Bridge Deck Deterioration

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INTRODUCTION

Concrete bridge deck deterioration is a phenomenon not isolated to one section of the country, but rather general throughout, except in the arid sections where moisture is at a minimum. This deterioration is far more prevalent in those areas subject to freezing temperatures, snowfall, sleet, etc., where the roadways are subject to freezing and thawing and de-icing chemicals are extensively used.

Much research has been and is being done to solve the problem, but no one source can be pin-pointed as the cause. It is generally believed that there are numerous contributing factors, all complimenting each other to the detriment of the concrete.

TYPES OF CONCRETE DECK DETERIORATION AND THEIR CAUSES

Scaling

Scaling is the deterioration of concrete surfaces due to forces exerted by the freezing and thawing of water or saline solution in the concrete. Air-entrainment aids in eliminating or reducing this scaling, but by itself is not a cure-all. Scaling is also caused by a high water cement ratio in the concrete at the wearing surface. This can be caused by a very wet mix, sprinkling of water on the surface during finishing, and overworking the concrete during finishing operations.

Transverse, Longitudinal, Diagonal and Map Cracking

All concrete decks are subject to cracking, both transversely and longitudinally as well as diagonal, and map cracking patterns.

Transverse cracking generally occurs over the top reinforcing bars and can be attributed to a stress rise over the bars; subsidence of the concrete around the bar, shrinking stresses due to the different rates of drying throughout the slab. Transverse crack patterns on poured-in-placed concrete bridges also reflect the live-load and dead-load stresses that exist in negative or positive moment areas.

Longitudinal cracking is generally more apparent in solid slab bridges with no beam or girder members. Again, the primary cause is resistance to subsidence of concrete around the top reinforcing bars and shrinkage stresses due to the different rate of drying throughout the slab as a result of improper curing methods.

Pattern Cracking

Pattern cracking or checking are shallow and are generally attributed to early, quick drying shrinkage due to poor curing procedures.

Random Cracking

Random cracking seemingly are those cracks that have no reason, but probably can be attributed to imperfections in the concrete and aggregate, shrinkage or temperature stresses or the affect of live load in a particular area.

Surface Spalling

Surface spalling, the separation of the surface concrete for varying degree of depths, is generally associated with cracking of the concrete deck. However, spalling does not invariably occur at all cracks.

CORROSION OF DECK REINFORCING STEEL

Cracks over reinforcing steel permits water and de-icing chemicals to penetrate to the steel accelerating the rusting of the steel which exerts great forces to pop the concrete. Also, water can accumulate in the pockets around the bar if subsidence noted previously has occurred, and be a source of trouble not only because of rust, but also due to the winter freeze-thaw periods.

Much discussion has been carried on and research conducted concerning the effect of live-load stresses, resultant deflections of the concrete deck, stress reversals, etc., as a contributor to deterioration. Research tends to lean to the theory that such is not the initial cause but, no doubt, where a floor has cracked, the effect of the live-load on opening cracks does contribute to deterioration.

Method of Corrosion Detection

In November 1970 the Highway Commission's Research and Training Center, under the direction of Mr. Walsh, developed a method of detecting corrosion in bridge deck reinforcing steel. A voltage meter device is used to detect where corrosion of reinforcing steel is occurring due to salt water penetrating cracks in the concrete and reaching the steel.

Some feel that this horizontal crack develops as a result of the corrosion, and some do not, but it is sure that all will agree that corrosion is certain to take place anywhere the crack exists. Further, during a repair, the concrete in all areas where the horizontal crack is present must be removed and replaced because it would eventually spall and the repair patch would have to be repeated. The meter also can be used to check the effectiveness of an epoxy or other sealing compound put on the deck of the bridge.

If the reinforcing steel is corroding, the meter will indicate a reading of 350 to 650 millivolts. In areas where the corrosion is not taking place, the reading will be much lower, say 100 to 350 millivolts. The border between a cracked and an uncracked area will demonstrate a sharp dividing line where this difference in the voltage will be measured over a width of not more than six inches. If the deck has been completely sealed with epoxy or any similar material, no voltage at all will be detected, because the solution from the porous rod tip will not penetrate, and these materials are good insulators also.

ELIMINATION OF SURFACE SPALLING

Design Changes in Steel Placement

The elimination of surface spalling naturally is of prime importance to provide longer life to our bridges and in reducing the maintenance and replacement cost. We have made many changes in the design and construction of our bridges to overcome some of the known causes that contribute to the deterioration of our bridges. We have increased the concrete cover over top reinforcing steel to two inches in an effort to minimize cracking over the steel. If cracking does occur, it is felt; with the increased cover the crack will not penetrate to the reinforcing bar. We also are placing #3 bars on top of and normal to the top concrete slab stress steel in an effort to minimize and control the surface cracks.

