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Combatting Road Salt Corrosion in Concrete Bridges – the Way Ahead

Propositions pour la lutte contre la corrosion des ponts en béton

Tausalz-Korrosion von Betonbrücken – Massnahmen für die Zukunft

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SUMMARY
The paper identifies de-icing salt generated corrosion as currently the most damaging threat to the integrity of our concrete bridge stock, requiring ever increasing expenditure on future maintenance. Examples are given of typical salt attack zones. A package of measures is proposed for the design, detailing and specification of future concrete bridges to improve their resistance to this insiduous form of attack.

RÉSUMÉ
La corrosion due aux sels de déverglaçage constitue le plus grand danger pour notre patrimoine de ponts en béton. Ce problème demandera à l'avenir des dépenses croissantes pour la maintenance. Dans cette contribution, les zones tout particulièrement menacées sont décrites. L'auteur propose un certain nombre de mesures concernant le projet, le dimensionnement et l'exécution de détails constructifs qui permettront aux futurs ponts en béton de résister mieux aux attaques des sels de déverglaçage.

ZUSAMMENFASSUNG
Tausalzeinwirkungen und die dadurch erzeugte Korrosion stellen für die Dauerhaftigkeit unserer Betonbrücken die grösste Gefahr dar. Sie werden in den nächsten Jahren stark steigende Kosten für die Instandhaltung verursachen. Besonders gefährdete Zonen für Tausalzangriffe werden aufgezeigt. Für die Betonbrücken der Zukunft werden Massnahmen auf dem Gebiet der Planung, der Projektierung und der Ausführung vorgeschlagen, um den Widerstand gegen Tausalzeinwirkungen zu erhöhen.

1. ROAD SALT CORROSION

1.1 Road Salt De-icing & Concrete Bridges

It is a tedious fact that most of the highly industrialised nations lie in the winter snow and ice regions of the northern hemisphere. These nations are very dependent upon sophisticated highway networks which must be kept clear during winter, when the common remedy of spreading road salt for de-icing is applied.

Unfortunately, winter salt spreading operations are inevitably accompanied by melting ice or snow and the water run-off from the treated roads turns into a harmful sodium chloride solution. In the form of spray or run-off the deposit can penetrate the exposed faces of concrete bridges carrying or crossing the treated roads, causing weakening corrosion of embedded reinforcement bars and/or prestressing cables in those bridges.

Where the salt penetration is very random & there is not much free oxygen available at reinforcement or cable level, the lower ferric variety of corrosion develops. This is characterised by a local pitting of the attacked steel leading to a soft black corrosion deposit. With cover concrete of a reasonable strength, this deposit will not expand with sufficient force to break away the concrete. Typical local pitting black corrosion is shown in Figure 1. If more oxygen is present, the corrosion process is the more familiar variety with a general red surface rust. Inevitably the concrete cover is forced off by this harder & more expansive corrosion product, allowing more oxygen & moisture penetration along the bar, giving the more familiar progressive visible and red corrosion.

Thus, black corrosion is a potentially much more dangerous phenomenon as loss of reinforcement or prestressing cable is proceeding unseen under the surface. The accompanying reductions in structural integrity give no visible early warning such as cracking and spalling.

In addition, the rapid heat withdrawal from salt treated concrete surfaces can cause a sudden local surface temperature drop of up to 10°C within one minute after application, or thermal shock. This can cause

Fig. 1 Black Corrosion

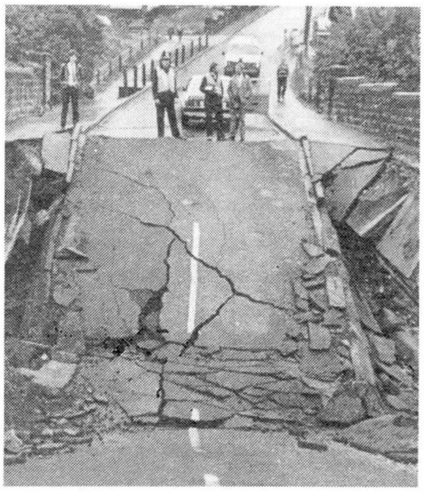


Fig. 2 Bridge Collapse

early surface cracking, leading to surface water penetration, ice formation and the familiar freeze-thaw surface spalling and concrete disintegration.

Concrete bridge corrosion damage arising from the winter salting of UK roads has become more evident of late, possibly because of the considerable increase in the stock of potentially vulnerable reinforced and prestressed concrete bridges which have dominated construction over the past three decades, combined with some recent severe winters and a massive increase in road salting of up to fifteenfold in the same period. It is also possible that the UK specification emphasis on concrete strength rather than impermeability has contributed to the apparent greater vulnerability of these more recent bridges.

