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Wind Profiles Over a Suburban Site and Wind Effects on a Half Full-scale Model Building

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Little information is available which allows comparison between the results of wind-tunnel studies on model buildings with full-scale effects experienced in the natural wind. What information there is often shows marked discrepancies in the wind-tunnel data. Very much more information is required concerning the influences experienced by full-scale buildings. The considerable complexities of instrumentation experienced in obtaining measurements on full sized buildings, together with the high inherent costs, have had limiting influences on the volume of experimental work undertaken. Results are given in this report of a study, carried out in the field, of wind effects on a half full-size single storey model building. The profiles in the natural wind over the site were measured and the pressure effects experienced by the model were recorded. Many interesting features were discovered in the results, which require careful consideration, and the investigation yielded valuable data which were used in a comparison with the results of a subsequent wind-tunnel study on small scale model buildings, the results of which will be published later.

INTRODUCTION

BETWEEN the years of 1930 and 1936 Irminger and Nøkkentved[1], working in Denmark, made a long series of fundamental investigations into the nature of air movement over buildings. A large part of their work was concerned with assessing the accuracy of wind-tunnel methods for reproducing the correct air-flow separation and reattachment positions of the vortices formed by winds passing over buildings.

This work, which was continued by Nøkkentved and culminated in the work of Martin Jensen, laid the foundations for present day practices which simulate in wind-tunnels the behaviour of the natural wind and its influences on buildings. It demonstrated clearly the critical relationship between the building and the height, shape and arrangement of projections above the ground level around it. Jensen's work extended this to show that not only is the shape and distribution of the projections above the ground surrounding the building critical in determining the flow separation behaviour and hence the pressure distribution around the building but that the pressure distribution is heavily modified by the character of the terrain for a considerable distance upwind of the building.

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Extensive investigations into the effects of varying the velocity gradient, and hence the turbulence of the air, produced by the wind passing over rough terrain led Jensen to publish his Model Law[2], in 1958. The necessity to reproduce the velocity gradient of the natural wind in wind-tunnels has been recognised by others[3–6], who have approached the problem of velocity gradient simulation using different methods.

In 1933 another important discovery was made. Millikan and Klein[7] found, from experiments made in the natural wind, that the scale of turbulence to that of the objects over which the wind flows is of considerable importance. They found that the pressures experienced by an object in the flow remained unaffected by increases in the intensity of the turbulence, provided that the scale of turbulence was large in relation to the size of the object. If the scale of the turbulence was small in relation to the object then the pressures experienced by the object altered rapidly with increases in the turbulence of the flow. As a result, the need to model the correct turbulence conditions in air-flows in order to obtain correct shearing and flow separation behaviour, together with a growing awareness among structural designers of the very significant importance of wind gust effects, of turbulence influences, of vortex shedding from structures having low structural damping, and of wake effects have greatly intensified work on the study of natural wind turbulence in particular and on flow separation behaviour in general[8–10]. Much has been learned about turbulence spectra and the scale of turbulence in the natural wind and in other air-flow conditions but much still remains to be learned. Attempts to create atmospheric turbulence in the wind-tunnel have been hindered by lack of adequate meteorological data. Information on the exact form of the velocity profiles of the natural wind, which exist over terrain of varying degrees of roughness, and the range and distribution of the eddy sizes in the flow is still incomplete and not yet fully reliable.

VELOCITY GRADIENTS

The first formula which allowed a calculation of the velocity gradient was produced by Hellman (1915). After a prolonged period of study of the frictional resistance of the ground surface on air-flow, he devised the following formula which corrected the wind speed for changes in height:

$$\frac{V_H}{V_{10}} = 0{\cdot}2337\,[1{\cdot}00+2{\cdot}81\log(H+4{\cdot}75)]:$$

where V_H is the wind velocity at any height H, in metres, above ground and V_{10} is the wind velocity at a height of 10 m.

Further attempts have been made to arrive at methods of defining the wind profile by a simple relationship which is more mathematically amenable. This has led to the development of the, so called, Power Law. However, at present an argument still ensues as to which is the more accurate version. Shellard[11] supports the formula:

$$\frac{V_h}{V_{10}} = \left(\frac{h}{10}\right)^{\alpha}$$

in which the reference mean velocity V_{10} is taken at the standard meteorological reference height of 10 m above ground level and in which V_h is the mean wind speed at h m. The power α varies from 0·1 to 0·4 (a value of 0·17 has been advocated for use throughout Britain).

Davenport[12] supports a different version of the Power Law:

$$\frac{V_Z}{V_G} = \left(\frac{Z}{Z_G}\right)^{\alpha}$$

in which the reference mean wind velocity is the gradient wind velocity G, measured at the gradient height Z_G and V_Z is the velocity at any height Z and α is a variable power of value between 0·16 and 0·40. Jensen[2], however, has defined the theory that the velocity profile follows the form:

$$\frac{V_Z}{V_*} = \frac{1}{K}\ln.\frac{Z+Z_0}{Z_0}$$

In this formula V_Z is the velocity at any height Z, K is von Karman's constant (0·4), Z_0 is the roughness parameter (or position of zero flow) and V_* is the friction velocity

$$\left[\frac{\sqrt{(J_0)}}{e}\right]$$

The above formula has been developed from the work of Nikuradse and others which has shown that the velocity profile at the boundary in pipes and ducts depends upon the roughness of the wall surface. In 1937, Paesche made experimental studies of the turbulence in the natural wind. From his results he was able to show that the motion of the natural wind was also controlled by the laws of friction governing the flow of fluid in rough walled pipes. That is, the effective roughness of the ground surface could be determined by measurements of the velocity distribution in the wind at heights immediately above the surface of the earth. This led to his obtaining values of the roughness parameter which varied between 3 and 130 cm, depending on the terrain.

JENSEN'S MODEL LAW

Following this work and from the logarithmic formula above, Jensen has shown that a graph of the natural log of the heights in the profile plotted against their respective velocities, expressed as a percentage of the maximum, will be a straight line. The point at which this straight line graph cuts the vertical axis can be regarded as the position of zero flow, i.e. the roughness parameter Z_0.

