Studies by the Division of Building Research related to rain penetration

Hutcheon, N. B.; Gibbons, E. V.

Publisher's version / Version de l'éditeur:
https://doi.org/10.4224/20337997
Report (National Research Council of Canada. Division of Building Research); no. DBR-R-123, 1957-05-01

NATIONAL RESEARCH COUNCIL

CANADA

DIVISION OF BUILDING RESEARCH

STUDIES BY THE DIVISION OF BUILDING RESEARCH RELATED TO RAIN PENETRATION

by

N.B. Hutcheon and E.V. Gibbons

Report No. 123
of the Division of Building Research

OTTAWA

May 1957

P R E F A C E

This brief review of the various activities and projects of the Division of Building Research which are related to the subject of rain penetration of building enclosures, was prepared in the first instance to serve as a report to the forthcoming meeting in Paris of the CIB Working Group on Rain Penetration. It is believed, however, that it may be of interest and perhaps of use to others, both as a review and a guide to the publications and reports of the Division on this subject.

Ottawa,
May, 1957.

N.B. Hutcheon,
Assistant Director.

STUDIES BY THE DIVISION OF BUILDING RESEARCH RELATED TO RAIN PENETRATION

by

N.B. Hutcheon and E.V. Gibbons

The interests of the Division of Building Research in rain penetration can be said to date from the day it was established in August, 1947. The incidence of serious difficulties with leakage and deterioration of brick masonry in the city of Halifax had already been established in preliminary studies made as part of the post-war study of housing research needs by the Research and Development Branch of the Department of Reconstruction and Supply.

By 1950, the staff and facilities of the Division had developed sufficiently so that it was possible to begin work through an extensive survey of masonry performance in the Atlantic Provinces. This was followed by visits to other cities, notably Quebec City, Montreal, and Toronto, as opportunities arose. As the work of the Division became known, requests for advice and assistance in connection with masonry leakage and deterioration began to come in. It soon became evident that problems with rain penetration of masonry were not confined to the Atlantic provinces, though they appeared to be most severe there, but were being experienced in central Canada as well.

As the work of the Division developed, appreciation of the important role played by moisture in the performance of buildings grew also. Canadian experience with cold weather conditions had been such as to emphasize the special moisture problems created by condensation within buildings, but it became apparent that many more problems were related to the moisture conditions resulting from the entry of rain into building constructions. Canadian experiences with efflorescence, failures of exterior coatings of all kinds, deterioration of materials by wetting and drying and by freezing when wet, as well as the influence of moisture upon heat transmission through building materials have confirmed the need for an adequate knowledge of the moisture conditions produced by the weather. This interest in rain penetration is shared by research agencies in many other countries and information is being exchanged. The experiences and activities of the Division of Building Research, which may be of some interest in this connection, will now be reviewed briefly. Reference will be made to work in progress and to work described only in internal reports of the Division, as well as to that already described in publications.

Rain Penetration of Unit Masonry

The results of the survey of masonry buildings in the Atlantic provinces are given in DBR Internal Report No. 65 (28). This survey confirmed the serious difficulties which had already been reported from the Atlantic Coast region, and indicated that the weather conditions are unusually severe. It was said that rain penetration through masonry walls frequently occurred when wind and rain conditions followed prolonged damp periods of light rain and mist. Freezing often follows closely on wet conditions and there was evidence of the destruction of walls by the freezing of trapped water as well as of deterioration of the mortar and the masonry units.

Subsequent visits to Quebec City and Montreal revealed that quite serious rain penetration and deterioration of masonry occurred in these locations also. Requests for assistance with specific cases of rain penetration have been received from Toronto, and Hamilton, and the southern Ontario region generally. In most cases these inquiries were in connection with new buildings, indicating that present practices in design and construction are not adequately preventing rain penetration and should be carefully reviewed.

A thorough study of the literature in English on rain penetration of unit masonry was begun in 1948. A résumé of these studies was presented as a paper at the Annual Meeting of the Royal Architectural Institute of Canada in Halifax in 1955; reprint copies have been issued as Technical Paper No. 30 of the Division, NRC No. 3754 (15). A more detailed and extensive report on the literature has been recently issued as Technical Paper No. 47, NRC No. 4336 (18).

