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Certainty Regarding Performance in Road Maintenance Works Entailing the Use of Marginal Materials

Eleonora Cesolini[a], Stefano Drusin[a], Pierluigi Bernardinetti[a]*

[a]*ANAS S.p.A., Direzione Centrale Ricerca e Nuove Tecnologie, Rome, Italy*

Abstract

ANAS has been working to develop the use of marginal materials and to guarantee the final result obtained.
A simplified fatigue test, a new method for conducting the final tests with the use of structural indicators (IS) and the use of a new device, the TSD, are been introduced.
ANAS rendered all of this operational with guidelines and with the Contract Specifications effect since July 2009 for road maintenance work.
This article deals with the case of construction of primary motorway.

Keywords: Environment

1. Introduction

The company ANAS S.p.A. manages and maintains Italy's primary road network; the overall extent, at present, is approximately 25,000 Km, plus the network of more than 6,000 Km entrusted to private motorway companies under concession agreements, over which ANAS S.p.A. exercises a control and surveillance function. The management of such an extensive and articulated infrastructural network poses considerable and complex problems, especially in the vital sector of pavement preservation.

The basic qualities of pavements, composed of materials with visco-plastic-elastic behaviour, are preserved; these may be subdivided into surface qualities, i.e., in direct contact with the wheels of vehicles, and deep, i.e. bearing capacity related with the complex road pavement structure of which it is composed.

It is normally subject to fatigue failure with a consequential loss of the rigidity and monolithicity needed to fulfil its bearing capacity.

* Corresponding author. Tel.: +39-06-44461
E-mail address: e.cesolini@stradeanas.it

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The problem of evaluating its condition was successfully managed as concerns the surface characteristics, for which "high performance" measurement machine exist and are used both to diagnose conditions and for work acceptance purposes.

To measure the load bearing capacity at the current time, equipment is used that must stop or that must proceed at low speed. Furthermore, given their slowness, their use is often limited to diagnosing road conditions for maintenance scheduling purposes; they are rarely used for work acceptance criteria.

Acceptance is still normally managed with indirect measurements performed on the mixes to be laid on-site and by indirect in situ evaluation, again based on slow methods.

The use of Falling Weight Deflectometers introduced the possibility of an overall performance measurement, measured within the deflection bowls on instantaneous dynamic load capable of defining the overall stiffness of the road pavement, however, the management of the measurement with the recalculation performed via "back analysis" on the data is complicated to apply, easily lending itself to dispute by the party performing the works when used as the final test on said works.

In addition to this, a new method is needed, capable of guaranteeing results that have certainty in terms of pavement life, even when marginal materials are used.

Finally, it is necessary to use equipment capable of true "High Performance" for final load bearing capacity tests, i.e. equipment capable of checking everything performed continuously and at high speed [1].

2. The study and definition of fatigue life for road materials

The Road Research Centre developed a simplified apparatus to conduct fatigue tests that can be evaluated by comparison [5]; this apparatus reproduces, in the laboratory, the fatigue behaviour of various materials, including those that employ marginal materials; the fatigue curves obtained are compared with the fatigue curves of a reference material employed in rational calculations to determine the theoretical life spans, in this way it is possible to calculate the thickness necessary to obtain a desired theoretical life in the presence of any type of material.

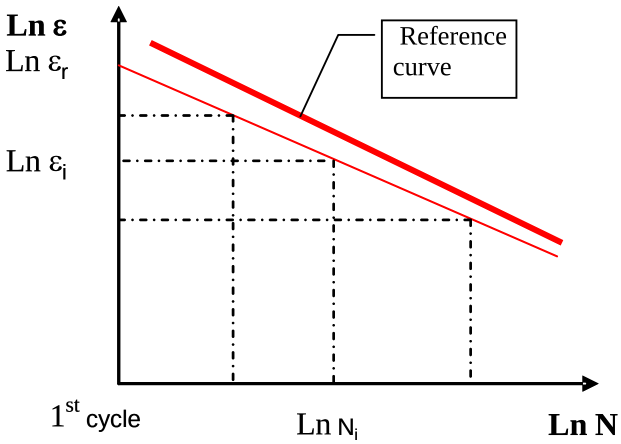


Fig. 1 (a) Fatigue test equipment; (b) Fatigue curves

3. Pavement design, criteria and methods for the final testing of bearing capacity

Road pavements have the role of distributing loads transmitted by vehicles, in particular the loads transmitted by heavy vehicles, over the ground.