The demolition of a 25 year-old prestressed concrete flyover in Berlin because of road salt damage was well publicised in 1985. Events moved uncomfortably closer to the UK in 1986 with the demolition of one bridge, and the collapse of another, (Figure 2).

1.2 Typical Salt Attack Zones

Figure 3 shows a typical concrete bridge unfortunate enough to be suffering all the winter de-icing salt attack zones which are commonly met with in bridge inspections. The vulnerable zones are indicated as subject to ponding, rundown, spray or direct penetration. The most troublesome areas are deck joints, parapets & piers. It should be emphasised that corrosion attack can be particularly rapid in local areas where the shelter of overlying structures prevents the beneficial cleansing actions of rain & salt-free spray.

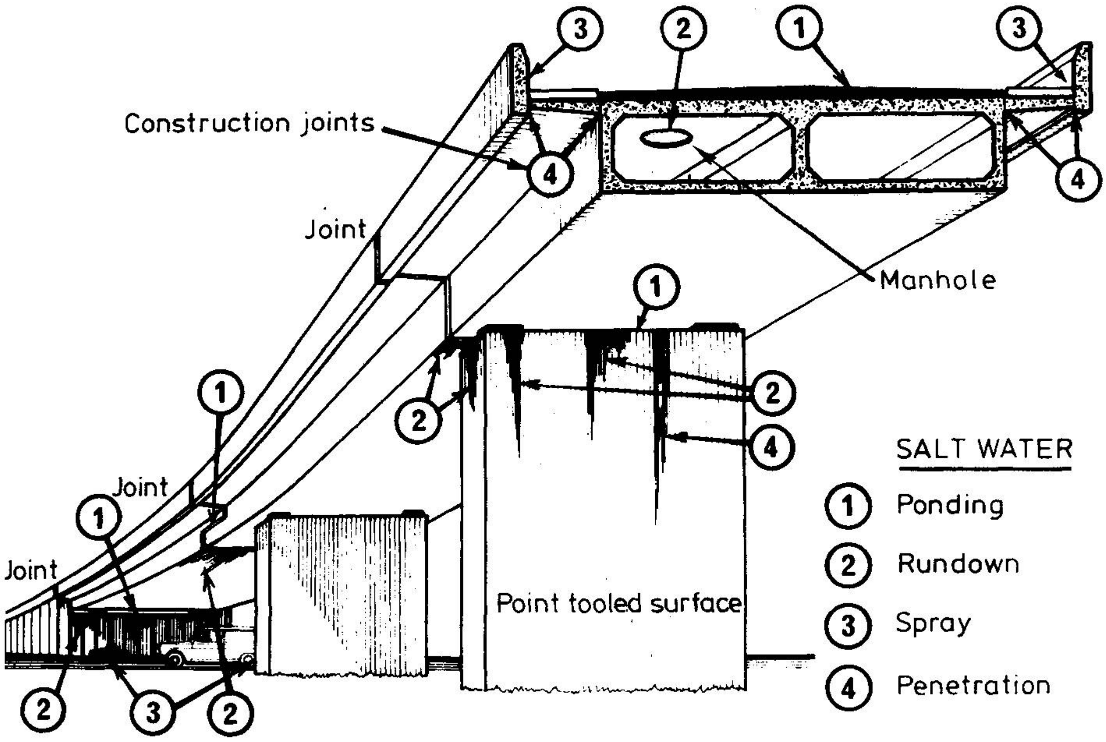


Fig. 3 Typical Salt-Vulnerable Zones

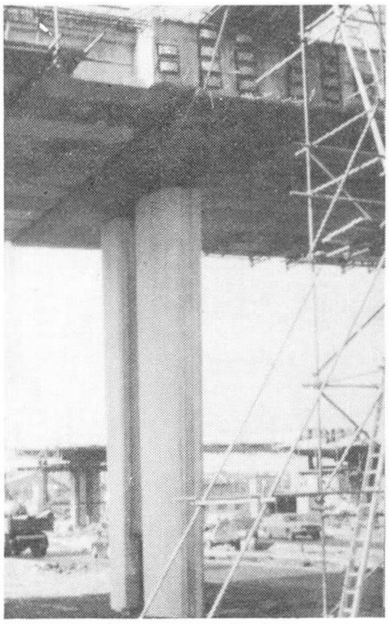
2. PROPOSED MEASURES TO REDUCE FUTURE VULNERABILITY OF BRIDGES TO SALT ATTACK

2.1 The Way Ahead

It is possible, with very little extra effort, to considerably reduce salt attack vulnerability in the design, detailing and specification of new concrete bridges. In addition, several new construction materials and techniques have offered varying degrees of protection to improve the salt resistance of new, existing or repaired bridges. These should be considered in conjunction with the design, detailing & specification procedures to reduce the future salt attack vulnerability of concrete bridges. Some of these are described.

