Build. Sci. Vol. 3, pp. 31–40. Pergamon Press 1968. Printed in Great Britain

SfB	Ba4
UDC	721

Wind Flow in an Urban Area:

A Comparison of Full Scale and Model Flows*†

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Although there has been an increasing use of wind-tunnel tests on models to examine the structure of wind around buildings, there has been surprisingly little research into the correlation between the results of such studies and the wind pattern around the full scale structures. This report gives the results of a comparison between the wind flow about a relatively open area of the City of Liverpool, as measured by the relative exposures of twelve field anemometers, and the flow observed in a 1:500 scale model of the same area immersed in a profiled, turbulent, wind tunnel flow. The comparison is encouraging and the investigation suggests some aspects of model study techniques which require more detailed study. This Final Report covers one of several aspects of the problem of wind loads on structures currently being examined under the sponsorship of CIRIA.

INTRODUCTION

SINCE the last century the effect of wind on buildings has been predicted by observing scale models placed in a uniform airstream generated in a wind-tunnel, but there have been remarkably few attempts to compare wind-tunnel observations with the full scale effects upon real buildings. This is particularly surprising since the structure of the natural wind differs markedly from the smooth uniform flow which has usually been used in wind-tunnel studies. In view of the temptation to apply model techniques to the prediction of wind behaviour in relation to building groups, and the almost complete lack of knowledge of the reliability of such techniques, the authors, working in the Department of Building Science at Liverpool University, mounted the experiment described in the report.

The experiment consisted of a simple comparison between the average wind speeds observed in an area of the City of Liverpool and the flow observed in a model of the same area in a wind-tunnel. It is becoming increasingly common in investigating building aerodynamics to attempt to incorporate in the tunnel flow both natural turbulence and the variation of wind speed with height. This was done in the present experiment using a combination of screens and simulated roughness. Despite a certain arbitrariness in the model techniques and the crudity of the field measurements, the comparison obtained was very encouraging and was certainly good enough to suggest that, where average speeds are required, building group model techniques may be used for design purposes.

While it is recognized that gust speeds or peak velocities are important from the final design viewpoint, it is first of all necessary to establish the overall pattern of air flow. This report is confined to the study of average flows until such time as more experience is obtained on the modelling of turbulence in urban areas. The only way in which absolute speeds can currently be predicted at a site distant from a

*This paper originally appeared as CIRIA Research Report No. 10 and is published here by courtesy of the Construction Industry Research and Information Association.

†The CIRIA project "Wind effect on buildings and other structures" comprises six separate investigations being undertaken for CIRIA by the Universities of Liverpool, Glasgow and Hong Kong, the Electrical Research Association, the National Physical Laboratory and the Building Research Station.

As essential first stage in these investigations was the assessment of the reliability of wind flow predictions using models. This first Reseaıch Report gives an account of the work carried out at Liverpool to examine the performance of 1:500 scale models of an urban area in relation to the full scale.

Other aspects of these investigations will be reported in subsequent Research Reports in this series.

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Meteorological Station is to make site measurements of the wind over a limited period and to extrapolate these by comparison with records at the nearest Meteorological Office. It is rarely possible to pick a suitably representative position for the site anemometer, but if the site observations from any one anemometer are supplemented by model studies of the sort described in the report, a complete picture of absolute average wind speeds which may be expected at the site can be obtained. (It is worth noting that the average 24 h wind runs at the site anemometers in this investigation varied between 13 per cent and 101 per cent of the runs observed simultaneously at the Meteorological Office Station at Liverpool Airport). An alternative approach, worth further study, is to argue that since a good comparison has been obtained between flows in scales differing by a factor of 500, it might be that scales of 1 : 5000 or even 1 : 50,000 could be used. By using appropriately scaled areas of randomly distributed roughness, gross wind conditions at one point could be related to those at another, corresponding to the site of a Meteorological Station. In this way a comprehensive model approach to the prediction of wind conditions at any site could be developed.

It has not so far been possible to investigate this or a number of aspects of the modelling methods which clearly need development (such as the value of profiling the tunnel flow). The second author intends to pursue some of these points as part of a further research programme supported by C.I.R.I.A. and the Science Research Council.

USE OF MODELS

The flow of natural wind about a large object appears to be predictable on the basis of observations of flow about a scaled model in a wind-tunnel. The early successes of model methods when applied to aircraft design and their apparent success when used to estimate the wind pressure distribution on elementary building forms have led to an increasing use of model studies and the range of objects investigated now ranges in size and complexity from wind baffles on grain trucks[1] to the Rock of Gibraltar[2]. There have, however, been very few attempts to confirm that the pattern of flow or pressure predicted by model studies is representative of the full scale. It is true that in the case of simple objects it is possible to produce theoretical evidence for the validity of model tests performed in uniform flows provided that simplifying assumptions are made about the structure of the natural wind. However, natural wind flow is not only characterized by speed and direction (the two parameters which are usually modelled in the tunnel) but also by a velocity profile (variation of speed and, possibly direction, with height) and by turbulence; these may make an important contribution to the interaction between the object and the wind. Additionally, once the object becomes complex (for instance in such a way that the upstream part modifies the characteristics of the flow over the rest, as in a group of buildings) it becomes impossible to make simple assumptions about the flow. This may not be entirely true if the group of objects is very large, as in a forest or a housing estate, when a few statistical parameters can be attached to the group of objects and only gross characteristics of the flow are required, but it is certainly true of the details of the flow about any one of the group of objects.

