## Performance of "T.T.W." brick buildings

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by

T. Ritchie



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# PREFACE

Single-leaf "T. T. W." (through-the-wall) brick walls, extensively used in recent years by the building industry of southern Ontario and to a lesser extent by builders elsewhere in Canada, have been employed as the non-load-bearing enclosing walls of buildings of structural frame construction and as the load-bearing walls of buildings up to 13 storeys in height.

Many papers and reports in the building science literature describe structural properties of single-leaf brick walls, but few reports deal with the weather resistance of such walls. Accordingly when the Canadian Structural Clay Association requested DBR to undertake laboratory studies of rain leakage of T. T. W. brick walls it was decided that a useful preliminary step would be the examination of a number of buildings of this construction. It was considered that such a study, even if undertaken mainly to determine the nature and extent of leakage problems, would also provide useful information on the materials and current practices of T. T. W. brick construction.

The survey, carried out with the co-operation and assistance of the Canadian Structural Clay Association (J. F. Cutler, Managing Director) is described in this report.

OTTAWA
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N. B. Hutcheon
Director

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The survey reported here was undertaken at the request of the Canadian Structural Clay Association to determine if the problem of rain penetration has occurred in buildings of "T. T. W." ("through-the-wall") brick construction, and, if so, what features of design and construction contributed to the problem. An additional purpose of the survey was to obtain general information concerning the practices of construction using T. T. W. bricks. The buildings inspected in the survey were selected from the listings and information compiled by J. F. Cutler, Managing Director of the Canadian Structural Clay Association, who accompanied the author during the survey. They are located in several cities, including Metropolitan Toronto, Hamilton, London, Niagara Falls, St. Catharines and Sarnia.

## T. T. W. BRICKS

T. T. W. bricks, designed to provide in one unit the required thickness of a wall exclusive of any finishing such as plaster or insulation, are modular in size. The length is nominally 12 in. and the width either 6 or 8 in.; the height is $2\frac{1}{4}$ in., the same as that of a conventional brick. The volume of a 6-in. T. T. W. brick accordingly is more than twice that of a conventional modular brick, while an 8-in. T. T. W. brick has three times its volume. Each T. T. W. brick laid in a wall thus provides greater volume than that of a conventional modular brick.

The 6-in. T. T. W. brick is essentially the "S. C. R." brick developed in the U. S. A. in 1952 by the Structural Clay Products Research Foundation for the construction of houses. Its manufacture in Canada for this market, however, appears to have met with limited success, but large-scale use of the brick has developed in recent years for the construction of large buildings. The T. T. W. brick has been used in buildings of reinforced concrete and steel frames for the non-load-bearing walls and panels which enclose the building, while another important and interesting use of the brick is for load-bearing walls in engineered masonry construction, a structural application of brickwork which was provided for in the 1965 edition of the National Building Code of Canada. In engineered masonry applications T. T. W. bricks were used in 1965 in a few 5- and 6-storey buildings, followed in 1967 by the construction of a 10-storey apartment containing more

than 100 suites (Figure 1). More recently, a large 13-storey apartment building has been erected of unreinforced T. T. W. brick walls which provide the structural capacity of the building.

## STRUCTURAL BRICK MASONRY

The use of relatively thin but strong brick walls to provide the structural capacity of high-rise buildings was started in Switzerland in the 1950's when many 13- to 18-storey buildings of unreinforced brick walls were constructed. Soon afterwards structural brickwork was being used extensively elsewhere in Europe, and eventually was introduced to Canada, as described briefly in DBR Visit Report No. 57, prepared in November, 1968.

The main economic advantage of using structural masonry walls is the elimination of a structural frame of reinforced concrete or steel from the building. To achieve this purpose structural masonry cross-walls must be combined with rigid floor elements to provide the necessary rigidity to the structure. The design of the walls must enable them to resist lateral loads applied to the building that are transmitted to the cross-walls by means of the floor slabs, and the walls, of course, must be designed to carry, in addition to the lateral loads, all the vertical loads imposed on the building. Where walls adjoin, as when cross-walls meet the perimeter walls, they are usually connected structurally by means of heavy steel ties, rather than by brick bonding units. Walls of engineered T. T. W. brickwork generally consist of bricks exceeding 8, 000 psi compressive strength, laid in strong mortar such as Type "M" or Type "S" of C.S.A. Specification A179. In the upper storeys of many buildings where the walls are subjected to lighter loads than those below, walls of concrete block masonry have frequently been used in place of T. T. W. brick walls.