Special attention was given, prior to the design of a masonry panel leakage apparatus, to the literature describing methods and apparatus used by others in assessing the leakage characteristics of wall panels. A summary of this literature together with a description of the design of the DBR apparatus is given in DBR Internal Report No. 85 (25). Results of tests on 27 masonry panels in the DBR apparatus are described in DBR Internal Report No. 108 (29).

Work with the panel leakage apparatus has emphasized the importance of the quality of the brick-mortar bond on the leakage characteristics of panels, and has generally confirmed the conclusions drawn from the literature study. The influence of brick and mortar properties upon leakage of the brick-mortar assembly is now under study at the laboratories in Ottawa as well as at the Atlantic Regional Station of the Division which has been established

at Halifax, with special interests in weather effects on masonry. The large panel size of $3\frac{1}{2}$ by $4\frac{1}{2}$ ft. (approx. 1 by $1\frac{1}{2}$ metres) used in the DBR panel apparatus is considered desirable but it is cumbersome for extended work. Studies are currently being carried out on smaller assemblages of five bricks.

It is proposed that the large panels tested in the panel leakage apparatus will be set out for outdoor exposure and re-tested and examined at intervals.

Pertinent properties of Canadian bricks have been described in Research Paper No. 8, NRC No. 2966 (14). Other items pertinent to unit masonry are discussed in sections on efflorescence and test huts, to follow.

Test Huts

The Division has made extensive use of small test huts as a means of examining materials and constructions on a pilot scale but under actual weather conditions. These were particularly useful as a means of investigation before the present laboratory facilities became available in 1953. These constructions are about 5 by 5 by 8 ft. and are provided with heating and humidification inside in winter.

Test huts are normally maintained at the Prairie Regional Station of the Division at Saskatoon, and at Ottawa. One of the huts at each of these locations is of "standard" wood frame construction and, with metered heat and moisture input, serves as a "weather calorimeter." Similar wood frame huts have been maintained for several years at a northern location at Churchill, Manitoba and at Pennsylvania University in the United States to provide a comparison of thermal performance under varied weather conditions. An additional six wood frame test huts at Saskatoon have provided a means of comparing several different kinds of insulated wood frame constructions. None of these huts was intended originally for rain penetration studies, but records have been kept of the moisture contents of siding and exterior sheathing which do reflect weather changes. The test hut at Pennsylvania University, which is operated there for the Division, has been used for several years for a series of studies of the effects of weather and various siding modifications upon the moisture contents of the siding and sheathing. These studies have not, as yet, been described in Divisional reports.

The test huts at Ottawa, with the exception of the "standard" wood frame hut, have been of masonry construction. The first series of huts was constructed in 1950 and

maintained until 1954 when they had to be cleared from the area in which they were built. These huts, although not primarily intended for rain penetration studies, provided an opportunity for observing many of its effects, and stimulated much interest. It was in connection with these huts that the need for some means of following moisture changes was first recognized. They provided also an opportunity for continuous observation of efflorescence, and demonstrated the very serious, inward moisture movements which could be produced in summer by direct sunshine following wetting of the exterior of a wall by rain. Since no reports have yet been made on these huts, brief reference to some of the results will be made.

Moisture gauges of the electrical resistance type were incorporated in the walls of one of the Ottawa masonry huts. Observations of moisture content were made also by direct sampling in both bricks and mortar. Later a silicone waterproofer was applied to one-half of one of the huts but, unfortunately, it had to be moved before a prolonged test of the effectiveness of this treatment could be made. More will be said in a later section about moisture gauges, which were mainly unsatisfactory.

The direct sampling of moisture content provided much interesting and stimulating information. The porous bricks of the hut were found to absorb large quantities of water (as much as 5 per cent by weight at the surface) following a single rain. Moisture contents varied markedly from one brick to another and between bricks and mortar. These latter observations led to an extensive interest in and study of the suction characteristics of bricks and mortar. The silicone waterproofing treatment was generally very effective in reducing the entry of water into the porous bricks.

