# Introductory report

# INTRODUCTORY REPORT

Rapport introductif

Einführungsbericht

A.L. ELLIOT
USA

## INTRODUCTION

A satisfactory lightweight deck for steel highway bridges has long been sought. Open grid decks and checkered plates have their drawbacks. Concrete, both regular and lightweight, has been used and found most satisfactory from a wear standpoint but the heavy dead weight leaves much to be desired. A really satisfactory lightweight deck system is still to be found.

The need for such a lightweight deck is widespread. Highly desirable on movable bridges, it is essential on temporary or portable bridges. It could result in a substantial saving in weight and cost on a long span bridge. It could provide a valuable increased load capacity in the reconstruction of an old bridge. With the coming of orthotropic deck construction, which has greatly reduced the dead load of the supporting structure, the search for a suitable lightweight wearing surfacing has become even more urgent. The orthotropic design provides a deck plate, but it is necessary to discover a wearing surface which can be applied to the steel plate to satisfactorily and safely carry the traffic.

Because the development of a thin surfacing is in a period of experimentation and discovery, it is necessary to cover a world-wide field to find just what the latest developments are. This report attempts to correlate all of the information received from many countries, to accurately portray the current state of the art. Much of the information from other countries was gathered by the German Group of IABSE who circulated a questionnaire throughout the world asking for experience with lightweight surfacings on steel decks.

To facilitate the reporting on currently used lightweight surfacings, they have been divided into three classes. Group I concerns layered asphaltic systems thicker than one inch. Group II concerns other types and specialized systems of surfacing. Group III concerns thin combination systems of synthetic adhesive materials less than one inch thick.

This report deals exclusively with the Group III surfacings - less than one inch thick.

## SUMMARY

The use of very thin surfacing on steel plate decks has not been outstandingly successful anywhere in the world. The thin surfacings have thus far been limited to a sprinkling of grits imbedded in a layer of adhesive or a mixture troweled onto the surface. The total resulting thickness is very small with the result that it abrades rather rapidly. Variations of thin systems have been used in a number of places and have given reasonably good service for relatively short periods but there are certain basic difficulties which have not yet been solved.

First, is the inherent wavy surface of steel plate decks and the impossibility of bringing the surface to a smooth plane with a surfacing whose thickness may not exceed the out-of-flatness of the deck. Second, is the rather limited life of the surfacing. Although the grits which may be imbedded in the adhesive are hard, with good wearing characteristics, as soon as the first layer is broken or worn away, traffic is running on the adhesive which wears away rather rapidly. This limits the effective life to a comparatively few years. Third, the application is rigorous and critical. Re-application is similarly rigorous, causing a serious disruption to traffic. These factors have combined to limit the use of these very thin surfacings.

Greater thickness is needed. There does not seem to have been much work done with a graded mix of aggregate bound together with a resin binder. Epoxy mortars have been used for patches of all sorts and sizes. They are used to level up steel decks and have been used extensively to patch concrete decks and pavements. The tendency of the harder epoxies in thin surfacings to crack would probably be accentuated in a thicker surfacing of the same material.

There is a need for further research to develop an epoxy which will be tough enough to stand the traffic pounding and yet flexible enough to stay with the flexing of a steel deck plate. Although this surfacing would be comparatively expensive, it could provide an appreciable thickness of up to one inch, would

act as a leveler, and would provide a thicker wearing surface with presumably a longer life. Further research should also develop processes which will make quick repair or replacement possible.

Right now, useage seems to favor the thicker surfacings (1½" - 2"). If the thin surfacing is to be adopted, it will be after more research and development. It may still be said to be in the experimental and trial stage.

## DESIRABLE CHARACTERISTICS OF A THIN SURFACING

There are certain basic characteristics which a successful thin surfacing should have. None of the surfacings tried to date have exhibited all of these features. This is to be expected of a new and experimental type of installation and it is to be expected that further development will result in surfacings which more nearly fulfill their objectives.

The desirable characteristics are:

1. The system should have an adhesive which will adhere to the steel with a moderate amount of surface preparation. It should seal and protect the surface so the steel deck plate will not corrode. It should firmly anchor the gritty surfacing material. It should retain its resiliancy under all conditions and not become brittle. It should resist salts, oils and chemicals normally to be found on a highway. It should be tough enough to wear well.
2. The non-skid material should be hard and durable. It should be easy to apply. It should be coarse enough so it will not be submerged in road oil or dirt. It should provide a good tractive and skid-resistant surface and exhibit a high degree of stability.
3. The system as a whole should be reasonably easy and foolproof to apply. It should have a life of at least five years and preferably more.
4. The surfacing should be easily replaced or refurbished. It would be desirable to have an adhesive which would adhere easily to the previously laid material without the necessity of cleaning down to bare steel again or extensively preparing the surface. The new surfacing should be placeable in a few hours of off-peak traffic and then immediately opened to use.

