Zeitschrift: IABSE reports of the working commissions = Rapports des commissions de travail AIPC = IVBH Berichte der Arbeitskommissionen

Band: 2 (1968)

Artikel: Introductory report

Autor: Henderson, W.

DOI: https://doi.org/10.5169/seals-3981

INTRODUCTORY REPORT

Rapport introductif

Einführungsbericht

W. HENDERSON
Great Britain

General and Historical. This theme is aimed at the miscellany of construction which does not fall into either theme I - Surfacing over 1" thick (2.54 cm) or theme III - Surfacing of less than 1" thick.

In fact, these themes, and indeed, the whole symposium, are primarily conceived in relation to road surfacing on steel plates which participate directly as part of the main structural members. This type of construction is itself the end product of various types of deck aimed at reducing deadweight, such as buckle plates, dished plates, steel trough floors, carrying comparatively thin layers of concrete or even roadstone filled with bitumen or tar.

In the past the problem of providing lightweight decks was most pressing on opening bridges. This was readily achieved on timber opening bridges by the use of timber deck construction with a top layer of timber planks which could be removed. This form of deck construction was transferred to iron and subsequently steel opening bridges and has continued to be used until comparatively recent times. Many such decks are still in service on important and busy roads. As a substitute for timber planks, wood block paving was adopted about the turn of the century on many large opening bridges, the blocks resting directly on a sand tar or bitumen layer directly over the steel plates, the joints being run in with hot tar. These blocks were frequently of Jarra wood, but, at least in Germany, beechwood has been used. In cases the blocks were elaborately dowelled together into panels with wooden pegs, key blocks being secured to the construction below in bascule bridges. The use of these blocks was originally made economical by their extensive use in paving city streets where they considerably reduced noise from horse-drawn and steel shod vehicles. So many of these bridges yet remain that efforts have been made to coat the wood blocks with epoxide resin or similar thin surfaces to provide skid resistance. The results do not seem to have been particularly successful, especially in regard to durability.

Buckle plate and dished plate decks. These have been used extensively from about the turn of the century until perhaps 25 to 30 years ago. Square plates arched on two axes at right angles, supported on two sides by the main beams and on the other two sides by stiffening ribs took advantage of the considerable enhancement of the strength of the shaped steel plate to carry local loads. The degree of arching varied but could be of the order of 3" (7.5 cm.) to 6" (15 cm.) on a 5 ft. (1.5 m) square.

These plates were generally filled over with concrete (sometimes tarred road surfacing only) the concrete being either very thin at the centre of the plate (buckle plates) or at its supports (dished plates). In spite of the lack of bonding techniques between the concrete and the steel, the relatively poor quality of concrete and generally its ready permeability to water, it is remarkable how durable this form of construction has been; this is no doubt due to the lack of oxygen in the water more or less permanently in contact with the steel plates.

The wearing surfaces used over this construction were originally tarmacadam, and today bituminous macadams or asphalts.

<u>Bare Steel Plates</u>. The most elementary of surfacing treatments falling in theme II is the bare steel plate itself. Variously this has been produced with projections, studs, corrugations and so forth, to give adhesion for traction, braking and resistance to centrifugal force.

Even when dry such surfaces are unreliable; when wet or fouled with the inevitable film of oil they become completely unreliable for vehicle control.

No protection is, of course, offered against corrosion and, in fact, the fretting caused by the action of wheels must inevitably accelerate deterioration.

<u>Bare steel plates with superimposed open plate</u>. In order to improve traffic adhesion, plates of expanded metal attached to the top of the steel plate have been used. This when new, clean and dry does to some extent improve skid resistance, but not to any satisfactory or reliable degree. The problems of corrosion are not alleviated and are probably increased by the existence of traps likely to hold grit and moisture in intimate contact with the plate.

Steel reinforcing fabric has also been used in the place of expanded metal, with even more unsatisfactory results.

So far as is known these techniques have only been used on temporary structures.

This type of construction has also been surfaced with a comparatively soft bituminous surfacing, having a thickness of some ½" (1.25 cm.) which relies almost entirely on the expanded metal or reinforcing fabric for its stability. This treatment is reported as being reasonably satisfactory on lightly trafficked roads and has been found to be quite useful, even placed directly on steel plates, on emergency bridges where long life is not a first requirement. Generally shear connected surfaces are dealt with in themes I and III.