Two of the brick masonry huts were provided with interior strapping, insulation, vapour barriers, and interior finish as is frequently used in Canada to reduce the heat transmission in brick wall construction for houses. In one of these, the masonry was parged on the inside and then lined with a building paper before the strapping was applied. This treatment was omitted in the second hut, with the result that within two years the untreated wood strapping had rotted very badly. While the interior of this hut was being refitted in the summer, it was discovered that serious wetting by condensation was occurring on the back (outside) of the vapour barrier. This was found to be caused by the action of the sun on the exterior surface of the brick following wetting by rain. A rise in temperature of the outside surface was driving the water in the brick inwards to condense on the cooler inner portions of the wall. As a

result of this experience, it was concluded that the parging and paper were desirable behind interior strapping or furring as a protection against wetting of the interior portions of the wall.

Before the brick masonry test huts at Ottawa were demolished in 1954 they were wetted on the outside with a water-soluble dye. Test portions of the walls were then carefully broken down and the paths of water penetration, as shown by the dye, were carefully noted. Very extensive paths along the brick-mortar interfaces were shown up by this method.

Two new brick test huts were erected in 1954 on a new permanent site. The masonry walls were made of SCR bricks. These bricks are a recent development intended to provide cheaper brick masonry walls for house construction and form a wall $5\frac{1}{2}$ in. thick in a single withe. One of the test huts was left uninsulated and the other was provided on the inside with building paper, strapping, insulation, vapour barrier and interior finish. Both huts have been heated and humidified in winter. Two bricks on each wall of each hut were specially cut to provide for the removal of a small test prism which is weighed at intervals to determine its moisture content. Rain cups, providing vertical openings, were placed at two elevations on each of the four walls of each hut and weekly records have been kept, together with records of heat and water input to the huts in winter and of relative humidity maintained in summer. Thermocouple strings were also incorporated in the walls at various distances from the outer face and continuous records have been kept. These records are now being analysed. They will provide information on the temperature and moisture cycles occurring within the walls of both insulated and uninsulated brick masonry construction. The directional rain data will be compared to the usual weather data which have been recorded on the site. Unfortunately, no directional rain gauge was in operation originally, but one has now been installed so that it will be possible to compare these readings with those of the rain cups at two elevations on each wall. Some difficulty was experienced in obtaining true readings of rain collected by the cups as originally designed, since insects were being caught in the oil film used to control evaporation. This problem has since been overcome.

Efflorescence

Efflorescence, particularly on new brickwork, is a frequent cause of complaints in Canada. Studies of it have been reported in Research Papers Nos. 19 and 20,

NRC Nos. 3773 and 3774 (16, 17). It is interesting to note that it usually appears in its most severe form in spring and fall, probably due to the prevalence of a combination of moisture and drying conditions which lead to surface evaporation in these seasons.

Several brick masonry piers have been maintained under outdoor exposure for several years. They have been under observation in the efflorescence studies, but are also being studied for signs of deterioration. Measurements have been made from time to time of the extent of the separation cracks between bricks and mortar.

Also included in this outdoor exposure program are several specimens of different types of Canadian bricks and a range of masonry mortars. The specimens are placed in trays of moist sand to obtain a comparison of their weathering properties under severe conditions of exposure. A number of the specimens have been coated with silicone, waxes, and cement washes to obtain an indication of the effect of surface treatments on durability.

Waterproofers

The Division participates in the work of committees of the American Society for Testing Materials concerned with the preparation of specifications for masonry bricks, tiles, blocks, and mortars. Of particular interest is the work of Subcommittee V of ASTM Committee C-15 which is currently studying methods for evaluating the usefulness of surface treatments in overcoming rain penetration. The progress to date in developing a method of test has been limited because of the inadequacy of information on the complicated role played by water in the performance of masonry walls.

Recent work undertaken by the Division on the development of methods for testing the effect of both integral and surface waterproofing are described in DBR Internal Report No. 112 (24). Information was obtained on the moisture movement through concrete specimens to which a number of waterproofing agents had been added.

Several tests were applied, covering vapour permeability, saturated permeability under a small head, capillary absorption, and evaporation. The results indicate that a waterproofer cannot be judged fairly by a single test.

Studies of a fundamental nature on moisture migration in porous materials have been in progress for some time. The effect of changes in moisture content and the

corresponding changes in dimension are of special interest. Measurements are regularly carried out on equilibrium moisture contents at various moisture potentials for materials under study. Fundamental studies are being made of the mechanism of moisture migration in porous materials. Some of the early work is reported in DBR Bulletin 1, NRC No. 3568 (12). More recent studies are described in two papers which have been accepted for publication in the October issue of Soil Science, (10).