After analysing the results of extensive field and wind-tunnel experiments, Jensen formed the conclusion that the value of Z_0 is the key to the correct simulation of natural conditions in the wind-tunnel. He claims that experiments in wind-tunnels must be carried out in air-flows in which are created the correct velocity profiles[13]. To obtain the necessary velocity profiles, it is claimed that the air-stream must be passed over a long "fetch" of rough material. The velocity profile so generated by frictional drag will have a form dependent upon the roughness of the material placed in the wind-tunnel. The straight line logarithmic graph of this profile will cut the vertical axis at a point representing the position of the roughness parameter z_0 of the wind-tunnel air-flow.

For model tests in wind-tunnels the Model Law rules that the ratio of the size of the model to that of the full-scale building must be exactly equal to the ratio of the roughness parameter in the wind-tunnel to the roughness parameter of the corresponding natural wind. That is:

$$\frac{Z_0}{z_0} = \frac{D}{d}$$

D being the height of the full sized building and d the height of the model building.

EXPERIMENTS IN THE FIELD

Even with increasing care in producing the supposedly correct conditions in wind-tunnels, discrepancies have been obvious between the results obtained in different tunnels and between these results and those available from experiments in nature. It has become clear that more information is necessary on the variations between the results obtained from wind-tunnel research and those obtained from measurements in full-scale conditions. Although Galileo and Newton, in the 17th century, considered wind loading on buildings, the work of Smeaton and Duchemin in the first half of the 19th Century produced the first usable information from measurements in the natural wind.

In the last decade of the nineteenth century and the first decade of the twentieth century Sir Benjamin Baker, at the site of the Forth Rail Bridge, and Stanton, on the Tower Bridge, London, carried out pressure experiments in the natural wind. Only isolated cases of wind measurements on and around buildings are on record in the forty years following Stanton's work. By far the most detailed and noteworthy example, in this period, was the work carried out on the Empire State Building. In recent years a considerable increase has occurred in the volume of research being carried out to determine full-scale natural wind effects. Jensen's work was probably one of the first and most significant in this recent research. This work covered the effects of shelter and the effects of wind pressure on buildings. Much work of significance in the sphere of shelter effects has been published in recent times. Davenport has made pressure measurements in connection with his work and interesting work on the measurement in nature of velocity profiles above urban areas, together with the wind effects to be expected at ground level in these areas, has been carried out at Liverpool University[14].

Perhaps the most important and extensive research programme, currently being undertaken, is that of the Building Research Station. In this programme, measurements from the full-scale are being made on large buildings in London. Pressure measuring devices[15], consisting of circular aluminium pressure plates set flush with the external walls and windows, allow the simultaneous recording of pressure measurements from large areas of the external surfaces of the buildings. One of the most interesting sections of this work will be the comparison of the results obtained from the field with those obtained from simulated conditions in the wind-tunnel. Indications have been obtained that the permeability of the wind-tunnel model should be equivalent to that of the full-scale building.

WIND PROFILE MEASUREMENTS

The mast and instruments

The experimental work described in this report consisted of measurements of the velocity profiles in the natural wind over a site upon which was constructed a half full-scale model of a single storey building. The object was to provide data to be used in testing certain profile generating techniques employed in the testing of model buildings in wind-tunnels. The results of the subsequent wind-tunnel studies will be contained in a later report.

Considerable care was taken in selecting the site for the experiment and a location was chosen in the western suburbs of the city of Edinburgh. The relationship of the site to its immediate surroundings are shown in figure 1 and the location of the model and instrument mast on the site are shown in figure 2.

It was necessary, in the work under discussion, for the apparatus employed in the wind profile measurement to function continuously. Therefore, a stout timber mast 40 ft (12·192 m) high was erected for the purpose of carrying the recording instruments. At heights of 5 ft (1·524 m), 10 ft (3·048 m), 20 ft (6·096 m) and 40 ft (12·192 m), 3 ft (0·914 m) long timber brackets were secured to the mast and positioned to point due South. The topography of the approaches to the site from the North was such as to render profile measurements from that direction undesirable.

In designing a suitable system of flow measuring instruments for the purpose of the experiments, the main problem lay in making provision for a reliable means of recording the results continuously. Sheppard type IV cup anemometers were modified by replacing the dial recording 10,000 ft (3048 m)

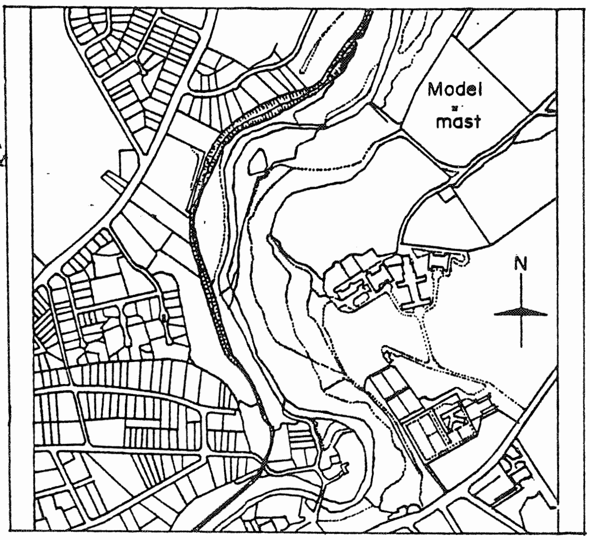

Fig. 1. Relationship of field site to surroundings.

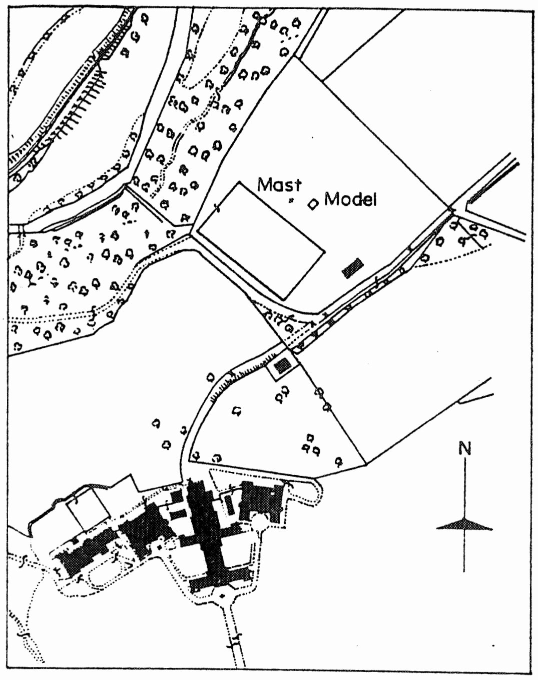

Fig. 2. Position of model and mast on field site.