## STRUCTURAL BRICKWORK AS A SYSTEM OF BUILDING

The acceptance by the building industry of structural T. T. W. brick masonry, as well as that of other masonry including conventional brick and concrete block, has been due to the economic advantage of frameless construction as well as to the fact that such construction provides a convenient "system" of building. The system involves completing the building's foundation, placing the masonry walls of the first storey, laid up to storey height on it, and then laying the floor on top of that. The walls of the next storey, positioned directly over the walls of the storey beneath them are then built on the floor, which may be precast concrete slabs or reinforced concrete cast in place, the latter frequently cast on steel pans over steel joists. The completion of the walls and floor of a storey makes it ready for the installation of plumbing and electrical

services, partitions and finishing; accordingly, a rational "flow" of work may be scheduled and conveniently organized to follow the operations of bricklaying and flooring.

A 10-storey apartment structure 300 feet in length (Figure 2), that was under construction in Hamilton when examined during the survey, provides an example of the T. T. W. building system. Each storey of this building, according to the construction superintendent, made use of 52, 000 T. T. W. bricks; the more than half-million bricks in the building were laid by 9 bricklayers, with the assistance of 4 labourers and the mortar-mixer operator. The rate of construction was such that each storey of the building (walls and floor slab) was completed within 10 days, even though much of the wall construction on this particular building was carried out in the winter months by bricklayers who had not previously laid T. T. W. bricks.

## WALL CONSTRUCTION

The construction of exterior walls of T. T. W. bricks generally appears to follow the practices illustrated in Figure 3; the construction involves the parging with $\frac{1}{2}$- to 3/8-in. mortar of the back surface of the brickwork, to which is applied rigid boards of foamed plastic insulating material 1 or more inches thick, stuck to the parging by means of an adhesive. Gypsum wallboard, 3/8 in. thick nailed to wooden strips at top and bottom, is then stuck to the insulation by means of an adhesive. Plaster, applied directly to the insulation, has also been used in the construction. The painted wallboard or plaster forms the interior finish of the wall.

Interior walls of T. T. W. bricks, which do not require parging or insulation, may be finished with wallboard, but in many buildings the brickwork itself has been used as the wall finish. In addition to economic advantages it has many desirable features including attractive colour, texture, and low maintenance resulting from the brickwork's high degree of resistance to damage and disfigurement. In a few such cases bricks have been used to provide a wall with both surfaces finished as soon as the bricks are laid. In many buildings of T. T. W. brick construction corridor walls and walls separating dwelling units are of brick finish (Figure 4).

## SCOPE OF THE SURVEY

Since T. T. W. brick construction is a relatively recent development in building, the structures examined in the survey have been in service only a few years, many of them in fact, having come into service during the year of the survey (1970). Of the 45 buildings examined, 9 were under construction at the time of the visit. In all except four the brick walls were load-bearing.

The information obtained about the performance of a particular building was provided by its caretaker and, in many cases, by the representative of the company that supplied bricks for the building. During that part of the survey made in London, for example, much information on the location, construction, and performance of buildings was obtained from Mr. F. Rinker, representing the Canada Brick Company of Streetsville, while in St. Catharines similar information was provided by Mr. G. Goodman of Burnstein Brick Ltd., St. Catharines.

## LEAKAGE PROBLEMS

Of the 36 completed buildings examined 22 were reported to have experienced no rain leakage or dampness problems. No information was available on the performance of four buildings, leaving 10 in which rain penetration or dampness had occurred. These 10 buildings included the "Windsor" Apartments, William St., London (Figure 5), a 5-storey structure erected in 1965 in which one apartment on the east-facing wall had some plaster fall only three years after construction. According to the caretaker of the building the plasterer making repairs attributed the failure to dampness in the wall resulting from rain penetration, although no free water or water stains were observed on the wall. The caretaker stated that no further plaster failure has occurred.

The caretaker of another apartment building, the 5-storey "Wellington Towers" on Wellington Rd. near Baseline Rd. in London, reported that leakage had taken place on occasion near a window of one of the apartment units but that the problem was restricted to this one location.

The three 7-storey apartment blocks that comprise "Northpark Towers" on Belfield St., London, erected in 1967, were reported to have experienced leakage problems, particularly in the penthouses where the walls lack parging and insulation. Leakage problems were also reported to have occurred in the apartment buildings of the "Regency Towers" development in London, where in one instance of leakage the water was believed to have entered through the corner of the building. The lack of resistance to rain penetration in this area of the wall was attributed to "toothing" of the walls during construction. "Toothing" results when one wall is built up in advance of the adjoining wall whose bricks are subsequently fitted into the toothing of the first wall, a method of construction which makes it difficult to achieve good bond between mortar and brick (Figure 6). This particular problem was reported to have been corrected by replacing the original parging and refinishing the wall.

