Performance of the Mark IX Steel Basement to 31 January 1975

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SUBJECT

PERFORMANCE OF THE MARK IX STEEL BASEMENT TO 31 JANUARY 1975

The Mark IX house was constructed in the late winter of 1972 by the Regina Chapter of the Housing and Urban Development Association of Canada (HUDAC). The major innovation in this house was an all-steel basement, designed and constructed under the supervision of Dominion Foundries and Steel Company Limited (DOFASCO). As described in Technical Note 579 (1), the foundation walls were instrumented by the Prairie Regional Station, Division of Building Research (PRS-DBR), with earth pressure cells, ground movement gauges, wall movement pins and thermocouples. The results of measurements by PRS-DBR for the first year (ending 31 March 1973) were also included in the Technical Note 579.

Since then, the insulation system on part of the basement exterior has been rebuilt, and a new series of thermocouples has been added to record temperatures in the soil adjacent to the basement. This Note records the principle results observed at the Mark IX to 31 January 1975.

Upgrading Basement Insulation

It was noticed early in the winter of 1972-73 that the soil around the basement had shrunk away from the wall, forming a gap 3 in. wide and, at points, more than 3.5 ft deep. There was also a gap at the jointing line where the insulation of the basement met that of the superstructure. The gaps are shown in Figures 1a and 1b. Because of these gaps, cold outside air was able to circulate in the corrugated spaces of the wall, severely undermining the effectiveness of the wall insulation system. As a temporary measure, in January 1973, the

12 in. below adjacent finished ground level.

Heat loss from uninsulated basements is usually more than sufficient to keep the ground near the walls and below footings from freezing. Insulating the walls will greatly reduce the heat loss from the near- and above-grade portions of the wall. There is some concern about the possible danger of continuing the insulation to full depth on the inside of the basement wall for fear that this may permit deeper frost penetration and possibly cause large forces on the wall due to lateral frost heaving.

Figure 2a shows that even at the end of a severely cold winter (in which the cumulative freezing index reached 4026 Fahrenheit degree-days), there was no frozen ground in proximity to the basement. The widely spread ground temperature isotherms also indicate that heat loss from the basement was much less than for the uninsulated concrete basement shown in Figure 3 (3). During extremely cold weather, when there was essentially no snow cover, such as experienced on 12 January 1975 (Figure 2b),the freezing front did penetrate into the ground at the basement wall contact. Figures 4,5 and 6 show a minor trend to reduction in lateral earth pressures during the period. Prairie clay soils typically shrink in the direction parallel to a freezing front, even when frost heaving takes place perpendicular to the front. Provided the freezing front remains essentially horizontal in its advance, basement walls should not be subjected to large additional horizontal forces due to frost action.

Wall Movements and Lateral Earth Pressures

As described in Technical Note 566 (4), the major displacement of the walls took place during backfilling operations. The backfill was placed in three stages: it reached above mid-height on the deep basement walls on 13 April 1973, was raised about another foot on 25 April, and then to final elevation on 17 May. The first lift of backfill, consisting of hard clay clods that ranged from small fragments to large clods a foot or more in longest dimension, was rolled into place by a bulldozer in a single lift. The backfilling started in the northwest corner, adjacent to section B1, and proceeded around the west and south walls. This caused displacements of the upper portions of the west wall averaging between 1/4 and 1/2 in., with one section of the wall showing displacements of 3/4 to 9/10 in. These displacements appear to have given the deepest portion of the basement a slight parallelogram configuration, trending in a southeasterly direction.

The correlation between the magnitude of measured earth pressures and deflections of the walls was best at section B2, where post-construction disturbances have been minimal. Comparison of the earth pressure results in Figure 5a with in-panel deflections at sections B22 and B23 in Figure 5c shows the best correlations of the three sets of results presented in Figures 4,5 and 6. This is as expected because section B2 is more uniformly flexible and less well restrained at the bottom than sections B1 and C1. For these two sections, peak earth pressures of 4.5 psi and 5.6 psi were reached at wall displacements of 0.55 in. and 0.39 in.,

Summary

1. The thermal performance of the basement walls improved substantially after the insulation repairs and modifications. Temperatures of the soil adjacent to insulated and uninsulated basements verify that heat flow is considerably reduced when insulation is provided.

2. Vertical movement of the foundation is insignificant to date, and the structural basement floor continued to perform very satisfactorily.