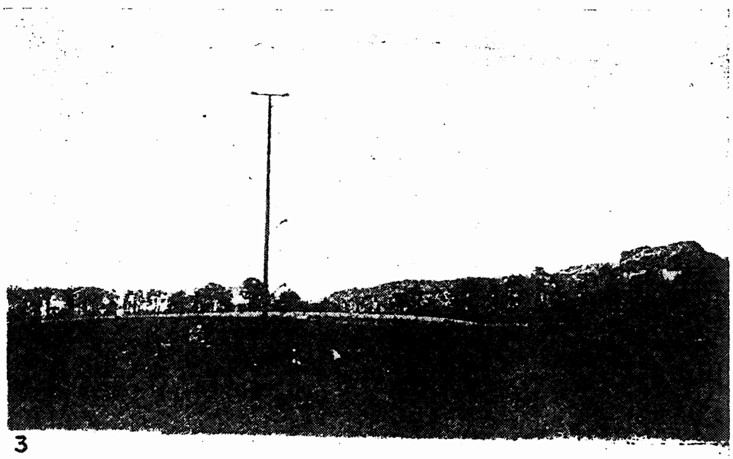

Fig. 3. Field model and instrument mast, view looking east.

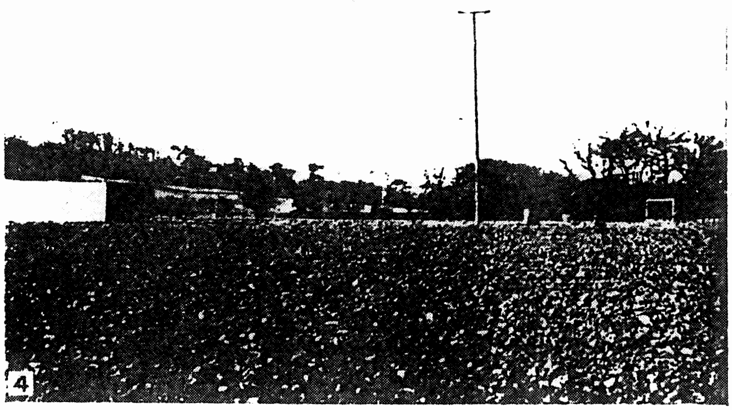

Fig. 4. Field model and instrument mast, view looking south west.

units with a low torque (700 dyne/cm) (7×10^{-5} N/mm) 357° toroidally wound potentiometer[16]. A 5 V standardised potential difference from a stabilised battery power source was applied across the potentiometer. The voltage drop across the potentiometer of each anemometer was recorded every 20 min on a battery operated data logger. In order to ensure complete water exclusion, the body of each anemometer was enclosed in a sealed metal canister.

An anemometer was installed on each of the four brackets of the mast. Due to difficulty of access for maintenance purposes to the topmost instrument a fifth bracket and anemometer were affixed to the mast at the 40 ft (12·19 m) level. Additional weather protection was given to the data logger and certain parts of the anemometer circuits by placing them in a housing, positioned some 12 ft (3·658 m) from the base of the mast, on top of which a wind direction indicator was mounted.

In the final stages of the programme of wind measurements a sixth anemometer was positioned on the mast at a height of 1 ft 6 in. (0·4572 m) from the mean ground surface. Additional care was taken in recording the measurements from this sixth instrument and the results obtained, when compared with the data obtained simultaneoulsy from the other five anemometers, were valuable in confirming the form of the velocity profiles measured. The signals recorded on the magnetic tape of the logger were translated automatically and printed direct on to punched tape for subsequent calculation by computer.

Figure 3 shows the completed instrument mast together with the model building, which is discussed below, and the Easterly approaches to the site. In figure 4 are shown the South Westerly approaches to the site, over which blew the prevailing winds used in the pressure measurements taken from the model building.

DISCUSSION

As stated above, measurements of the profile in the winds approaching the site from the North were not carried out. It was subsequently found that the presence of the building to the South of the mast had introduced large-scale eddying which had so distorted the measurements obtained in winds from that direction that this data had to be discarded. Throughout the periods during which recordings were made from the anemometers the mean wind direction was registered at hourly and, when found necessary, half hourly intervals.

Measurements from the anemometers were taken over a four month period, being the months of December 1965 to March 1966 inclusive. The maximum mean hourly wind speed recorded was 25·2 m.p.h. (11·268 m/sec) and the maximum 20 min wind speed obtained was 28·1 m.p.h. (12·565 m/sec), indicating that 2–3 sec gust speeds were experienced which probably reached 65 m.p.h. (29·064 m/sec) thereby exceeding the maximum design speed of the anemometers for short periods of time. No evidence of long term damage to the anemometers could be detected.

Typical examples of the wind profiles measured are shown in figure 5, in which the relative velocities, expressed as a percentage of the velocity at 40 ft (12·19 m), have been plotted against the height. The curvature of the profiles was rather lighter than had been anticipated. Subsequent consideration of this discovery attributed the cause to the absence of foliage from the deciduous trees surrounding the

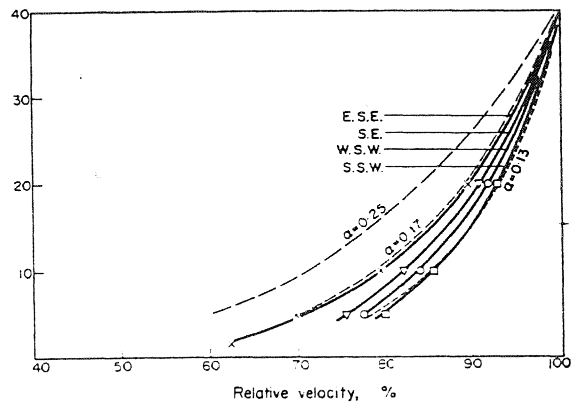

Fig. 5. Wind profiles over field site.

site and to the relatively large expanse of open land to the East and West of the mast. In addition, in the case of the profiles measured from the directions West of South, the land sloped gently downward towards the experimental station thereby causing the wind profiles to "open out".

