Use Of Ultra-Thin Whitetopping In The Rehabilitation Of Degraded Flexible Pavements

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Synopsis

The choice of the most appropriate functional and structural rehabilitation technique for damaged road pavements obviously mainly depends on the type of surface degradation. The most common rehabilitation technique for flexible pavements deals with the resurfacing of the degraded wearing course by means of a bituminous layer, when it can't be completely replaced by similar mixtures.

Nevertheless, maintenance of degraded flexible pavements can be carried out resorting to a different procedure, which is rarely used in Italy, although it is quite popular abroad: Ultra-Thin Whitetopping (UTW). It involves the damaged pavement being resurfaced with small thin cement concrete slabs.

The interaction between the existing bituminous pavement and concrete layer generates a monolithic system, the performance of which is conditioned by various parameters: the volume of vehicular traffic, environmental conditions, the thickness of cement and bituminous concrete layers, the distance between joints, the adhesion between layers and maintenance technique.

The paper describes the results of an Italian application of this technique. The experiments regarded the identification and characterization of the existing bituminous pavements (through cores and bearing capacity tests), the design of the UTW, the cement concrete mix design (PP and SB fibres were added to the mixture to enhance compressive strength and elasticity), the mechanical characterization of the new layer (by means of compressive strength and dynamic modulus), the construction of joints, the execution of loading tests on the slabs and measurement of longitudinal, transversal and vertical deflections by strain gauges and LVDTs.

The study emphasizes the effectiveness of the maintenance technique. The UTW ensures a good bearing capacity to the pavement, thanks to high values of compressive strength and elastic modulus of the concrete, according to future traffic needs. Moreover, deflections are rather limited. Adequate functional properties (evenness, skid resistance) are also guaranteed.

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A road pavement, like any other work of engineering, has a “service life” determined at the design stage. This service life, under the combined action of vehicular traffic and environmental stresses, can modify over time and this may generate premature degradation of the pavement that requires more or less radical maintenance work.

There are obviously many diverse reasons for road pavement maintenance:

- to maintain the plani-altimetric characteristics of the roadway designed at the planning stages, then implemented (it is assumed, properly) when being built;
- preserve or restore the characteristics of surface evenness and texture;
- preserve or restore the skid resistance properties of the road surface;
- rehabilitate the structural properties;
- limit the repercussions on driving comfort and environmental liveability (noise, vibrations) caused by surface degradations.

For flexible pavements, which are by far the most widely-used in Italy, maintenance is usually carried out with bituminous mixes, which are used, according to the extent of the damage, for patching, resurfacing, reconstruction of the superficial layers, or reinforcement interventions at depth, also through hot or cold recycling.

A valid alternative to the standard application of bituminous concrete layers consists of resurfacing the damaged flexible pavement with a layer of cement concrete. This resurfacing can consist of a continuous slab in concrete, united or not to the underlying surface, or else of a series of small thin slabs, again in cement mixes, according to the technique known as Ultra-Thin Whitetopping (UTW).

This paper describes an applied study on the efficacy of the UTW technique for the maintenance of flexible pavements in Italy. The experiments, carried out in both the laboratory and on site, demonstrated that high levels of pavement resistance can be reached with this type of upgrading. Although the construction costs of resurfacing in concrete are nowadays higher than the costs of the usual rehabilitation of flexible pavements with bituminous mixtures, the performances guaranteed by the former are such that UTW should be taken into consideration as an alternative maintenance solution to other conventional techniques.

THE ULTRA-THIN WHITETOPPING (UTW) TECHNIQUE

Among the techniques that can be used for rehabilitating the structural and functional properties of a pavement, the technique known as Ultra-Thin Whitetopping is worthy of mention, which runs counter to the so-called “Conventional Whitetopping”.