3. As a side effect, the excavation and backfilling operation necessary for the insulation repairs induced new peak pressures against the wall after July 1974. These ranged from 69.5 pcf to 143 pcf, equivalent fluid pressure. These pressures are considerably higher than those commonly assumed for basement wall design in Regina. In some cases. they are more than twice as high.

4. Horizontal displacements and in-panel deflections of the basement walls continued to be within the acceptable range.

Acknowledgements

Calibration, installation and monitoring of the instrumentation at the Mark IX basement has been carried out by Messrs. L.J. Snodgrass, D. M. Guenter and J. Y. Makohon of the Prairie Regional Station, DBR, Saskatoon. The enthusiastic assistance provided by Mr. K. Sexton, occupant of the Mark IX and member of the HUDAR Research Committee from its inception, is gratefully acknowledged. During construction and consistently since, Mr. Sexton has given many hours of his personal time to record ground temperatures, earth pressures and foundation drainage with monitoring devices installed in the basement by the Prairie Regional Station and to record in written and photographic form the numerous details that are so important in compiling a complete record of performance. Without his dedicated and vigorous contributions the assessment of the performance of the steel basement and other innovative aspects of the Mark IX house would be lacking much valuable detail which could not be obtained otherwise because of the restrictions which distance and available staff resources place on the capacity of P.R.S. to carry out more frequent observations.

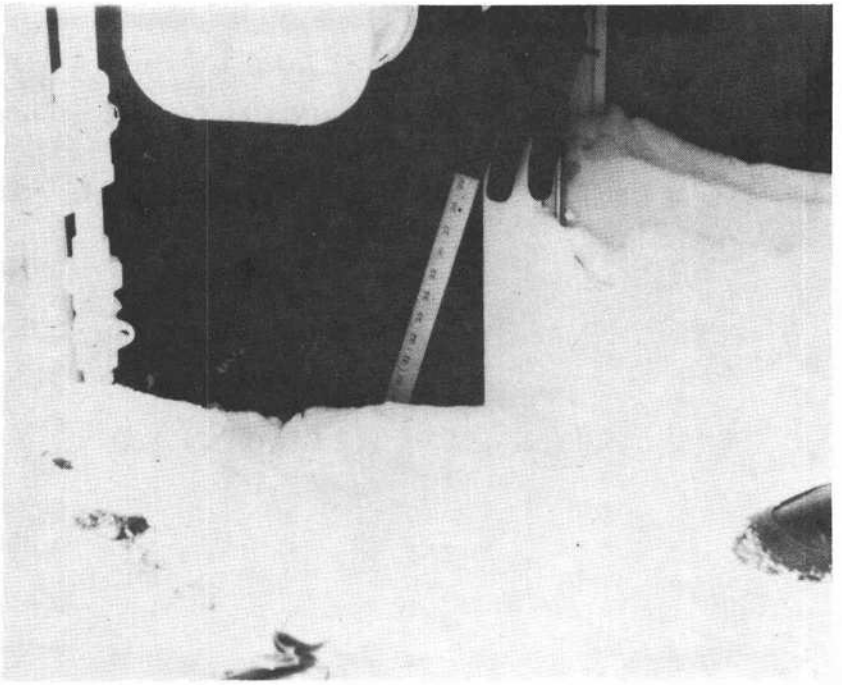

FIGURE 1a

Shrinkage of backfill soil during the fall and early winter of 1972-73 opened a crack between the soil and the basement insulation near the NW corner of the basement.

