Influence of orientation on exterior cladding

Crocker, C. R.

Publisher's version / Version de l'éditeur:
https://doi.org/10.4224/40000816
Canadian Building Digest, 1970-06

Canadian Building Digest

Division of Building Research, National Research Council Canada

CBD 126

Influence of Orientation on Exterior Cladding

Originally published June 1970

C.R. Crocker

Please note

This publication is a part of a discontinued series and is archived here as an historical reference. Readers should consult design and regulatory experts for guidance on the applicability of the information to current construction practice.

The service life of materials is greatly influenced by the environment in which they are required to serve. In most cases the limits of the environmental conditions are known, but the variations that exist because of orientation often have a profound effect on the durability of sealants, mortar, masonry and other wall components. It is the purpose of this Digest to indicate the effects of orientation, particularly as it relates to temperature and moisture.

Solar Radiation

Under ideal conditions absorption of solar radiation can increase the exterior wall surface temperature above the ambient air temperature by almost 90 fahrenheit degrees. This creates large variations in the conditions of exposure of exterior wall materials because solar radiation is not received uniformly on all elevations of a building.

Vertical walls receive their maximum irradiation on a clear day with the sun at an altitude of 25 or 30 degrees and directly in front of the wall. At lower sun angles irradiation is reduced by atmospheric absorption. The time of day and day of the year when a wall receives its maximum irradiation depend on both latitude and orientation.

In southern Canada north-facing walls receive solar radiation from sunrise until about 8 a.m. and again from about 4 p.m. until sunset during most of the spring and summer. At Ottawa the maximum irradiation on a north wall, sufficient under ideal conditions to raise the surface temperature by 16 degrees, is received at about 6 a.m. and again at 6 p.m., standard time, on 21 June.

East and west elevations receive large amounts of irradiation during the summer because they face directly into the sun when its altitude is around 30 degrees. Both elevations receive their maximum irradiation, regardless of latitude, around 21 April, the east wall about 8 a.m. and the west wall about 4 p.m. Irradiation remains at a high level throughout the summer months, but starts to fall off in September.

Although south walls receive the greatest total annual irradiation, they do not receive the maximum in summer, because the sun is too high in the sky. During the winter the sun is at a much lower altitude and it is then they receive the maximum. At Ottawa, this is recorded at noon near the end of January; at Edmonton, at a higher latitude, it is received at the end of February. Prior to these dates, the sun is below the optimum altitude for maximum irradiation.

The figures in Table I give the maximum rise above ambient air temperature that a vertical surface attains as a result of absorption of solar radiation. The given values are for 21 July. It has been assumed that the day is cloudless with no wind, that the atmosphere is clear, the surface of the wall black, and the wall lightweight and well insulated. (Light coloured walls could reduce the temperature rise by half.) For massive concrete or masonry walls the values would be lower due to the conduction of heat into the walls and the high heat storage capacity of such constructions.

Table I. Maximum Temperature Rise of Vertical Wall Surface due to solar Radiation. Ottawa, 21 July

Time				**Wall Orientation**					
(Sundial)	**N**	**NE**	**E**	**SE**	**S**	**SW**	**W**	**NW**	**N**
6	13	46	51	26	4	4	4	4	13
7	10	55	71	46	7	7	7	7	10
8	10	48	74	58	12	9	9	9	10
9	11	31	66	62	23	10	10	10	11
10	12	16	50	59	35	12	12	12	12
11	12	13	27	49	43	16	12	12	12
12	12	13	14	33	43	33	14	13	12
1	12	12	12	16	43	49	27	13	12
2	12	12	12	12	35	59	50	16	12
3	11	10	10	10	23	62	66	31	11
4	10	9	9	9	12	58	74	48	10
5	10	7	7	7	7	46	71	55	10
6	13	4	4	4	4	26	51	46	13

Temperature Variations

Variation in temperature at any given time of surfaces with different orientations can be quite large. For example, in summer at 8 a.m. there can be a 65 degree temperature difference between the surface of an east wall and that of a west wall. The same variation can occur, in reverse, at 4 p.m. In the afternoon the actual surface temperatures will be higher because the ambient air temperatures are invariably higher.