PROBLEM AREAS

There are certain general difficulties which have to date plagued any attempt to develop a successful thin surfacing:

1. Surface irregularities in the steel plate deck. It is generally considered that a good riding surface should not vary more than 1/8" in 10 or 12 feet. Under present day steel fabrication methods, the flatness of the deck plates is not usually within this tolerance. Variations of 3/8" are not unusual and as much as 1/2" can be expected.

In practice most of the thin surfacings are 3/8" (1 cm) or less in thickness. The virtue of such a surfacing is its extremely small dead weight, making it all the more attractive for orthotropic construction. However, a surfacing of only 3/8" thickness cannot smooth out the riding surface when the plate variations amount to 3/8" or 1/2" or more.

It is necessary therefore to place patches to fill up the hollows in the steel plates. In many ways this defeats the purpose of the thin surfacing in that these patches build up the dead weight, and the surface preparation becomes more difficult, costly, and time consuming. Difficulty has also been experienced in holding these thick patches in place. They apparently are sprung loose by the flexing of the plates. This points up the need of an adhesive which will bend with the plate without cracking or popping loose.

2. Wear of the adhesive material. Heavy traffic causes appreciable wear to the best of surfaces. Steel plates will wear thin under constant traffic. Concrete decks gradually wear away. Some of the very hard grit materials used in thin surfacings have excellent wear records as long as they are firmly held in place. However, as soon as the grit surface is lost and traffic begins to wear on the adhesive, the deterioration becomes quite rapid.

Even the hardest resin is still somewhat softer and more prone to wear than a concrete or steel surface. What we seek is a toughness to withstand wear; a flexibility to go along with flexure; as well as a superior adhesive ability. With the best we have today, it would seem that under moderately heavy traffic, renewal every five years might be necessary.

3. Replacement. Assuming then that a surfacing will perform satisfactorily for about five years and that the traffic will be quite heavy, it becomes very important to have a replacement method and material which may be easily and rapidly applied in a very short time. Having once sandblasted the surface for the first application, the subsequent applications should be made before the surface is worn down to the bare steel. It is highly desirable that there be no problem of bonding the new materials to the old after a superficial cleaning. Present materials leave something to be desired in this characteristic.

To be a practical solution, it should be possible to lay a considerable length of surfacing on a traffic lane in the early morning hours of one morning. Any complicated process which will require closing a traffic lane for any appreciable length of time will seriously detract from the desirability of the surfacing.

4. Steel plate preparation and protection. There is a universally recognized need for a clean surface to which the thin surfacing can adhere. In most cases, the steel has been sandblasted. Some agencies took special care with heavy blasting to assure that a "tooth" was developed in the surface of the steel which would retain the adhesive by a mechanical bond. As a bonding agent as well as corrosion protection, some applications have coated the steel with a metallic zinc layer, usually applied as a metal spray. This has met with different degrees of success.

In one case in the United States, the metallic zinc was applied in two layers. Owing to the inherent characteristics of the zinc, the two layers did not bond together and the surfacing peeled off at the interface between the two zinc layers. Other applications use a coat of zinc-rich paint as corrosion protection. Most agencies using an epoxy-type of adhesive seemed to feel that the adhesive itself provided all the required corrosion protection.

MATERIALS

1. Adhesives and binders. Although one country reported the use of asphalt in a thin surfacing, it is generally recognized that a surfacing using a bituminous material as a binder cannot

be successfully used in thicknesses less than 1½". Most of the thin surfacings have utilized the new resin adhesives: epoxy resins, epoxy asphalts, polyurethanes, acrylic resins, etc. Because the physical characteristics of a resin depend so heavily on its formulation, a multitude of combinations are available.

Looking back on the very rapid development of the past few years, it seems highly unlikely that anyone would assert that we have achieved the ultimate in these materials. It seems quite probable that a much more suitable adhesive or formulation of currently available adhesives will in all probability be developed in coming years.

2. Granular wearing surface. To provide a wearing surface with good tractive capabilities and non-skid characteristics, many natural and synthetic materials have been used. The natural materials include sharp sands, finely crushed rock, and crusher screenings. The synthetic materials include the abrasive grits such as carborundum, aluminum oxide, silicon carbide, and similar abrasives. Properly held in place, in some installations these materials have been judged to be superior to concrete in skid resistance. Under wear, however, the particles loosen and come out, impairing the roughness of the surface.