As a check, the measured profiles were compared with profiles calculated using the version of the Power Law supported by Davenport. These theoretical profiles are shown in figure 5, plotted with the profiles obtained in the field. Very close fits were obtained using exponents between 0·13 and 0·17. The calculated profile using the exponent of 0·13 was an almost perfect match for the S.S.W. field profile. The Power Law exponents thus revealed are somewhat smaller than those supported by Davenport, coming much nearer to the values advanced by Shellard. Figure 6 shows the measured wind profiles plotted in straight line logarithmic graph form, the Power Law profiles having exponents of 0·13, 0·17 and 0·25 are included for comparison.

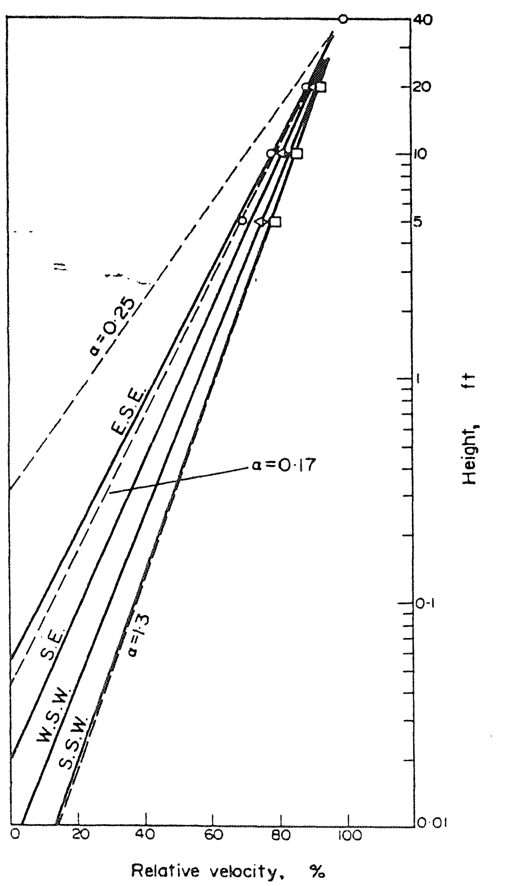

Fig. 6. Log graph of wind profiles over field site.

The value of the roughness parameter obtained from the log graphs of the natural wind profiles lies between 0·70 in. (17·78 mm) for the E.S.E. profile and 0·024 in. (0·61 mm) for the S.S.W. profile. This corresponds closely with the roughness parameter for the Power Law graph with exponents of 0·17 and 0·13 being 0·50 in. (12·70 mm) and 0·022 in. (0·56 mm) respectively. The value of these roughness parameters was of considerable importance when later relating the results obtained from the field model with those from the models studied in the wind-tunnel.

PRESSURE MEASUREMENTS

The model building

The greatest problem encountered in designing the half full-scale field model was in considering its orientation in relation to wind direction. The relatively small number of reported field experiments in which wind effects on model buildings have been studied has suffered from the grave disadvantage that the models have been constructed in fixed, stationary positions. Consequently, it was decided that the model should be designed and constructed in such a manner that it could be rotated and positioned in any relationship to the wind path. In this way the effects of the wind could be obtained when approaching the model at right angles to one wall or over one of the corners, or from whatever direction chosen.

The final design of the model, as constructed, is shown in figures 7 and 8. Access doors were constructed in the rear wall and in one of the walls enclosing the central patio. A total of 136 pressure tappings were inserted in the model; 45 covering the whole face of the front wall, 27 in the patio walls and 64 in one quarter of the roof surface area located as shown in figure 8. The positioning of the pressure tappings permitted measurements to be made from the pressure points in each of the four locations produced by rotating the model three times through 90° and thus a record of the pressure distribution over the whole of the external surface area could be obtained. A tilting multi-tube manometer, located inside the model, was employed in making the pressure measurements on the model. Fourteen of the manometer's fifteen tubes were utilised for measuring the surface pressures experienced by the model. The fifteenth manometer

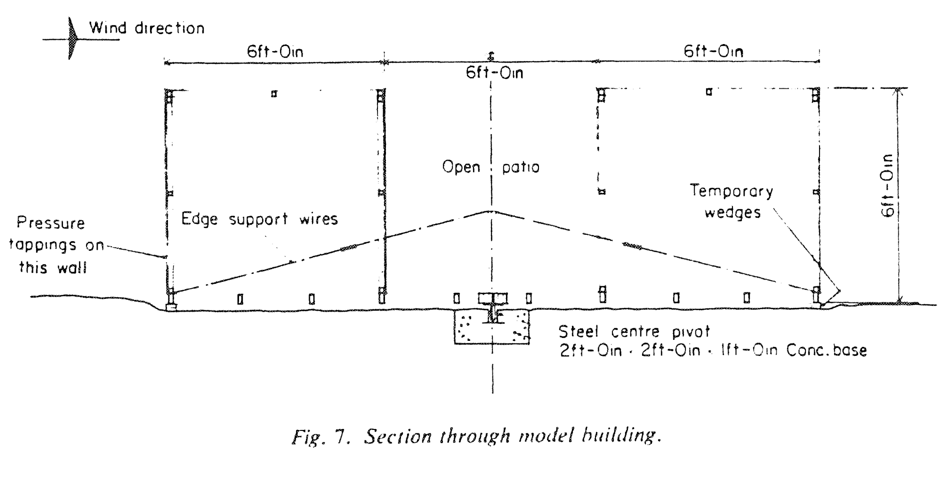

Fig. 7. Section through model building.

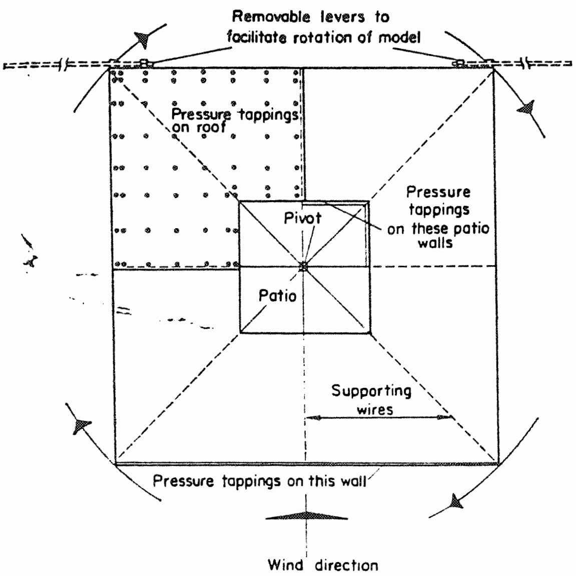

Fig. 8. Roof plan of model building.

tube was connected to the total head pressure recorded by an N.P.L. type pitot static tube mounted on a rigid post at a height of 5 ft 6 in. (1·6764 m) and positioned at a distance of 20 ft (6·096 m) from the model. The static pressure from the pitot static tube was connected to the manometer fluid reservoir. When recording the pressure measurements from the model great care was taken to ensure the correct alignment of both the model and the head of the pitot static tube with the mean wind direction.