The latter dates back to 1918 when, for the first time in the world, a flexible pavement was resurfaced with a layer of concrete. “Conventional” Whitetopping involved covering the flexible pavement with a concrete slab with a minimum thickness of 100-125 mm. The flexible pavement and slab remained independent of one another, as conventional Whitetopping made no attempt at adhesion between the layers.

This technique was refined over the years, and in 1991, in the American state of Iowa alone, more than 659 Km of state roads were rehabilitated with conventional Whitetopping.

A new method of rehabilitation of degraded pavements appeared in the early 1990s, which consisted of connecting a thin layer of concrete, between 50 and 100 mm thick, to the existing bituminous surface: this new technique was called Ultra-Thin Whitetopping.

Compared to “conventional” Whitetopping, with UTW there must be perfect adhesion between the two overlaid surfaces, so that the system is composed of a composite section, with monolithic behaviour. A second difference between the two techniques regards the interaxle between the joints, which is radically shortened in UTW.

Adhesion Between The Bituminous Concrete And UTW

As mentioned above, there must be perfect adhesion between the surface of the existing flexible pavement and the concrete layer, in such a way that the system behaves like a composite structure. There is no primer application between the two layers, but the friction that is generated between the roughened surface of the bituminous concrete layer (lightly scarified to improve adhesion) and the concrete, forms a purely mechanical bond.

Thanks to the establishing of this bond, the neutral axle of the concrete layer lowers. In this way the stressed part (in traction) of the slab reduces and the compressed part increases. The tensile stresses therefore reduce to a level supportable by the concrete pavement (Figure 1).

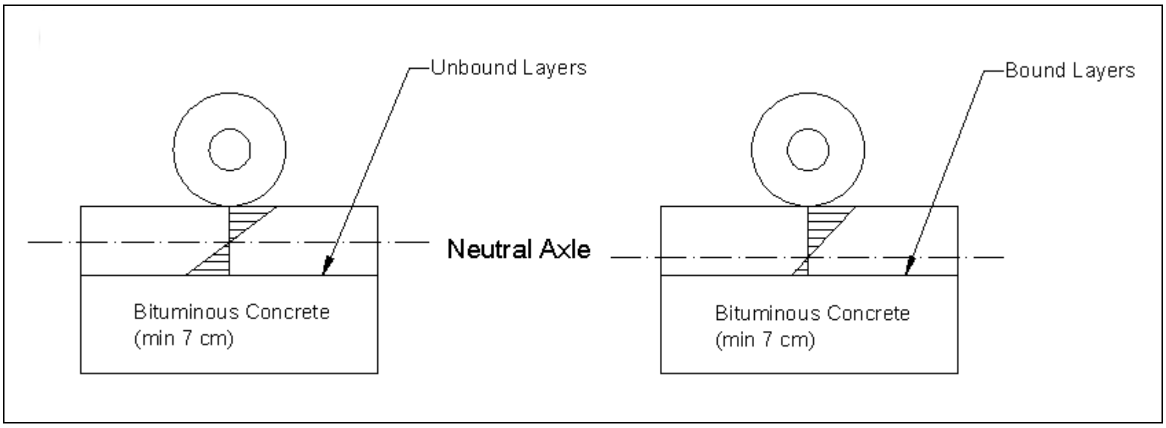

Figure 1: Lowering of the neutral axle

The lowering of the neutral axle can also be influenced by the thickness of the bituminous layer on top of which the resurfacing is done. If this layer is thicker, the neutral axle lowers and consequently the tensile stresses reduce. In general, the minimum thickness of the bituminous layer, after milling, should be 70 mm.

Interaxle Between The Joints In UTW

The interaxle between two consecutive joints is intentionally kept short. In this way the arm of the applied load diminishes and, with this, the bending moment. The load-bearing slab changes from a condition of stress of flexure (the case with a big distance between joints) to one of just compressive stress (short interaxle between the joints, Figure 2).