In the last few years, largely because of a demand for higher environmental standards and the increasing numbers of very tall buildings, the designer has made greater use of model studies of wind flow than in the past when interest was largely confined to the estimation of pressure distributions on basic building shapes or on specific structures. One particularly useful application of model techniques is in the investigation of flow about groups of buildings and in the detailed prediction of wind conditions at a site surrounded by buildings. The functional planning of new towns on exposed sites, the prediction of the effects of high buildings on wind conditions at ground level, the design of environmentally good pedestrian precincts and parks, and the rational design of small structures within cities are all helped considerably by model studies—but only, of course, if the model techniques give a sufficiently accurate prediction of conditions at full scale.

If a suitable wind-tunnel is available it is a straightforward matter to build a model of the group of buildings which surround the proposed site, and to observe the modelled flow. It seems very likely that there will be some relation between the model and full-scale flows providing sufficient care is taken with the model and with the modelled free wind, but it is not certain that the model results may be applied directly in design nor is it clear how much care must be taken with the model or reproduction of the free wind.

The science is in its infancy and it will be a long time before it is put on a fully rational basis. As a start, and with the hope of giving encouragement to those who already use model studies in these fields, this investigation was mounted. It comprises essentially a comparison between model predictions of average flow in an urban area and the flow as observed in full scale. Without going to much higher expense than seemed justified in the preliminary stage, the only characteristic of the wind which could be measured in the field was the 24 h run of wind during periods when the overall wind direction was fairly constant. This was observed at twelve positions in an open site in the centre of Liverpool over a period of about a year. By making a suitable analysis the observations have been reduced to a simple form which gives an immediate comparison with similar results obtained from an investigation of flow in a model of the site. The comparison is encouraging and the investigation suggests a number of aspects of the modelling techniques which require further study.

PREVIOUS MODEL/FULL-SCALE COMPARISONS

There have been remarkably few attempts to compare predictions of wind pressure or flow based on wind tunnel observations with the actual behaviour at full scale. Stanton[3] investigated overall pressures on plates in both natural and uniform model flows. Bailey[4] repeated some of Stanton's experiments and extended them to a comparison of pressure distributions on a large shed. Kamei[5] has has also performed comparative pressure measurements on buildings but using a turbulent flow model. In none of these cases was good agreement found between the model and full-scale pressure distributions, particularly on the leeward face [see discussion in reference 6]; Dryden and Hill[7], and Rathbun[8] used the Empire State Building for such a comparison but the experiment was not conclusive. The present authors have made a comparative study of flow about an isolated building[9]. Some relevant work has also been done in connection with model studies applied to ventilation[10]. The Building Research Station is conducting an extensive field experiment on pressure distributions[11] and has reported some comparative measurements on flow between a low and a high building which indicated good agreement[12]. The National Physical Laboratory have made an extensive comparison between model and full scale air flow over open deck spaces on two ships[13] and considered that the full scale measurements "... clearly indicated the value of wind-tunnel experiments".

The most comprehensive investigation of modelling techniques has been carried out by Jensen and Franck[14]. They maintain that satisfactory agreement can only be obtained provided the natural turbulence and velocity profile are modelled in the tunnel flow. As a practical verification they performed three sets of model/full-scale comparisons: two of shelter behind groups of objects, and one of the pressure distribution on a house. In the first two cases they found good agreement if the models were observed in flow having a correctly developed turbulence and velocity profile. They used a tunnel with a long working section and developed the boundary layer naturally using a rough floor whose roughness was scaled in the same way as the model. In the pressure distribution on a house they found a better comparison than Kamei—particularly on the leeward face—but there were still small discrepancies on the windward face.

The conclusion drawn from a survey of previous work on the verification of model predictions is that there is a marked lack of experimental field data but that on the whole model investigations are probably best performed in a turbulent profiled flow.

THE SITE UNDER STUDY

The site chosen for this investigation was an open area of Liverpool which includes the St. John's Gardens and the main Mersey Tunnel entrance (figures 1 and 2). It was particularly suitable for