Variation of temperatures in winter is even more striking. At noon, for example, an 81 degree temperature difference can occur between the surface of a south wall and all others oriented 90 degrees or more from the south. Even with an ambient temperature of -20°F, the surface of a wall oriented south-east, south or south-west can attain temperatures well above the freezing point.

Freeze-Thaw Action

The exterior surface temperature of materials on walls with a northern orientation is close to ambient air temperature during the winter months (see Table II). Materials with a southern exposure, on the other hand, are subjected to wide variations in temperature. Not only does this place greater stress on sealants and mortars but also increases the number of freeze-thaw cycles.

Table II. Maximum Temperature Rise of Vertical Wall Surface due to solar Radiation. Ottawa, 21 January

Time (Sundial)	Wall Orientation N	NE	E	SE	S	SW	W	NW	N
8	1	1	22	26	15	1	1	1	1
9	3	3	46	68	50	4	3	3	3
10	4	4	39	78	70	18	4	4	4
11	6	6	19	74	82	41	6	6	6
12	6	6	6	61	87	61	6	6	6
1	6	6	6	41	82	74	19	6	6
2	4	4	4	18	70	78	39	4	4
3	3	3	3	4	50	68	46	3	3
4	1	1	1	1	15	26	22	1	1

To illustrate the influence of orientation in freeze-thaw cycling, graphs in Figure 1 show the air temperature and corresponding surface temperatures of north- and south-facing walls of a DBR test building constructed of brick and located in Ottawa. The temperature of the bricks on the south wall rose above and fell below 32°F, causing a thawing and freezing cycle in the brickwork. The air temperature remained below 32°F, as did the temperature of the bricks on the north wall.

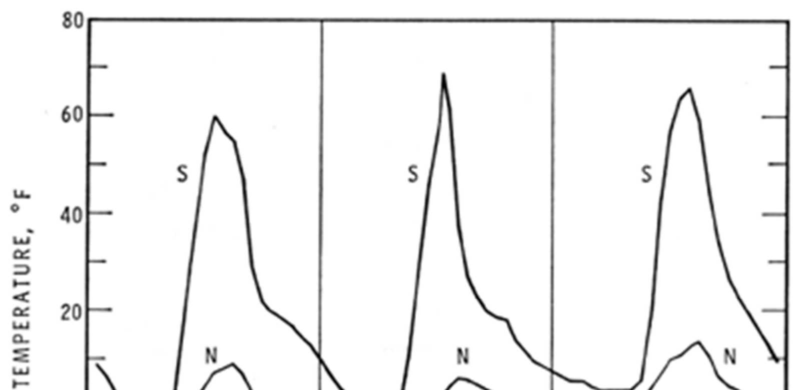

Figure 1. Air temperature and brick surface temperature of north- and south-facing walls. Legend: A air temperature; N north wall surface temperature; S south wall surface temperature.

During the three winter months bricks of the north wall of the test building were subjected to 27 freeze-thaw cycles, while those of the south wall experienced 67 cycles. The number of freeze-thaw cycles experienced by bricks exposed over one winter in Ottawa and Halifax is given in Table III. Winters with below-normal temperatures would show the greatest variation in freeze-thaw cycling for northern and southern exposures. In most areas of Canada such winters have above-normal sunshine, with corresponding increase in freeze-thaw cycles for walls with a southern exposure.

Table III. Geographical and Directional Effects On Freeze-Thaw Cycles of Bricks

Brick Facing	Number of Freeze-Thaw Cycles In One Winter	
	Ottawa	**Halifax**
North	65	81
East	70	83
South	98	108
West	79	88

Wind

Wind affects the exterior surface temperature of all elevations of a building more or less equally. The more important aspects of wind in relation to the orientation of walls have to do with air leakage out of buildings and rain wetting of walls.