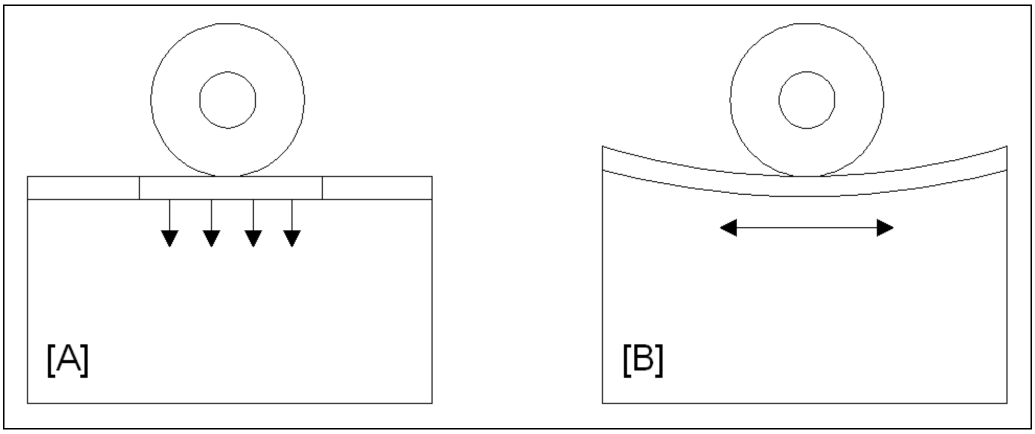

Figure 2: Effect of distance between the joints for UTW [A] and for conventional Whitetopping [B]

The short interaxle between joints reduces deformations of the slab caused by phenomena of curling and warping. In this way a system is formed that can transfer the load to the damaged flexible pavement by deflexion, rather than flexion.
The interaxle is generally between 0.6 and 1.20 m. Conventionally, this interval should be equal to 12-15 times the thickness of the concrete slab.

The Advantages Of UTW And Fields Of Use

The choice of the UTW technique for the maintenance of flexible pavements has undoubted advantages over the traditional methods:

- good skid resistance: the surface of the UTW is characterized by a good microtexture and macrotexture;
- good surface evenness;
- high durability: concrete resurfacing, as long as it is done well, lasts longer than bituminous mixtures; this involves a lengthening of the service life of the pavement, in that no works of ordinary maintenance are required on the bituminous surface;
- road safety: the light colour of the concrete guarantees improved night-time visibility; furthermore, after heavy rainfall, no film of water forms on the surface to cause phenomena of aquaplaning;
- high performance/cost ratio: although the costs of resurfacing in concrete are higher than those of a flexible pavement, maintenance costs are much lower;
- immediate opening of the road to traffic: high-resistance and fast-hardening concretes are generally used for producing the UTW slabs; this means that the concrete can already have reached high resistance

within 24 hours of being laid and that the slabs are therefore negotiable two days after laying, minimising the inconvenience to users caused by road closure.

The rehabilitation of the surface characteristics of the pavement with the UTW technique is possible if the pavement has not suffered structural damage. The UTW solution can be applied on roads with average-low volumes of traffic, on road intersections and parking areas. More research is required into its efficiency on roads subject to heavy traffic.

THE EXPERIMENTS: LABORATORY CHARACTERISATION OF THE MATERIALS

The laboratory tests consisted of mechanical trials to investigate the basic properties of the UTW, on 4 different types of cement concrete mixtures.

The laboratory tests can be summarised as follows:

- preparation of the bituminous supports and their characterisation;
- preparation of the cement mixtures;
- testing the concrete specimens;
- analysis of the results;
- evaluation of the adherence between bituminous supports and concrete resurfacing.

Preparation Of The Bituminous Supports And Their Characterisation

The bituminous concrete used to simulate the base layer of a pavement consisted of a mixture of aggregates hot-bound with normal semi-solid bitumen. The mixture was produced in a fixed discontinuous-type plant for the production of traditional bituminous mixtures, equipped with control systems for temperature and rates of aggregates and binder.