One of the main criticalities in road pavement design is the difficulty in identifying the behaviour of materials, which furthermore can vary with climatic conditions and with the methods by which the loads are applied [8].

The rational methods based on multi elastic layers allow theoretical behaviour of the pavement to be reproduced as the conditions previously defined vary, approximating the real behaviour of the pavement.

Using this model, it's possible in fact to calculate the stress and strain conditions of the various layers of which the pavement is composed, the value of the horizontal tensile strain at the base of the layers is compared with the fatigue curves, obtained from the laboratory tests with the method previously described, to derive the maximum number of cycles leading to pavement failure.

As said before, as the ambient conditions vary, the mechanical behaviour of the materials changes, the year is therefore subdivided into four seasons, on the assumption that its mechanical conditions do not vary during said periods; likewise, the stress and strain conditions vary with the applied loads, which depend on the traffic, therefore the traffic is converted into the passages of equivalent axles loads of 12 t.

The total number of equivalent axles loads that produces fatigue failure of the pavement is obtained applying Miner's rule or the rule of fatigue linear damage accumulation.

The rule dictates that if ε_1, ε_2, …., ε_k are the strain corresponding to n_1, n_2, … n_k load cycles applied to the material, in no particular order, fatigue failure is produced when the following inequality or equality relationship holds:

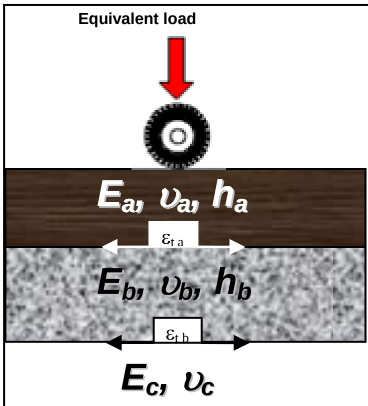
$$\sum_{i=1}^{k} \frac{n_i}{N_i} \leq 1 \qquad (1)$$

where:

N_i: represents the total number of cycles that would lead to the failure of the pavement if the strain were kept constant at ε_i.

Allowing a proportional distribution of traffic in the four seasons, solving the multilayer elastic model, it's possible to calculate the 4 values of ε_i with which the 4 values of N_i can be associated through the fatigue curves obtained with the previously described procedure, the total number N_x of passages referring to standard axles that the pavement can support will be obtained with the following formula:

$$N_x = \frac{4 \times N_1 \times N_2 \times N_3 \times N_4}{N_2 \times N_3 \times N_4 + N_1 \times N_3 \times N_4 + N_1 \times N_2 \times N_4 + N_1 \times N_2 \times N_3} \qquad (2)$$

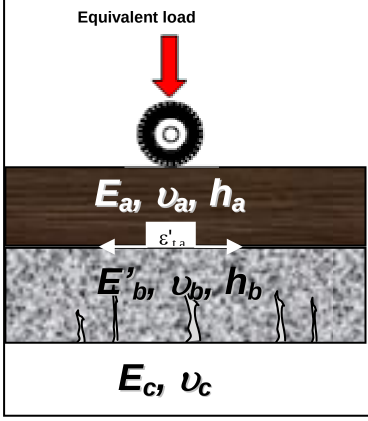


$$N_a = \frac{4 \times N_{a,1} \times N_{a,2} \times N_{a,3} \times N_{a,4}}{N_{a,2} \times N_{a,3} \times N_{a,4} + N_{a,1} \times N_{a,3} \times N_{a,4} + N_{a,1} \times N_{a,2} \times N_{a,4} + N_{a,1} \times N_{a,2} \times N_{a,3}}$$

$$N_b = \frac{4 \times N_{b,1} \times N_{b,2} \times N_{b,3} \times N_{b,4}}{N_{b,2} \times N_{b,3} \times N_{b,4} + N_{b,1} \times N_{b,3} \times N_{b,4} + N_{b,1} \times N_{b,2} \times N_{b,4} + N_{b,1} \times N_{b,2} \times N_{b,3}}$$

