Canadian Research on Durability of Concrete

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SUBJECT CANADIAN RESEARCH ON DURABILITY OF CONCRETE

In Canada concrete may be subjected to a wide range of exposure conditions, some of which severely tax its durability. The most important are those associated with freezing and thawing cycles, with the highly sulphated soils in Western Canada, with sea water, and with aggressive acid waters in forested regions.

There are also extremes in geology so that many different kinds of rocks, gravels, and sands are available for use as concrete aggregate. These range from the most ancient Precambrian in the Canadian Shield to the glacial deposits of the Pleistocene and Recent deposits. Such variety has had considerable influence on the relative durabilities of concretes in different areas.

Despite these undesirable factors, Canadian concretes have had a good performance record. This is due in part to the early application of results of pioneer studies carried out in Canada, and in part to close liaison with agencies engaged in concrete research in the United States and other countries.

A classic pioneering study was that conducted by Dr. T. Thorvaldson at the University of Saskatchewan (1). It had been observed that concrete in contact with soils and soil waters that contained high concentrations of sulphates disintegrated rapidly. His discovery that the vulnerable cement component was the tricalcium aluminate led to the development of the first sulphate resistant cement by the Canada Cement Company (2). Successful field performance of concrete made with this cement now extends over many years. Good examples occur in the city of Winnipeg where the Engineering Department has pioneered in field application of such concretes. A recent

example of special application is a development by the concrete laboratory of the Prairie Farm Rehabilitation Administration (PFRA): a high strength, sulphate-resistant cement is being used in conjunction with fly ash in certain dam concretes. The main activity of the Division of Building Research in this area of study has been the development and dissemination of information on laboratory investigations and field performance (3, 4).

The research laboratory of the Hydro-Electric Power Commission of Ontario has a long history of notable concrete research, including studies on durability to frost action (5). This laboratory was among the first to develop a freeze-thaw cycling apparatus (6), and to develop test apparatus for determining rate and extent of concrete deterioration by pulse velocity (7). More recently the PFRA laboratory has developed similar cycling apparatus and has carried out extensive aggregate evaluation studies in Western Canada based on resistance of concrete to freezing and thawing (8). Similar testing and research studies are carried out elsewhere in Canada, notably at the testing laboratories of the Federal Department of Public Works and the Ecole Polytechnique of the University of Montreal. The Division of Building Research has engaged mainly in the dissemination of existing research and performance information (8, 9, 10).

The great contribution of air entrainment to resistance of concrete to frost action was recognized from the first, and its use has become general in Canada for all exposed concretes. The importance of properly entrained air in the resistance of concrete to de-icing salts has also been amply demonstrated in our severe Canadian exposures (11). Separate studies have been made and are being made in various parts of the country on this serious problem. Typical of the progressive approach and the early application to practice is the work of the engineering departments of many Canadian cities, notably Winnipeg and Montreal. The latter has published details of a successful program of study on sidewalks (12).

Field and laboratory studies by the Division of Building Research, National Research Council, have led to recognition of the reactive aggregate problem in certain areas in Canada (13, 14). Its investigation of a concrete problem at Kingston, Ontario, resulted in the discovery of the alkali-carbonate rock reaction, as distinct from the alkali-silica type of reaction (15). This phenomenom is associated with certain argillaceous dolomitic limestones. When used as coarse aggregate, they produce excessive expansion and cracking of concrete (16). Certain problems with concrete in the United States have since been found to have been due to a carbonate rock reactivity, and considerable published literature has accumulated on this subject (17, 18, 19, 20). In Ontario the laboratory of the provincial Department of Highways is active in continuing research on the alkali reactivity of dolomitic limestones being considered for use in concrete (21). In Nova Scotia the Hydro-Electric Power Commission and other provincial agencies are beginning a joint study of the cause of excessive expansion of concrete in that province.

The role played by aggregates in the durability of concrete has been widely studied in Canada (22). In Eastern Canada the Federal Department of Mines (23) and the Hydro-Electric Power Commission of Ontario have pioneered in the evaluation of aggregates (24). In Western Canada the studies of the PFRA laboratory are perhaps the best known (25).

Canadian agencies or laboratories other than those already mentioned have contributed and continue to contribute to applied research on these and other problems associated with the durability of concrete. An unusual problem is the air-entraining properties of certain natural sands found in Canada (26). Another example is the study of concrete behaviour at high temperatures (27).

Considerable dependence is placed on research investigations carried out by U.S. agencies, particularly the Portland Cement Association and the U.S. National Bureau of Standards. There is a considerable Canadian membership on Committee C-9 of the American Society for Testing and Materials and also in the American Concrete Institute. Participation in these and other U.S. and foreign societies supplements the work of active Canadian groups, such as the concrete committee of the Canadian Standards Association.

In addition to its activities in, and in support of, studies of practical problems relating to durability of concrete, the Division of Building Research is engaged in research on certain basic aspects. The stability and durability of concrete are related to physical, chemical, and physico-chemical processes common to many porous systems. The relationship between sorption of water and the resulting dimensional changes of various porous materials, such as cement paste, are being studied in order to gain an understanding of the processes of swelling on wetting and shrinkage on drying. The phase change of water in these porous systems is being studied in order to understand the mechanism of failure of materials such as concrete when exposed to cycles of freezing and thawing. New techniques have been developed and new approaches to the problems of stability and durability are expected to yield important practical benefits.

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