Concrete Scaling

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South Bend, like a number of other cities, has found the use of salts and abrasives effective in keeping streets open to traffic and in providing safe driving conditions during the winter months.

Four materials are in common use in municipalities for the elimination of icy and slippery conditions on pavements—sand, cinders, salt, and calcium chloride. There is no agreement among street-cleaning officials as to which is best. Some cities use each of these materials separately; other cities believe that certain combinations of these materials do the work most effectively and economically.

Sand is probably used most frequently. Several disadvantages in the use of sand are: (1) it must be removed from the pavements promptly after thaws, (2) unprotected stockpiles are liable to freeze so that the material cannot be used, and (3) it tends to roll unless the individual particles are sharp. To overcome some of these, sodium chloride or calcium chloride is added. Stockpiles will not freeze; moreover, when such mixtures are spread on icy surfaces, the chemicals cause the ice to melt sufficiently to permit the sand particles to become partially embedded in the ice. A rather large number of cities use mixtures of one part of salt or calcium chloride to three or four parts of sand.

Cinders are believed by some city officials to be an ideal material for icy pavements to prevent skidding. When used, they are mixed with salt or calcium chloride in approximately the same proportions as for sand.

Sodium chloride is used in the form of rock salt, and it is sometimes used alone. When it is used alone, it is spread over the street surfaces primarily to melt the ice and snow so that the pavement surface is exposed. This is expensive, however, and so it is usually mixed with sand or cinders.

Calcium chloride is used alone in some communities in the same manner as salt. Because of the cost, however, such use is confined almost wholly to the covering of small areas of ice rather than the surfaces of entire pavements. Many cities use calcium chloride mixed with sand or cinders for extensive spreading operations.

In South Bend a combination of rock salt and cinders has been used. Cinders are obtained from three or four of the larger industries of the City, for the cost of hauling. An agreement is made, however, to take all the cinders so that the industry is assured of continuous disposal. These cinders are stockpiled in the Street Department yard during the summer months. Rock salt is purchased in carload lots and stored at the Street Department in a building near the cinder stockpile.

When the streets become icy or are covered with snow, the entire fleet of Street Department trucks is put to hauling cinders. The trucks are loaded by hand from the stockpile, with about four men shoveling the cinders and one man hauling the rock salt to the truck in a wheelbarrow and dumping the bags of rock salt on top of the cinders.

Only one tail-gate spreader has been available; consequently, most of the cinders are spread by hand. Cinders are thrown across the pavement in streaks by shovels as the truck moves along slowly. A total of 2,607 truck loads of cinders and 165 tons of rock salt was used last year.

Last winter created one of the most severe snow-and-ice-removal problems in South Bend history. Snow fell early in the fall and was never completely clear of the streets until spring. As new snow fell, application after application of cinders and rock salt was placed on the streets and was never completely cleaned off the pavement until spring.

It has been definitely proved that the use of salts and cinders, separately or together, in snow and ice removal is a cause of concrete scaling. The degree of scaling depends upon the concentration of salt, the combination of cinders, and the age of the concrete.

It became evident last spring that our concrete streets which had been treated with applications of salt and cinders were developing rather extensive scale. It was also observed that the extent and severity of the scaling depended upon the amount and frequency of salt applications as well as the age of the pavement. Concrete pavements three or four years of age are less susceptible to scale from salt and cinder applications than pavements of lesser age.

In general, the scale does not extend much below the surface mortar. In extreme cases where frequent applications of salts are made, such as at important street intersections, the scale may extend to expose the top layer of the coarse aggregate in the concrete. Rarely does the scale impair the riding qualities of the pavement to any great extent, but it is unsightly in appearance and for that reason is objectionable to property owners.

In an attempt to find some method of protecting these concrete pavements from the effects of salt applications, our attention was called to a comprehensive program of research which had been carried on since 1938 to solve this problem. A number of interested agencies have co-operated in this program, including the federal and state highway departments, cities, cement manufacturers, and the Portland Cement Association. The results of the research so far have been conclusive. It has been definitely demonstrated both by laboratory and field experimental projects that concrete having high resistance to freezing and thawing and to applications of salts can be made with air-entraining portland cements. These are portland cements with which small quantities of certain air-entraining materials have been incorporated during their manufacture.

Numerous resinous or fatty materials have been tried, and when interground with the cement clinker they have the ability to impart air-entraining properties to the portland cement. Among these are beef tallow, fish-oil stearate, and Vinsol resin.

