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Artikel: Discussion on experience in application and behaviour of resin-based wearing surfaces on steel bridge decks in Holland

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DISCUSSION ON EXPERIENCE IN APPLICATION AND BEHAVIOUR OF RESIN-BASED WEARING SURFACES ON STEEL BRIDGE DECKS IN HOLLAND

Expériences dans l'application et le comportement de revêtements à base de résine sur des ponts à travée d'acier aux Pays-Bas

Erfahrungen in der Anwendung und im Verhalten von Belägen auf Harzgrundlage auf Stahlbrückendecken in Holland

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1 Introduction

Trials on the application of thin wearing courses on orthotropic steel decks started in Rotterdam in 1955 with latex-cement binders and in 1956 with synthetic resins as binder. The first practical application based on polyester resin was in 1959 on a bascule bridge.

Since then the new bridges were designed as orthotropic plate construction. The movable spans, about 10 with a total area of 6000 m^2, mainly were equipped with a thin wearing course based on epoxy-tar, while for the fixed spans mainly a 50 mm. asphalt has been chosen, the exceptions for special reason.

For maintenance purposes on old bridges with wooden decks thin wearing surfaces,(surface dressings), directly applied on the deck, have been tried, but not with much succes. The last years prefabricated wearing courses have been applied. Rolled up mats, about 10x1 m. in size and consisting of the wearing course fixed on cloth like emery-cloth, are glued on the wooden deck with hot asphalt. The surface is practicable immediately after cooling.

2 Description of constructions used

2.1 12 mm. thick mortars

This wearing surface is specially used for the movable bridges to meet the disadvantages of the asphalt surfaces for this type of bridges, viz., the relative heavy weight of the 50 mm. asphalt and the risk of sliding down in the vertical position when the bridge is opened for a considerable time during sunshine.

The layer is applied on orthotropic steel deckplates of 12 mm. thickness, stiffened at about 300 mm. distance as a maximum with either flat bulb steels or with box-sections.

The wearing surface is applied as a mortar of a graded quartz-sand of about 2 mm. max. size and a binder. As a binder resins of the polyester-, polyurethane- and epoxy-type are available now as very flexible(rúbbery) to very hard materials. The elastic behaviour is more or less influenced by the plastic (liquid) behaviour and is determined by the stiffness-modulus S, being a function of time and temperature. An apparatus measuring the deflection of a short beam at constant load, applied by air pressure to make the measurement at short loadingtime possible without mass effects, gave very useful results.

For the first applications a polyester binder was used. Test panels generally showed good behaviour, but in practical applications polyester proved to be very critical. To meet this problem softer polyesters were used with the disadvantage of being more sensitive for water.

Epoxy-tar proved to be so much better in general behaviour that now only this binder is used.

Tests and experiance on executed bridges showed that the formation of haircracks formes the main problem.

If we make a calculation of the stresses due to traffic, we see that 12 mm. thickness is unfavourable in this respect. Fig. 1 gives the calculated bending stresses σ_w in the wearing course as a function of the stiffnessmodulus S of the mortar and the thickness δ_w of the wearing course. The figures are based on a 12 mm. steelplate, stiffened at 300 mm. distance and a regularly occurring moment due to local bending of 250kgf.cm per cm. For the wearing surface the short time stiffnessmodulus is important with a loading time of less than 0.1 sec. At low temperature, -20°C, the stiffness may rise up to 250000 kgf/cm^2. and more. By applying 15% by weight of binder it is possible to keep the stiffness below 200000. Though the breaking strength in bending of the mortar at this condition of temperature and loadingtime is well beyond 250 kg/cm^2, due to fatigue the reserve in strength is small.