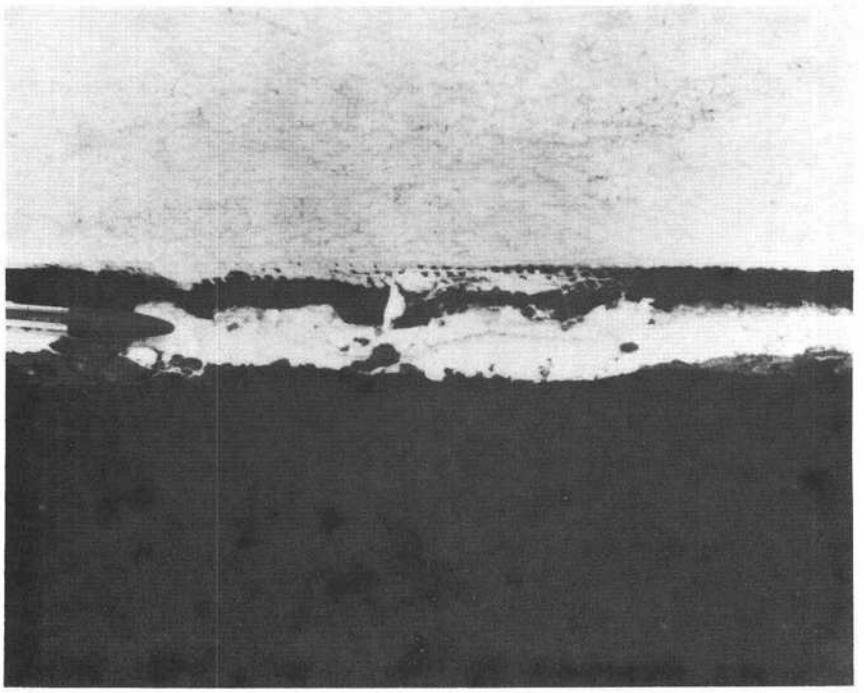

FIGURE 1b

Downdrag and shrinkage of soil away from the basement caused this gap at the jointing line of the basement and superstructure insulation near the centre of the N wall.