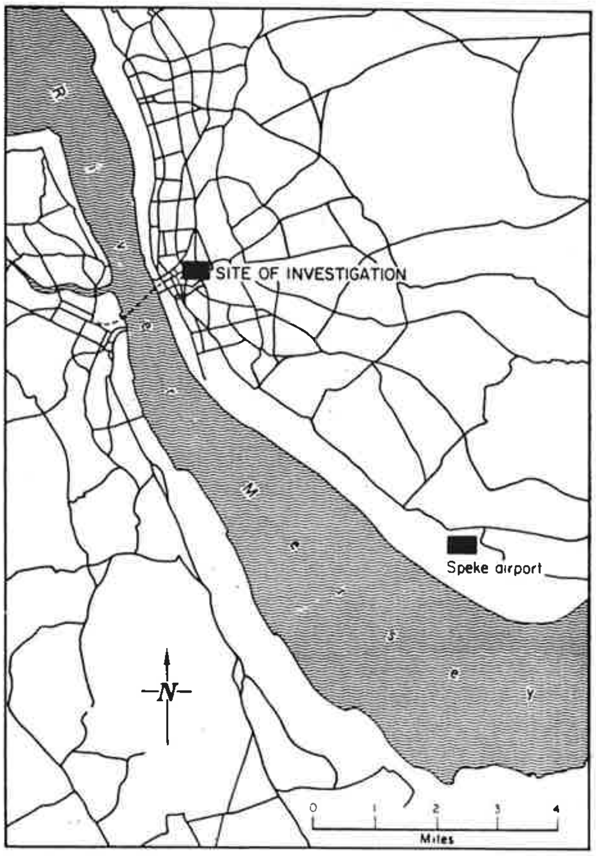


Fig. 1. Sketch map of Liverpool and District showing relative positions of test site and Speke airport meteorological station.

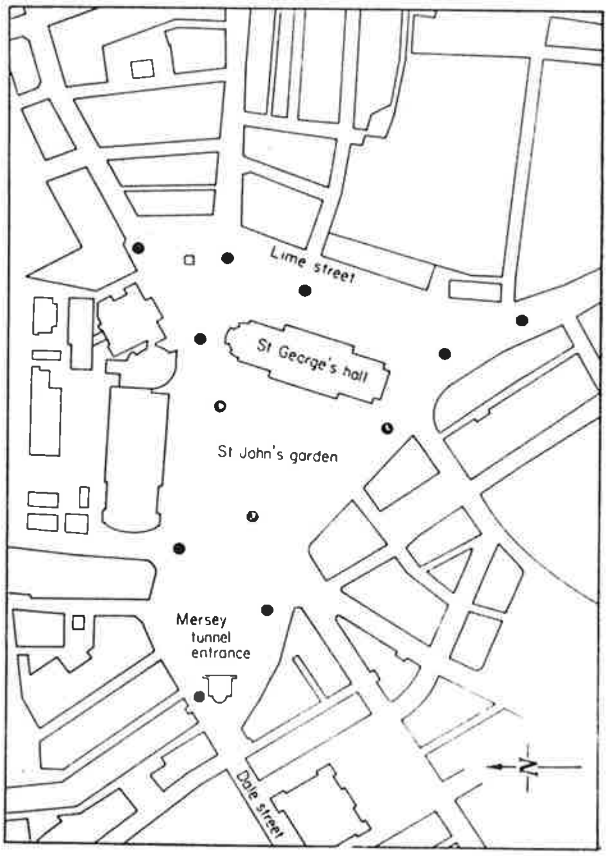


Fig. 2. The site, showing distribution of anemometers.

two reasons: a detailed scale model which included the area was available on loan for short periods from the City Planning Department and it was easier to study a fairly open area because it reduced the difficulties of modelling position accurately in steep horizontal velocity gradients. The site slopes upward towards the East and at the top of it is the St. George's Hall. It is surrounded by a wide variety of building types mostly 40–80 ft high. The nearest large unbuilt area to the site is the river, but this is over half a mile away.

INSTRUMENTATION

The field anemometers which were used for the investigation were commercial instruments of the heavy cup counter type built to standard Meteorological Office specification. They have a small window in the side, angled downwards at 45°, showing a mechanical counter which measures revolutions of the anemometer shaft and is calibrated in miles run of wind. Twelve anemometers were supported on lamp-posts sited as shown in figure 2, at a height of 20 ft above ground level. The supports held the anemometers 3 ft from the 5 in. dia. posts (figure 3). As far as possible lamp-posts were chosen which had a good exposure in all directions. A wind-tunnel experiment showed that if the lamp-post was directly windward, large errors would be introduced into the anemometer reading. To avoid the necessity of making detailed corrections for this, the anemometers were placed randomly about the posts and moved part-way through the investigation. The figures on the counter were large enough to be read from the ground using a small telescope or binoculars. The daily reading of the anemometers was very kindly organized by Prof. A. B. Semple, Liverpool's Medical Officer of Health, and continued for a period of about 12 months. Measures of wind direction at each of the sites were obtained by spot observations using an indicator on a long pole, there being no satisfactory way of obtaining these continuously within the cost scale of the investigation. In any case it was felt that it would be unlikely for the full-scale/model directions to disagree if the speeds were in substantial agreement.

Fig. 3. Typical mounting of anemometer on lamp-post.