3. Some general comments.

Asphalt latex. There seems to be a lack of durability. Adhesion to the steel deck is not permanent. Constant patching is required. At Ulatis Creek, the complete surfacing was replaced twice during six years. The asphalt latex is better, however, than neoprene latex lumnite.

Epoxy binders. Only known uses are on the Camphill-Birmingham bridge (1961), New Jersey Turnpike Bridge near Elizabeth (1965), and the Route 680/580 grade separation near Dublin, California (1965).

SPECIFIC CASES

West Germany. A great deal of work has been done on the thin surfacings. They have tried a number of different synthetic resins and other materials, and have likewise experimented with different abrasives and methods of application. On some of the surfacings, they have more than four years of experience to draw upon.

They have tried epoxies, plain and modified with tar, polyurethane, and some acrylic resin. As abrasive material, they have used quartz sand, silicon carbide, and carborundum grits. They have also tried some latex binding agents.

In general their experience parallels that of others who have tried these materials. When properly compounded, they are hard and wear resistant, resistant to chemicals found on highways and immune to the normal hazards. They are stable under extremes of temperature. They do not ripple, or rut under traffic, or depress under a standing vehicle. Being thin, however, it is inevitable that some wear is visible after two to three years. No expected life is predicted, this depending largely upon the traffic volume. However, it is certain that in a few years, replacement will be necessary. Replacement will not be easy as the original precautions of protection from the weather and cleanliness must be observed and it is difficult to bond the new to the old surfacing.

Recent experience in West Germany. Most development has been made since 1964. Several demountable bridges have been built with surfacings between 3/4 and 2.0 lbs/sq ft. The adhesive has been a two-part synthetic resin. The steel was sandblasted and a resin prime coat applied. While still soft, a coat of plastic resin and finely grained filler is placed. Then carborundum is sprinkled and pressed into the adhesive with a hand roller. A surface coat of synthetic resin is then laid on as a sealer and surface coat.

Results: Failures have resulted in the polyester resins. Owing to the deflection of the steel deck, it is important that the surfacing be flexible. Hard epoxy and hard polyurethane have many favorable characteristics. All of these surfacings are damaged during the winter by the spiked tires.

Bituminous surfacing in thicknesses of 3/8" to 5/8" (10 to 15 mm) have been used. The plates are cleaned of rust and then bituminous adhesive is applied through a flame jet. On this a thin mastic layer is flowed on hot and rock chips are rolled in. Three years without damage has been reported.

1958 the Eider-Friedrichstadf bascule bridge in Germany was given two types of surfacing: a 13 mm sand-cement-rubber latex in the east lane and a 13 mm sand-cement-neoprene latex in the west lane. No progress reports.

East Germany. East Berlin reports little success with thin surfacings of a bituminous base but they have used epoxy with some success over a rather short service life. They point out the danger of getting the epoxy too hard (causing cracking) or too soft (accelerating wear). Proper formulation is important. The surfacing has good traction characteristics but they have been unable to determine the life or wear characteristics because of a relatively short service life to date.

England. Gloucester Lock Bridge, Gloucester, England. October 1962. To achieve extreme lightness in a bascule span, experiments were run with 1/8 to 3/8" surfacing on an aluminum deck. Epoxy resin coatings were used with net weights ranging from 15 to 45 lbs/sq yd. Four different test applications were made: three of epoxy resin mixtures and one of thin plastic tiles.

Two of the epoxy surfacings were mixed with the aggregate and troweled onto the deck, one 3/8" thick and the other 1/4" thick. For the third epoxy type, the aggregate was sprinkled over the resin. The fourth application, that of embossed plastic tiles of filled polyvinyl chloride, would more properly fall within the scope of Theme II.

This small aluminum bascule bridge spans the lock where the Gloucester and Berkeley canals join the Severn River. It carries fairly heavy traffic. It is a one-lane bridge, 10½ feet wide and skewed so it is 30 feet long on one side and 34 on the other. The deck consists of 13" wide aluminum extrusions with longitudinal ribbed surfaces, welded together to form an unjointed deck surface. The entire deck was grit blasted before placing a different surfacing type in each section.

Section 1: Blasted, then a tar-modified epoxy resin tack coat was applied, after which a mixture of grit and tar-modified epoxy resin was troweled on 3/8" thick.

