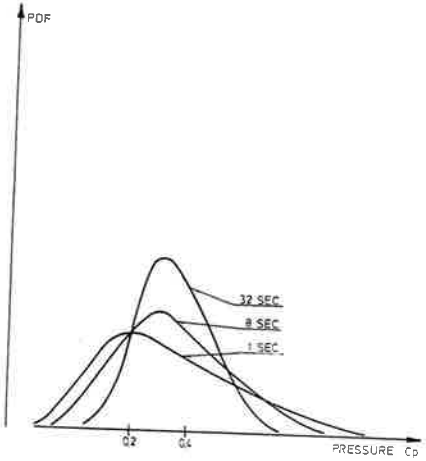


Fig. 23. Measured probability density function at location 3WW3 in run A7.

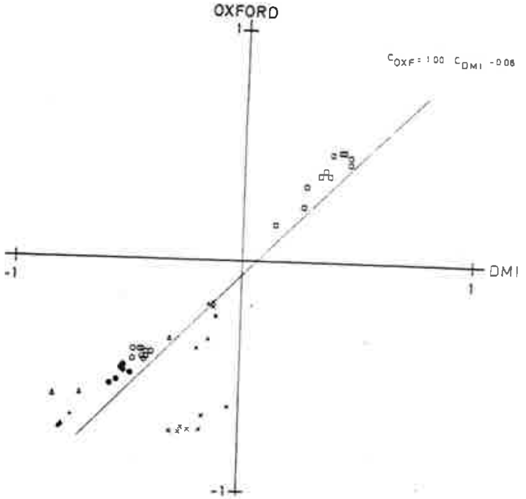


Fig. 24. Comparison of mean pressure coefficients in run A32. University of Oxford/ Danish Maritime Institute. For symbols, see Fig. 6.

TABLE 8

Regression lines for correlation between mean pressures obtained at the University of Oxford and the Danish Maritime Institute

Run	Slope	Intercept	Correlation coefficient
A32	1.00	−0.08	0.88
A38A	0.89	−0.07	0.95

The following conclusions can be drawn.

(A) The correlation between wind-tunnel test results from the different wind tunnels is much better than that between full to model scale results. This conclusion is similar to the conclusion drawn by Greenway and Wood [5].

(B) The intercept is about the same size in both runs indicating the use of a slightly different (−0.08) static reference pressure in the two wind tunnels. In fact, the importance of a suitable reference pressure is discussed extensively by Greenway and Wood [4]. Hopefully, the International Aylesbury Comparative Study will throw some light on this point.

6. Conclusions

The full-scale experiments carried out by the Building Research Establishment at Aylesbury have provided a unique data base with respect to wind pressures on low-rise buildings. However, some of the full-scale data are obviously subject to errors originating from reference pressure shifts, gain errors or simply transducer failure. These variabilities limit the obtainable agreement between the full- and model-scale test results.

In spite of uncertainties mentioned above the wind-tunnel test results have generally shown a reasonable agreement with full-scale data. However, the results obtained at the University of Oxford, the University of Western Ontario and the Danish Maritime Institute are in considerably closer correspondence with each other than with the full-scale results.

Hopefully, the International Aylesbury Comparative Study will throw some light on the exact accuracy of the full-scale pressures, that is, a determination of how much variability is caused by measurement errors and how much by natural variations. The Aylesbury experiment could conclusively provide a comprehensive data base suitable for future wind-tunnel engineers working with wind pressures on low-rise buildings.

7. Acknowledgements

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AEROELASTIC BEHAVIOR OF A PAIR OF THIN CIRCULAR CYLINDRICAL SHELLS IN STAGGERED ARRANGEMENT

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Summary

A series of wind-tunnel tests have been conducted on the aeroelastic characteristics of a pair of closed-ended, thin, circular cylindrical shells of identical size in a staggered arrangement. The streamwise and transverse separations between the centers of the two cylinders were varied in the range from 0 to $2.5D$ and from $0.5D$ to $1.5D$, respectively, with D being the cylinder diameter. Detailed measurements of the prebuckling and buckling behavior of the downstream cylinder were made with a variety of elastic cylinders in both smooth and turbulent flows. Wind pressure distributions around the downstream cylinder were also measured.

The results indicate that the prebuckling deflection can be predicted by the linearized Donnell's equations with a reasonable degree of accuracy, though the deflection is extremely sensitive to the relative position of the two cylinders. When the downstream cylinder is partially immersed in the wake of the upstream cylinder, the pressure distribution in the circumferential direction exhibits a marked asymmetry with respect to the shifted stagnation point and the buckling pressure of the cylinder is relatively low compared to that of an isolated cylinder. Furthermore, a brief examination was made of the relation between buckling pressure and circumferential Fourier components in the pressure distribution, by using the methods of multivariate statistical analysis.

1. Introduction

Circular cylindrical shells are widely used for silos, oil-storage tanks, and other civil-engineering structures. Recently, for the development of large-sized, thin-walled cylindrical shells by the use of high-tensile steels, the aeroelastic characteristics, i.e., the deflection and buckling behavior of such shells under wind loads, has become more and more important. On this subject, some theoretical and experimental studies [1—6] have been made. From their results, the fundamental nature of the behavior was clarified concerning an isolated cylindrical shell. However, more than two cylinders are often located in close proximity. In such a case, the flow around the shells seems to be extremely complicated.

The subject of flow interference between two circular cylinders of infinite height in various arrangements has received considerable attention in the past for their practical applications in various areas of engineering:

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