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EurolinK

PONTE SULLO STRETTO DI MESSINA

PROGETTO DEFINITIVO

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INDICE

1 Executive Summary

This report describes the pavement systems proposed for the road way deck and the railway deck for the Messina Bridge.

A thin resin based surfacing has been specified for the road way due to it's low weight compared to more traditional asphalt based pavement systems. Low weight is naturally of significant importance for long span bridges.

Thin resin based surfacings are succesfully used on bridges world wide due to the excellent performance. Presently, there are no system of codes and standards internationally recognized for these types of surfacing, however due to the extensive experience gathered over more than 35 years on surfacings applied in Denmark, the Danish National Road Directorate has issued specifications and guidelines for the design, application and testing of thin surfacing. These specifications and guidelines will form the basis for the specification of the roadway surfacing on the Messina Bridge.

For the railway deck a standard type waterproofing membrane is specified. These waterproofing membranes based on polymer resins have a long track record for application on railway bridges and further specific testing of these products is not required.

Roadway deck

Thin resin based surfacing is a relevant and excellent alternative to the traditional 40 to 60 mm surfacing. It is believed that the experience gathered over many years in Denmark and internationaly is applicable also for the Messina Bridge. Knowledge and experience have been formed into standard specifications, guidelines and testing system of quality and will secure the durability and easy maintenance of the surfacing.

The roadway on the Messina Bridge covers close to 100.000m2 and in order to obtain an excellent and homogeneous quality of the thin surfacing in combination with fast application it is essential to develop procedures and equipment for industrial and mechanized application of the surfacing system.

More than 35 years experience from many steel and concrete bridges constructed since start of the 1970's is available and this section summarizes the reasons for specifying a thin resin based surfacing on the Messina Bridge.

Even though a thin resin pavement system has been selected SdM has instructed Eurolink to prepare the design of the structures for the weight of a 40 mm thick asphalt pavement in order to allow for possible future replacement of the thin resin based surfacing by more traditional asphalt pavement systems. The specification of a 40mm pavement has not been included in this report, but will more likely consist of an epoxy asphalt type comprising a zinc rich primer, a tack coat and a 40mm thick wearing course in epoxy asphalt. Should the 40mm pavement be selected the detailed specification will be developed in Progetto Esecutivo.

Through a number of research projects in the 1970's and 1980's the concept of thin surfacing was developed by the Danish National Road Directorate. Based on a combination of desk studies, material selection tests and mechanical testing, excellent performance, durability and maintenance properties were achieved for the thin surfacing. The basic concept has only been modified marginally during this more than 35 years, which confirms a long and stable track record.

The surfacing system specified for the Messina Bridge is based on a Danish standard specification for thin surfacing and include the following:

Primer	0.3 mm pure resin
Membrane layer/stress absorbing layer	2.0 mm pure resin
Wearing course	8-9 mm resin mixed with sand and chippings.

The fatigue performance of the thin surfacing is governed by the local stiffness of the steel structure supporting the surfacing. Even though experience of the service life of thin resin based surfacing on long span suspension bridges currently not is available, many years of excellent experience is available from smaller heavy trafficked steel bridges, including bridges with rather flexible steel decks. A flexible steel deck presents far larger fatigue loads in the surfacing than a rigid orthotropic steel decks like the one designed for the Messina Bridge.

Appendix 1 presents a list of reference bridges with thin surfacing demonstrating more than 15 years of service life.

The surfacing on the Messina Bridge will be designed to be waterproof, stable and flexible in order to protect the steel deck against corrosion. The surfacing must be sufficiently hard to eliminate the risk of rutting and at the same time with elastic behavior to allow deck deformations and avoid cracks and delamination during the expected lifetime subjected to the climate conditions of the region and the traffic load expected on the Messina Bridge.

A test program has been prepared with the purpose to identify suitable resin products to be used in the thin surfacing system and to verify that the surfacing system meets the requirements. Based on the results of the test it may be required to adjust the composition of the surfacing. Furthermore, the investigations and tests included in the program shall define the required working conditions under which the thin surfacing shall be applied and develop suitable methods and equipment for the application, maintenance and removal of thin surfacing on the Messina Bridge.