Open Grid Floors. The open steel grid cover, long used in U.S.A. carries this pattern of development still further, although, of course, it actually precedes the steel plate deck in point of time and appears to have been used in U.S.A. for upwards of 40 years.

The construction consists of close spaced steel bars (generally small I sections) with suitable spacers, open top and bottom and resembling closely cattle grid construction as used in U.K. and elsewhere.

Its advantages are its extreme lightweight, excellent drainage, ready disposal of snow, and, as in the case of the Mackinac Bridge where open grids are used on two traffic lanes and the narrow centre median, improved aerodynamic stability.

Against this there remains the major disadvantages of lack of protection against corrosion accelerated by traffic abrasion and the considerable danger of skidding. It is understood that in certain locations the icing problem in these open grids can be exceptionally serious and that it has been necessary to limit traffic speeds in such conditions to between 3 and 5 m.p.h.

Efforts have been made in certain quarters to improve the skid resistance by applying thin epoxide coatings to the bars, the coating being impregnated with skid resistant materials such as aluminium oxide grits. As is to be expected these treatments have not proved durable and require to be replaced at quite short intervals (as little as 2 or 3 yearly periods).

While this expensive treatment is likely to give better skid resistance in dry or wet conditions, it seems unlikely to offer more than marginal improvements where icing occurs.

Filled Grid Floors. Filled grid floors are essentially an American development although it is understood they have also been used in Sweden and elsewhere. The steel construction is similar to the open grid deck but has the bottom surface completely closed with lightweight steel former strips. Typically, the main steel members would be of the order of 3" (7.5 cm.) deep rolled I beams at 4 " centres, combined with internal reinforcement.

The prefabricated steel grid is filled with concrete to a depth of some $\frac{3}{4}$" (20 mm.) over the top of the grid, to provide an integrated steel/concrete slab of approximately 4" (10 cm.) overall depth. Traffic may run on the concrete surface, or this can again be surfaced by one or other of the surfacings generally used on concrete decks, as e.g. 1$\frac{1}{2}$" (4 cm.) asphalt.

The concrete used may be either normal or lightweight. The lightweight concrete used on Mackinac bridge (where two lanes are carried on filled grids) is reported to have had a density of 108 lbs/cub.ft. (1730 Kg/cub. m) and a crushing strength of 4250 lbs/sq.in (298 Kg/s.cm.) at 28 days.

This type of construction clearly provides the facility of forming a road surface as good in its skid resistance and durability as can be provided on any rigid deck. The durability and performance have been reported as being very good. For example, a case is instanced of a filled grid deck some 27 years old carrying heavy traffic where no appreciable maintenance has been required. This appears to be generally the case.

As against normal concrete decks the system appears to present clear advantages in time of construction, dispensing with form work construction and the use of scarce types of labour. Particularly when lightweight concrete is used, a comparatively lightweight deck is provided which could be composite with main structural members.

The chief disadvantages are reported to be high cost and the problems of placing and fitting where the deck is warped because of curves and superelevation.

Laminated timber decks. Timber baulks have in the past been used extensively on lift bridges to provide light, stout and resilient decks. The chief objections to their use have been deterioration due to fungoid attack, swelling of the timber due to absorbtion of water and the difficulty of providing a reasonably non-skid surface to protect the timber. Wearing surfaces were often comprised of wood block paving or wooden

Asphalt Planks. Interesting reports have been received of the use of Asphalt Planks on the Harlem River and Bronx Kill Bridges in New York City.

The plank is 24" x 12" x 1" thick (60 cm. x 30 cm. x 2.5 cm.); it contains up to 50% asphalt, 35% to 45% Mineral Filler, and not less than 12% organic fibre. The materials are mixed at high temperatures and extruded under high pressure. Coarse trap rock aggregate is forced into the surface of the plank under pressure.

The planks are bonded to the steel plate by asphalt cement consisting of pure bitumen cut back by volatile solvents, applied at the rate of 0.2 gallons per square yard (1.1 L/sq.m.).

Prior to application of the cement the plate was painted with red lead paint.

The decks on which these planks were laid comprised a $\frac{5}{8}$" (1.5 cm.) thick deck plate supported on 7" (18 cm.) deep I beams at 14" (36 cm.) centres. This battle deck floor was not designed to participate with the main structural members. The battle deck units were broken into panels 22' (6.5 m.) long x a traffic lane width by welding 13/16" x $\frac{3}{8}$" (21 x 9.5 mm.) bars to the plate. This was intended to provide lateral and longitudinal support to the planks.

