Wall tile failure in the physical and recreational training building, HMCS Shearwater, Dartmouth, N.S.

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SUBJECT WALL TILE FAILURE IN THE PHYSICAL AND RECREATIONAL TRAINING BUILDING, HMCS SHEARWATER, DARTMOUTH, N.S.

In February 1959 the DBR Atlantic Regional Station learned of the failure of ceramic wall tile in the swimming pool area of the Navy's Recreation Building at HMCS Shearwater. This was brought to the attention of the Division by the Foundation Co. of Canada Ltd., general contractors for the building.

At that time the tile was loose and some of it had fallen off. The walls over which much of the tile had been applied consisted from outside to inside of 4-in. brick, 8-in. terra cotta tile, and $1\frac{1}{2}$ to $2\frac{1}{2}$ in. of portland cement plaster applied in three layers. The tile were Richards mosaic applied with white Medusa cement reportedly in accordance with the manufacturer's recommendations.

The plaster was applied in July 1957 and the tile placed in August and September of that year. Tile on the walls of the pool itself and on the floor areas around the pool appeared to be well adhered. The water temperature in the pool is maintained at 80°F, and an attempt is made to keep the area temperature at 72°F. Needless to say the relative humidity is generally high in this area.

The building, as are a number of buildings at Shearwater, is founded on piles and soil bearing properties in the area are generally considered poor. The general contractor was of the opinion, and reportedly so advised Defence Construction Limited (D. C. L.) early in the construction, that the building specifications called for the masonry to be too close to the steel frame. He also believed the specifications to be wrong in calling for the plaster to be so thick

over the terra cotta. The only departure from the specifications suggested was that Medusa white cement be used to bed the tiles rather than ordinary portland cement.

A field inspection in May 1959 showed that failure had occurred on all walls with two of these being other than exterior walls. Similar failure occurred on various backup materials, e.g. plaster over terra cotta, thinner plaster layers over metal lath (above window lintels), thinner plaster over a concrete parapet and around interior columns. At that time there appeared to be only minute or hairline cracks in exterior brickwork. Other parts of the building, e.g. the basketball area, have painted concrete block walls as the interior finish. These were cracked vertically at every column (20 ft centre to centre) and to a lesser extent midway between columns.

Where the worst condition existed the wall had been stripped to the terra cotta, and three distinct layers of plaster could be seen. The plaster surface showed crazing cracks encompassing rough elliptical areas of approximately 5 sq ft. Some fine diagonal cracking was in evidence on the terra cotta. Tiles near this area could be removed easily, exposing clean surfaces on the backs of tiles but with the tile adhesive adhering well to the plaster.

At that time the principals concerned were attempting to assess the cause of failure in order to determine who would be responsible for tile replacement. Also, the general contractor had engaged in a consulting capacity the firm of Racey MacCallum and Associates and were awaiting a report on cause of failure from that firm. It appeared that while there may have been some building movement and plaster was map-crazed, the main cause of failure was lack of adhesion between the tile and the setting bed.

Although the cause of failure would be difficult to prove, it was thought that information pertaining to tile application would be useful and subsequently notes were made from a report prepared by the Division of Building Research in Australia entitled "Failure of Wall and Floor Tiling -- Their Causes and Prevention" and provided to the Foundation Co. It might be useful to refer to some of the statements in that report.

(1) "Expansion and contraction of tiles, tile bed, or background produces a compressive force that may be large enough to cause the thin sheet of tiling to fail by buckling." No evidence of buckling existed at the Shearwater building.

(2) "Where the adhesion is strong enough to prevent bulging, the compressive stresses may cause spalling and splitting of the tiles." There was no evidence of this.

(3) "Tension failures usually show as an opening up of the joints between the tiles or in more severe cases as cracks extending through several rows of tiles." No evidence of this.

In view of the lack of evidence that would suggest the above causes of failure, no attempt is made here to explain the causes of these forces and their effects. Explanatory material is, however, well covered in the above-mentioned report.

Further in the report but now on the more obvious cause of failure, in this case lack of adhesion between tile and backing material, it is stated, "In extreme cases poor adhesion between tiles and their bed, or the bed and any rendering, can be the sole cause of the failure, but usually it is a contributory factor only, permitting stresses that would not dislodge well-bedded tiles."

Some causes of poor tile/mortar bond cited in the report are: "(1) rapid drying of the work in hot weather;
(2) disturbance of the work during setting;
(3) unsuitable mortar -- the error is usually to make the mix "fat" and unsuitability is rarely due to the use of too lean a mix;
(4) the lack of a good mechanical key is sometimes cited although its absence is generally thought to be only a minor contributory cause of failure."