Another example of leakage, involving a 6-storey motel (Figure 7) erected at Niagara Falls in 1968, was reported by the clerk who stated that leakage had occurred during the early life of the building where the

one-storey restaurant wing joins the remainder of the building; leakage had not been a problem elsewhere. At the time of our visit, however, when heavy rain fell several damp spots were observed on the inner wall surface of a stairwell of brickwork without plaster or insulation; seven small areas of dampness had formed on the inner surface of the stairwell through all 6 storeys of the building. There was no indication of rain penetration through the parged and insulated exterior wall of a room adjacent to the stairwell.

The leakage problems affecting the buildings investigated did not appear to follow a general pattern by which the problems could be related to any particular feature of the buildings' design or construction, except, perhaps, that walls that lack parging and insulation, such as those in penthouses and stairways, appear to be more susceptible to rain penetration than walls that have parging and insulation, a situation that would be expected.

An interesting observation was made by one person interviewed who stated that the incidence of leakage problems in buildings of T. T. W. bricks was no more extensive than in buildings of other constructions. Accordingly this aspect of building performance should not influence the builder to choose another type of building construction over that of T. T. W. bricks, provided the latter offered other advantages.

## WORKMANSHIP

The standard of workmanship in the construction of the buildings examined during the survey varied greatly. Most of the buildings, fortunately, were considered to be examples of careful construction, although the brickwork of a few buildings had obviously been laid carelessly. One fault noted in the latter buildings was the extreme variation in the width of vertical joints which ranged from almost a butt connection of adjoining bricks (Figure 8), to a joint width of about one inch. Incompletely filled joints, both vertical and horizontal, were also noted in the walls of some of the buildings. Both faults undoubtedly adversely influence the weather resistance of the walls and more important, the structural capacity of the walls in load-bearing applications.

In many buildings, even of brickwork that appeared to have been laid with care, non-alignment of vertical joints was noted. This detracted from the appearance of the walls if not from their technical properties. One reason given for the non-alignment of joints was the relatively high individual cost of a T. T. W. brick, which necessitated the use of any parts broken from a whole brick, these smaller parts being worked into the brickwork wherever convenient thus producing the haphazard appearance illustrated in Figure 9.

## CRACKS IN BRICKS AND WALLS

Cracks were observed in the exterior walls of several buildings, in some cases passing vertically through bricks and mortar, in others occurring as step-cracks from the corner of the buildings. In one instance a crack extended horizontally several feet along a mortar joint separating the bricks and mortar. The causes of the cracks were not determined.

Cracking of individual bricks in one building was particularly extensive (Figure 10), the cracks apparently having been present in the bricks before they were laid. This particular building also had many vertical cracks in the horizontal mortar joints. In a few other buildings some of the bricks were excessively warped imparting an uneven aspect to the wall surface and to the line of the horizontal mortar joints.

Cracking of interior walls was reported to have occurred in some buildings, particularly where cross-walls of concrete block masonry adjoined the exterior walls. The large apartment building in Sarnia, pictured in Figure 1, showed step-cracking of a concrete wall of the top storey (Figure 11), but the caretaker stated that such cracking was not extensive in the building.

## STAINING AND EFFLORESCENCE

Although his building had not been affected by leakage the caretaker of the Sarnia apartment building complained about the efflorescence problem. Many of the buildings examined showed efflorescence on the brickwork near concrete balcony slabs (Figure 12), the wetting of the brickwork in this area and the contribution of salts to it by the concrete probably accounting for its occurrence.

Concrete floor slabs cast on brick walls frequently resulted in staining of the walls due to moisture running down the wall from the concrete. This effect was seen in a 10-storey building in Hamilton (Figure 13) that was affected as soon as the concrete of the top floor slab was placed when a high wind blew fluid from the concrete over the forms to run down the entire height of the walls. The cleaning of walls stained in this way, however, was not considered by the construction superintendent to be a serious problem.

## CONCLUSIONS

In recent years a considerable number of buildings have been constructed in the southwestern part of Ontario with T. T. W. bricks, which have been used for the enclosing walls of structural-frame buildings as well as for the unreinforced load-bearing walls of buildings, one of which has walls 13 storeys high. The large unit volume of a T. T. W. brick (2 to 3 times that of a conventional brick), the possible elimination of the structural frame by using engineered T. T. W. brickwork, the reduced wall

thickness, and other features of the building system of T. T. W. bricks have given it sufficient economic advantages that it has found a place in the current building industry.