Section 2: An acid-etch primer was applied and dried, followed by a tar-modified epoxy resin tack coat. Into the wet tack coat, a 5:1 mixture of calcined bauxite aggregate and tar-modified epoxy resin (2 parts resin, 1 part hardener, 1 part tar) was troweled, averaging 1/4" thick.

Section 3: Same acid-etch primer as Section 2. No tack coat. Epoxy resin/sand slurry spread 1/8" thick (3 parts flint sand, 2 parts epoxy resin, by weight). Calcined bauxite aggregate (#6-#10 B.S. sieve) was then spread at about 9 lbs/sq yd.

Section 4. The longitudinal grooves were filled with acid-etch primer and epoxy/sand slurry. The proprietary tiles were then stuck down with a proprietary bituminous adhesive.

All work was done in the shop and the bridge carried to the site in one piece.

Reports a year later reported no distress other than a few hair cracks in Section 1.

Camphill-Birmingham bridge. 1961. Epoxy resin-sand mixture, shop applied. No report.

Scotland. The Scottish Section reports some moderate success with thin surfacings provided the traffic is not too heavy and the steel deck plate is adequately stiffened. They have had trouble with the surfacing cracking, although they say this has not necessarily led to any material corrosion problem.

United States. California. 1952. Ulatis Creek, 50 miles north of San Francisco. Location is warm and dry (20° - 110°). Heavy traffic. Deck plates are 7/16" some plain, some checkered. Stiffening plates welded normal to deck plate. Two types of 1/4" surfacing tried. Rubber-latex and rubber-latex with lumnite cement with imbedded crushed rock chips. The mixture containing the lumnite cement was the poorer of the two, though neither performed satisfactorily. Four years later, after continual patching and sealing, a new surface was applied using asphalt-latex with crushed rock chips. In 1958 the structure was widened and on the new portion a modified coal tar epoxy resin with aluminum oxide grit was used. Wear was soon evident and about 6% was worn bare after a year. In 1965, the complete bridge was resurfaced using surfacing at least 1½" thick.

California. Dublin Bridge. 30 miles east of San Francisco. Moderately heavy traffic. Orthotropic plate deck 4-span bridge (75', 85', 85', 75'). Spans 1 and 2: 3/8" plate were given 1½" surfacing. Spans 3 and 4: 7/16" plate were given thin (1/4") surfacing. Span 3: Metallized zinc sprayed on hot to 0.002" thick (2 coats). Span 4: Sandblasted. Low areas primed with epoxy adhesive and filled with epoxy grout, struck off and troweled level. Both spans then given a coat of epoxy resin applied with an automatic spreading machine and the surface covered with an aluminum oxide grit. After one year, holes 6" to 1' in diameter were visible. The adhesion between the zinc coats apparently failed and large sections of surfacing could be lifted like a rug off the deck. Both decks were repaired in 1967. The loose and worn places were cleaned and sandblasted and given a coat of inorganic zinc paint and then the surfacing of epoxy and grits was replaced.

California. Thin surfacings on concrete decks. As a matter of interest in this type of surfacing, in 1964 a number of decks on concrete bridges in the mountains at about 6000' elevation were resurfaced. Epoxy adhesive and harsh sand were used to 1/4" thick. After two years bare spots developed in the heavily traveled lanes. The epoxy does not seem to have the necessary toughness to resist the abrasion of the traffic and tire chains.

In 1964 also both decks of the San Francisco-Oakland Bay Bridge were resurfaced with 1/4" of silica sand bonded with a coal tar epoxy adhesive. This surfacing is standing up very well under extremely heavy traffic.

New Jersey Turnpike Bridge. In 1965 two types of thin surfacing were tried on steel decks. One was "Relgrit", a saturated epoxy resin and grit mixture applied over an expanded metal mesh. The other was "Cybond" Polyester, a two-part polyester resin with a silica sand grit. Both were applied about 3/8" thick. Both seem to have worn about equally, though the presence of the expanded mesh has increased the wear resistance of the Relgrit surface. The application of the Relgrit material turned out to be expensive and time consuming. Both have stood up well for over a year.

Miscellaneous United States Examples:

1958

Pennypack Creek Bridge - Philadelphia 5/16" thick

50% with expanded metal reinforcement, 50% without.

Epoxy adhesive. Aggregate (Emery) passed #12, caught on #20 sieve.

OK after 5 years.

1960

Strawberry Mansion Bridge - Philadelphia 5/16" thick

Prefab steel panels with epoxy and imbedded abrasive aggregate.

Applied in shop. Cured at 200-250°F.

OK after 3 years.