In the greater part of Canada prevailing winds blow from a north-westerly direction during the winter months. Thus buildings are frequently subjected to suction pressures on the southerly exposures. These negative pressures combine with those of stack effect to induce air leakage outward from the interior of the building (**CBD 104**). As has been discussed in another Digest (**CBD 72**), air leakage is the principal mechanism by which water vapour is transferred into the wall. Thus, in winter, conditions prevail that may lead to additional condensation in walls with southerly exposure. then sufficient moisture is available, porous materials can become saturated, with consequent damage when frozen. Observations confirm, however, that solar radiation promotes drying of wall materials and on southerly exposures there is actually less damage than on easterly exposures where materials dry more slowly, although still subjected to increased freeze-thaw cycling. Here, moisture content may be a more critical factor than the number of freeze-thaw cycles.

The wetting of walls by rain is the result of wind action. Studies carried out in Ottawa and Halifax show great variations in the moisture content of brick exposed to the cardinal points of the compass. The graphs in Figure 2 show the moisture content of bricks exposed at Ottawa during the winter 1963-64 in such a way that only the face could be wetted by rain. The bricks facing south and west received very little rain, but those facing north and east had a high moisture content from wind-driven rain.

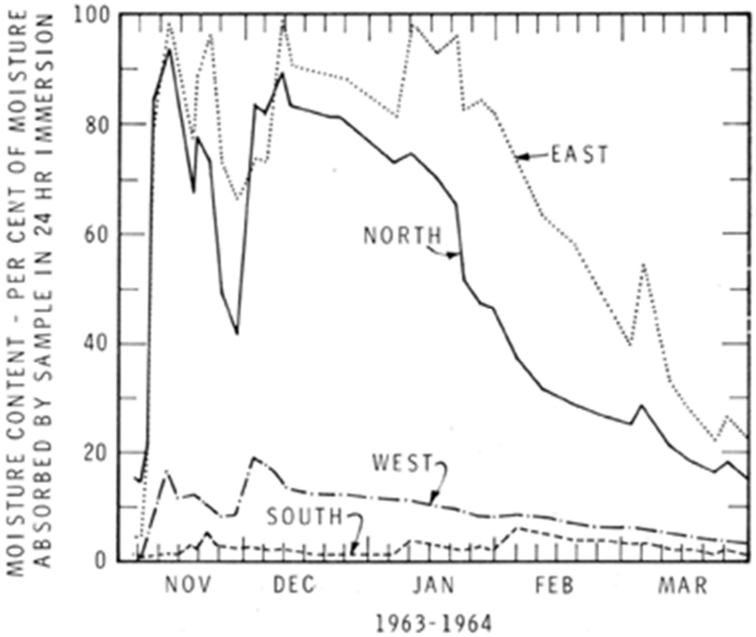

Figure 2. Directional effect on the rain-wetting of bricks exposed at Ottawa.

Similar bricks exposed at Halifax during the same period received more moisture than those in Ottawa and the directional effect was different. Bricks facing north received the least rain; those facing east and south received the most and reached the highest moisture content.

The wetting of full-scale building walls exhibits a more complex pattern influenced by the aerodynamics of the particular situation and projections on the surface that deflect the flow of water. Again, materials on the southerly exposure, even if wetted by rain, may be able to dry more quickly and are less liable to damage from freeze-thaw cycling.

Summary

Orientation influences the severity of the exposure to which walls are subjected. Temperatures at any given time can vary as much as 90 degrees due to solar radiation; and the number of freeze-thaw cycles can subsequently be increased as the result of solar radiation. wetting of walls, as influenced by prevailing winds and air leakage patterns, is also of significance with respect to the environment in which materials must serve.