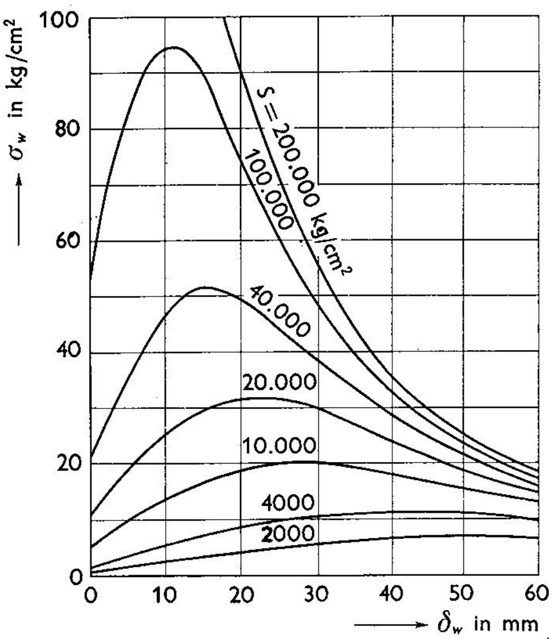

Fig. 1 Bending stresses in the wearing surface.

Plastic flow caracteristics appeared to be important too. Stresses due to temperature changes and due to shrinking of the binder are both present. Measurements with a special frame with built-in straingauges showed that, when cooling the mortar at a rate of 40°C. in 4 hours, above the glass transitiontemperature stresses do not build up, while under this temperature there is but little stress relaxation.

Application of the layer needs careful sandblasting of the steelplate. After blasting a primer based on epoxy-resin is applied. Short before the mortar is troweled a heavy coat of the pure binder is applied in which the mortar is troweled before this coat is cured. The coat gives an extra corrosion protection and an excellent adhesion.

Experience on a bridgedeck where haircracks occurred learned that a good adhesion prevents the cracks to penetrate to the steelplate. The primer and tackcoat should have at least the same or greater strength than the binder of the mortar. Zinc-rich primers do not seem to have good properties in this respect.

A practical testmethod is just chipping testpieces of the cured layer from the steelplate. If it is not possible to cleave the layer from the steel as a whole, but if the layer is cleaved in little pieces, breaking through the mortar itself, then adhesion is good.

A detailed description about application and behaviour of testpanels and executed bridges can be found in ref.[1])

Briefly it can be stated about the experience gained that the polyester wearing surface of the first bridge, finished in 1959 is still present with a few damaged spots. The traffic is moderately heavy. Though there are still no visible haircracks or detachements beside the damaged spots mentioned, the surface shows signs of penetration of water when the surface dries after being wet and tiny spots of rust can be seen. Replacing is planned within the near future, so that the service life of this surface is about 10 years.

A second bridge with polyester is still in good condition. During the execution difficulties were encountered by cracking due to shrinkage. The waterresistance seems to be better than the first.

In 1963 a bridge with epoxy-tar mortar (1500 m^2) was completed. The traffic on this bridge is very heavy. A few month afterwards, at the end of the winter, the whole surface was full of haircracks, above the stiffeners as well as between. The pattern between the stiffeners shows that beside bending of the steelplate, stresses due to shrinkage have played an important role. In the further 4 years till now the situation did not change. Beside a single spot no rust developed under the cracks and measurements of the electric resistance at places of haircracks showed that the cracks do not penetrate to the steel. Testpieces chipped out of the surface affirmed this.

Further bridges have been executed with epoxy-tar mortar, but instead of the polyamine hardener a polyamide is used now. Some disadvantage being a slower rate of curing. This hardener shows more plastic flow in bending tests.

The surfaces of these bridges are still in good condition after 3 years, though still some haircracks have been found above the stiffeners.

A comparison with the experience gained from the testpanels laid in 1962 on a bridge with very heavy traffic and from experience from executed bridges, giving the possibility to compare the behaviour of the formulation of the first bridges mentioned with the construction used now, justifies the expectation that the servicelife of these wearingcourses will be much beyond 10 years.

1) A.J.van Neste,"Kunstharsen op stalen brugdekken"(Synthetic resins on steel bridgedecks),Mededeling 18, febr. '68. Stichting Studie Centrum Wegenbouw, ARNHEM-HOLLAND.

A steelplate of 10 mm. thickness is believed to be too thin and a 12 mm. plate at least necessary to limit the formation of haircracks and their influence on servicelife of the wearing course.