Paint

The blistering and peeling of oil-type paints on the wood siding of houses has been a serious problem in Canada. This premature failure of the paint has been caused by high moisture conditions in the exterior walls. Field studies have indicated that the penetration of rain through joints in sidings has been a major factor in increasing the moisture content of the walls. The results of these field observations and laboratory studies are described in DBR Reports R1, R8, and Research Paper No. 13, NRC No. 3453, (22, 23, 9).

Analysis of Weather Data

The close connection between climate and building problems has been recognized from the beginning of the work of the Division. A most satisfactory working arrangement was made with the Meteorological Division which in Canada is maintained by the Department of Transport and has headquarters in Toronto. A climatologist from the staff of the Meteorological Division has been assigned to work full-time on building problems and pays monthly visits to Ottawa for consultation.

The first climate studies were made to satisfy the needs of the Climate Section of the National Building Code. In the course of this work far more data were developed than could be used in the Code and provided a basis for a Climatological Atlas of Canada which was published jointly by the Meteorological Division and the Division of Building Research as NRC 3151 (19).

Following the surveys of masonry problems in Eastern Canadian cities, an attempt was made to develop simple indices from the regular weather records which would describe the severity of the weather at these locations in terms of wetting and of freezing following wetting. These indices are described in Technical Paper No. 32, NRC 3794 (3). Although no correlation could be made because of the

difficulty of assigning quantitative values to the incidence of wetting and deterioration in practice, there were some useful coincidences between the indices developed and the field observations.

The data being obtained from the directional rain gauge, and from the measurements made on the two brick test huts at Ottawa may provide a basis for further evaluation of these relatively crude indices.

Studies are being made of the variations in local climate. The results thus far obtained for the cities of Ottawa and Vancouver are covered in DBR Internal Reports Nos. 70 and 103 (20, 21).

The moisture content of an exposed material or construction which is often of importance represents a level of moisture storage which may result largely from the interplay of wetting and drying conditions. Evaporation measurements, therefore, are of interest. These are made in Canada at certain selected stations, largely in the interests of agriculture. They are believed to be limited to measurements of evaporation from free water surfaces. A more complete statement of the measurements made and the records available in Canada is being prepared.

Measurement of Moisture Content

Studies of rain penetration would be greatly facilitated if the changing moisture content of the exposed material or construction could be measured non-destructively. Means for measuring moisture contents readily would be also of great assistance in many other cases. The Division of Building Research, like other building research agencies, has tried many methods and has hopefully investigated any new devices when they have been proposed.

The first moisture gauges investigated were those of the electrical resistance type proposed for use in soils. Many frustrating experiences followed in the attempt to calibrate these gauges by using soil samples in the laboratory. These earlier experiences, and descriptions of various other methods which have been proposed have been described in a paper "The Measurement of Moisture Content" contained in DBR Bulletin No. 1, NRC No. 3568 (12).

In later work, several commercially available meters of the electrical resistance type have been calibrated in contact with ceramic plates and membranes held at known moisture tensions. All have shown hysteresis, a great lag in the establishment of equilibrium, and lack of

reproducibility in the wetting cycle. They are currently undergoing evaluation in the field.

Similar results were obtained earlier in work done with small meters of the electrical resistance type which were designed and constructed in the laboratory for use in the masonry test hut studies. Very substantial hysteresis effects and lack of response over certain portions of the range of moisture contents were found.

Attempts by others to develop neutron methods have been followed with interest. A soil moisture probe of the neutron source, indium foil, and counter type has been constructed and calibrated. This shows some promise for certain studies in soils, but is much more cumbersome in use than are the continuous reading devices employing BF_3 tubes which are being developed by others.

Pawliw and Spinks at the University of Saskatchewan have recently reported on a neutron contact meter for concrete. Torchinsky, at the same University, is using a surface type meter for soils in which the neutron source is contained in a spike which is driven in a fixed distance from the soil surface. Both of these devices may have some application to masonry walls, provided that moisture content gradients are not a complicating factor.