The reports on the behaviour of the plank surfacing indicate that it can be very satisfactory. On Harlem Bridge after 27 years life, 70% of the surface was still covered by the original planks. On the Bronx Bridge on the other hand the planking deteriorated much more rapidly and severely. It is understood that the difference in behaviour has been attributed primarily to variations in quality of materials, manufacture and placing, and that subsequent supplies of planks for replacement appear to have fallen short in quality as compared to the best of the original material.

Generally it seems clear that the adhesion of the planks, where workmanship was at its best, was very good and reports stress the difficulty of removing them after 27 years use.

Protection against corrosion also appears to have been very good, although a limited amount of not serious damage occurred at and near the joints between the planks where a certain amount of breakdown of the corners of the planks and the adhesion seems to have taken place.

planks attached over the baulks.

It was generally considered necessary to leave narrow gaps between baulks and planks of the wearing surface to allow circulation of air and permit a degree of swelling. This operated against the use of asphaltic or bituminous wearing surfaces which tended to break up at the joints and deteriorate progressively from these points. Adhesion was rarely good.

Recently a timber decked rolling lift bridge has had the deck renewed in laminated timber. The baulks are some 6" (15 cm.) thick, 9" (23 cm.) wide and 24' (7.25 m.) long, made up of 9" x 1" (23 cm. x 2.5 cm.) thick planks fabricated in the factory, glued with an epoxy glue and shaped to the camber defined by the levels of the steel stringers by bending round formers. Impregnation of the timber with fungicides and sealing with epoxide resins appears likely to have minimised dangers from rotting and swelling of the timber. Tests have shown that there is no danger of failure of the glued joints in fatigue. The accuracy to which the baulks were shaped to the required curvature was remarkable, and, since they are tied down to the stringers they provide an effective distributing medium.

Surfacing is provided by a $\frac{1}{8}$" (3.25 mm.) thick epoxide resin dosed with calcined chips laid under tents in controlled conditions on $1\frac{1}{4}$" (3 cm.) thick timber planks screwed to the laminated timber baulks. On other opening bridges similar plank wearing surfaces have been used, but with the epoxide resin surface factory applied before laying the planks. Where these have been used and conditions on the bridge caused vehicles to follow closely on the same tracks, the wearing surface has tended to break up at the joints and then to deteriorate fairly rapidly. In other circumstances the method appears to be behaving more satisfactorily.

It has also been evident that where the planking has not been uniformly supported its flexure between "high" points rapidly promotes deterioration. This can be remedied by regulating with an epoxy mortar.

It is understood that the riding quality and skid resistance of these planks was quite satisfactory, and it would seem that they offer a potentially useful expedient provided satisfactory control of materials and workmanship can be ensured. A fairly stiff steel deck also seems likely to be essential in order to avoid damage at the joints between planks and loss of adhesion at these points.

P.V.C. Tiling. Surfacing formed from tiles of Polyvinylchloride have been used on several ferry ramps in U.K. The tiles are 2 ft (50 cm.) square x $\frac{1}{8}$ in (.32 cm.) thick and have a finely roughened surface on both sides. The tiles are cemented to the steel plate by a suitable compatible adhesive after thorough cleaning of the surface and grinding smooth of all welds.

The steel plate itself is grit blasted and zinc sprayed, any damaged areas of zinc spray being restored with a suitable zinc rich paint before laying the tiles.

Decks so surfaced have been in use for up to two years and are reported to have behaved in a thoroughly satisfactory manner despite the fact that they have been subjected to severe loading from solid wheeled vehicles and side loaders; traction forces are also considerable on these ferry ramps although traffic speeds are, of course, comparatively low.

Neoprene tiles. Experiments with neoprene rubber tiles have been conducted in Germany by Krupps. The principal difficulty with these tiles appears to have been in finding a suitable adhesive which would stand up to the strains occurring under moving traffic, the difficulties being particularly severe at the joints. The tiles were vulcanised on to the steel plate decks of two emergency bridges subjected to heavy traffic densities and on a gradient. After a year's use the surface appears to have responded very well. It is reported to have excellent properties, adhering firmly, being very wear resistant and having a good damping effect.

The vulcanising calls for high pressures and temperatures and the costs are stated to be considerable.

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