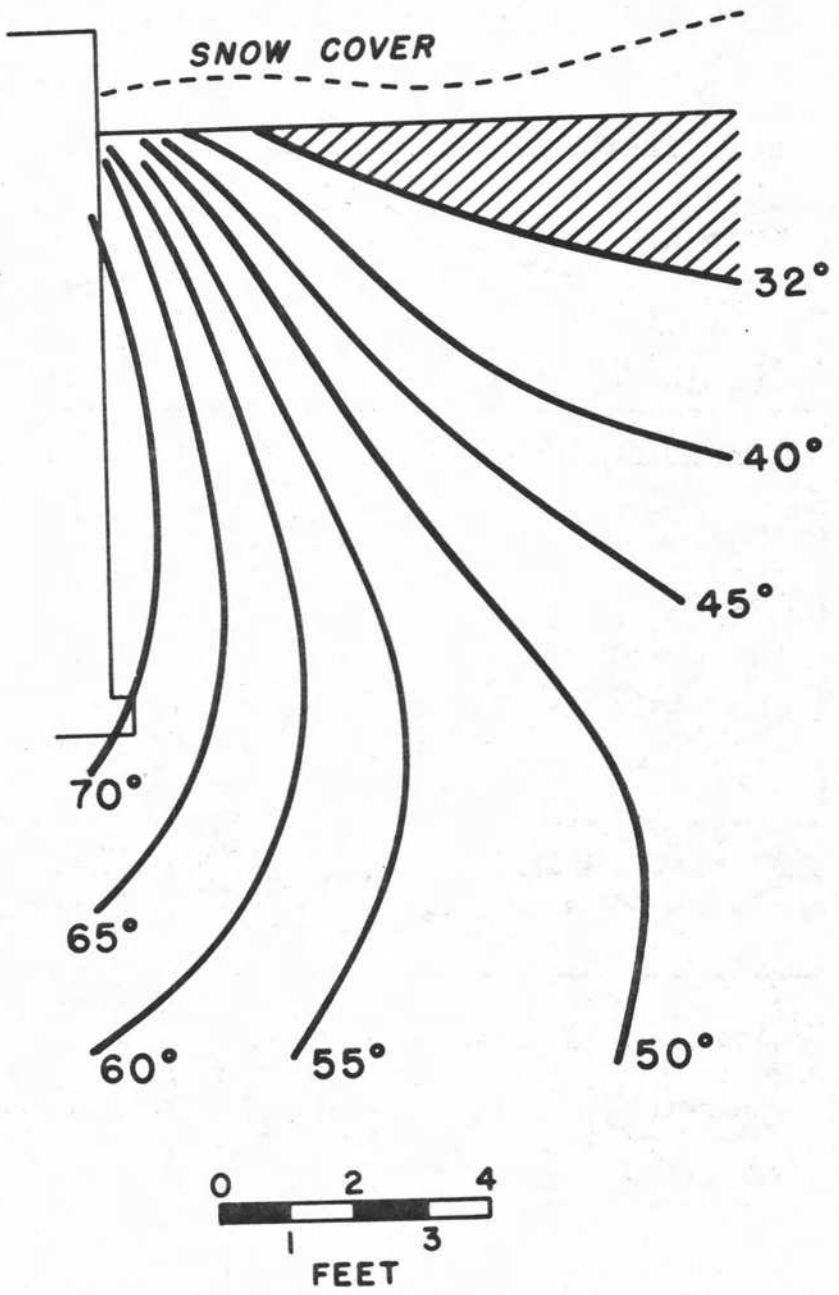

FIGURE 3: Ground temperature isotherms for an uninsulated concrete basement on March 13, 1956 (after Solvason and Handegord 1959 (3).

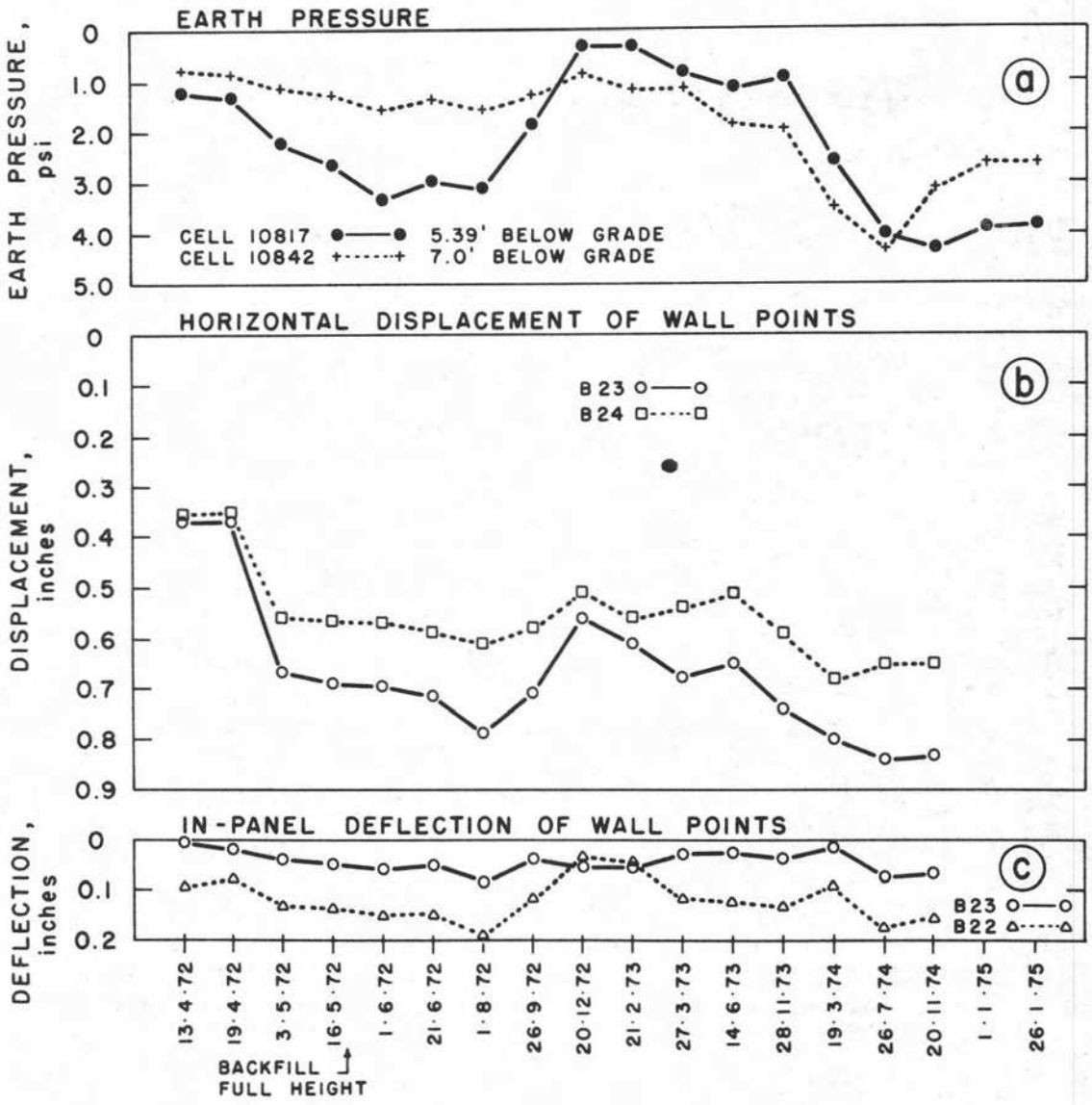

FIGURE 5: Earth pressures, horizontal displacements and in-panel deflections at Section B2.