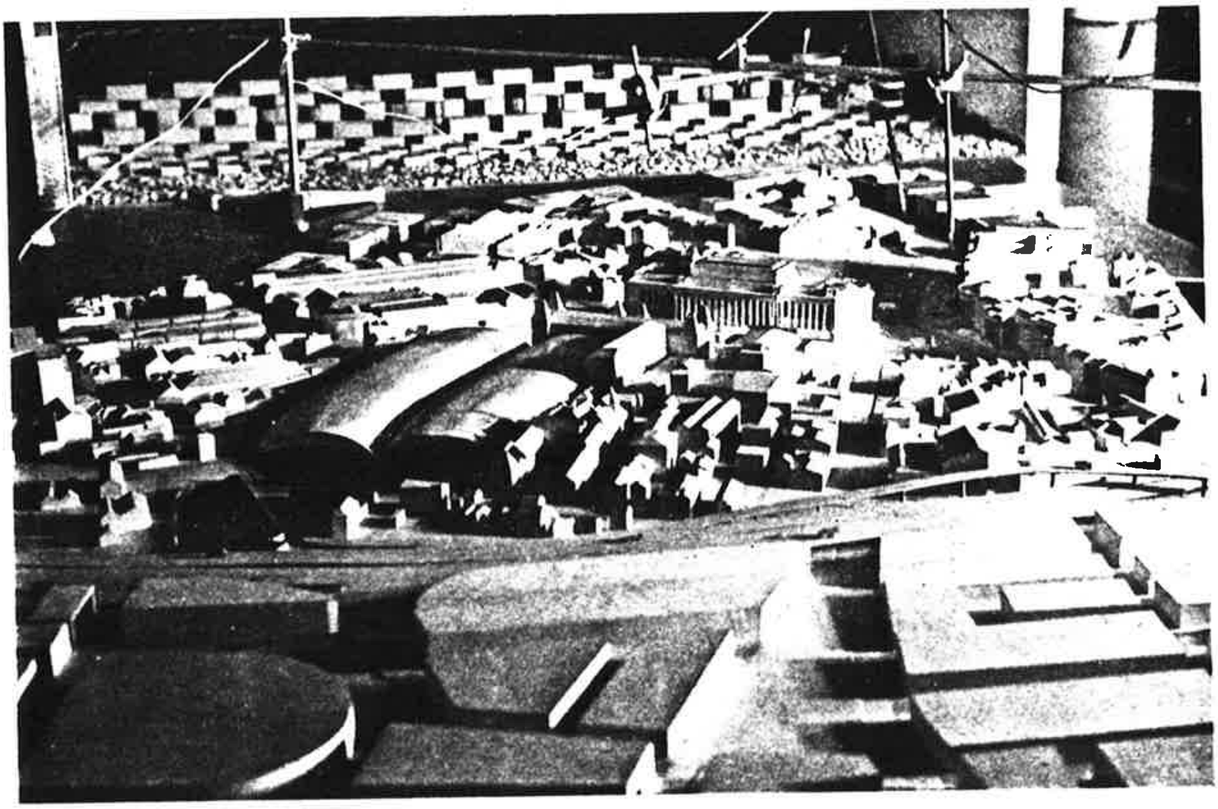
The model flow speeds were measured using a constant voltage thermistor anemometer whose small size made it ideal for the very careful positioning which was necessary. The instrument was originally designed for a single building flow comparison [9] so that it could be used in the field and in the tunnel to avoid differences due to the use of different types of anemometer. In the present investigation it was not possible to take advantage of this as the large cup anemometers were the only satisfactory field instrument. Since cup anemometers must be mounted with the shaft vertical and the ground rises over the area of the investigation, errors were immediately introduced by the cups being out of the plane of the wind. However this was never more than a few degrees which introduces only very small errors and in view of the nature of the investigation, no corrections have been made to allow for this. Much greater deviations from the horizontal would be introduced into the wind by buildings than by the slope of the ground and this is a general difficulty in using cup-anemometers. Again no specific corrections have been made as there was no way of recording the vertical component of the wind at each site for each wind direction at the height of the anemometer. This error could, however, be remembered in interpreting anomalies in the comparisons with model flow. (The thermistor anemometer is non-directional and there seems to be no simple way of making such a small electro-thermal anemometer with the directional characteristics of a cup-anemometer).

The flow in the model is turbulent and consequently the output of the anemometer has to be averaged in some way. This was done by integrating the output over a known period using an electromechanical integrator. The response of the anemometer is not symmetrical with respect to rising and falling air speeds, but neither is that of the cup-anemometers and without considerably more information than is available about the turbulence both in the field and in the model, no allowance can be made for this error. This is not of great importance, for, as is discussed in more detail later, it is not possible to compare absolute speeds but only those normalized to an average for all the sites for each direction and this procedure will cancel out the first order contribution of such errors. Flow directions in the model were observed using tufts of goose-down.

MODELLED FREE WIND

There is evidence that models should be tested in a profiled, turbulent flow[14] and this procedure was adopted from the beginning. A simple power law profile was established having an exponent equal to about 1/3. Subsequent field work on the measurement of profiles over built-up areas[15] and further wind-tunnel studies on model areas of randomly distributed scaled roughness to simulate the City, suggest 1/2 would have been a better

Fig. 4. Two views of the 1 : 500 scale model under test.



choice, but at the height at which the measurements were taken this is unlikely to be critical. Another argument for the use of a modelled flow which is profiled is that the only contribution of the surroundings distant from the site is in the introduction of such a profile and its associated turbulence. The use of an unsheared model wind would probably mean modelling a much greater area of the surroundings of the site in order to obtain a satisfactory reproduction of the full-scale flow.