The profile, the evenness, the skid resistance and the texture of the surfacing must be designed for the long term performance and the following questions shall be addressed:

- How the geometric imperfections in the steel deck can be compensated to achieve good driving comfort.
- How to avoid flowing of the materials prior to hardening on sloping decks.
- How to identify and/or develop equipment for large scale application of the fluid resin over large areas.

The test program proposed for the thin surfacing for the roadway is described in detail in document MEM-6-004, which is attached as Appendix 2.

The prodecures and conditions under which the resin based surfacing are applied have significant impact on the quality of the final surfacing. Failing to respect the guidelines for application will risk to deteriorate the quality and will reduce the service life dramatically. Cleaning and preparation of the steel surface and application of surfacing shall be executed under controlled conditions using movable shelters equipped with dehumidifiers and equipment for humidity control of the work area.

Railway deck

The waterproofing for the Messina Bridge will be designed impermeable, stable and flexible in order to protect the steel deck against corrosion. The waterproofing membrane shall be sufficiently tough to resist local impacts and abrasion but at the same time with elastic behavior to allow steel deck deformations during the expected lifetime under the climate conditions of the region.

The waterproofing system specified for the railway deck include the following:

Primer:	0.5 mm pure resin
Waterproofing membrane:	2.0 mm pure resin

Several manufacturers are available for the supply of waterproofing membranes and have long track record with expected service life of 30 years or more.

The resin based waterproofing membranes provides long and effective service life. The membranes are impermeable to chloride ions and provides excellent chemical and abrasion resistance. Further, high bonding strength to the steel surfaces below is obtained.

Using airless spray techniques rapid application rates can be obtained providing non-critical overcoating time.

2 Introduction

2.1 Scope

This report describes the pavement systems proposed for the roadway and the railway bridge girder.

The report is organized into the following sections:

- Section 2 includes this introduction, provides a list of reference materials, including design specifications, design codes, material specifications, reference drawings and complementary reports;
- Section 3 provides definitions for terms that are commonly used in referencing particular pavement components;
- Section 4 describes the pavement system specified for the roadway deck;
- Section 5 describes the pavement system specified for the railway deck.

2.2 References

2.2.1 Design Specifications and Material Specifications

GCG.F.04.01 “Engineering – Definitive and Detailed Design: Basis of Design and Expected Performance Levels,” Stretto di Messina, 2004 October 27.

CG.10.00-P-RG-D-P-GE-00-00-00-00-00-02 - Design Basis, Structure.

CG.1000-P-SP-D-P-SS-P2-SR-00-00-00-01 - Pavement, Test specification for thin surfacing

The National Danish Guidelines and Standard Specifications for thin resin based surfacing.

2.2.2 Drawings

CG.10.00-P-AX-D-P-SS-P2-SR-00-00-00-01	Roadway Deck, Surfacing
CG.10.00-P-AX-D-P-SS-P2-SR-00-00-00-02	Railway Deck, Surfacing

3 Nomenclature

The section provides descriptions of terms commonly used throughout the report to refer to various components of the pavement system:

3.1 Thin resin based surfacing

Thin resin based surfacing is a surfacing system 10 to 12 mm thick, consisting of 2 or 3 layers of chemical curing polymer binder (primer and membrane) on which the wearing course comprising resin with applied sand and aggregates.

3.2 Resins

The resin is a chemical curing polymer and will be selected through a test program screening different Methyl Met Acrylate (MMA) systems or Polyurethane Epoxy systems (PU-EP).

3.3 Chippings

Chippings special resistant to polishing like bauxite will be chosen through a test program screening different materials.

3.4 Additives

Application of different additives like tixotropic agent and gel-agent will be considered.

4 Pavement - roadway deck

A thin resin based surfacing has been specified due to the low weight compared to more traditional asphalt based pavement systems.

Thin resin based surfacing is a relevant and excellent alternative to the traditional 40 to 60 mm surfacing. It is believed that the experience gathered over many years in Denmark and internationaly is applicable also for the Messina Bridge. Knowledge and experience have been formed into standard specifications, guidelines and testing system of quality and will secure the durability and easy maintenance of the surfacing.