In a survey of the use of T. T. W. bricks 45 buildings were examined, 9 of which were under construction when visited. The standard of workmanship of the buildings' brickwork was generally high but a few instances of very careless work were noted, particularly where mortar joints were unfilled and vertical mortar joints were inconsistent in width, both faults known to lessen the weather resistance and strength of brick masonry. Of the 36 buildings in service, 22 had experienced no rain leakage problems while 10 had. The leakage problems did not appear to be related to any particular feature of design or construction of the walls, except that when unparged and uninsulated brickwork was used, as in penthouses and stairwells, its resistance to rain penetration was apparently much less than that of brick walls that were parged and insulated. The "toothing" of intersecting walls, apparently a common practice, seems also to introduce a weakness in a wall's resistance to rain penetration.

In the course of the survey other problems besides leakage were noted. In some of the buildings examined cracking in the walls and in individual bricks and mortar joints was apparent. Efflorescence and staining of walls was observed in many buildings, particularly where the concrete balcony slab adjoined the walls. These faults, and that of rain penetration, may or may not be experienced more often in buildings of T. T. W. brick construction than in buildings of any other construction. The possibility of such faults occurring in T. T. W. buildings, however, has not deterred builders from using the system.

It is again noted that buildings of T. T. W. brick construction are a recent development in the Canadian building industry, so recent that none of the structures examined in this survey was more than 5 years old. It remains to be seen if problems other than those described, e.g., durability problems, will arise with T. T. W. brickwork, the performance of which, even though satisfactory in many buildings at present, may well change as a result of long-term exposure to the weather, as well as a result of the long-term dimensional changes of the materials. It would be useful, therefore, to examine periodically the buildings seen in this survey to determine if changes occur in their performance over a long period of time.

Figure 1 - 10-storey, 112-suite, "Fairway Towers" apartment building, Sarnia, erected in 1967; described in the Daily Commercial News as "Canada's first high rise engineered clay masonry bearing wall apartment house ..."