The tunnel used was a very simple one of the open jet, free recirculation type having a working cross-section of 5ft 0in. × 3ft 6in. It is impossible in an open jet tunnel to use a sufficiently long working section to develop a deep, natural boundary layer using simulated roughness of suitable scale for the model. On the other hand profiles developed by screens or grids show a tendency to decay. A satisfactory solution was found in developing an initial profile using a graded mesh and maintaining it up to the model by a surface roughness whose size and disposition was established empirically (figure 4). The scaling of turbulence developed by such a system may bear little relationship to that of the model, although in the present case the profile was stable over the model suggesting turbulence was correctly scaled. Turbulence measurements were not made and the effect of turbulence scale on the average flow about the model is a point which requires further investigation.

The model used was to 1 : 500 scale (figure 4). Preliminary measurements, which were made when this experiment was being planned, were made on another model to the scale of 1 : 1250 but this was no longer available when the time came to make the detailed flow measurements. The models, built for display purposes, were very detailed, but even so, such small objects as trees were not included. An interesting issue was raised by the use of the two models. The 1 : 1250 scale model contained substantial areas of surrounding buildings (down to the river for instance in the westerly direction) whereas the other had considerably less. However, no significant differences were observed between the two models in the flow fields in the area under study. It is clearly a matter of some importance in using these techniques to know how much of the area surrounding the site or building group under study need be modelled (and how accurately—a random simulation of suitable roughness might be sufficient for some parts). The present investigation suggests that accurately modelled surroundings having a depth equal to a few times their height are quite sufficient for studies where the flow is not being investigated at greater heights than the surroundings and where the modelled flow is profiled and turbulent before it reaches the edge of the model.

ANALYSIS OF OBSERVATIONS

The raw data from the field consisted of about three hundred sets of readings from each of the twelve anemometers together with the times at which the readings were taken. These were supplemented by recordings of hourly wind speed and

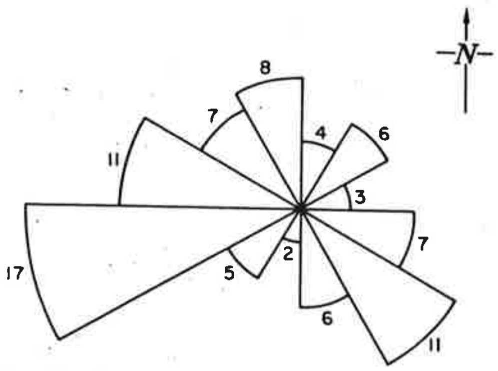


Fig. 5. Distribution of wind periods in each sector occurring during investigation.

direction taken by the Meteorological Office at Liverpool Airport which is situated about 6 miles from the City area where the field anemometers were sited. From the Meteorological Office data, it was possible to pick periods when the overall wind direction (as observed at the airport) was substantially constant between consecutive sets of anemometer readings. The criterion adopted was that the wind direction should remain within ±30° of the average direction during the 24 h. Eighty-seven such periods were observed. The field anemometer

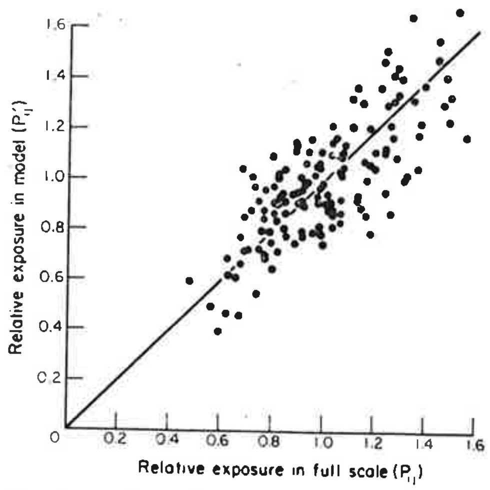


Fig. 6. Comparison of relative exposures in the model with full scale.

readings taken during these periods were then reduced to exactly 24 h runs of wind and grouped into twelve 30° sectors (i) according to the average wind direction during the period. The distribution of occurrence of periods in the 12 sectors is shown in figure 5.

A fundamental difficulty in analysing the field observations lies in the lack of reference wind speed. Each of the periods used may be thought of as a single experiment, each experiment being performed with a different and unknown overall wind speed. It is therefore necessary to remove the dependency of the observations on the mean wind and this can be done in a number of ways. The way chosen in the present case was to normalise the corrected 24 h runs to the average wind run over all anemometers in that period.

Thus, for a given anemometer j, and period s of the wind in the i^{th} sector, the field observations, when corrected to 24 h, give a 24 h run of wind R_{ij}^s. For a given period, the twelve values of R_{ij}^s may be averaged over the twelve anemometers to give

$$\bar{R}_{ij}^s = \frac{1}{12} \sum_{j=1}^{12} R_{ij}^s$$

Table 1. Comparison of P_{ij} (field) and P'_{ij} (model).