Deck Sealing Materials Applied

We have also in a number of cases sealed the new deck with a penetrating epoxy sealer in an effort to seal the surface and cracks against the intrusion of water and de-icing chemicals. This is done after the deck has cured and pattern and/or shrinkage cracking has occurred. The cost of this application is approximately 25 cents per square foot.

The districts under the direction of the maintenance engineer have applied a linseed oil treatment to the deck. This is a short term preventative measure and should be applied at regular intervals. Some states have had varying degrees of success with this treatment.

Curing Techniques

Adequate curing of the concrete, of course, is of prime importance and in many cases we are sure this is not being accomplished. We now use a chlorinated rubber curing compound on our decks and have had pro and con reactions as to the job it does. Of course, the optimum method would be to steam cure, but the cost of this method of curing is almost prohibitive.

Favorable Weather for Concrete Placement

Some states limit placement of bridge deck concrete to the most favorable temperature, humidity and wind velocity conditions. Some of our people also question winter placement of concrete, due to the adverse conditions which could seriously effect the durability of the concrete.

PREVENTATIVE MAINTENANCE

Early Preventative Maintenance

Preventative maintenance, starting the first year a structure is opened to traffic, is important to the ultimate life of a bridge structure.

Numerous Minor Maintenance Techniques

Preventative maintenance at a cost of a few hundred dollars would, in most cases, prevent major repairs at a future date at a cost of thousands of dollars. Such maintenance would fall into the category of good housekeeping in removing dirt, de-icing chemicals and debris from the deck and around the bearing areas, as well as repairing slopewalls, eroded areas, and cleaning the channel of debris. This could be accomplished by sub-district personnel, but a regular schedule should be a set-up and a follow-up made to see the job is getting accomplished.

District Bridge Maintenance Crews

Permanent qualified maintenance crews are needed in each district to handle more difficult maintenance such as repairing and resealing joints; cleaning and patching spalled deck areas and other deteriorated areas; making minor repairs to damaged bridges; washing down decks and bearing areas. Such crews should have experienced personnel thoroughly trained in inspecting, reporting and getting the work accomplished.

Central Office Control and Assistance

Such organizational procedure should be backed-up with a staff in the central office, under the maintenance engineer, responsible for bridge inspections and maintenance to supervise and provide specialized assistance to the districts in this field. A comprehensive and expensive program to get started, but one which we feel would pay dividends in reduced deterioration and resultant repair or replacement costs.

REPAIR OF SPALLED DECKS

Once deterioration of a bridge deck has progressed to the point where spalling is taking place, a major effort is required generally by contract to repair the damage. This requires a thorough cleaning of the surface to remove all deteriorated concrete down to sound concrete and building the surface back to grade. We have used a number of methods in this work as follows:

Cement Slurries and Epoxy Mortars

a. A neat cement slurry as a bonding agent with 1½-in. to 2-in. layer of concrete.
b. A minimum ⅜-in. layer of Shell Guardkote 250 epoxy mortar.
c. A minimum ⅜-in. layer of Dow Chemical SM 100 modified Portland Cement concrete.
d. A minimum ⅜-in. layer of Celanese 100 epoxvy mortar.

We have had varying degrees of success with all of the systems just mentioned. The success of any such system depends in great measure on the complete removal of any deteriorated material to sound concrete and getting a good bond. The systems cost from $3 to $5 per square foot. This is quite expensive as you can see and emphasizes the need for complete preventative maintenance starting with the first year a bridge is completed.

Bituminous Wearing Surfaces

On structures that are to have a bituminous wearing surface we have sealed the concrete surface first with a layer of coal-tar epoxy or a penetrating epoxy sealer in an effort to minimize deterioration, as we know the bituminous surface acts as a sponge, trapping water on the concrete surface.

DETERIORATION OF THE SUBSTRUCTURE

We have discussed primarily deck deterioration but deterioration of the substructure also occurs as you all know. This is particularly true in those areas where joints occur in the bridge deck permitting saline water to penetrate down to the bearing areas on caps, piers or abutments. You have all seen, I'm sure, these bearing areas that are deteriorated to varying degrees and extending down to the columns or stems.

As yet, we have found no completely successful joint sealer, especially ones that are reasonably economical. General Tires Transflex Rubber Joint has been used rather successfully and we are looking into modular compression seal joints and aluminum joints that should also be water tight to a satisfactory degree. These joints are expensive, ranging upward to $50 to $70 per lineal foot.

NEED FOR MUCH PREVENTATIVE AND MAJOR MAINTENANCE

Many of the bridges on the interstate system have been in service for five to ten years and already are showing signs of serious deck deterioration. Preventative as well as major maintenance effort by qualified personnel with all equipment necessary is required on a continuing basis to protect the huge investment.

Approximately 60 to 70 percent of our bridges on the ABC system were constructed prior to 1935. Most in this category are in a bad state of disrepair requiring major repair or replacement as funds are available.

This data reflects the magnitude of the problems related to bridge floor deterioration and emphasizes the need to continue our efforts in this vital phase of bridge design, construction and maintenance.