More than 35 years experience from many steel and concrete bridges constructed since start of the 1970's is available and this section includes the arguments for specifying a thin resin based surfacing on the Messina Bridge.

SdM has instructed Eurolink, ref. prot. 0462, dated 18-05-2010, to prepare the design of the structures for the weight of a 40 mm thick asphalt pavement in order to allow for future replacement of the thin resin based surfacing by more traditional asphalt pavement types. Many types of asphalt based pavement could be applied. Taking the thickness of 40mm into account however the more likely pavement system would consist of an epoxy asphalt type with a built-up as follows:

- Cleaning of the steel surface to SA 2½ according to ISO 8501-1
- Zinc rich epoxy primer
- Tack coat to ensure adhesion of the wearing course
- 40 mm Epoxy Asphalt Type IC based on binder Type III

It may be of benefit for the future maintenance operations if the 40 mm wearing course is substituted by 2 layers of 20 mm.

The specification of the surfacing system for roadway deck remains to be based on the use of thin resin based types. In the case that an alternative pavement would be selected a detailed specification of a 40mm thick pavement will be developed in Progetto Esecutivo.

4.1 Thin surfacings in Denmark - development and experience

4.1.1 Development of thin surfacing concept

Through a number of research projects in Denmark and elsewhere in the 1970's and 1980's the concept of thin surfacing was developed by the Danish National Road Directorate. Based on a combination of desk studies, material selection tests and mechanical testing, excellent performance, durability and maintenance properties were achieved for the thin surfacing. The basic concept has only been modified marginally during this more than 35 years, which confirms a long track record and experience.

An important consequence of traffic loads on steel bridges with orthotropic deck is the local deflections of the steel deck occurring with a high frequency. The influence from these deflections is a crucial factor in the fatigue performance and thus the service life of the surfacing. Through laboratory testing incorporating fatigue test, the development of thin surfacing concept has taken place.

In the start of the 1970's the Technical University of Copenhagen developed hydraulic test equipment for the National Road Directorates Research Laboratory, based on the theory of Professor Eisenmann of Technical University of Munich. The equipment simulated a truck passing a orthotropic steel deck having double wheels placed with one wheel on each side of a longitudinal support (web of the stiffener below). This load situation is by Professor Eisenmann considered the most critical load on an orthotropic steel bridge deck. Similar equipment has been developed and used for development of surfacing technology by LCPC, Lyon and Otto Graf Institute, Stuttgart.

Using this equipment National Road Directorates Research Laboratory developed the concept of thin surfacing for the Danish bridges.

Testing carried out for different projects up through the 1980's and 1990's showed the superior fatigue performance was achieved by introducing a 2 mm layer of pure binder in the stress zone immediately over the steel plate where the shear and the compression introduced by traffic was the highest.

The pure binder (for acrylic systems, MMA) has a very high static elongation at breaking point (approximately 200 %) and therefore able to deform and to absorb the shear force.

When adding filler material to the pure resin, which is often proposed for economical reasons, the static eleongation of the material is significantly reduced and in MMA slurry based systems containing filler in the stress zone, delamination and cracks occurred much earlier due to the decreased elasticity in the layers close to the steel plate.

Rutting does not normally occur in the thin surfacing due to the high resistance to plastic deformations. The fatigue testing is therefore the most important mechanical test in a development program. The fatigue test used to develop thin surfacing concept is described in the test program, ref. document MEM-6-004 attached in Appendix 2.

The excellent long time operational experience from many steel bridges surfaced with thin surfacing has supported the test results. The thin surfacing performs very well and is long time

durable if a membrane layer is applied as stress absorber and - most importantly - if excellent workmanship is observed during construction.

4.1.2 Quality of the thin surfacing

In some cases bridges in Denmark with thin surfacing have experienced problems with delamination or cracking of the surfacing. Analyzing the problem, it was found that a pure resin membrane layer between the binder and the wearing course is an absolute prerequisite for good performance of the surfacing and that systems comprising slurry filler often cracks, are delaminated or observe fatigue failures earlier than surfacing complying with Danish standard specifications.