Sector of wind direction, i		Anemometer position—j 1	2	3	4	5	6	7	8	9	10	11	12
1	model	0·61	1·03	1·03	1·10	0·99	1·32	1·12	1·07	1·24	0·92	0·87	0·69
	field	0·65	0·82	0·96	0·80	0·99	1·15	1·24	1·18	1·38	1·02	1·03	0·77
	difference	−0·04	+0·21	+0·07	+0·30	0·00	+0·17	−0·12	−0·11	−0·14	−0·10	−0·16	−0·08
2	model	0·80	0·97	0·95	0·91	1·16	1·08	1·01	1·10	1·10	0·94	1·06	1·02
	field	0·75	0·77	0·83	0·80	1·03	1·32	1·32	1·07	1·29	0·97	1·20	0·82
	difference	+0·05	+0·20	+0·12	+0·11	+0·13	−0·08	−0·31	+0·03	−0·19	−0·03	−0·14	+0·20
3	model	1·00	1·12	1·07	0·99	1·06	0·85	0·88	1·02	0·88	0·84	1·24	1·15
	field	0·93	1·06	0·93	0·92	1·07	0·76	1·01	0·72	1·06	1·06	1·49	0·98
	difference	+0·07	+0·06	+0·14	+0·07	−0·01	+0·09	−0·13	+0·30	−0·18	−0·22	−0·25	+0·17
4	model	0·97	1·15	1·41	1·06	0·97	1·06	0·93	0·92	0·78	0·80	1·03	1·12
	field	0·91	0·89	1·31	0·98	0·98	1·37	1·13	0·74	0·91	0·78	1·07	0·93
	difference	+0·06	+0·26	+0·10	+0·08	−0·01	−0·31	−0·20	+0·18	−0·13	+0·02	−0·04	+0·17
5	model	0·84	1·02	1·42	1·06	0·81	1·31	0·96	0·78	1·04	0·88	0·89	0·98
	field	0·81	0·91	1·28	0·97	0·84	1·47	1·24	0·85	1·06	0·71	1·03	0·80
	difference	+0·03	+0·11	+0·14	+0·09	−0·03	−0·16	−0·28	−0·07	−0·02	+0·17	−0·14	+0·18
6	model	0·72	0·65	1·33	1·02	0·75	1·34	0·88	0·75	1·31	1·05	0·91	1·17
	field	0·81	0·79	1·35	0·91	0·79	1·50	1·26	0·88	1·25	0·68	0·81	0·95
	difference	−0·09	−0·14	−0·02	+0·11	−0·04	−0·16	−0·38	−0·13	+0·06	+0·37	+0·10	+0·22
7	model	0·69	0·40	1·14	0·77	0·87	0·87	0·79	0·95	1·57	1·52	1·12	1·33
	field	0·62	0·59	0·99	0·67	0·95	1·16	0·98	1·13	1·45	1·25	1·07	1·11
	difference	+0·07	−0·19	+0·15	+0·10	−0·15	−0·29	−0·19	−0·18	+0·12	+0·27	+0·05	+0·22
8	model	0·72	0·46	0·95	0·73	0·90	0·70	0·82	0·88	1·49	1·68	1·23	1·38
	field	0·68	0·67	0·87	0·74	1·14	0·77	0·98	0·76	1·45	1·53	1·26	1·13
	difference	+0·04	−0·21	+0·08	−0·01	−0·24	−0·07	−0·16	+0·12	+0·04	+0·15	−0·03	+0·25
9	model	0·67	0·72	0·87	0·87	0·91	0·80	1·07	0·98	1·42	1·45	1·18	1·11
	field	0·67	0·69	0·80	0·84	1·00	0·91	0·98	0·73	1·48	1·30	1·56	1·06
	difference	0·00	+0·03	+0·07	+0·03	−0·09	−0·11	+0·09	+0·25	−0·06	+0·15	−0·38	+0·05
10	model	0·59	0·96	0·92	0·90	0·93	1·22	1·13	0·94	1·38	1·01	1·19	0·85
	field	0·47	0·89	0·84	0·91	1·06	1·11	1·24	0·82	1·40	1·17	1·37	0·68
	difference	+0·12	+0·07	+0·08	−0·01	−0·13	+0·11	−0·11	+0·12	−0·02	−0·16	−0·18	+0·17
11	model	0·49	1·10	1·17	1·14	0·80	1·38	1·22	1·12	1·35	0·75	1·03	0·62
	field	0·56	0·80	1·04	0·89	1·18	1·22	1·18	0·89	1·29	0·99	1·33	0·62
	difference	−0·07	+0·30	+0·13	+0·25	−0·38	+0·16	+0·04	+0·23	+0·06	−0·24	−0·30	0·00
12	model	0·47	1·05	1·22	0·95	0·91	1·48	1·18	1·12	1·32	0·91	0·92	0·55
	field	0·62	0·84	1·03	1·01	0·89	1·24	1·27	1·20	1·27	0·97	0·91	0·74
	difference	−0·15	+0·21	+0·19	−0·06	+0·02	+0·24	−0·09	−0·08	+0·05	−0·06	+0·01	−0·19

and each of the twelve runs may then be expressed in dimensionless, normalized form as

