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CORROSION IN BUILDINGS

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A variety of metals are used in buildings in many different ways. It is for this reason that the problems of corrosion in buildings cover a very wide range. In this brief article only an outline or classification of the main problems can be given, along with the basic principles, to guide the designer in his efforts to reduce the huge economic loss caused by corrosion. For specific information on the practical problems of corrosion the reader is directed to the extensive work of the various corrosion committees of the ASTM and of the British Iron and Steel Research Association. The National Association of Corrosion Engineers has published the results of much research in the field of corrosion.

Corrosion technology is now well established and is taking its place as another branch of engineering. Specialists are available to give advice on various methods that can be used to prevent corrosion. Their services can be of great value in the building field, especially if sought during the design stages. Revision of a specification at the planning stage may require only minor changes while changes made after a building has been completed are often very costly.

Corrosion refers to any process involving the deterioration or degradation of metal components. The best known case is that of the rusting of steel. Corrosion processes are usually electro-chemical in nature, having the essential features of a battery. Dissimilar metals in the presence of a conducting liquid, known as the electrolyte, develop an electrical potential that causes a current to flow whenever a suitable path is provided. Such electrical potentials may also be developed between two areas of a component made of a single metal as a result of small differences in composition or structure or of differences in the conditions to which the metal surface is exposed. That part of a metal component which becomes the corroding area is called the "anode"; that which acts as the other plate of the battery is called the "cathode" and does not corrode, but is an essential part of the system.

In the corrosion systems commonly involved in buildings there may often be only a single metal involved, with water containing some salts in solution as the electrolyte. Corrosion may even take place with pure water, provided that oxygen is present. In such cases oxygen combines with the hydrogen generated at the cathode, removing it and permitting the reaction to go on. Other agents, notably certain bacteria in the soil which remove hydrogen, can also act as depolarizing agents and thus promote the corrosion reaction.

Steel, because of its low cost together with its many desirable properties, is the most common metal used in buildings. It can often be protected adequately by the application of suitable coatings. For certain purposes other metals more resistant to corrosion may be a better choice, depending on initial cost and expected service life.

Metal components used in buildings can be grouped for purposes of discussing corrosion into four general categories: 1) those used on the exterior as cladding, roofing and flashings, 2) those incorporated in the construction as structural and reinforcing steel, masonry ties and damp courses, 3) those used in the services to a building as piping, storage tanks for hot water, drains and heating ducts, 4) those buried in the ground.

Corrosion of Metals used on the Exterior of Buildings

Metals in use on the exterior of buildings are subject primarily to atmospheric conditions but the effects of these may be modified by the particular elements of design. The principal atmospheric factors affecting the corrosion of metals are temperature, extent of pollution by sulphur dioxide and chlorides and the length of time during which metal remains wet by water. These factors can now be measured at different localities to provide a comparison of the corrosion to be expected at different sites. A more direct method has been used by exposing samples of different metals at different sites and determining the rate of corrosion from the weight loss after cleaning. Such testing has shown that the corrosiveness of different sites varies greatly and that the variation is different for each metal tested. The outdoor exposure of architectural metals at eight sites in Canada has been carried out under the direction of the Associate Committee on Corrosion Research and Prevention. Progress reports giving the results for 2 and 5 years' exposure are being published by the National Research Council. Similarly in the United States the American Society for Testing and Materials has for many years sponsored outdoor exposure studies and much information is available for ten U.S. sites.