This latter air-entraining material is the only one so far which has been recognized in official specifications by the American Society of Testing Materials.

Air-entraining portland cements when combined with water and aggregates produce a concrete having minute and well-distributed air bubbles. Other characteristics not common to concrete made with portland cement containing no air-entraining material are also imparted.

The amount of entrained air can be measured by the reduced weight per cubic foot of freshly mixed concrete as compared to concrete of similar properties and consistency made of portland cement containing no air-entraining material.

Mr. William H. Droege, Materials Chemist for the City of Fort Wayne, has made considerable study of concretes made with air-entraining cement in his city; and laboratory data that he has very graciously given me for use in this paper show a weight of about 145 to 147 pounds per cubic foot. The concrete made with regular portland cement weighs from 149 to 151 pounds per cubic foot, the average slump of the concrete being two to four inches, depending upon the purpose of its use.

Research has shown that the best results with pavement mixes are obtained when this reduction in weight is not less than about three pounds nor more than six pounds per cubic foot. The lower limit of three pounds per cubic foot gives the required resistance to salt applications, and a reduction of more than six pounds will result in an undesirable and unnecessary reduction in strength without any appreciable added durability.

The incorporation of air, corresponding to a drop of unit weight of from three pounds to six pounds per cubic foot, will reduce the flexural strength of the concrete about ten to fifteen percent as compared with concrete of the same cement content and consistency made of normal cement. This small reduction in strength is not considered critical, as present-day pavement mixes ordinarily give strength considerably over the minimum requirements of the specifications. If desired, however, this loss in strength may be restored by an increase in cement content.

Entirely by accident, a comparison of the two types of concrete was made in South Bend. The City paved the block of LaSalle Avenue between Michigan and Main Streets. In accordance with the utility franchise, the South Shore Railroad paved its track area. It so happened that the Railroad Company used air-entraining cement and the City used normal portland cement. The work progressed simultaneously. The scaling effects of the salt and cinders are very noticeable on the City's portion of the work, while no scaling is apparent on the Railroad's portion.

Air-entraining portland cement has been used, experimentally, on other paving projects during the last five years. So far none of the streets where this cement was used has been given salt applications for ice removal, but experience has been gained in the placing of concrete with this type of cement.

There is a noticeable difference in characteristics of concrete made with Vinsol-resin cement and that made with normal cement. It is more cohesive and sticky and has a more fatty appearance. There is practically no segregation, and objectionable bleeding is greatly reduced. The placing and finishing procedures are the same for concrete made from air-entraining cement as for normal cement except that the concrete must be finished sooner. Finishers after a few days' experience do not object to this type of cement; in fact, they generally prefer it.

Some adjustment of the mixes usually used for normal portland cement is necessary when using air-entraining portland cement. Consideration must be given to the increased volume of mortar resulting from the bulking effect of the entrained air.

In order to maintain the same cement factor as for normal portland cement, the amount of aggregates used per bag of cement must be reduced. Since the increased volume is due to bulking of the mortar alone, it is suggested that this reduction be made in the sand content only. In this way the volume of mortar per unit volume of concrete is kept about the same as for mixes designed for normal portland-cement concrete. For the first trial batches, a reduction of sand content equal to three percent of the total weight of the fine and coarse aggregate is recommended. Yield tests of the freshly-mixed concrete should then be made and used as a basis for further correction of the mix to obtain the specified cement content. Reducing the sand content to compensate for the entrained air will require about one-fourth gallon of water less per sack of cement for the same slump.

Air-entraining cements in the dry state are more fluffy and flow more freely than normal portland cements. All holes and cracks in the bins for storing bulk cement should be plugged to prevent leakage.

Batch trucks should be equipped with separate containers for cement or the cement should be placed near the middle of the aggregate compartment between the fine and coarse aggregate. If the cement is placed in the corner of the compartment, leakage from one batch to another during dumping at the mixer skip may occur unless the gates fit tightly.

A mixing time of one minute is ample for concrete made from air-entraining cements. Inadequate mixing will not permit entrainment of sufficient air in the concrete, and over-mixing may in some instances tend to increase the air content beyond the limits which are desired for maintaining adequate structural strength.

It has been our experience that the use of an air-entraining cement will eliminate scaling of concrete pavements due to application of salts. To minimize the scaling effects on normal portland cement concrete pavements, we are using sand instead of cinders and calcium chloride instead of rock salt. A more uniform mix of these two materials is being obtained in loading, and six tail-gate spreaders have replaced the hand spreaders, reducing the concentration of salt on the pavements.