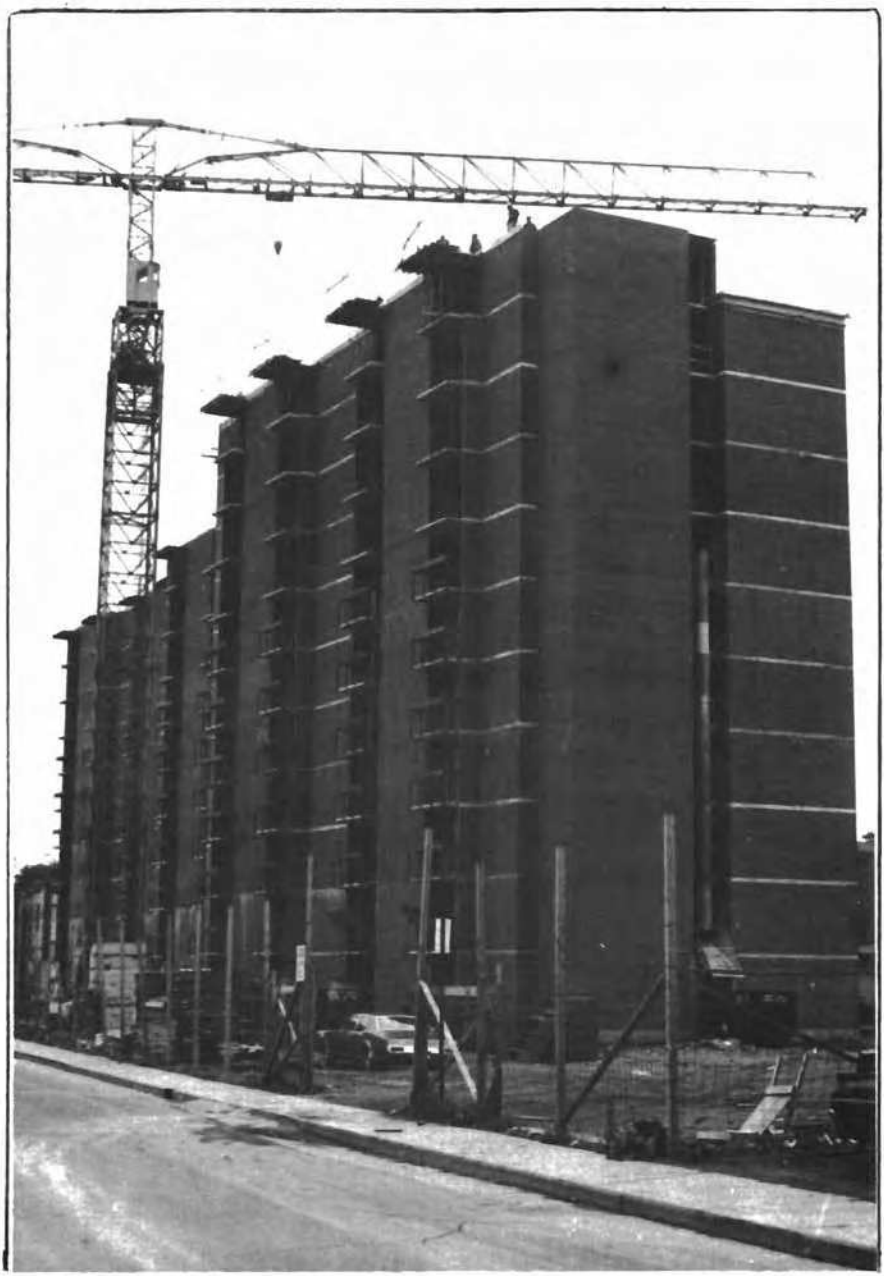

Figure 2 - 10-storey building of load-bearing "T. T. W." brick walls, under construction in June, 1970.

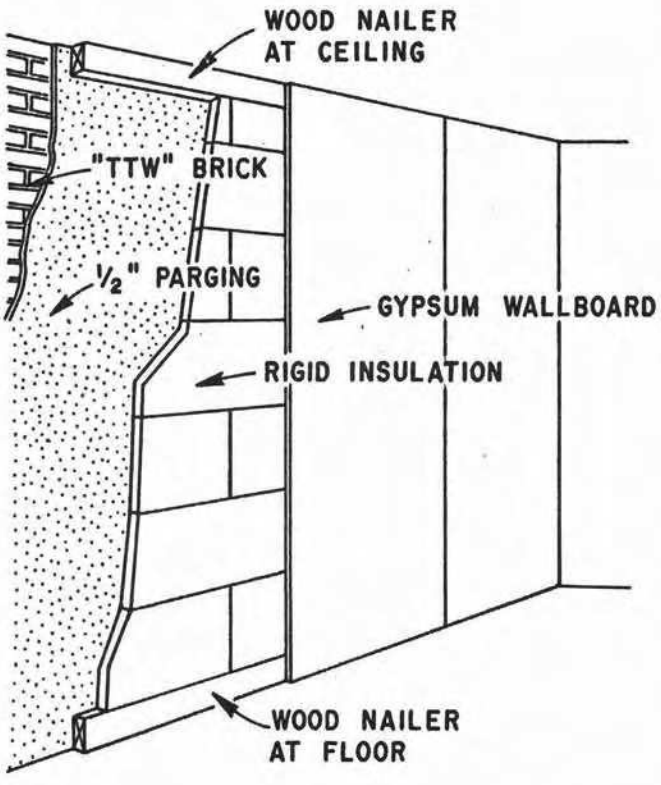


FIGURE 3
EXTERIOR WALL CONSTRUCTION

BR 4615

Figure 4 - Brick-finished, load-bearing interior wall of a motel in Niagara Falls; the floors consist of post-tensioned beams made up of concrete blocks, the rough-textured faces of which form the ceiling surface. An external view of this building is given in Figure 7.

Figure 5 - The "Windsor" apartment building, London.

Figure 6 - "Toothing" of walls during construction.

Figure 7 - Motel at Niagara Falls; in a heavy rain dampness appeared on the interior surface of the unparged and uninsulated stairwell on the wall on the right.

Figure 8 - Faulty bricklaying; vertical joints not uniform in width and mortar joints not completely filled.