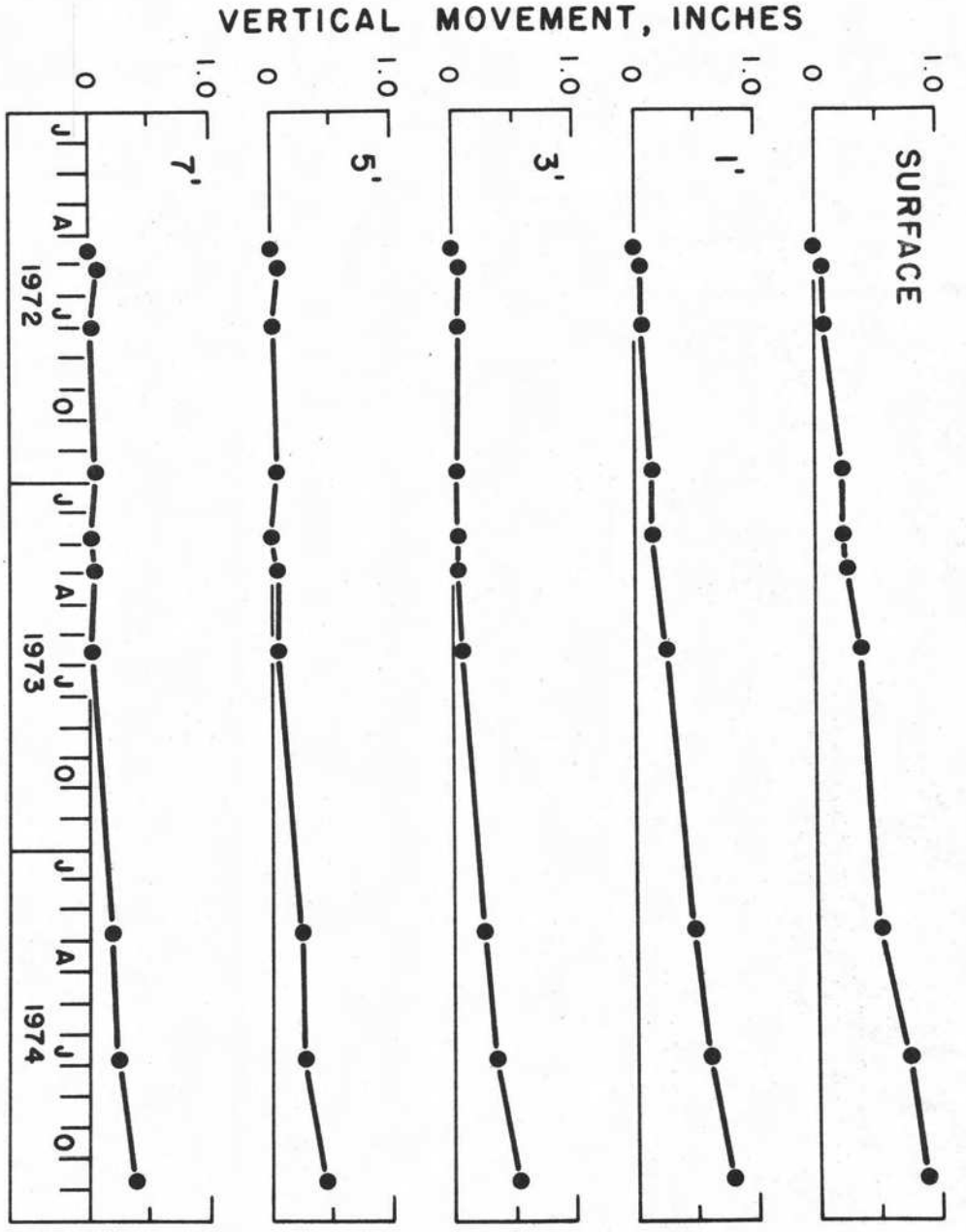

FIGURE 7: Vertical ground movements in crawl space of the Mark IX house.