$$\hat{R}^s_{ij} = \frac{R^s_{ij}}{\bar{R}^s_1}$$

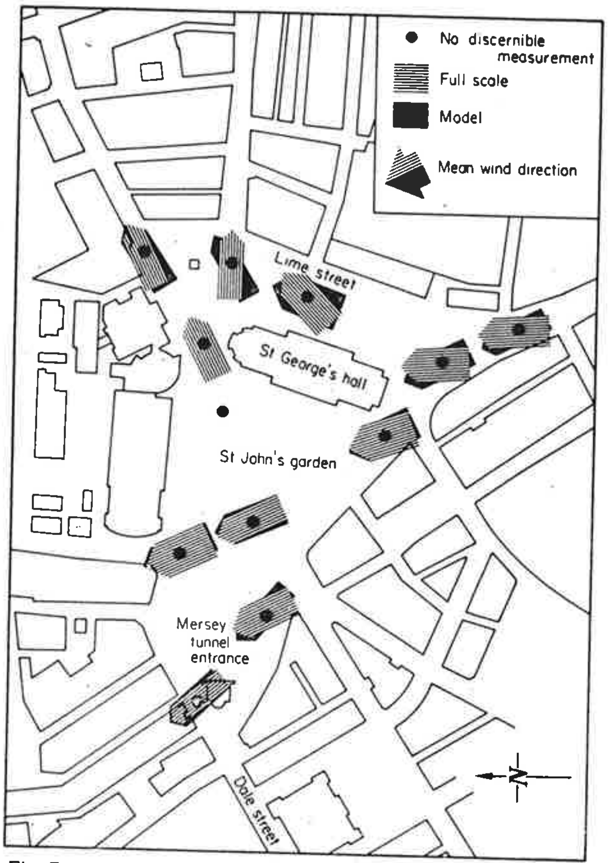


Fig. 7. Comparison of model and full scale flows for wind in sector 5.

The $\hat{R}^s_{ij}$ were then averaged over all periods s in each sector to give a set of 144 values of P_{ij} for the twelve anemometers j and the twelve sectors i. P_{ij} is the full-scale relative exposure of the j^{th} anemometer to winds in the i^{th} sector, and is independent of overall wind speed.

The data from the wind-tunnel observations were analysed in an exactly parallel way to give a set of model relative exposures, P'_{ij}. An important point here is that, to allow for both the variation in direction of the natural wind and the sectorial grouping of the wind directions, it was necessary to average the model relative exposures over a range of directions. This was done by averaging over the exposures which were observed for model wind flows in the nominal wind direction and in the centres of the two adjacent sectors.

P_{ij} and P'_{ij} are given in Table 1 and figure 6 is a plot of the points (P_{ij}, P'_{ij}). Wind directions were observed at the anemometer positions in the model and, by spot measurements, in full-scale. Such a procedure could, at best, only provide corrobative evidence of the similarity of the full-scale and model flows, but the comparisons were surprisingly good and an example is given in figure 7.

DISCUSSION OF RESULTS

If there were complete agreement between the model and full-scale observations, the points in figure 6 would all lie on the 45° straight line. If there were no agreement, the points would be randomly distributed on circles about the point (1, 1). The agreement between P_{ij} and P'_{ij} is good; encouragingly so considering the experimental circumstances.

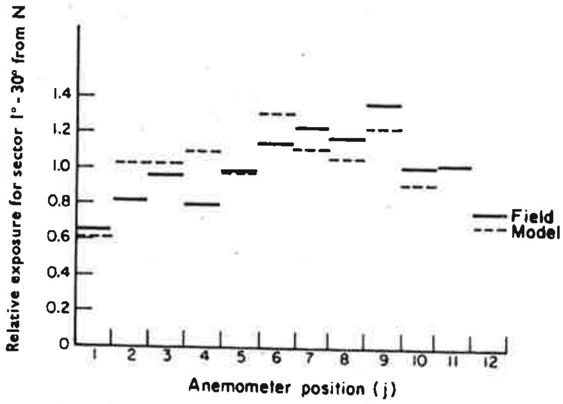


Fig. 8. Model and full scale relative flows in sector 1.

In such full-scale/model comparisons as this, there must always be difficulty in making an objective assessment of the results. There are many uncontrolled and unmeasured variables in the field (and, to a lesser extent, in the tunnel) and it is only possible to make the comparison between two scales so that there is no possibility of seeing a trend in the degree of a comparison with changing scale. It is not feasible to use enough anemometers over a long enough period to get a really unambiguous picture of the flow in the field, nor, without going to a much bigger scale of expenditure, is it possible to make any measurements of the variations in either speed or direction of the flow over shorter periods than 24 h. However, it is possible to take the analysis of the results a little further by imagining the experiment in reverse and asking how well the model measurements predicted the relative exposures of the field anemometers.

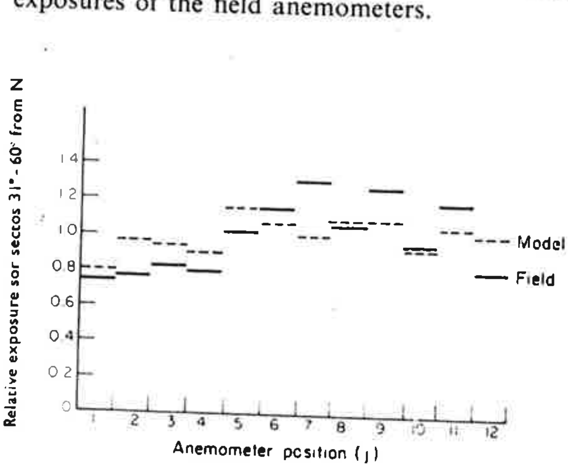


Fig. 9. Model and full scale relative flows in sector 2.