2.2 Design for Deck Continuity

Bridge deck expansion joints are particularly vulnerable to salt attack, not only affecting the surrounding concrete but also the underlying piers and abutments. It therefore appears logical that deck designs should set out to minimise the number of expansion joints. These occur at deck ends over the abutments, with intermediate joints if multi-span decks are designed as a series of simply supported spans or, worse, with cantilever & drop-in span half-joint arrangements. The end abutment joints may always be with us, except in the case of very short built-in single span decks. Intermediate joints are generally unnecessary if deck continuity is adopted for multi-span bridges & flyovers. Continuity possesses many other beneficial features, such as reductions in deck construction depths and pier bearings, widths & foundations, in addition to a better running quality. A major proposal is therefore that multi-span deck continuity should be mandatory, unless soil conditions dictate otherwise, and that cantilever and drop-in spans should never be permitted. Fortunately, deck continuity is now commonplace and is encouraged by several national bridge authorities. The technique of building precast beams into prestressed insitu crossheads has been used successfully to form continuous decks on several large flyovers, (Figure 4). It can readily be adapted to avoid drop-in arrangements, (Figure 5).



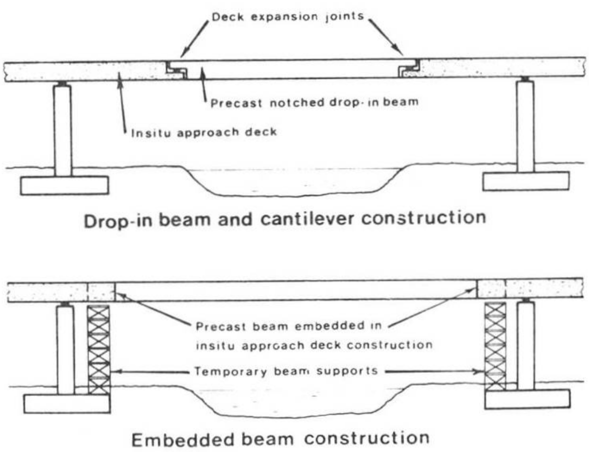


Fig. 4 Precast Beam Deck Continuity   Fig. 5 Avoiding Half-Joints

2.3 Detail Accessible End Deck Joints

Figure 6 shows a proposed treatment to an end abutment expansion joint to avoid some of the common rundown & access problems. The ballast wall is set back and the abutment shelf dropped as necessary to provide sufficient access way at the back of the deck for future inspections & maintenance. Concrete corbels cantilever from the deck and the ballast wall to contain the expansion joint. The deck waterproofing is carried down the vertical/inclined edges of this joint and tucked into a drip formed under the corbel, providing rundown protection. The remaining soffit of the corbels and the deck vertical edge are treated with a thick bitumen paint or silane impreganation. This is particularly important in prestressed decks, where anchored cables lie just under the surface. Similar waterproofing treatment is provided on the ballast wall and abutment shelf, all applied from the access way. A drip is provided to the rear of the bearings to prevent any moisture migration across the deck soffit, which might occur due to failure of the drainage arrangements or excessive condensation within the access chamber. Adequate falls are provided to a substantial drain at the back of the abutment to prevent any rundown on the abutment face.

2.4 Detail Pier & Parapet Protection

It is not difficult to design adequate protection for bridge piers & parapets subject to salt splash corrosion. Splash tends to concentrate its attack just above the adjacent road surface and dogs often use columns as a tree-substitute, promoting further attack! Figure 7 shows typical treatments to a circular column pier and a parapet. The lower vulnerable zone of the pier is treated with a tough black bitumastic paint. To protect the bearings at the top from any salt laden mist, which may collect under the deck soffit, a matching black removable plastic collar is added. The overall effect can add aesthetic interest. The parapet can be treated with silane impregnation or grp sheeting.