Such values as these can be used only as a guide for assessing the corrosivity of metals when they are exposed on a building as flashing, roofing or cladding, because design features can greatly modify the conditions of local exposure. For example, the overhang on a roof can shield cladding on a wall from much wetting by rain and dew. Such design features should be considered where possible because they can save the metal from normal corrosion. In the design of roofs, gutters and spouts, any traps and recesses where water will collect and remain for long periods should be avoided because corrosion will proceed as long as the metal is wet. Such features of design are particularly significant in bridges, towers and other exposed structures made of metal; channels may be welded in such a way as to form troughs where water may collect and cause serious corrosion by exposing such a member to periods of wetness much in excess of the normal wet periods imposed by rain or dew. **It can be stated that faulty design is the first major factor leading to the corrosion of iron and steel in buildings.**

Air pollution by sulphur dioxide derived from the burning of coal is a serious factor in corrosion. A chimney located on top of a building can release high concentrations of sulphur dioxide and expose roofing and flashing on that or adjoining buildings to very severe corroding conditions. One of the ACCRP sites is located on the Federal Building in Halifax where such conditions exist. There sulphur dioxide pollution is about 20 times as high as the average for the city, and the corrosion is proportionately higher than elsewhere. Different metals are affected in different ways by changes in the environmental factors.

Recently it has been shown that temperature is an important factor in the corrosion of steel in the atmosphere. For this reason steel used in the North where the average temperature is lower does not need as much protection from corrosion. Such localities also have lower sulphur dioxide pollution and perhaps a lower wetness period, which would help to explain why steel corrosion rates were found to be 33 times greater in Ottawa than in Norman Wells.

Corrosion of Metals Within Building Constructions

Structural steel usually accounts for the major portion of the metal used in buildings. Fortunately it is often located within the construction and is shielded from the outdoor environment by cladding and roofing and from the indoor environment by the interior finish. In cases where structural steel is exposed to water, either from rain penetration or from condensation of water vapour, corrosion does occur and may endanger the structure itself. Only good design and proper use of materials can avoid this condition. Proper venting of corrosive fumes from factories can assist greatly in preventing corrosion of structural steel in such buildings.

Corrosion of Steel in Concrete and Masonry

Reinforcing steel and prestressing steel may account for a large portion of the metal used in buildings. The conditions inside bulk concrete and mortar are favourable to steel, and many old concrete structures testify to the satisfactory performance of these materials. There are, however, examples of failures of various metal components encased in concrete and mortar. Usually these can be traced to poor quality concrete and masonry as well as to poor design, where the thickness of cover over the steel or faulty joints resulting in cracks have permitted water to penetrate easily. Poor quality concrete, such as results when high water:cement ratio is used, will have a high permeability to water; and if the water contains salts, as in salt spray from the ocean, the reinforcing steel is almost certain to suffer corrosion attack. In all these cases there is no substitute for an adequate cover of good quality concrete.

Evidence of corrosion of steel in concrete has been associated with the use of calcium chloride as an additive when placing concrete in cold weather. Cases of severe corrosion of steel radiant heating coils have been observed where calcium chloride was used. Serious buckling of a vault door frame was observed where grouting around the door contained calcium chloride; corrosion of the frame at the concrete face caused it to buckle inward, thus preventing closure of the vault door. There can no longer be doubt that addition of calcium chloride to concrete can accelerate corrosion of the metal parts embedded in it.

The problem of corrosion of steel embedded in concrete is receiving a great deal of attention at present because of the advent of prestressed concrete, in which even small amounts of corrosion are likely to be serious. Similarly, the effect of calcium chloride on other metals should be considered. Early failure of aluminum conduit embedded in concrete containing calcium chloride has also been observed.

Corrosion of metal ties in masonry is dependent upon the penetration of water into the masonry. If rain does not penetrate then corrosion will be negligible. Metal ties taken from a building in Halifax after 75 years' service showed only moderate corrosion and were still serving their purpose adequately. Certain metals such as aluminium, when used as flashing embedded in mortar, should be protected by a suitable bituminous coating.

Corrosion of Metals Used in Building Services

A variety of metals are used in providing the necessary services to a building. Those in which corrosion is most likely to be a problem include the heating, water supply and sewage disposal systems.

