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«Weathertight joints for walls»

Influence of wind pressures on joint performance

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Rain penetration is one of the major considerations in the design of weathertight joints. There are several approaches to preventing rain penetration, but the one that has the greatest promise is based on controlling the four forces which act to cause it. These forces are the kinetic energy of the raindrop, capillary suction, gravity, and an inward air pressure drop through the wetted surface of a wall. Control methods for the first three forces have long been understood, but need and methods for controlling the fourth have only recently been recognized. The control of this force can be achieved by the incorporation of a space in the wall or joint which is sufficiently open to outside, so that the air pressure in the space can equalize with that outside. The achievement of this pressure equalization is obviously influenced by the air pressure on the outside of a building, especially if there are variations of air pressure from one point to another.

Wind causes a wide variation of air pressures on the surfaces of a building. The over-all pressure distributions which are of importance in determining wind loads have been under study for many years. Information is available on these pressure variations for many building shapes and many wind directions. There are indications, however, that abrupt local pressure variations from side to side of projections and recesses on a wall surface also occur. These have seldom been determined and the authors have found very little information in the literature on detailed point-to-point pressure differences. A knowledge of both the over-all and local pressure variations is necessary for the full exploitation of the priciple of pressure equalization as a means of controlling rain penetration.

Wind Flow Over Building Surfaces

Wind flow around a building can be broadly divided into the two regions of attached flow and separated flow. The air flowing around a building maintains contact with the building surfaces (attached flow) until a sharp edge or other point of separation is reached. Here, the streamlines separate from the building causing a wake region of moderate suction. This suction is uniform over walls located in the wake, flow velocities are small, and projections or recesses on the wall surfaces will have no significant influence on the pressure pattern.

Attached flow consists of the boundary layer, where friction retards the flow down to zero velocity at the wall surface, and the main flow, where the effects of friction are negligible. Near the building the streamlines are «squeezed together» and the flow speeds up so that the same amount of air can pass through a reduced «channel» area. In the main flow, when the velocity increases, the pressure decreases, and the resulting pressure variations from point-to-point are transmitted across the boundary layer and act on the walls of the building.

Projections on Wall Surfaces

If projections on a wall are small enough to be entirely submerged in the boundary layer, they will not affect the over-all pressure distribution resulting from the deflection of the airflow around the building. Pressure differences across such projections will depend on the flow velocities in the boundary layer as the wall surface is approached. Over much of the boundary layer turbulent mixing is effective and the rate of decrease in velocity is comparatively small. Adjacent to the wall, however, there is an extremely thin laminar sublayer where the rate of velocity decrease is very great. Outside this laminar sublayer there is still a significant porportion of velocity energy available that could be converted into a pressure difference across projections.

Studies of surface friction drag (1, 2) show that projections on a flat surface experience pressure differentials unless they are submerged within the laminar sublayer. The net pressure difference across such projections, expressed as a pressure coefficient (C_p) based on the free stream velocity, is in the range $0.4 < C_p < 0.8$. The pressure difference is obtained as the product of C_p multiplied by the free-stream velocity pressure. The critical height for surface projections, beyond which pressure differences could occur, is evidently the depth of the laminar sublayer. The two most important factors on which this depth depends are the flow velocity and the length of the surface over which the flow has passed. Judging from criteria developed for surface friction calculations on streamlined bodies, the depth of the laminar sublayer on a building in moderate to high winds would be 10^{-4} to 10^{-6} times the distance along the wall. Mullions, for example, may project as much as 10^{-2} times the total length of the wall and would, therefore, be subject to pressure differentials.

Measured Pressure Differences on Bluff Bodies

The only information found in the literature to illustrate pressure differences across projections on bluff bodies was for sylindrical tanks with vertical fins (3, 4). The pressure pattern found in one case *(Figure 1)* indicates a pressure difference across the fins up to 1.2 times the dynamic pressure of the free wind stream. The ratio of fin height to tank diameter was 1:150, and the ratio of tank height to diameter was 1.8:1. The separation points occur somewhat to the rear of the widest part, and as mentioned previously, ribs in the wake region have no effect on the pressure pattern. Similar results for two-dimensional circular cylinders with a ratio of rib height to cylinder diameter of 1:300 have also been reported (4). Such information, although relevant for many of the round buildings being designed today cannot be applied to angular buldings with plane walls.