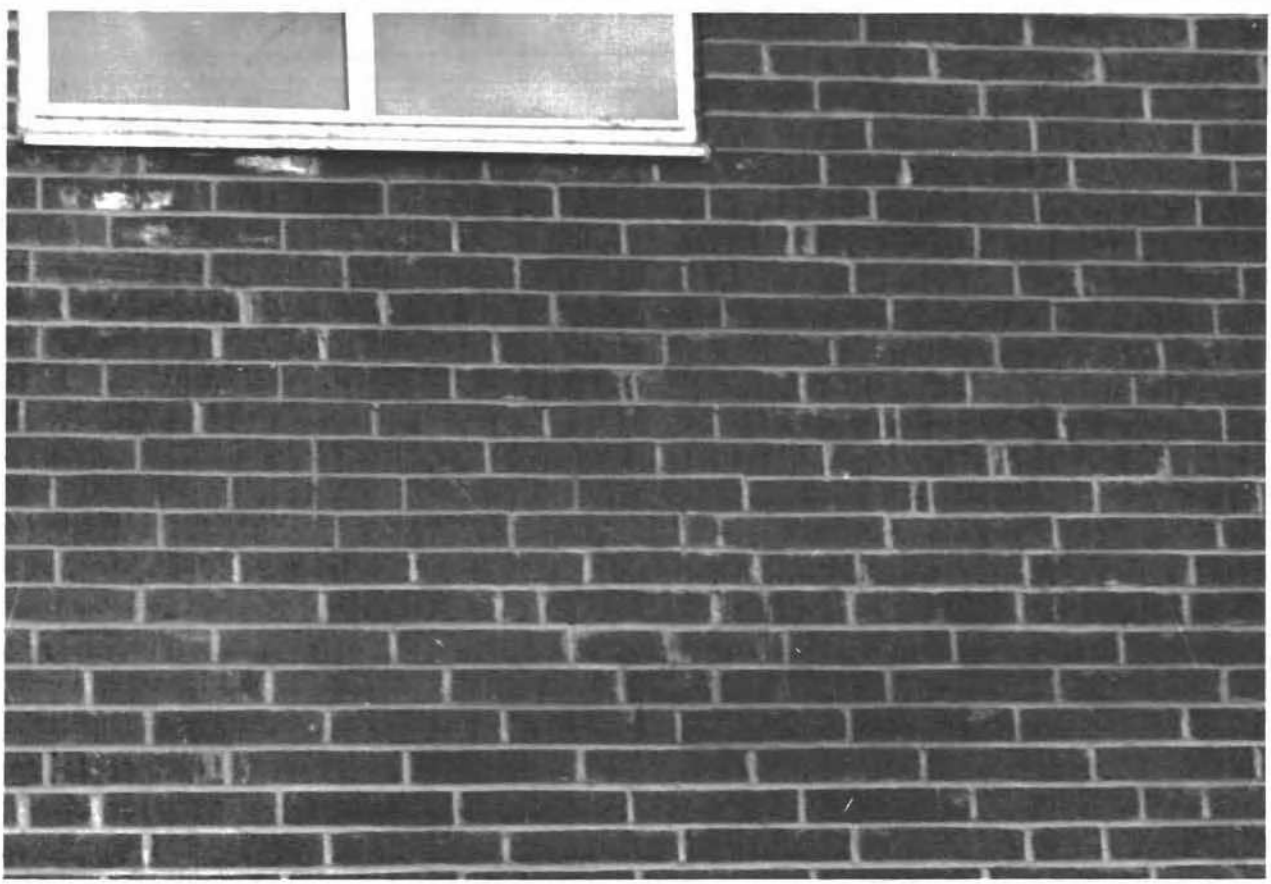

Figure 9 - Irregular bonding produced by the use of bricks of non-uniform length.