Future Work

It is planned that much of the current work related to rain penetration will be continued and, in some cases, extended. Directional rain gauge and wall cup measurements will be continued, for comparison with normal meteorological observations of weather factors. It may be possible to make such measurements at several stations in Canada. Measurements of the cyclical variations of temperature and moisture content in masonry walls will be continued.

The studies of the resistance of unit masonry to rain penetration will be carried on as a major project. The large panel apparatus will be used as the standard method of test. Panels made for testing will be set out for outdoor exposure. The small panel test will be studied further, and if found to be useful will be used extensively in the continuation of the studies of brick-mortar bond, in conjunction with the large panel test.

Studies of the properties and performance of materials and of the action and effects of moisture in materials will continue as part of the regular work of the

Building Materials Section. The measurement of moisture content is of such importance in all this work that efforts to develop and to evaluate new techniques must be continued.

LIST OF DBR PUBLICATIONS, REPORTS AND TRANSLATIONS RELATED TO RAIN PENETRATION

PUBLICATIONS

Publications of the Division of Building Research cover a wide range and are described in the list of publications which is revised yearly with interim addenda. This list is available upon request, without charge. The National Research Council follows the policy applicable to all Government departments with regard to the pricing of publications.

1. Boyd, D.W., Rainfall intensities at seven Canadian cities. National Research Council, Division of Building Research, BN 15, February 1955, 2 p.

2. Dickens, H.B., Good practice in masonry wall construction. National Research Council, Division of Building Research, BN 22, June 1956, 8 p.

3. Dorey, D.B., Weather as a factor in masonry problems. Reprint from Journal, Royal Architectural Institute of Canada, Vol. 32, No. 10, October 1955, p. 394-397. National Research Council, Division of Building Research, Tech. Paper No. 32, NRC No. 3794.

4. Gibbons, E.V. and M.F. Goudge, The effect of low temperature on the performance of building materials in Canada. Reprint of one of three Canadian papers presented at the Building Research Congress 1951. DBR No. 26, Tech. Report No. 10, November 1951.

5. Goodwin, M.J., Efflorescence on the exterior surface of masonry. National Research Council, Division of Building Research, BN 8, July 1950, 10 p.

6. Hutcheon, N.B., Fundamental considerations in the design of exterior walls for buildings. Reprint from Engineering Journal, Vol. 36, No. 6, June 1953, p. 687. National Research Council, Division of Building Research, Tech. Report No. 13, NRC No. 3057.

7. Hutcheon, N.B., Stability and durability of masonry materials. Reprint from Journal, Royal Architectural Institute of Canada, Vol. 32, September 1955, p. 338-341. National Research Council, Division of Building Research, Tech. Paper No. 29, NRC No. 3753, October 1955.

8. Hutcheon, N.B., Humidity in Canadian buildings. National Research Council, Division of Building Research, BN 19, May 1956, 10 p.

9. Kuzmak, J.M. and P.J. Sereda, The blistering of paint in the presence of water. Reprint from the Canadian Journal of Technology, Vol. 33, January 1955, p. 67-76. National Research Council, Division of Building Research, Research Paper No. 13, NRC No. 3453.

10. Kuzmak, J.M. and P.J. Sereda, The mechanism by which water moves through a porous material subjected to a temperature gradient, Parts I and II. Accepted for publication in Soil Science, October 1957 issue.

11. Legget, Robert F., Climate and building. Reprint from Engineering and Contract Record, Vol. 64, No. 8, August 1951, p. 71. National Research Council, Division of Building Research, Tech. Paper No. 24.

12. Proceedings of the Conference on Building Research, Ottawa, October 21 to 23, 1953. National Research Council, Division of Building Research, Bulletin No. 1, NRC 3568, 137 p.

13. Ritchie, T., Some aspects of the problem of moisture penetration of brick masonry. National Research Council, Division of Building Research, BN 12, April 1952, 7 p.

14. Ritchie, T. and H. Meincke, Capillary absorption of some Canadian building bricks. Research Paper No. 8, NRC No. 2966, March 1953, 16 p.

15. Ritchie, T. and W.G. Plewes, Design of unit masonry for weather resistance. Reprint from Journal, Royal Architectural Institute of Canada, Vol. 32, September 1955, p. 342-348. National Research Council, Division of Building Research, Tech. Paper No. 30, NRC No. 3754.