In order to ensure clearly defined manometer readings, pressure recordings were only taken in wind speeds of 30 m.p.h. (13·413 m/sec) and over. Three recordings were taken of every complete set of manometer readings for later comparison and rejection of spurious results. Permanent records of the pressures displayed on the manometer were obtained by photographing each set of readings.

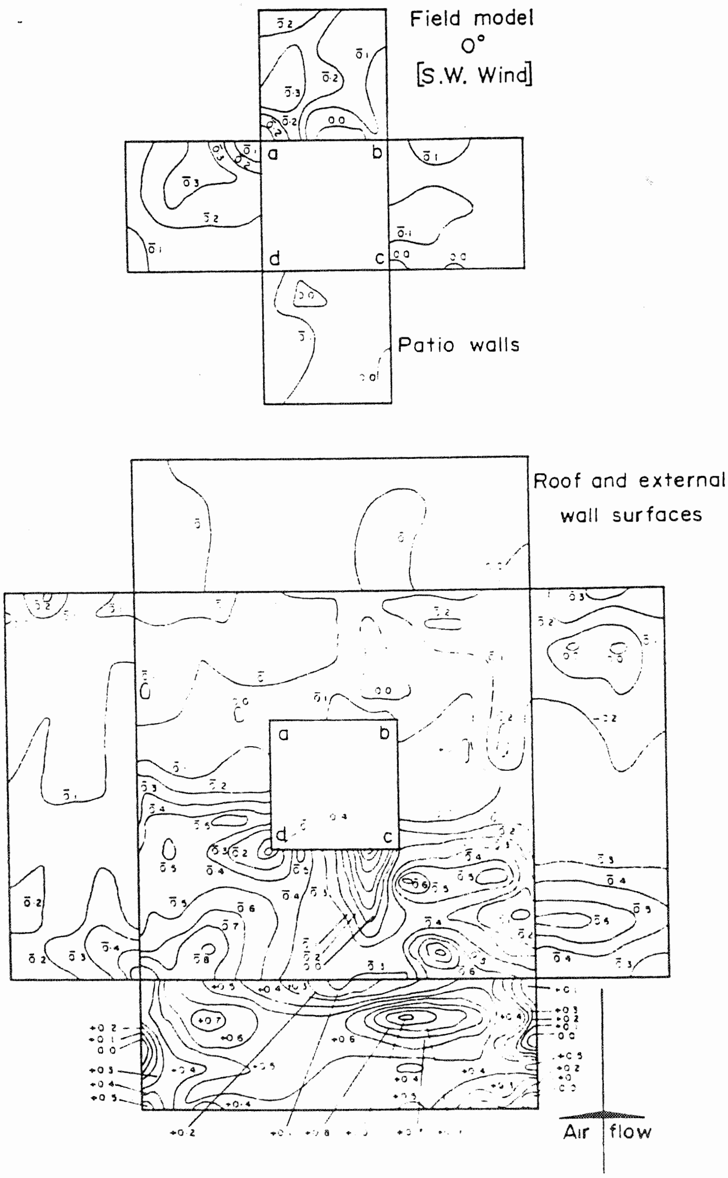

Fig. 9. Pressure diagram from the model positioned at 0°.

Computer calculation of the coefficients of the model surface pressure was effected simply by expressing the surface dynamic pressures, positive or negative, as a fraction of the free wind dynamic pressure. The coefficients were finally plotted, on the position in which they were recorded, on drawings of the model external surfaces and interpolation between the coefficients allowed the diagrams of pressure distribution, as shown in figures 9, 10 and 11, to be drawn up.

During the period of time over which the measurements from the instrumented mast and the field model were obtained the direction from which winds with greatest strength and frequency blew was South Westerly. Therefore, only winds from that direction were employed when pressure measurements from the field model were recorded. Pressures from the total external model wall surface area were obtained with the model located in three different positions in relation to the mean wind direction, that is with the front wall of the model at 90° to the wind, then with the model repositioned with the front wall first 30° then 45° from that position. (This is shown in figure 12). For reference purposes each of these positions was designated by the displacement from the first position, i.e. 0°, 30° and 45°.

Studies of the pressures experienced by the model at the 30° position were carried out as a result of an earlier series of wind-tunnel experiments into the nature and effects of air movement in and around the central patios of 14 model buildings, the results of which will be published later. These experiments showed that at and around the 30° position vortex behaviour across the model roofs caused significant alterations to the character of the air movement