Furthermore, it was often found that poor workmanship, poor work conditions and violation of the requirements and specifications generally were provoking the failures.

The Danish Road Directorate early took hand of the problem by introducing specifications and guidelines for thin surfacings:

- Standard specifications for thin surfacing
- Guidelines for design/specifications of thin surfacing
- Template for specification of thin surfacing
- Certificate approving system for thin surfacing systems

4.1.3 Experience with thin surfacings

Many years of experience (more than 35 years, from 1970 to 2010) is available from heavy trafficked steel bridges, including bridges with rather flexible steel decks and thus larger fatigue loads than for the orthotropic steel deck specified for the Messina Bridge.

In Denmark, among others, the Limfjords Bridge in Aalborg have 46.000 vehicles/day with 15% heavy traffic in operation now on the third thin acrylic surfacing since the 1970's. The last surfacing was applied in 1998 and is still performing well. This traffic intensity can be compared to the expected traffic on the Messina Bridge in 2048 of app. 23.500 vehicles/day with app. 30% lorries.

In Appendix 1 is found a list of reference bridges build in Denmark, many of which thin surfacing have shown more than 15 years service time. Further, a list of international bridges has been included and data regarding applied systems, traffic and performance of the surfacing are being collected.

The Danish National Road Directorate concludes in an evaluation reports from year 2000 and 2006 that the thin surfacing is performing excellently. Service life of 15 to 20 years can expected without major maintenance if the the national specifications and guidelines are applied. Slurry based surfacing systems without membrane, which observe earlier and more frequent failure, are not approved to be used on bridges in Denmark.

The bridges in Denmark have traditionally been designed orthotropic decks comprising a 12 mm steel deck, 7mm longitudinal trough stiffeners and 4.0 m between transverse bulkheads. The Messina Bridge is designed with 17 mm deck plate, 9mm stiffeners and 3.75 m between bulk heads, providing a significantly stiffer deck. This means that the traffic-induced local deflections of the deck between the webs of the longitudinal trough stiffeners, which is the most important parameter in the fatigue performance, will be reduced by approximately 45 %.

By specifying the thin surfacing system in accordance with the Danish national specifications and guidelines and in combination with excellent engineering and in particular skilled labor significantly better fatigue performances can be expected on Messina Bridge than experienced on the Danish bridges.

4.2 Surfacing system.

The surfacing for the Messina Bridge will be designed to be impermeable, stable and flexible in order to protect the steel deck against corrosion. The thin surfacing must be sufficiently hard to eliminate rutting and at the same time with elastic behavior to allow local deformations of the steel deck and to avoid the risk of cracks and delamination during the expected lifetime under the climate conditions of the region and the traffic load expected on the Messina Bridge.

The surfacing system specified for the Messina Bridge is based on a Danish standard specification for thin surfacing and include the following:

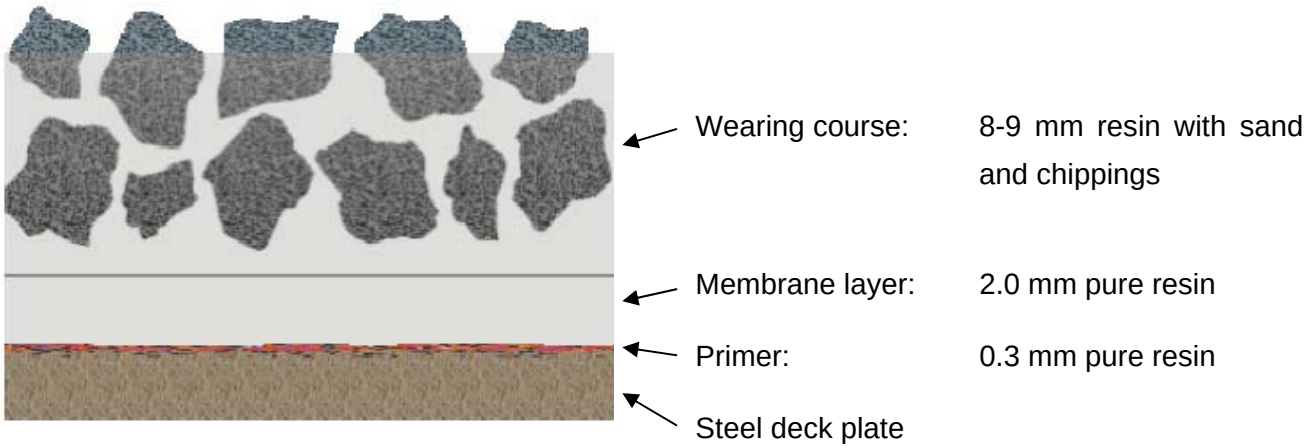

Figure 1 Roadway surfacing, composition

If the thin surfacing is correctly specified and excellent work procedures are followed by experienced workers the following properties can be expected and will be applied to as function requirements:

- Corrosion protection of the steel surface by means of the membrane
- High long time durable adhesion to the steel deck.
- Flexible with high mechanical strength, stability and ability to resist stress from vehicles.
- High resistance to plastic deformations so no rutting or sliding will occur.
- Durable mechanical performances, skid resistance and resistance to wear.
- Easy to repair and easy to partly or totally renew.

In order to meet the functionional requirements the thin surfacing will be designed based on materials and work procedures in accordance with the Danish national specifications and guidelines, see Section 4.1.2.

4.3 Pre-construction test program

The purpose of the test program is to identify suitable resin products to be included in the thin surfacing system and to verify by testing under relevant climatic conditions that the specified surfacing system meets the requirements. Based on the results of the test it may be required to

adjust the composition of the surfacing. The investigations and tests included in this program shall define the required working conditions under which the thin surfacing shall be applied and develop suitable methods and equipment for the application and maintenance of thin surfacing on the Messina Bridge.

The profile, the evenness, the skid resistance and the texture of the surfacing course shall be designed for the long term performance and the following questions shall be addressed:

- How the geometric imperfections in the steel deck can be compensated to achieve good driving comfort.
- How to avoid flowing of the materials during application on sloping decks.
- How to identify and/or develop equipment for large scale application of the fluid resin over large areas.

The pre-construction test programs is divided into the following phases:

- Desk study to identify suitable products and to prepare the technical specfication of the thin surfacing
- Testing of the specified surfacing
- Based on test results adjustment of the technical specification if required.
- Development of methods for industrialized large scale application, maintenance and renewal of the thin surfacing.

The test program proposed for the thin surfacing for the roadway is described in details in document MEM-6-004, which is attached in Appendix 2.

For detailed information regarding testing and test methods, please refer to doc. no. CG.1000-P-SP-D-P-SS-P2-SR-00-00-00-01 - Pavement, Test specification for thin surfacing.

4.4 Application of thin surfacing

The roadway on the Messina Bridge covers close to 100.000m^2 and in order to obtain an excellent and homogeneous quality of the thin surfacing in combination with fast application it is essential to develop procedures and equipment for industrial and mechanized application of the surfacing system.

Cleaning and preparation of the steel surface and application of surfacing shall be executed under controlled conditions using movable shelters equipped with dehumidifiers and equipment for humidity control of the work area.

Before installation of the thin resin surfacing the steel bridge deck shall be cleaned to provide a clean metal surface to min. SA 2½ according to ISO 8501-1.

The primer shall be applied by roller or airless spray equipment within 2-4 hours of the blasting operation to avoid oxidation of the deck surfaces.

Figure 2 Application of primer by airless spray

The membrane is discharged from a mobile continuous mixing plant between two temporary forms.

The imperfections of the steel deck shall be measured and recorded to determine the distribution of the areas which needs further leveling.

Figure 3 Application of the membrane by roller

Leveling of deck imperfections will take place on top of the membrane layer. Leveling is carried out with materials selected by test program and according to work procedures complying with results from test program.

The wearing course is applied in the same manner. The binder shall be spike rolled to create a resin rich surface into which the chippings shall be dispersed via a mobile hopper. Excess chippings shall be removed from the surface after minimum 1 hour.