Se $N_a > N_b$

The second phase, in which layer b reacts in fracture conditions, is considered



$$N_{Ta} = \frac{N_{b,1}}{N_{a,1}} + \frac{N_{b,2}}{N_{a,2}} + \frac{N_{b,3}}{N_{a,3}} + \frac{N_{b,4}}{N_{a,4}} + \frac{4 \times N'_{a,1} \times N'_{a,2} \times N'_{a,3} \times N'_{a,4}}{N'_{a,2} \times N'_{a,3} \times N'_{a,4} + N'_{a,1} \times N'_{a,3} \times N'_{a,4} + N'_{a,1} \times N'_{a,2} \times N'_{a,4} + N'_{a,1} \times N'_{a,2} \times N'_{a,3}}$$

The determination of the useful life expressed in years is calculated starting from N_x using the coefficient of equivalence to transform the passages of equivalent standard axles into commercial vehicle traffic; this coefficient is assumed to be equal to 2.5.

Having defined the thickness to be assigned to each pavement layer to obtain a desired theoretical life span, it is necessary to define a criteria that allows the evaluation of the work performed to guarantee that the installed theoretical lives are met; Structural Indicators IS were introduced for this purpose [3].

The structural indicator IS_{300} is used in particular; this is defined as the difference of the deflection at the centre plate and at 300 mm from said centre, to evaluate the Deep Repairs (RP) as better specified further on, and the structural indicator IS_{200} is defined as the difference of the deflection at centre plate and at 200 mm from said centre, to evaluate the Surface Repairs (RS).

The structural indicators depend on the pressure applied, on the temperature of the asphalt concrete present during the test and, possibly, on the aging of the material used to construct the pavement.

Fig. 3 FWD device

Fig. 4 TSD device

Fig. 5 TSD-FWD comparison

In the Performance Specifications †, where these indicators are included to test the pavements bearing capacity, a control curve is provided for each pressure applied (to enable parallel controls with equipment that can be used by the manufacturers, such as FWD) for a given degree of material aging; each control curve then varies as a function of air temperature that depends upon the test conditions; the temperature of the bituminous conglomerate will depend on the air temperature.

Finally, an air temperature interval, in which the test is considered valid for inspection purposes, is assigned [4].

The final objective is to produce road pavements that guarantee a long life and that are always constructed as best as possible in relation to an effective and efficient control and verification system of all the work performed.

Final testing in fact verifies the pavement bearing capacity, this performance correlated with its life, is measured discretely by the FWD equipment and continuously and at high speed by the TSD equipment, both devices in fact measure the same Structural Indicators.

The on-site bearing capacity measurements are traditionally conducted by the FWD equipment.

This equipment, as is well known, must stop for each test. It consists of hammer mass that applies a force on the pavement, and of a series of geophones that discretely record the deflection bowls produced by the applied load.

For more than a year ANAS has had an innovative equipment known as the TSD capable of performing the bearing capacity measurement of pavements at high speed without causing any disturbance to traffic.

Numerous tests have been conducted to

† Available from ANAS DCRNT - css.cesano@stradeanas.it - upon request

verify the repeatability of the measurements conducted by TSD and measured in terms of the Structural Indicator, recorded with a controlled boundary conditions defined by the speed, by the equipment calibration conditions, and by the temperature of the asphalt concrete during the test.

Measurements were then conducted in which one condition was made to vary cyclically while holding the others constant (with regard to the calibration conditions, the TSD was of course under the same conditions, however it was assumed that the velocity and temperature of the asphalt concrete had been equal, with two distinct calibrations).

The tests have demonstrated that the bearing capacity of the pavement is not affected by the calibration conditions and by the speed, in the 40-75 kph interval, but predominately by the temperature of the asphalt concrete present during the test.

Numerous tests were then performed during 2011 to compare the FWD and TSD devices; these test demonstrated good comparability between the two devices in terms of structural indicators.

For the Surface Repairs (RS), which we will speak of more extensively further on, it must be remembered that the subbase/subgrade is not affected by the repair operation therefore his contribution must be cleansed from the final bearing capacity test so that only the work actually performed is evaluated. To do this, in addition to the Structural Indicator IS_{200}, the structural indicator IS_{fond}, defined as the difference in the deflection read at 900 and 1500 mm from the centre plate, is also read; the contribution of the layers not affected by the repair operation to the bearing capacity is evaluated with this indicator; in this way it's possible to correct the structural indicator IS_{200} through the following formula and to use it for the final testing of RS-type works.

$$IS_{200corretto} = IS_{200} \times (2{,}18 - 0{,}50 \times LOG(IS_{fond})) \qquad (3)$$