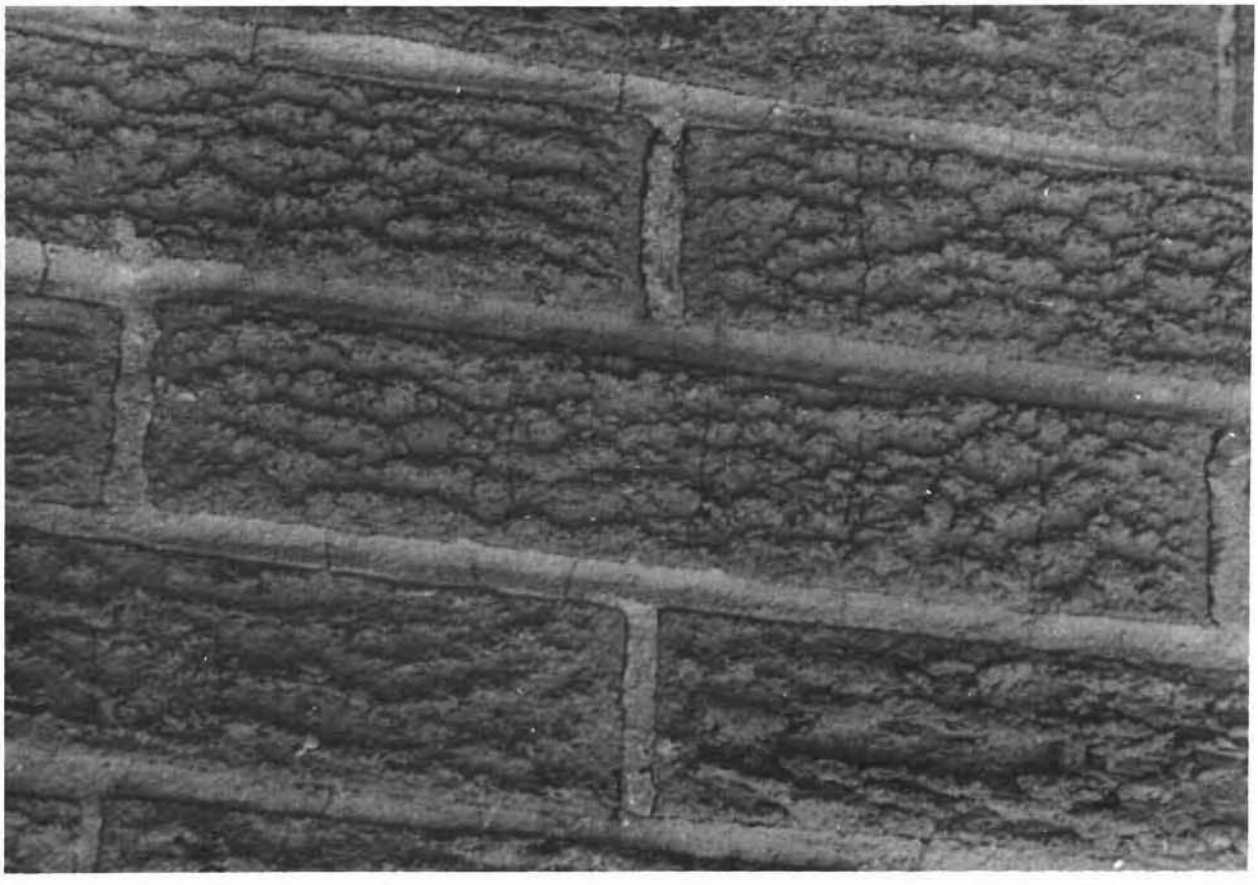

Figure 10 - Cracks in bricks and in mortar joints (of the same wall as shown in Figure 8).

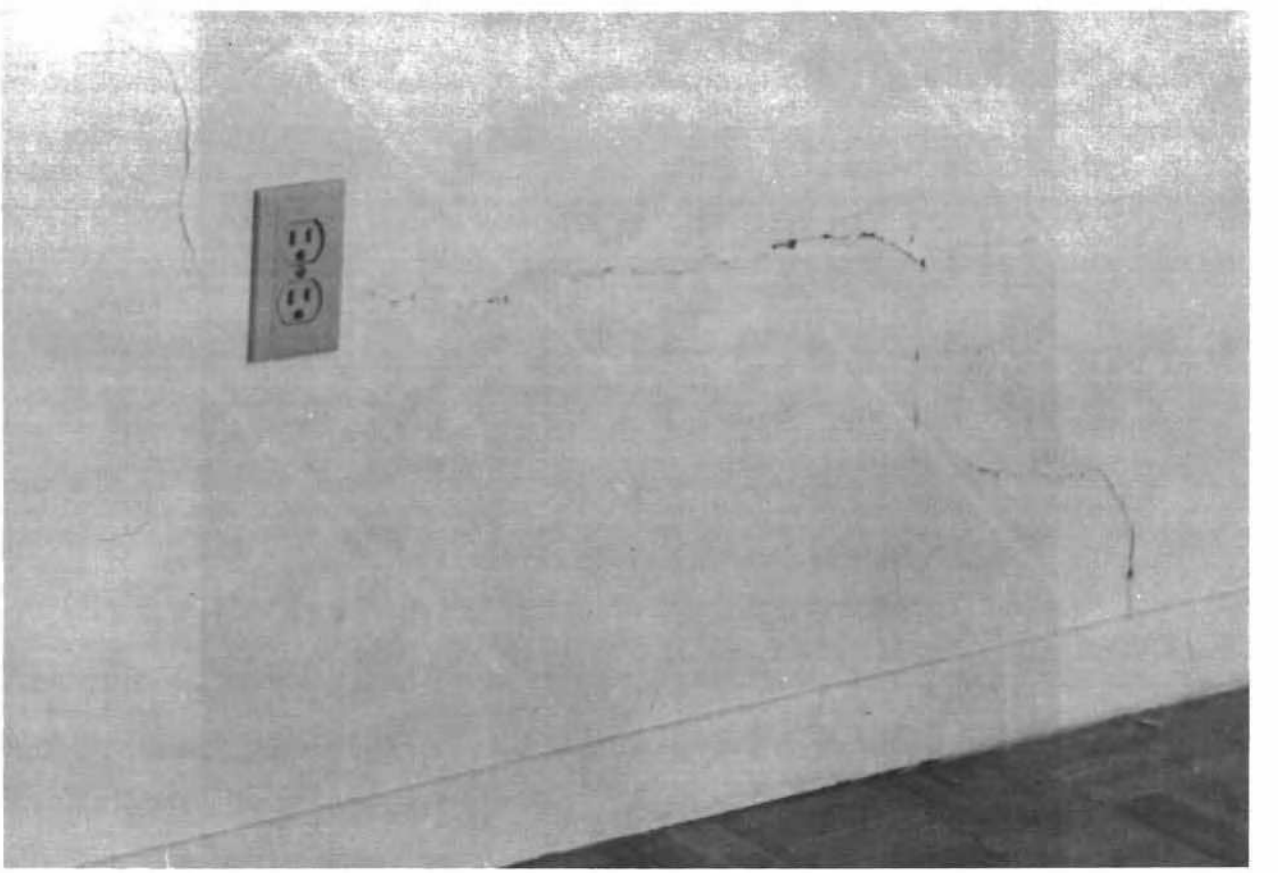

Figure 11 - Cracking of concrete cross-wall (same apartment as shown in Figure 1).