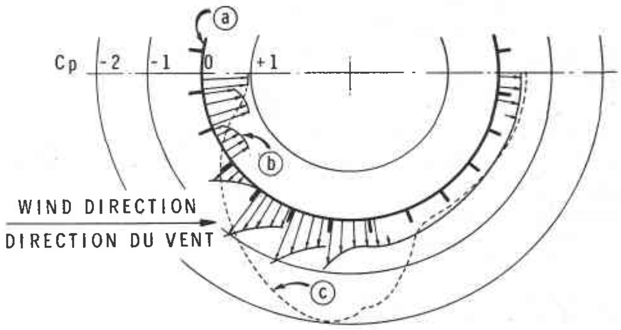

Fig. 1. Wind pressure on a large cylinder with vertical fins. Adapted from Fluid-Dynamics by S. F. Hoerner.
a. Wall of cylinder with fins
b. Wind pressure variations due to fins
c. Wind pressure for smooth cylinder.

Wind tunnel tests are now underway in the United States to investigate the pressure differences at mullions on at least one tall, rectangular bulding but results are not yet available. Field investigation of the problem is also necessary for proper application of wind tunnel results to full-scale structures because of possible scale effects.

Preliminary field measurements were started in February 1967 by the Division of Building Research, National Research Council of Canada, to confirm that such pressure differentials occur and to determine their magnitudes. To the date of writing this paper, only one set of measurements has been recorded. On this occasion, the wind direction was, unfortunately, almost perpendicular to one wall with the result that the other three walls were essentially in the wake zone of separated flow.

Under these conditions, pressure variations between mullions were not expected except perhaps very near the corners on the windward face. Of the seven 4-ft (120 cm) mullion spaces investigated on two elevations, no significant pressure variations were recorded except at one location — at a mullion space on a wall parallel to the wind direction. Here a steady pressure differential of 1.5 to 2.0 psf (7 to 10 kg/m^2) was measured when the wind speed was 30 to 40 ft/sec (9 to 12 m/sec). This indicates a pressure coefficient of $Cp = 0.7$ for the differential pressure. An air intake for the mechanical system of the building was located upstream in the adjacent mullion space. The probable explanation for the pressure differential recorded is that the inflow at the duct opening may have caused localized reattachement of the flow.

Although this one case cannot be considered as evidence either for or against the general occurence of significant pressure differentials in mullion spaces on buildings, it is an indicaton that factors other than simply the speed and direction of the wind may require attention. Funnelling between adjacent buildings may also lead to attached flow along a wall even though the wind is essentially normal to one face of the buildings

Effects of Pressure Differences

It is apparent from the available information that the air pressure on a building varies from point to point and from wall to wall. There are also strong indications that abrupt, local pressure differences occur at projections and recesses on wall surfaces. Pressure differences from point to point on a wall must be recognized since they influence the design of weathertight joints. Abrupt, local pressure variations should also be considered in the structural design of projecting elements and their connections.

Information on the patterns and magnitudes of pressure differences is required for the design of mullions, column covers, and other non-structural elements which could otherwise be considered not subject to wind loading. Until such detailed information becomes available, however, projections must continue to be overdesigned. A different situation is faced in the case of rain penetration. Having recognized that these pressure differences do occur, it is possible to take steps in the design of cladding and joints to ensure that their influence will be reduced or eliminated.

Rain penetration can be most positively and most easily prevented by controlling the forces which cause it (5). The main force in most occurrences of rain penetration is an inward air pressure drop through the wetted plane of the wall or joint. A space in a wall or joint which is sufficiently open to the outside, so that the pressure in it can equalize with that outside, can prevent the development of the inward pressure drop at the wetted plane. The required pressure equalization will not be obtained however in a space which is open at two or more locations if the outside pressure differs from one opening to another. Under such conditions, inward air pressure may still drive water into the construction, even at minute openings. Air flow through the space from one intentional opening to another may also transport water droplets or snow into the space.

Pressure equalization spaces should be drained and, therefore, small quantities of water in the cavity may be of little concern. The partial penetration of rain into the outer layer of the wall, however, may produce undesirable effects and should be minimized. If water in the space bridges gaps in the air barrier portion of the wall or joint, through-wall penetration of rain can also result. Although there is little likelihood of through-wall penetration when a well-designed cavity is employed, the occurrence of a pressure drop across the outer materials should nevertheless be prevented, if possible.