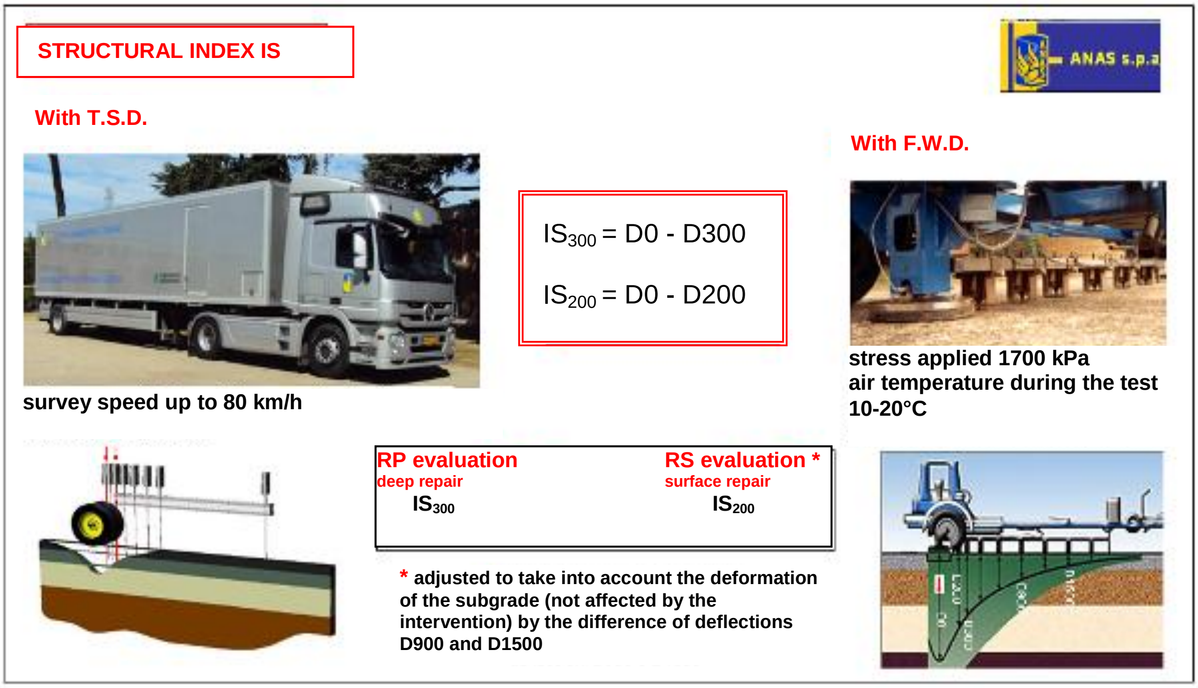


Fig. 6 Structural Indexes

4. Repair operations with pre-calculated life and certainty in results for road maintenance work

Repair operations classified as Deep Repairs (RP), Surface Repairs (RS), Emergency Repairs (RSS), and Surface Treatments (TS) have been defined within the scope of the repair operations to be performed during ordinary and extraordinary pavement maintenance [6], [7].

The Deep Repair (RP) are long-lasting solutions to repair and restore highly degraded pavements where it is also necessary to reconstruct the subgrade; The Surface Repairs (RS) are solutions, with a shorter live span compared with the RP-type repair, that can be adopted in case of budget limitations or in less accentuated cases of degradation.

During these types of repair operations, all the solutions proposed, predefined, and pre-calculated in terms of life span expressed in the number of passages of equivalent axle loads of 12 t or in terms of ADT (Average Daily Traffic), were chosen respecting the following conditions:

- The maximum possible reuse of milled materials and other marginal materials readily available at the operation site, evaluated and verified in the fatigue life calculations, to reduce transportation and costs, and to preserve the environment.
- The generalized use of modified bitumen, to increase lifespan with certainty [2].
- The definition of the general work criteria to take into account problems concerning the practical application on roads in operation; the thicknesses anticipated are correlated with the bearing capacity requirements and also with the feasibility associated with the techniques employed.
- The design of road pavement through the use of rational methods for calculating road pavement as an elastic multilayer using specific fatigue curves those allow the life of the repair operation.
- The definition of the performance verification methods, on the individual materials, on the mixes to be made during the operations, and of the finished works with High Performance means to continuously control the work performed.