While expansion, shrinkage, or building movement may have served to dislodge the tile, it appears extremely unlikely that this would have occurred if a bond had existed between the setting bed and the tile -- no such bond appeared to exist at the time of the field examination.

For future reference the use of adhesives for tile setting has two features which appear promising to building research workers in Australia:

(1) "the elimination of the bed of cement mortar and its inevitable shrinkage,"
(2) "the alleged permanent flexibility of the bond, allowing tiling to be used in places where continuous vibration had previously made its use impracticable."

In addition a Short Specification Guide of the Tile Council of America Inc. has recommendations for applying and curing scratch coats and mortar setting beds for ceramic mosaic tiles with the recommended setting bed to be not more than $\frac{3}{4}$ in. thick. They recommend a neat cement

layer to bond tile to the setting bed. They also recommend the following mix for mortar levelling coats and setting beds.

Materials	Parts by Volume
Portland cement	1
Sand dry, or	4
Sand damp	5
Hydrated lime	$\frac{1}{2}$

As a follow-up to the original inquiry the Station on learning that the tiles were to be completely stripped and replaced made arrangements with the local office of D. C. L. with the knowledge of Mr. Sullivan of the Foundation Co. and Mr. Stirling of D. C. L. to follow this work beginning on 12 February 1962.

A visit preliminary to this work was made in January. At this time general failure of tiles was noted with the conditions not unlike those observed in 1959. There were more tiles off the wall than was the case in 1959, but the same evidence of lack of adhesion between tile and the setting bed existed over all areas. The sharp impression of the back of the tiles remained in the mortar bed. By contrast the Medusa cement was well bonded to the 2- to 3-in. thick plaster. While there was evidence of lack of bond between the three plaster layers, this did not appear to have affected the tile failure. Although wall cracks existed, they were not thought to account for the failure. With a satisfactory bond such cracking may have caused buckling or tile cracking over limited areas. No such evidence of these types of failures or damage existed. The temperature in the area the time of the January visit was 86°F. Tile samples were obtained in order to establish their absorption properties in the laboratory. A 16-hr cold soak indicated absorption of 1.9 per cent and 3.2 per cent for light and dark tiles respectively.

A visit made on 13 February showed that large areas had already been stripped with the east wall and about one-half the north wall having been stripped by two men the previous day. Large areas could readily be removed with little effort. In some instances adjacent tiles were well adhered to each other by the pointing mortar used following tile setting. Another visit was made on 16 February. At that time the tiles had been removed from the east and north walls, and it was expected that the west wall would be completely stripped by the end of that day. The rapidity of the stripping work and the ease with which tile were removed gave some indication of the general lack of bond. Removal of tile from the concrete parapet was reportedly more difficult than on walls and columns.

By 26 February the new tile setting operation was well in progress. This work was being done by the York Tile Co. under the supervision of Mr. Charles Sanford. Frontenac tiles were being bedded with a mortar consisting of Laticrete Tile Setting Liquid (Dominion Rubber Co.) and white portland cement (D'Hamignies, Belgium) in the proportions of 1 gallon of the liquid to 22 lb of cement. Sand can be added to the mortar in amounts equalling the cement content but was not generally used in this case. Mr. Sanford explained that sand could be used if extra body were required to level the base course. Samples of Frontenac tile given a 16-hr cold soak in the laboratory indicated no absorption.

Mr. Sanford noted that white Medusa cement is difficult to use in tile work but can produce excellent results. On some occasions he finds that the cement paste dries too quickly as would appear to be the case with the original application. A contributory factor could have been the dryness of the backup producing an effect similar to that noted in brick studies where the top brick has less bond with the mortar joint than does the brick below.

A visit on 14 March showed that the work of re-tiling had been completed, and there appeared to be a good adhesion as indicated by tapping. It was learned that the Navy had awarded a contract for repointing the tile in the pool and adjacent floor areas. This does not necessitate replacing tiles but is merely a repointing job. It is not known what effect chlorine in swimming pool water has on commonly used pointing materials. The cement being used for this repointing work is a white portland cement of German manufacture (Dykerhoff).

Summary

Observations made by the Atlantic Regional Station indicate that failure of the wall tile in the swimming pool area of the Navy's Recreation Building at HMCS Shearwater was due to the lack of adhesion between the tile and the mortar setting bed. The most probable cause of poor tile adhesion is dryness of the backup material at the time the tiles were applied. This would result in removal of sufficient water from the tile setting mortar to reduce greatly the adhesion of mortar to tiles. If the tile had been well adhered, then cracking of the backup or building movement may have caused local failure due to cracking, splitting or buckling; but it is extremely doubtful that this would have caused or contributed to the cause of the over-all failure that occurred.