Figure 12 - Efflorescence and staining at balcony slabs.

Figure 13 - Staining of brick walls under construction resulting from the run-off of water from concrete (same building as shown in Figure 2).

## APPENDIX A

## BUILDINGS EXAMINED DURING THE SURVEY

| ADDRESS | FUNCTION | NO. OF STOREYS | YEAR OF CONSTRUCTION |
|---|---|---|---|
| Richmond St. at Elizabeth St., Richmond Hill | Apartment | 7 | 1969 |
| 444 Lumsden Ave. E., Toronto | (1) Apartment | 16 NLB(*) | 1969 |
| | (2) Apartment | 25 NLB | 1970 |
| North Service Rd. of Q. E. Highway, east of #10 Highway, south of Brampton | Apartment | 7 | 1970 |
| Queensway Rd. at #10 Highway, south of Brampton | Nursing Home | 3 | 1970 |
| 6th Line Road, Oakville | Nursing Home | 3 | U. C. (**) |
| Talbot St. at Albert St. London ("Meredith House") | Apartment | 7 | 1966 |
| Talbot St., London ("Barclay Towers") | Apartment | 9 | U. C. |
| Albert St., London (Old Persons' Home) | Apartment | 6 | 1969 |
| William St., London ("The Windsor") | Apartment | 5 | 1965 |
| Adelaide St. N., London | (1) Apartment | 6 NLB | ? |
| | (2) Apartment | 6 NLB | ? |
| Belfield St., London ("Northpark Towers") | (1) Apartment | 7 | 1967 |
| | (2) Apartment | 7 | 1967 |
| | (3) Apartment | 7 | 1967 |
| Huron St. at Briarhill St. | Apartment | 4 | ? |
| "Regency Towers", London (address not recorded) | (1) Apartment | 7 | ? |
| | (2) Apartment | 7 | ? |
| | (3) Apartment | 7 | ? |
| | (4) Apartment | 13 | 1970 |
| | (5) Apartment | ? | U. C. |
| 80 King Edward St., London ("Barry View Towers") | Apartment | 7 | 1967 |
| Waterloo St. N., London | Nursing Home | 4 | U. C. |
| Oxford St., London ("Westwood Park") | (1) Apartment | 3 | 1967 |
| | (2) Apartment | 7 | 1967 |
| | (3) Apartment | 7 | 1967 |
| | (4) Apartment | 7 | 1967 |

| ADDRESS | FUNCTION | NO. OF STOREYS | YEAR OF CONSTRUCTION |
|---|---|---|---|
| Commissioners Rd., London (Old Persons' Home) | Apartment | 7 | 1970 |
| Wonderland Ave., London | (1) Apartment ("Canterbury Towers") | ? | 1969 (?) |
| | (2) Apartment ("Tiffany Apts.") | 10 | ? |
| | (3) Apartment | 4 | U. C. |
| Commissioners Rd., London | (1) Apartment | 7 | 1969 (?) |
| | (2) Apartment | 9 | U. C. |
| | (3) Apartment | 11 | U. C. |
| Wellington Rd. near Baseline Rd. | Apartment | 5 | 1967 |
| 115 Alice St., Sarnia | Apartment | 3 | 1969 |
| "Fairway Towers", Sarnia | Apartment | 10 | 1967 |
| 264 Grantham Ave., St. Catharines ("Grantham Square") | Apartment | 6 | 1969 |
| Leaside Dr., St. Catharines | (1) Apartment | 6 | 1968 |
| | (2) Apartment | 6 | 1968 |
| | (3) Apartment | 6 | 1968 |
| 50 Queenston St., St. Catharines | Apartment | 3 | 1969 |
| Elm St., Welland | Apartment | 2 | U. C. |
| Near the Skylon Tower, Niagara Falls ("Holiday Inn") | Motel | 6 | 1968 |
| Rebecca St. at Wellington St., Hamilton | Apartment | 10 | U. C. |

(*) NLB = walls of building are non-load-bearing; those of all other buildings listed are load-bearing.

(**) U. C. = under construction in 1970.