Emergency Repairs (RSS) are defined together with the repairs and restorations; they consist in surface operations performed to make the pavement safe or bring it to an acceptable quality level, though for a brief interval and Surface Treatments (TS), used to restore the adherence and to seal or seal micro-damage in zones without obvious failure; the latter types of repair operations in the Specifications have not occurred in terms of load bearing capacity and therefore are not encompassed in the issue currently in discussion.

All repair operations defined must undergo final testing to verify that the works were performed correctly.

Each repair operation requires the attainment of a specific performance that, within the scope of the maintenance operation, are the main reason why the operation was necessary, we refer in particular to RP and RS operations that are used in case of structural deficiencies, in fact we wish to concentrate on the evaluation of bearing capacity as a pavement performance characteristics capable of evaluating its life span.

Within the scope of the RP-type operations, observing the conditions listed above, three different repair solutions are proposed that anticipate in-place recycling with foamed bitumen or a layer with mix cemented to produce the subbase, the use of modified bitumen to produce layers of asphalt concrete, and a cold recycled layer with the use of bitumen emulsion. The thickness assigned to each layer as a function of the traffic and life span required thus varies in each solution.

A repair solution with the relevant bearing capacity control curves evaluated in terms of the Structural Indicator IS_{300} is shown.

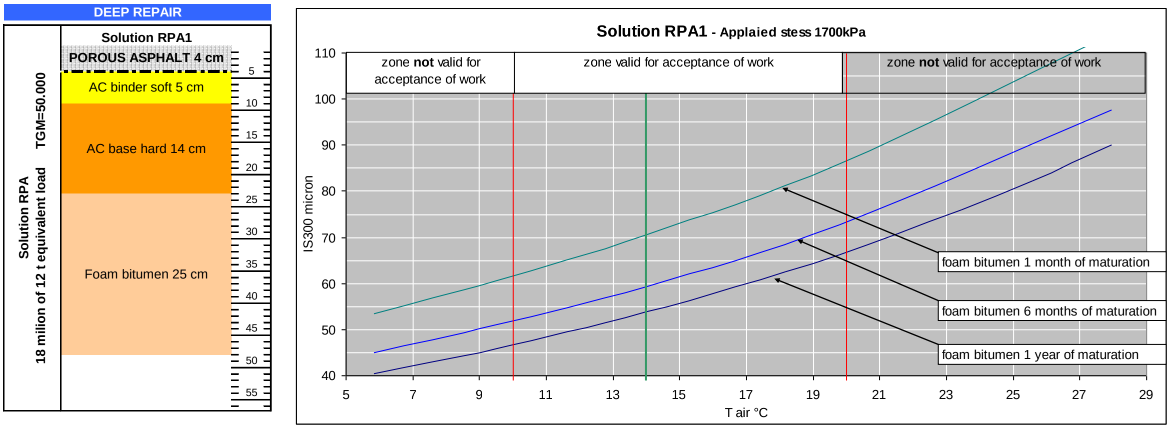


Fig. 7 (a) RPA1- deep repair; (b) Control curve with Structural Indicator IS300

Within the scope of RS type operations, a repair operation is proposed that anticipates the construction of a binder or base-binder layer and the wearing course, the repair operation thickness varies as a function of traffic and actual pavement condition.

The solutions for RS1-type repair operation, to be used for pavements with accentuated cracks, with the relevant bearing capacity control curves evaluated in terms of the Structural Indicator IS_{200} are shown below.