16. Ritchie, T., Study of efflorescence on experimental brickwork piers. Reprint from Journal of the American Ceramic Society, Vol. 38, No. 10, 1955, p. 357-361. National Research Council, Division of Building Research, Research Paper No. 19, NRC No. 3773, October 1955.

17. Ritchie, T., Study of efflorescence produced on ceramic wicks by masonry mortars. Reprint from Journal of the American Ceramic Society, Vol. 38, No. 10, 1955, p. 362-366. National Research Council, Division of Building Research, Research Paper No. 20, NRC No. 3774.

18. Ritchie, T. and W.G. Plewes, A review of literature on rain penetration of unit masonry. National Research Council, Division of Building Research, Tech. Paper No. 47, NRC No. 4336, May 1957, 58 p. 5 Appendices.

19. Thomas, Morley K., Climatological atlas of Canada (a joint publication of the Meteorological Division, Department of Transport and the Division of Building Research, National Research Council, Canada). NRC No. 3151, December 1953, 253 p.

REPORTS

Note: Reports are prepared for internal use only and are not included in the list of Divisional publications. Internal reports are not to be cited as a reference in any publication but may be made available to those specially interested in the subjects with which they deal. All technical information of value in these reports will eventually be presented in regular publications of the Division.

20. Boyd, D.W., Local climate in the Ottawa region: 1954. National Research Council, Division of Building Research, DBR Internal Report No. 70, July 1955, 19 p.

21. Boyd, D.W., Local climate in the Vancouver region: 1954. National Research Council, Division of Building Research, DBR Internal Report No. 103, August 1956, 11 p.

22. Hopkins, C.Y. and E.V. Gibbons, Report on examination of paint on exterior of houses in Vancouver. National Research Council, Division of Building Research, DBR Research Report R. 1, October 1948, 23 p.

23. Hopkins, C.Y. and E.V. Gibbons, Report on the performance of exterior paints on houses: (second progress report). National Research Council, Division of Building Research, DBR Research Report R. 8, February 1953, 29 p.

24. Kocataskin, F. and E.G. Swenson, Methods for rating concrete waterproofers. National Research Council, Division of Building Research, DBR Internal Report No. 112, January 1957, 42 p.

25. Plewes, W.G., Design of a masonry leakage test apparatus. National Research Council, Division of Building Research, DBR Internal Report No. 85, August 1956, 15 p.

26. Ritchie, T., Properties of bricks received from Elmsdale, Nova Scotia. National Research Council, Division of Building Research, TN 156, September 1953.

27. Ritchie, T., Report on the materials and methods of construction of some brickwork piers erected in Ottawa for experimental purposes. National Research Council, Division of Building Research, DBR Study Report S 43, October 1953, 8 p.

28. Ritchie, T., A survey of the performance of masonry structures in the Maritime Provinces. National Research Council, Division of Building Research, DBR Internal Report No. 65, May 1955, 44 p.

29. Ritchie, T. and W.G. Plewes, Preliminary tests of the rain resistance of brickwork panels. National Research Council, Division of Building Research, DBR Internal Report No. 108, September 1956, 25 p.

TECHNICAL TRANSLATIONS

The Translations Section of the National Research Council prepares translations for all the Divisions in the Council. They are issued in a numbered series.

30. Edenholm, H., Moisture movement and moisture distribution on the walls of buildings. From Meddelanden fråm Statens Forskningskommittee för Lantmannabyggnader No. 5:53-76, 1945. National Research Council, Tech. Trans. TT-361, August 1956.

31. Holmquist, Nils, Swedish test hut research program (heat and moisture problems in barns). Translation of a reprint from Teknisk Tidskrift, 1948, No. 5, 8 p. National Research Council, Tech. Trans. TT-96, January 1950.

32. Johansson, C.H., Moisture transmission and moisture distribution in building materials. Translation of Fuktgenomgång och Fuktfördelning i Byggnadsmaterial, Tidskrift för Värme, Vent. och Sanitet, 19.S.67, 1948, 33 p. National Research Council, Tech. Trans. TT-189, July 1951.

33. Jonell, P. and T. Möller, Moisture penetration of solid facing brick walls. From Byggmästaren, 17:277-284, 1951. National Research Council, Tech. Trans. TT-618, 1956.