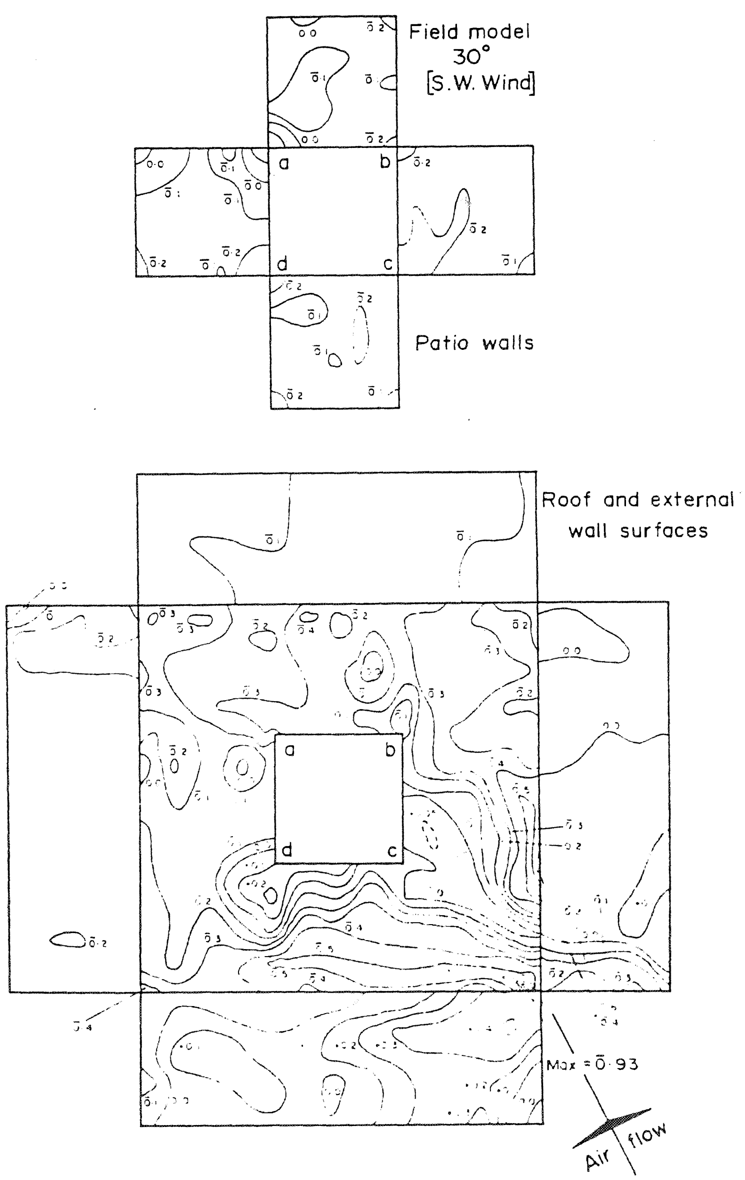

Fig. 10. Pressure diagram from the model positioned at 30°.

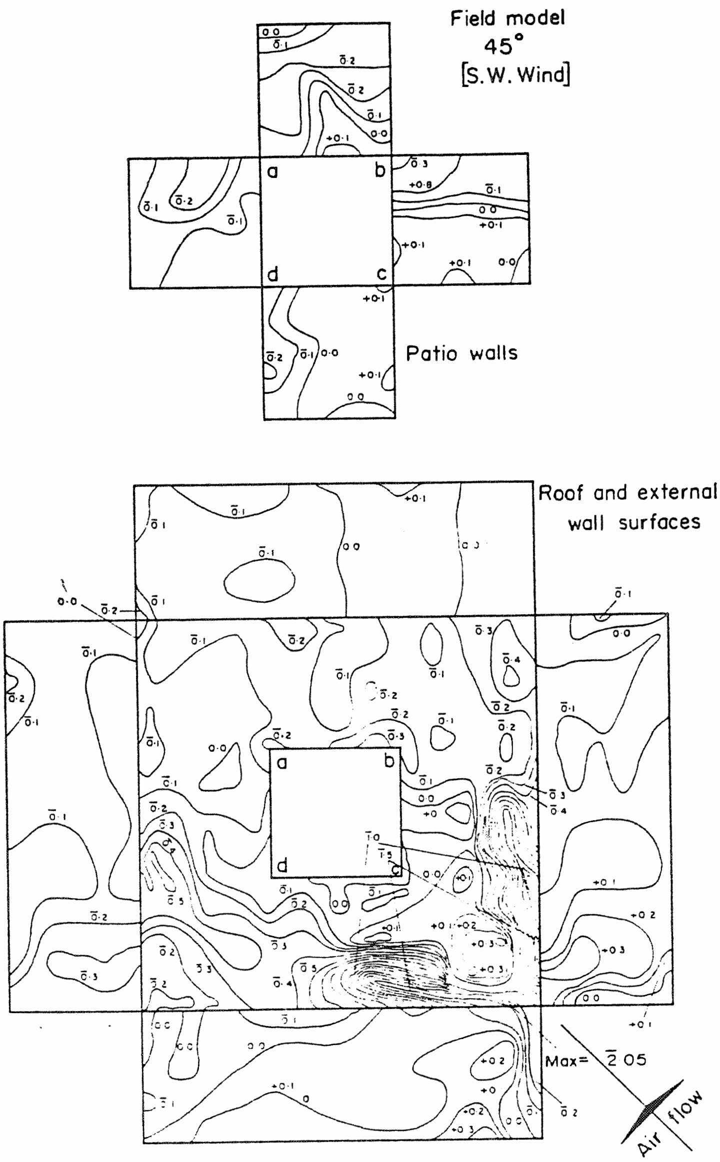

Fig. 11. *Pressure diagram from the model positioned at* 45°.

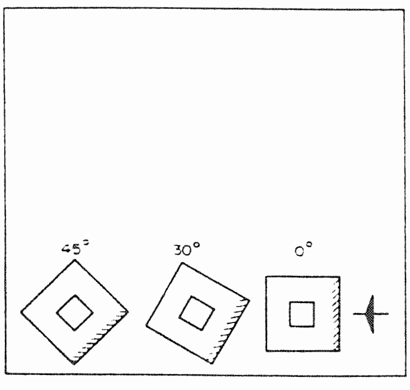

Fig. 12. *Orientation of model building to wind direction in the three test positions.*

within the central patio and in the pressure distribution on the roof.

When computing the pressure measurements an adjustment had to be made. The reason for this was the difference in the position in which the wind reference pressures were measured in the wind-tunnel and field studies. In the wind-tunnel the total head and static pressures were measured in a location in which they equated with similar pressures at a height of 32 ft (9·7536 m) in the field. By necessity, the total head and static pressures in the field, as discussed above, had been measured at a height of 5 ft 6 in. (1·6764 m). In the profile of the S.W. wind over the field site the difference in the dynamic pressure at 5 ft 6 in. and 32 ft was 16·3 per cent.

As a result, the value of the free wind dynamic pressure, recorded with each set of surface pressure measurements from the model, was reduced by 16·3 per cent before each set of pressure coefficients was calculated. This had the effect of causing a corresponding reduction in all of the pressure coefficients.