Control of Potential Problems

In recognition of the general pressure variations that occur on a building, it has been recommended that the pressure equalization cavities in walls be closed at frequent intervals (5). By compartmentation of the cavity, the range of pressure differences acting on any cavity compartment can be greatly reduced. It is proposed that until further pertinent information becomes available vertical closures should be provided at each outside corner of a building and at 4-ft (120 cm) intervals for about 20 ft (6 m) from corners (6). Horizontal closures should be used near the top of a wall. It is also considered advisable that both vertical and horizontal closures be positioned up to 30 ft (6 m) on centres over the total wall area. It should be noted that these cavity closures need not provide a complete air seal but must be sufficient to allow the appropriate pressure differences between cavity compartments to develop. It is possible to follow a similar approach to deal with the problem of achieving pressure equalization in spaces or cavities where abrupt pressure variations occur at projections and recesses.

Where there is an air pressure difference from side to side of projecting mullions, there will obviously be a pressure difference between the two jambs of each window located between them. Any spaces that are continuous between mullions and open at both ends are subject to the same problems that could occur in cavity walls. Here, again, division of the space into separate cavities, each open to one pressure area, should ease the problem.

The space between double windows cannot be compartmented unless there are two more windows to allow water which may enter the space to flow along the sill and drain outward at the low pressure side of the window. In smaller concealed spaces, such as those between the glass and sash or sash and frame, a plug can readily be incorporated. Because these spaces usually are continuous around four sides of the window, a cavity closure should be located in both the head and sill spaces. They should not, however, be located where they would interfere with the required drainage of the space.

Conclusion

It is generally well recognized that the wind pressure varies from point to point on building surfaces. Abrupt pressure differences across surface projections are a distinct possibility. Fortunately, there are some practical steps which can be taken to minimize the risk of rain penetration. There is great need, however, for research to provide much more detailed information on pressure magnitudes and the influence of height and spacing of projections and recesses.

This is a contribution from the Division of Building Research, National Research Council of Canada and is published with the approval of the Director of the Division.

References

(1) Schlichting, H. Boundary layer theory. McGraw-Hill, New York, 1955, p. 454.

(2) Hoerner, S. F. Fluid-dynamic drag; practical information on aerodynamic drag and hydrodynamic resistance. Midland Park, N. J. Published by the author, 1965, p. 5-6.

(3) Pris, R. Études aérodynamiques, III: Réservoirs et cheminées; recherches préliminaires. Influence de la rugosité et de la nervuration sur la résistance aérodynamique des cylindres. Annales de l'Institut Technique du Bâtiment et des Travaux Publics, No. 155, nov. 1960, p. 1231—1246. (Série: Essais et Mesures (49). (English summary).
Études aérodynamiques, IV: Réservoirs et cheminées. Résistance de cylindre à base polygonale à arêtes vives ou munis de nervures; Résistance de cylindres à base circulaire et à surface rugueuse. Annales de l'Institut Technique du Bâtiment et des Travaux Publics, Nos. 163—164, juillet-août 1961, p. 735—755. (Série: Essais et Mesures (51). (English summary).

(4) Garden, G. K. Rain penetration and its control. National Research Council of Canada, Division of Building Research, Canadian Building Digest No. 40, Ottawa, April 1963.

(5) Garden, G. K. Some experiences with joints. CIB Symposium on Weathertight Joints for Walls. Oslo, September 1967.

Résumé

Influence de la poussée du vent sur l'efficacité des joints

L'infiltration de la pluie à travers les joints d'un bâtiment peut être empêchée par le contrôle des forces qui en sont la cause. La principale force d'infiltration est une réduction de pression dirigée vers l'intérieur. Le contrôle de cette force peut être atteint en maintenant l'espace â l'arrière du mur extérieur détrempé à une pression égale à celle de l'ambiance extérieure. La pression du vent, toutefois, varie considérablement d'un endroit à un autre â la face d'un mur. De plus, l'expérience semble indiquer qu'il existe des différences localisées, mais sévères à l'endroit des projections ou de recoins dans les murs.

L'équilibre des pressions ne peut être atteint dans un espace, ouvert à plus d'un endroit, si les surcharges du vent varient d'un endroit à un autre. Si la cavité est obturée à des endroits stratégiques, on pourra quand même réaliser, ou à peu près, cet équilibre des pressions.

Malgré les lacunes dans nos connaissances sur les différences de pression à la face des bâtiments, il existe des moyens pratiques de réduire les risques d'infiltration de la pluie. On doit ajouter, cependant, ques de sérieuses recherches sont nécessaires sur l'amplitude des surcharges du vent et sur les influences qui découlent de la hauteur et de l'espacement de toute projection ou recoin dans les murs.