1959

Interchange #14 New Jersey Turnpike (Applied to Expansion Dams only) Epoxy with sharp broken sand.

Netherlands. Reports that only an epoxy-tar resin has worked satisfactorily for them in thicknesses of 1/2 inch. Using stone chips, they have gotten good skid resistance and over the brief period on which they can report, they feel it has good wear resistance.

Poland. The Polish Group reports that they have had only two years experience with lightweight wearing surfaces. They have performed many laboratory tests but the time of use has been so short that they cannot yet derive any conclusions.

Russia, the German group reports, has not tried any of these thin surfacings. Most of theirs are 2" to 3" thick.

Czechoslovakia. The Czechoslovakian Group has had no experience with thin surfacings in the past but they are intending to try them in the future. Some of the new bridges they are building over the Danube River will be given lightweight decks and they are planning on experimenting with the lightweight surfacings.

These are only a few of the specific examples of where thin surfacings have been tried. All over the world there has been a need and a desire for a satisfactory thin, lightweight surfacing. Undoubtedly there are many experimental installations we do not even know of. Possibly there are some which have proven to be moderately successful. Certainly in some light traffic situations, some installations are demonstrating a quite acceptable life. However, in the main, as near as could be determined from personal knowledge and from the questionnaire, these examples given are typical. The perfect thin surfacing has yet to be discovered.

## THE FUTURE OF THIN SURFACINGS

It may well be that by their very nature thin surfacings have a future of only limited applications. The practical aspects of the problem lead to the conclusion that very thin surfacings cannot be used under heavy traffic for long periods of time. These surfacings are commonly called "wearing surfaces", indicating that they are placed upon the bridge deck to absorb the wear. This further implies a gradual reduction in thickness and, at some future date a necessary renewal. With only a thin surfacing there is not enough thickness available to suffer any material amount of wear. So, without the discovery of some material yet unheard of which would resist heavy abrasion without material wear, it seems highly likely that there is no place for thin surfacings in heavy traffic situations.

Thin surfacing may be used to advantage on temporary bridges where, after a period of heavy use, the deck panels may be returned to the shop and resurfaced. They also may well be used under light traffic, where the period of replacement would be sufficiently long to make the application advantageous.

In the last analysis the use of thin surfacings becomes a matter of economics and safety. Their use must maintain a balance between the savings in weight on one hand and the cost of replacement and the inconvenience and hazard to traffic on the other. When this balance may be advantageously accepted, then thin surfacings may well have a place. Normally, however, where we seek a durable surfacing which may be placed and given a minimum of maintenance over a long period of time, it would seem that the surfacings under one inch (2.50cm), at the present state of development, are inadequate.

**SUMMARY**

The satisfactory thin surfacing for steel decks has not yet been found. Surfacing materials tried thus far have shown deficiencies because: they require too careful surface preparation and placing; they are too brittle to flex with the steel plates; they wear away too rapidly under heavy traffic; and they cause too much traffic disruption when the surfacing must be renewed. Therefore, in the present state of the art, surfacing less than one inch thick should be used only for light traffic or for temporary bridges.

RESUME

On n'a pas encore trouvé un revêtement mince satisfaisant pour les platelages métalliques. Les matériaux de revêtement jusqu'ici essayés présentaient les inconvénients suivants: ils exigent trop de soins pour la préparation des surfaces et pour la mise en place; ils sont trop cassants pour suivre la flexion du platelage; ils s'usent trop rapidement sous l'effet du trafic lourd, et sont dès lors trop souvent la cause d'interruptions de trafic lorsque le revêtement doit être refait à neuf. Pour ces raisons, dans l'état actuel des connaissances, des revêtements de moins de 25 mm d'épaisseur ne devraient être utilisés que pour le trafic léger ou pour des ponts provisoires.

ZUSAMMENFASSUNG

Bisher wurden noch keine zufriedenstellenden dünnenBeläge für Stahlleichtfahrbahnen gefunden. Diejenigen Beläge, die bis jetzt zur Untersuchung gelangten, zeigten folgende Nachteile: Sie erfordern eine zu sorgfältige Vorbereitung und Verlegung; sie sind zu starr, um sich den elastischen Verformungen der Stahlplatten anzupassen; sie werden bei starkem Verkehr zu schnell abgenützt und ihre Ausbesserung bewirkt zu grosse Verkehrsstörungen. Daraus folgt, dass - im jetzigen Zeitpunkt der Forschungen - Beläge, die dünner als 25 mm sind, nur für leichten Verkehr oder für Brücken mit temporärem Charakter in Frage kommen.