Figure 4 Completed thin surfacing on small bridge in Denmark, 2010

5 Pavement - railway deck

The waterproofing for the Messina Bridge will be designed impermeable, stable and flexible in order to protect the steel deck against corrosion. The waterproofing membrane shall be sufficiently tough to resist local impact and abrasion but at the same time with elastic behavior to accept deformations during the expected lifetime with attention to the climate conditions of the region.

The waterproofing system specified for the Messina Bridge include the following:

Primer:	0.5 mm pure resin
Waterproofing membrane:	2.0 mm pure resin

Several manufacturers are available for the supply of waterproofing membranes and have long track record with expected service life of 30 years or more.

As for the roadway surfacing the steel surface shall be cleaned by blasting to SA 2½ according to ISO 8501-1.

The primer is applied by airless spray equipment in one single layer of 0.5mm immediately after the blasting.

The waterproofing can then be applied also by airless spray equipment to give a dry film thickness of minimum 2mm. The airless spray equipment facilitate the metering, mixing and application of the resin in one operation.

The MMA based waterproofing membranes provides the following features:

- Long and effective service life
- Impermeable to chloride ions
- Excellent chemical and abrasion resistance
- High bonding strength to the substrate
- Non-critical overcoating time
- Rapid application rates

6 Appendices

6.1 Appendix 1: Application of thin resin surfacing

Bridges in Denmark with thin resin surfacing

Bridge	**Area m^2**	**Surfacing system**	**Year of application of last surfacing system**	**Traffic load vehicles/day – % heavy traffic- number of lanes**	**Performance- condition today**
Låsebyvej, Denmark	300 carriage way	PU-Epoxy Cicol ET	1991	6000 to 8000 2 lanes	Minor damages in joints, but no repair after 19 years
Limfjords Bridge Bascule bridge, Denmark	400 carriage way 5700 pedestrian and bicycle lanes	Acrylic resin Acrydur M	1995	45.000 to 51.000 15 % Heavy 4 lanes	Performing well, no fatigue damages- friction to be improved in near future, no repair registered after 15years.
Egernsund Bridge Bascular Bridge, Denmark	Ca.400 Carriage way	Epoxy-tar Cicol ET	1992	4.500 to 7.000 4 lanes	Performing well, minor corrosion along edges. No repair. 18 years.
Frederiks Bridge, Bascular Bridge, Denmark	400 Carriage way 500 pedestrian and bicycle lanes	Epoxy-tar Kubic TK	1993	5.500-8.000 8% Heavy 2 lanes	No damage. Minor repair after 17 years.
Guldborg Bridge	270 Carriage way	PU-Epoxy Cicol ET	1991	2.500 to 3.500 10% Heavy 2 lanes	Only damages is a transversal joint not proper constructed. Will be renewed in3 years in an age of 22 years.
Kong Chr. X Bridge	300 Carriage way	PU-Epoxy Cicol ET	1986	7.000 to 9.000 2 lanes	Partial repair to be executed after 15 years.
Vilsund Bridge Bascule Bridge	600 Carriage way	Acrylic resin Acrydur M	1992	5.600 to 8.000 10% Heavy 2 lanes	No damage, after 18 years, friction to be improved soon

List of international bridges with thin resin surfacing to be investigated

Bridge	**Area m^2**
Poplar Street Bridge, St. Luis, Missouri, USA	20,500
A.L. Mcdonald Bridge	Not informed
Al Makhtum Bridge, Dubai	1,200
Dola Bridge, Libanon	6,000
Jal Al Dib Bridge	App. 6,000
Al Makhtoum Bridge, Dubai, Bascular Bridge	1200
Williamsburg Bridge New York, USA	14630
Seongsugoy Bridge, Seoul, Korea	3500
Queensborough Bridge, New York, USA	Not informed
Route M-44 over the Grand River in Grand Rapids, Michigan	Not Informed
Triborough Bridge	41.000
Marine Parkway Bridge, New York, USA	2000

6.2 Appendix 2: Test program for thin surfacing Doc. no. MEM-6-004