The wear resistance is good provided the binder is not too flexible. At the testplates wear was measured by inserting white coloured flat cones in the wearing course. Increase of the diameter of the visible white circle being a measure for the amount of wear. The epoxy-tar mortar used at the moment shows a wear of about 1 mm. in 5 yars, 2 million vehicles passing the testplates a yar, among which relative much heavy traffic.

These mortars show good skid resistance at moderate speeds. Measurements with a skid testing vehicle (slip 86%, measuring speed 50 km/h.) yielded breaking coefficients from 0.50-0.70.

2.2 Surface dressings

This very thin type has been used for special circumstances on small removable bridges and in 1966 for a series of panels on the railway track of an existing bridge of 500 m. length, to add an extra bridge lane for peak hours of traffic.

The steelplate is 8 mm. thick and stiffened at 250 mm. intervals. After blasting with aluminum oxyde and priming with an epoxy-primer, a slurry of epoxy-tar, sand and a natural aluminum oxyde has been spead at a rate of 5 kg/m^2.,directly covered with the same aluminum oxyde at a rate of 6 kg/m^2.

The epoxy-tar binder is a very hard, polyamine cured type, giving excellent adhesion to the grains.

The surface is still in a perfect condition.

Experience with these dressings on steelplate showed that the binder should be very hard to prevent the grains to be worn out, flexible binders are not believed to give sufficient fixation of the graines, so that the steelplate should not be too thin with a view of the restricted bending ability of the surface.

2.3 30 mm. thick mortar.

An experimental execution of 700 m^2. is carried out on a part of a new bridge. This wearing surface is thought as an alternative for the 50 mm. asphalt surfaces used normal on the fixed spans.

From fig. 1 it is clear that the bending stresses decrease rapidly when the thickness is over 15 mm. This gives the possibility to decrease the amount of epoxy-tar binder inthe mortar to 8%. Measurements of the stiffness modulus gave values up to 270000 kgf/cm^2., but bending stresses remain at about half the level which has to be calculated for with a 12 mm. thick surface.

Compared with the asphalt surfaces the reduction in weight is about 40% or 50 kg/m^2.

Due to the low content of the most expensive material, the epoxy resin, which is less than 2 kg/m^2. and the fact that this wearing surface is laid in one layer, the difference in cost compared with the three- layer asphalt surface seems to be favourable.

3 Technical and economical prospects.

The use of thin wearing surfaces is believed to be justified for these applications, where a 5 cm. asphalt surface has disadvantages like on movable bridges. It is not likely that they will replace the use of asphalt on fixed spans, both for technical as for economical reasons.

Specially for the bigger bascule bridges a substantial saving may be gained, the reduction of weight having a very favourable influence on the cost of all parts of the construction.

The mortar type seems to be preferable, though surface dressings on steelplate seem to have good prospects too, provided they are based on a very hard binder and mineral.

SUMMARY

A 12 mm thick mortar seems to be an acceptable solution for movable bridges. Epoxytar with a polyamide hardener showed to be preferable. A service life of much more than 10 years may be expected. For fixed bridges the thin wearing surfaces are not believed to replace the 50 mm asphalt, but an alternative may be a 30 mm one-layer epoxy tar surface with a binder content of 8 percent.

RESUME

Un mortier de 12 mm d'épaisseur s'est montré utile pour les ponts mobiles. Cependant le goudron avec époxy, additionné d'un durcisseur du type polyamide est préférable. On pourrait s'attendre à une durée de vie de bien plus de 10 années. Il n'est guère probable que les revêtements minces remplacent l'asphalte épais de 50 mm, mais une alternative serait un revêtement à une couche de 30 mm de goudron avec époxy, contenant 8 % de liant.

ZUSAMMENFASSUNG

Ein 12 mm dicker Mörtel hat sich für bewegliche Brücken als annehmbare Lösung gezeigt. Teerepoxydharz mit einem Polyamid-Härter erwies sich überlegen; so kann eine Lebensdauer von über zehn Jahren erwartet werden. Für feste Brücken werden die dünnen Verschleißschichten nicht als Ersatz für die Asphaltbeläge betrachtet, aber eine mögliche Alternative kann ein 30 mm dicker, einschichtiger Teerepoxydbelag mit 8 % Bindergehalt sein.

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