The heating system can present corrosion problems where steam or hot water is used. A boiler will corrode and scale if the water is not properly treated, and although the technology for such treatment is well established, in practice it is often ignored, sometimes with disastrous results. Corrosion of condensate return lines may also often present a serious problem that is usually associated with the presence of oxygen or carbon dioxide.

Where hot water is used in conjunction with radiant heating panels corrosion can be a problem, as already mentioned, due to corrosion of the coil from the outside. In this and in the normal hot water heating system corrosion on the inside of piping can be a problem also. It is a wise precaution to avoid the use of different metals in a system in order to eliminate galvanic corrosion at points of contact of dissimilar metals as well as to prevent the deposition of ions of one metal upon another, as in the case of copper and zinc. A variety of corrosion inhibitors such as phosphates or silicates can be used to minimize corrosion on the water side. There is a danger, however, that partial treatment can be worse than no treatment in the case of some inhibitors, and to be effective regular attention is required with all.

Systems supplying fresh water, especially when hot, present many serious corrosion problems. The primary factor is the water which contains dissolved oxygen and dissolved salts. Each municipality has a water supply that is unique from the standpoint of its composition and specific corrosiveness. Because no part of the fresh water supply is recirculated, the supply of oxygen is not depleted as in a hot water heating system, nor is it as convenient or economical to add chemical inhibitors to mitigate corrosion. Where the water supply is classed as hard the water may be softened but this often results in increasing the corrosiveness of the water because some of the scale-forming constituents are removed. Scale usually reduces corrosion since it may act as a protective coating.

Temperature is an important factor in corrosion by fresh water. Thus storage tanks for hot water are subject to the most severe corrosion. Those most commonly affected are the galvanized steel tanks, which are economical and under favourable conditions of service with certain types of water do give satisfactory performance. However, in many localities the corrosion of galvanized steel tanks is a serious problem and much study has been directed toward finding a solution. Hot water tanks should be operated at as low a temperature as is feasible (no more than 150°F) because it has been found that service life can be extended threefold in some localities when the temperature is decreased from 170 to 150°F. Copper piping should be kept out of a galvanized tank and for a distance of several feet adjacent to it. The use of large-capacity external (side arm) heaters, which are turned off when not required, have been found to produce less corrosion than small, thermostatically controlled immersion heaters. In any specific case of corrosion the problem can only be resolved by considering the combined effect of the two basic factors: characteristics of the water, and the design and resultant conditions of operation of the system.

The use of corrosion-resistant materials such as copper does not always guarantee that the system will be free from corrosion. There are instances where water containing dissolved carbon dioxide, under certain conditions of service, have caused severe corrosion of copper tubing. Soft waters which are slightly acidic (low pH) can also attack copper. This further emphasizes the fact that every material will perform well only when the conditions for its service are favourable and that these conditions are specific and different for each material. This is one reason why the mixing of different materials in one system can lead to trouble because of the introduction of a possible weak "link" in addition to the problem of the interaction of dissimilar materials which may cause galvanic corrosion.

Metals Buried in the Ground

Some metal components of a building may be buried in the soil, as are piles and service piping for water and sewage. From the standpoint of metallic corrosion soil conditions vary a great deal because of the variety of soils that can be encountered. Particularly severe corrosion problems can sometimes arise as a result of the presence of certain soil bacteria. These are usually found in clay soils or muds at the bottoms of certain rivers and lakes. Engineers should be constantly on the lookout for such conditions because damage by corrosion to buried metals may not be detected until it is too late to apply remedial action, and replacement of the components may be expensive if not impossible. Cathodic protection by means of an imposed electric current, combined with the use of asphalt coatings, is usually the best method of protecting metals buried in the ground when potentially corrosive conditions exist. Care should be taken to avoid the use of materials for backfilling which may contain corrosive chemicals.

Designers of buildings can, by keeping in mind the principles involved in metallic corrosion, do much to ensure that metals will always be used under favourable conditions. Large savings to building owners and to the country as a whole are possible through improved design and selection.

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