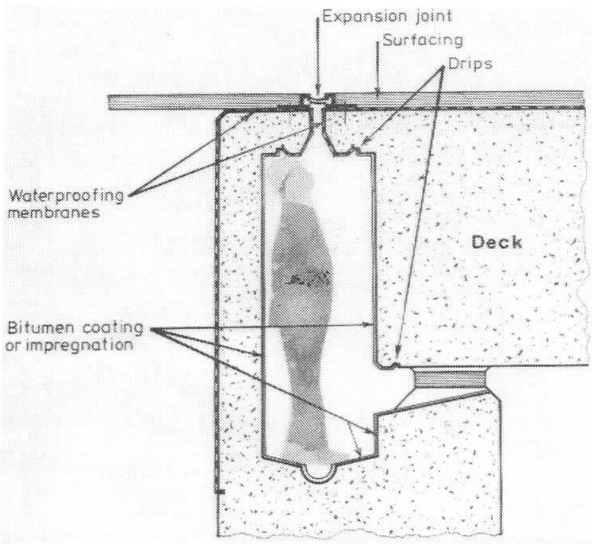


Fig. 6 Deck End Treatment

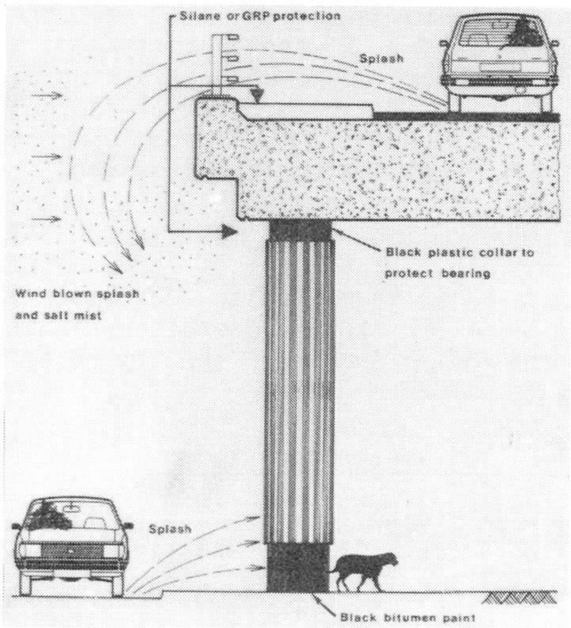


Fig. 7 Pier & Parapet Protection

2.5. Specify Durable, Less Permeable Concrete. Add Quality Assurance

Concrete durability is generally vested in the outer 50mm or so of cover, because most long term attack comes from the surrounding environment. It would be useful if permeability could be monitored, with concrete permeability testing included alongside conventional strength testing. Quality Assurance procedures are recommended to ensure this concrete durability attainment. QA also includes providing maintenance manuals.

3. NEW MATERIALS & REPAIR TECHNIQUES

3.1. New Materials

In recent years, with the realisation of the growing problems of maintenance, there has been a quickening development, particularly in Germany & America, of materials which can be used for protecting concrete bridges from salt attack. The more promising are described.

Prefabricated sheet materials rely on relatively inert and impermeable material bonded to vulnerable concrete surfaces to form a barrier to salt penetration. A familiar example is the bridge deck waterproofing membrane, which cannot be used on visible vulnerable areas. More acceptable is grc or grp sheeting, which can be colour matched & bonded in to the surrounding concrete. These materials have been used on bridge parapets, also fulfilling the role of permanent formwork.

Liquid surface coatings can be applied to vulnerable surfaces by spray, roller or brush. They dry to form barrier coatings resistant to salt and other forms of attack. Their very success in acting as an impermeable one way barrier to the concrete can sometimes prove a weakness, as they may be susceptible to blistering from the inevitable moisture vapour seeking to get out from the concrete. Some materials offer a 'breathing' property to minimise this risk.

There is little doubt that silane and siloxane surface impregnations applied to a depth of 2-4mm form a water-repellent pore lining material which acts as a strong barrier to salt penetration. The material also allows some concrete breathing, is more or less invisible and is claimed to last at least the life of the concrete structure.

The inclusion of polypropylene or steel fibres in the concrete mix adds a crack arresting function & toughness throughout the whole body of the structure including, most importantly, the environment - resisting cover concrete. The use of ground granulated blast furnace slag as a partial cement replacement also adds impermeability. An effective last line of defence is to use corrosion resistant epoxy coated reinforcement, much in evidence in America & shortly to be produced in the UK.

3.2 New Repair Techniques

Several techniques are now available or under consideration for improving the durability of existing structures, including cathodic protection & patch repairs using vacuum or cooling panel formwork to minimise restrained early thermal shrinkage effects and associated cracking.