DISCUSSION

Figures 9, 10 and 11 show the pressure diagrams produced from the pressure measurements. In Table 1 the maximum and minimum values of the pressure ranges found on each external surface are listed. The most striking feature of these results is the large areas of positive pressure measured on the roof surfaces. These positive pressures varied in intensity from +0·18, in the case of the model in the 45° position, to the surprisingly large value of +0·43 when the model was located in the 0° position. One other significant characteristic of the results is the extremely high positive pressures obtained from the front face of the model at the 0° position. The value of +1·00 (stagnation pressure), which occurred in one small area, is indeed very high, much higher than thought possible for a relatively small surface area with a small aspect ratio. In addition, no negative pressure was measured on this front face and the two areas of zero pressure obtained were exceedingly small. This indicates that flow separation did not take place on the front face but occurred at the edges.

Table 1. Pressure ranges from field model.

Position of model	Surface	Pressure ranges
0°	Roof surface	−0·89 to +0.43
	Front walls	+1·00 to 0·00
	Side walls	−0·64 to 0·00
	Back walls	−0·14 to 0·00
	Patio walls	−0·37 to +0·06
30°	Roof surface	−0·93 to +0·23
	Windward walls	+0·41 to −0·31
	Leeward walls	−0·20 to 0·00
	Patio walls	−0·21 to +0·14
45	Roof surface	−2·05 to +0·31
	Windward walls	+0·37 to −0·29
	Leeward walls	−0·34 to +0·12
	Patio walls	−0·34 to +0·15

On further examination of the results from the 0° position, it can be seen that small areas of zero pressure were found on the side walls. This, together with the distinct areas of positive pressure on the front and rear patio walls, gives further evidence of the recontact of the air-flow with the surfaces of the model. This is a different set of flow conditions from those later obtained in the wind-tunnel.

The conclusions to be drawn from the pressure measurements from the field model are that there was extremely vigorous eddying in front of the model when positioned at 0°. Not one but two areas of peak positive pressure are found on the front wall surface, located beneath the two areas of maximum negative pressure at the front of the roof surface. This indicates that not one but two alternating vortices existed against the front wall at the 0° position. In all three positions in which the model was studied the recontact of the flow with the model surfaces was extremely rapid, particularly with the roof surfaces. In addition, the low negative pressures on the side and back walls of the model show that the vortex pocket which formed around the model was relatively small. The reason would appear to be primarily centred upon the character of the air movement within the structure of the natural wind. The gusts which engulfed the model, at the time when pressure measurements were recorded, had their axes of rotation in the horizontal plane. As a result, the direction of the air-flow over the model was not truly horizontal but had an angular component in the vertical plane, directed towards the ground.

It is considered that it was this factor which caused the vigorous recontact of the air-flow with the model roof, trapped the windward vortices firmly against the front wall surfaces and reduced the size of the vortex pocket formed around the model. Initially it was considered that the angular movement of the air in the wind had prevented the formation of the windward vortex at the 0° position, thereby exposing the wall surface to the total potential pressure energy of the wind. However, if this had been the case the escape of the air at the vertical edges of the front wall would have produced areas of high negative pressure down the sides of the front wall but these areas of negative pressure were not found in the results.

Some flow visualisation experiments, employing dense smoke, were made in the final stages of the field experiments and showed that a vortex roll did form against the front face of the model. It can be deduced, therefore, that the windward vortex movement was extremely vigorous, causing the high positive pressures. That two alternating vortices formed before the front face, with their centres located on either side of the mid-point of the wall, would explain the divided pressure areas and the lack of negative pressure at the edges. The escape of these vortices over the top edge of the front wall and thereafter across the roof would result in the two separate areas of high negative pressure recorded on the front roof area.

It is considered that the angular movement of the mean wind direction also had the effect of reducing the vortex pockets along the side walls of the model when positioned at 0° and behind the leeward walls at the 30° and 45° positions. The total effect was to produce a much smaller overall vortex pattern around the whole model than is normally found in wind-tunnel studies. Proof of this behaviour can be had from the pressures measured from the back wall of the model when positioned at 0° and from the leeward wall surfaces of the model when positioned at 30° and 45°. It can be seen that the pressures obtained from the back and leeward walls at 0° and 30° were extremely low, with a small pocket of positive pressure appearing on one of the leeward walls of the model in the 45° position.

Some alteration or distortion of the configuration of the pressure lines drawn up in the pressure diagrams is evident. Much of this was caused by the effects discussed above. That is, due to the accelerated recontact of the flow, areas of positive pressure were produced at the boundaries of the vortices on the roof and the size and form of the vortices were restricted. However, in addition, the photographic method employed to record the pressure measurements contributed to these alterations. Even by waiting two or three seconds after each gust of wind enveloped the model the manometer readings were never stationary and when photographed indicated neither the mean nor the modal points of the levels but had a certain amount of displacement. Had the level in each manometer tube been recorded individually then it would have been possible to ascertain and record the modal point. Study of and selection from the three recorded sets of readings from each of the manometer set-ups eliminated major discrepancies.

Quite certainly, fluctuations in the position of the vortices in the flow around the model must take place. By obtaining the modal value of the pressure readings the mean position of the pressure patterns around the model is obtained and the resultant pressure lines in the pressure diagrams are smooth and of a uniform shape. Pressure measurements above or below the modal position would cause local displacement of the pressure lines or would cause abnormally high or low results at random positions in the pressure diagrams. Out of these effects variations resulted in the pressure diagrams produced from the measurements on the field model.

CONCLUSIONS

The investigations described in this report formed the first section of a study of the validity of certain techniques used in wind-tunnels to generate velocity profiles similar to those found in the natural wind. Although the scope of the work had to be limited to determining the character of the natural wind profiles over one area of terrain and to recording the wind effects experienced by one large-scale model, sufficiently detailed and comprehensive results were obtained to make possible a meaningful comparison with wind-tunnel studies of a similar form.

In interpreting the results of the field experiments, difficulty was experienced due to the inadequacy of the information which currently exists on the form of the velocity profiles in the natural wind. The results from the instrument mast were in agreement with the profiles calculated using the version of the Power Law supported by Davenport. However, confusion still exists concerning the exact form of the profiles generated over various types of terrain and the exponents for the Power Law which correspond with these profiles. The field measurements recorded agreed with those exponents advocated by Shellard. However, in the argument concerning the heights to which natural wind profiles extend, Davenport's assertions are in closer agreement with boundary layer theory. It is to be hoped that current and future investigations of natural wind profiles will soon disclose the true nature of conditions.

