Corrosion of wrought-iron radiant heating coils

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Publisher's version / Version de l'éditeur:
https://doi.org/10.4224/20358688
Technical Note (National Research Council of Canada. Division of Building Research); no. TN-213, 1956-09-01

NATIONAL RESEARCH COUNCIL OF CANADA

DIVISION OF BUILDING RESEARCH

No. 213

TECHNICAL NOTE

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PREPARED FOR discussion

DATE

SUBJECT

Corrosion of Wrought-iron Radiant Heating Coils

Two failures by corrosion of wrought-iron pipe used as radiant heating coils embedded in concrete floors have recently come to the attention of the Division. Since both failures occurred after a very short service life, nine months in one case and four years in the other, and because these installations did not differ, as far as is known, from many others which are being installed, it is considered worthwhile to report them.

Case 1 - Private House

One-inch wrought-iron pipe, welded at the joints, was formed into a radiant heating coil. The pipe was placed on a 4-inch concrete structural slab located on crushed rock at ground level. Three inches of concrete were placed over the structural slab to encase the coil. Asphalt tile flooring was placed over the concrete. No vapour barrier was used under the slab.

The failure occurred after approximately four years of service. The pipe had corroded from the outside by general pitting which had penetrated the wall of the pipe in many places. Over the floor area uncovered for examination, amounting to about 50 square feet, there was no significant difference in the extent of corrosion on any of the pipe. It is understood that an analysis of the pipe was done by a reputable laboratory and that it was found to conform to specifications.

The concrete appeared to be sound but no bond existed between the 3-inch topping and the structural slab. Analysis showed the presence of about 1.5 per cent calcium chloride by weight of cement.

Case 2 - Institutional Building

One-inch wrought iron pipe was used as the radiant heating coil. The coil was formed directly over the structural floor slab and covered with $1\frac{1}{2}$ inches of concrete and then finished with 2 inches of terrazzo.

The coil was installed during the construction of the building in the spring of 1955. In January 1956, after the heat had been turned on for about three months, the first failure occurred in the coil on the second floor in the dormitory. Altogether, three leaks developed, within about 10 feet of each other. The failure was caused by corrosion of the pipe by pitting from the outside. All the corrosion was confined to the bottom section of pipe resting on the structural slab.

On examination, it was apparent that the corroded section of the pipe was not encased in concrete. It is not known whether calcium chloride was used in the concrete.

Comment

The presence of moisture and air is essential for corrosion.

In the first case, where no vapour barrier was used under a slab on crushed rock, the moisture may have entered the slab from the ground. Since crushed rock fill would normally be considered a good barrier to the transfer of water by capillarity, and since the operation of the heating system would tend to dry out the slab, it must be supposed that water was transferred from the ground to the slab, probably by a combination of vapour transfer and condensation, during times of the year when heating was not required.

In the second case, where corrosion occurred in a second-floor slab it is likely that only the original mixing water was involved. It is known that structural sections of concrete may take as long as two years to lose their original water and to adjust to an equilibrium moisture content with their environment. Failure occurred in this case in nine months.

It seems probable in the cases reported here that special precautions were not taken to lift the pipes during placing of the cover coat so that the pipes would be completely encased. Furthermore, the cover coat was not bonded to the base coat so that an air channel was provided to the atmosphere. Therefore air pockets connected to the atmosphere existed below each pipe in the area of contact with the base slab. The presence of air and moisture at these points, particularly when calcium chloride was present, would constitute corrosive conditions.

It has generally been accepted that reinforcing steel embedded in concrete will not corrode under normal conditions, since the chemical environment provided by the cement paste in the concrete is not favourable for corrosion. However, the occurrence of serious corrosion in a number of cases, some involving high-tensile steel wire in prestressed concrete, has recently forced a re-examination of this. Calcium chloride frequently used in amounts up to 2 per cent of the weight of cement to accelerate set, particularly in cold weather, has been suspected, as has the use of cement, in cover coats or toppings, that is chemically different from that used in the base.

It should be remembered that factors affecting the rate of corrosion are themselves affected in various ways by changes in temperature. It is generally recognized that the rate of corrosion is increased with an increase in temperature. In this instance the increase in temperature was accompanied by the presence of a temperature gradient. These conditions could increase the rate of reaction due to the increased chemical activity as well as cause ion concentration gradients which could impose local differences of potential and thus increase or even initiate the corrosion.

It has been observed that when a confined sample of soil containing water and a soluble salt are subjected to a temperature gradient that the salt will concentrate at the hot end. In the case where concrete containing calcium chloride was heated by the coil, it is possible that the salt was being concentrated at the pipe. If salt concentration was a factor in promoting corrosion then the presence of the temperature gradient also contributed to the failure.

It would seem advisable to insist upon construction practices in the embedment of pipes in slabs which will ensure complete encasement of the pipe in one layer of the slab. The use of calcium chloride, which is seldom an essential ingredient in concrete, might well be avoided. Partial embedment of pipes in one layer of concrete to be completed by a following layer would not appear to be good practice, particularly where the concretes in the two layers may differ chemically because of the cement or additives used.