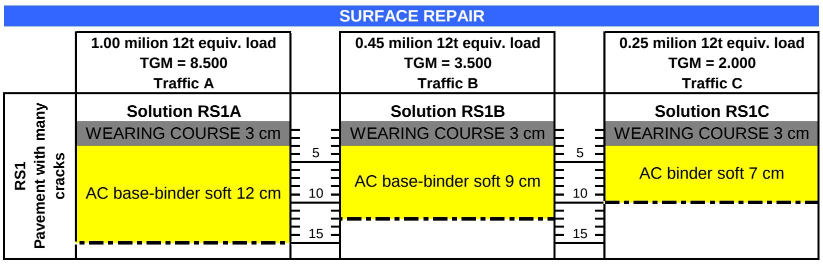


Fig. 8 RS1-surface repair

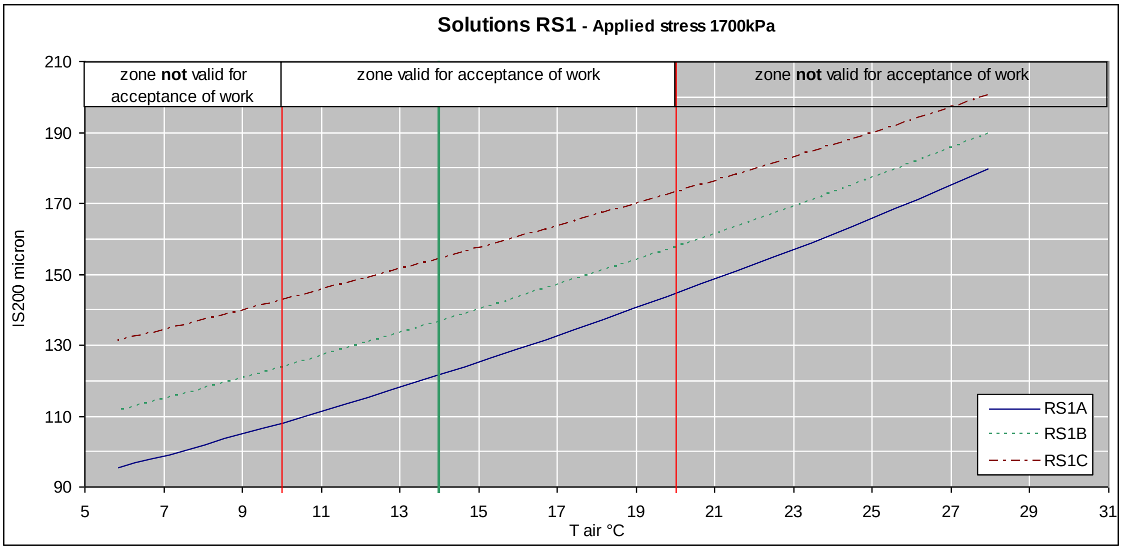


Fig. 9 Control curves with Structural Indicator IS200

5. The application on Macrolot IVb of the Salerno Reggio Calabria motorway

Fig. 10 Motorway A3 SA-RC Macrolot IVb

The SC-RC motorway and in particular Macrolot IVb has been constructed with a road pavement that used marginal materials recycled with cold emulsion and the use of modified bitumen for the construction of the asphalt concrete layers.

The studies conducted have demonstrated the validity of the repair operation adopted with respect to the design solution in terms of increasing the life.

At the present time, new pavements have been partially constructed with the exclusion of the porous wearing course that will be constructed as the last operation.

Inspection tests had already been conducted with the FWD and TSD apparatus.

This apparatus verified the successful completion of the work performed, having attained suitable bearing capacities, measured via the structural indicator IS_{300}.

The method therefore demonstrates its validity, repeatability, and effectiveness with regard to the quality attained and operational management.

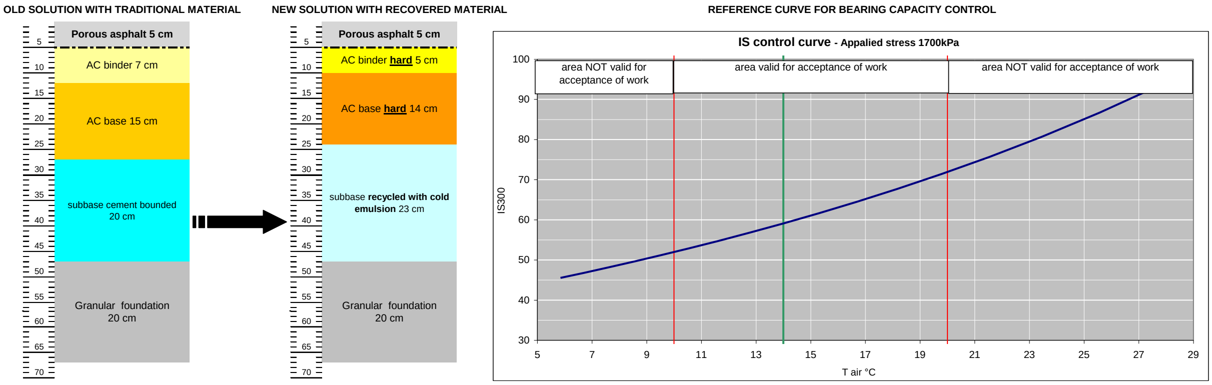


Fig. 11 Old and new repair solution and control curve with Structural Indicator IS300

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