Figures 8 and 9 show a direct comparison of P_{ij} and P'_{ij} for two sectorial wind direction; similar diagrams were prepared for all sectors.

Figure 10 is a histogram of the differences between full scale and model relative exposures arranged as percentages of the average exposure. Over 80 per cent of the model measurements predicted the full-scale exposure to better than 20 per cent. Allowing for the large errors which must exist in the field measurements, this suggests that the model observations give a good prediction of the full-scale average flow. The figures could doubtless be improved by looking carefully at the larger differences to see if any of them may be rejected (many of them can for such reasons as unmodelled trees, a demolished building, etc.), but this hardly seems necessary.

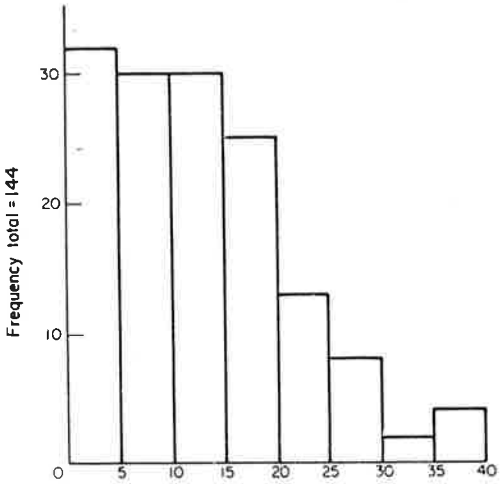


Fig. 10. *Reliability of predicted flows.*

CONCLUSIONS

The work described in this report formed the first stage in a study of the performance of models as a tool for prediction of wind flow. The number of tests conducted were, of necessity, limited; nonetheless, the agreement achieved proves the feasibility and reliability of such techniques and the following conclusions may be drawn.

(1) The use of a 1 : 500 scale model, in a wind tunnel providing an appropriately profiled turbulent flow, can reproduce the local wind velocities in a built up area generally to an accuracy within ±20 per cent. Reproduction of wind direction is also generally satisfactory.

(2) Some comparative tests with a 1 : 1250 scale model suggest that accurate modelling is necessary only to within a radius of a few times the height of the buildings. Beyond this radius a random simulation of suitable roughness is probably adequate.

(3) Further improvement may be possible by study of the influence of different scales of turbulence and profile of the modelled wind on average flows close to the ground.

(4) Additional work to determine the minimum amount of detail necessary in the model and its surroundings without loss of reliability in performance will form the subject of a later study.

Acknowledgements—The Liverpool City Planning Department and Planning Consultants for lending models; the Medical Officer of Health for Liverpool, Professor A. B. Semple, for organising the reading of the anemometers; the Liverpool City Lighting Engineer's Department for assistance with the erection of the anemometers.

The Science Research Council and the Civil Engineering Research Association for financial support for a programme of research into wind in urban areas of which the investigation described in this report is a part.

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Quoique l'on utilise d'une façon croissante des essais de soufflerie sur des maquettes pour examiner la structure du vent autour des bâtiments, il n'a été procédé qu'à des recherches étonnamment réduites sur la corrélation existant entre les résultats de telles études et le type de vent autour des constructions de grandeur naturelle. Ce rapport donne les résultats entre l'écoulement du vent et une région relativement dégagée de la Ville de Liverpool, comme on en a établi les mesures au moyen des expositions relatives de douze anémomètres sur place, et l'écoulement observé sur une maquette au 1/500ème de la même région immergée dans un écoulement turbulent, profilé de soufflerie. La comparaison est encourageante et l'examen suggère quelques aspects des techniques d'étude de maquettes qui nécessitent une étude plus détaillée. Ce Rapport Final s'occupe d'un parmi plusieurs aspects du problème des surcharges de vent relatives aux constructions en train d'être examinés sous le parrainage de CIRIA.

Obwohl Windkanalversuche zur Prüfung von Verhalten und Beschaffenheit des Windes rund um Gebäude an Modellen in ständig zunehmendem Maße durchgeführt werden, wurden erstaunlich wenig Untersuchungen über die Beziehung zwischen den Ergebnissen *dieser* Untersuchungen und dem Windverhalten rund um Strukturen in natürlicher Größe unternommen. Der vorliegende Bericht gibt die Ergebnisse eines Vergleichs zwischen der Windströmung in einem (und um ein) verhältnismäßig offenes Gebiet der Innenstadt (City) von Liverpool einerseits—gemessen durch die jeweilige Anzeige von zwölf Feldanemometern—und der Strömung, die in einem Modell im Maßstab 1:500 gemessen wurde; wobei das Modell (des gleichen Stadtgebietes) sich in einer profilierten, turbulenten Windkanalströmung befand. Der Vergleich erfüllt die Erwartungen, und die Untersuchung weist auf einige Aspekte des Modelltestverfahrens hin, die genaueres Studium erfordern. Dieser Abschlußbericht befaßt sich mit einem der verschiedenen Aspekte des Problems der Windbelastungen an Bauten, die derzeit—von der CIRIA gefördert—geprüft werden.