The results from the half full-scale field model were in themselves interesting and were found to contain significant features. Gust effects influenced these results in a manner which is not normally possible to reproduce in wind-tunnels. The data obtained indicates that the use of large-scale field models, relatively inexpensive to construct and instrument, can be of considerable importance in obtaining valuable information concerning conditions in the field.

Further important aspects of the field results were revealed by their subsequent comparison with the results of wind-tunnel studies on model buildings, the findings of which will be published in a later report. Much usable information was obtained on the veracity and reliability of methods of wind-tunnel testing of small-scale models of buildings.

REFERENCES

1. J. O. V. Irminger and C. Nokkentved, Wind pressure on buildings, Series I and II *Ingeniør Vedenskabelige Skrifter*, Copenhagen, Nos. 23 (1930) and 42 (1936).
2. M. Jensen, The model law for phenomena in the natural wind, *Ingeniøren*—International Edition, Vol. 2 No. 4, November (1958).

3. J. ARMIT, The simulation of the atmospheric boundary layer in a wind-tunnel, *C.E.G.B. Res. & Dev. Dept.*, 9th Aug. (1966).
4. W. D. BAINES, Effect of velocity distribution on wind loads on a tall building, University of Toronto, T.P.6203, June (1962).
5. P. G. G. O'NEILL, Experiments to simulate a natural wind gradient in a compressed air tunnel, N.P.L./Aero/313, (1956).
6. C. F. COWDREY, A simple method for the design of Wind-tunnel velocity—profile grids, N.P.L. Aero Note 1055, (1967).
7. C. B. MILLIKAN and A. L. KLEIN, The effect of turbulence, *Aircraft Engng.* 169, Aug. (1933).
8. J. C. RATHBUN, Wind forces on a tall building, *Trans. Amer. Soc. Civ. Engrs.*, **105**, 2056 (1940).
9. A. G. Davenport, The buffeting of structures by gusts, paper 9, *Proc. Symp. on Wind Effects on Buildings and Structures*, N.P.L., (1963).
10. D. E. WALSHE, The investigation of the aeroelastic behaviour in steady winds of the pinnacles of the Metropolitan Cathedral, Liverpool, N.P.L./Aero. Report 1190, (1966).
11. H. C. SHELLARD, The estimation of design wind speeds, Paper 1, *Proc. Symp. on Wind Effects on Buildings and Structures*, N.P.L., (1963).
12. A. G. DAVENPORT, The relationship of wind structure to wind loading, Paper 2, *Proc. Symp. on Wind Effects on Buildings and Structures*, N.P.L., (1963).
13. M. JENSEN and N. FRANCK, *Model-scale tests in turbulent wind*, Parts I and II, Danish Technical Press, Copenhagen, (1963).
14. P. M. JONES and C. B. WILSON, Wind flow in an urban area: A comparison of full scale and model flows, *Build. Sci.* Aug. (1968).
15. C. W. NEWBERRY, K. J. EATON and J. R. MAYNE, Wind loading of a tall building in an urban environment, a comparison of full scale and wind-tunnel tests, Paper 3, *Proc. Symp. on Wind Effects on Buildings and Structures, Loughborough Univ. of Techn.*, (1968).
16. J. K. MARSHALL, Automatic battery operated windspeed and direction recording system, *First U.N.E.S.C.O. Int. Symp. on Methods in Agroclimatology*, Paper H. 5, (1966).

Peu d'information est disponible permettant la comparaison entre les résultats d'études obtenus en tunnel aérodynamique sur des édifices modèles et les effets éprouvés par des bâtiments à l'échelle naturelle soumis au vent météorologique. Le peu d'information disponible est souvent sujet à des déviations marquées comparé aux données du tunnel aérodynamique. Enormément d'information supplémentaire est nécessaire concernant les influences auxquelles sont sujets les édifices à l'échelle standard. Les complexités très appréciables en matière d'instruments étudiés pour l'obtention de mesures sur les édifices à l'échelle naturelle, aussi bien que l'investissement intrinsèque élevé, ont contribué à restreindre le volume de travail expérimental entrepris à ce jour. Le présent rapport énumère les résultats d'une étude, faite sur chantier, quant aux effets du vent sur un édifice à un étage à l'échelle 0,5:1. Les profiles du vent météorologique au-dessus du terrain furent mesurés et les effets de pression subis par le modèle enregistrés. Maintes caractéristiques intéressantes furent déterminées à partir des résultats, exigeant un scrutin soigné; la recherche a fourni des données de grande valeur que l'on a utilisé pour une comparaison des résultats obtenus par une étude ultérieure en tunnel aérodynamique sur des édifices modèles à faible échelle. Les résultats de ces derniers seront publiés ultérieurement.

Man kann wenig Kenntnis erhalten, die es möglich macht, einen Vergleich zwischen den Ergebnissen einer Windkanaluntersuchung an Gebäudemodellen und den Erfahrungen der Wirkungen des natürlichen Windes im wirklichen Masstab zu ziehen. Die wenig vorhandene Information weist of bemerkenswerte Widersprüche der Windkanalangaben auf. Es wird sehr viel mehr Wissen in Bezug auf die praktischen Einflüsse auf wirkliche Gebäude benötigt. Die beträchtlichen Komplizierungen der Instrumentierung, denen man bei Messungen an wirklichen Gebäuden gegenübersteht, haben gemeinsam mit den dazugehörigen grossen Kosten einschränkenden Einfluss auf die Ausmasse der unternommenen experimentellen Arbeiten ausgeübt. In diesem Bericht einer im Freien durchgeführten Untersuchung werden Ergebnisse der Wirkungen des Windes auf ein einstöckiges Modellgebäude in halbnatürlicher Grösse wiedergegeben. Es wurden die Profile in dem natürlichen Wind über dem Gelände gemessen, und die Wirkungen des Druckes, der auf das Moddel ausgeübt wurde, wurden niedergelegt. In den Ergebnissen wurden viele interessante Merkmale entdeckt, welche gründliche Berücksichtigung erfordern, und die Untersuchung ergab wertvolle Angaben, welche in einem Vergleich mit den Ergebnissen einer darauffolgenden Windkanaluntersuchung an kleinen Modellgebäuden verwandt wurden, dessen Ergebnisse später veröffentlicht werden.