Aggregates with the following characteristics were used:

- coarse aggregate: quantity crushed > 70%, Los Angeles coefficient < 25%;
- fine aggregate (sand): Los Angeles coefficient < 25%, equivalent in sand > 50%;
- filler: UNI 0.42 sieve passing fraction of 100% and 80% at UNI 0.075.

A bituminous binder 70-100 pen was used, at a rate of 4% of the weight of the aggregates. The bituminous mixture was produced in accordance with the minimum requisites in Table 1.

Tab 1: Characteristics of the bituminous concrete

CHARACTERISTICS	VALUES
MARSHALL STABILITY [daN]	> 700
MARSHALL STIFFNESS [daN/mm]	> 200
DENSITY OF CORES (MARSHALL SPECIMENS) [%]	> 97
FINAL VOIDS CONTENT [%]	4 - 9

The mixture was cast in side-forms immediately after being produced, at a temperature of 160 °C. The external air temperature was 17 °C. The bituminous concrete was then compacted by a manual vibrating tamper, applying a pressure of 145 daN/cm^2. The final thickness of the bituminous concrete layer was 10 cm.

The mixtures were subjected to traditional characterisation with the Marshall test, which resulted in Stability of more than 1,150 kN and Stiffness of 0.426 kN/mm; the indirect tensile strength was 0.35 N/mm^2.

These bituminous concrete supports represented the underlying layer for the concrete resurfacing; the pull-off test was subsequently used to verify adhesion at the interface of the two materials.

Preparation Of The Cement Mixtures

Four cement mixtures were formulated, as follows:

- mixture 1: high resistance cement concrete;
- mixture 2: concrete modified with the addition of polypropylene fibre;
- mixture 3: concrete modified with the addition of styrene-butadiene latex;
- mixture 4: concrete in which part of the aggregates were substituted by granulated tyre rubber.

A CEM II/A-L 42.5 R cement was used for all 4 mixtures. In order to achieve a good workability of the fresh concrete, with low water/cement ratios, all the mixtures had a neftalensulfonate-based superplasticizer added. The use of this additive gives the fresh concrete high fluidity and workability, even with low water/cement ratios, and no segregation. For the hardened concrete it favours an increase in the mechanical resistance in the short-term (16 or 24 hours), the achieving of high mechanical resistance at 7 and 28 days, an improvement in impermeableness, durability and skid resistance, and a reduction of shrinkage and fluage.

The superplasticizer rate used was around 1-2 Kg per 100 Kg of cement.

To increase the mechanical resistance of the mixtures, silica fume was also added to all 4 mixtures. The rate adopted was 5% of the weight of the cement.

For mixture 2, polypropylene fibres were added to the solid matrix, at a rate of 1.2 Kg/m^3. In fresh concrete the fibres improve cohesion and prevent segregation; in hardened concrete they increase the tensile strength and resistance to flexural stress (especially in the short-term), reduce permeability, improve resistance to freeze-thaw cycles and reduce micro-cracks.

Styrene-butadiene latex (dosed at approx. 8% of the weight of the cement) and granulated tyre rubber (maximum size 2-3 mm, in partial substitution of a fraction of aggregate; 8-10% in volume) were added to mixtures 3 and 4, respectively. The latex and tyre rubber granules were used with the aim of reducing the elastic modulus of the concrete.

The composition of the mixtures are reported in Table 2.

Tab 2: Composition of the cement mixtures

MIXTURE	1	2	3	4
CEMENT CLASS	CEM II/A-L 42.5 R			
RATE OF CEMENT [Kg/m^3]	450			
RATIO w/c	0.38			
TOTAL WATER [l/m^3]	170			
AGGREGATES [Kg/m^3]	1,820	1,820	1,820	1,456
SUPERPLASTICIZER [% of cement weight]	1.2	1.2	0.5	1.2
SILICA FUME [Kg/m^3]	10	10	10	10
POLYPROPYLENE FIBRE [Kg/m^3]	---	1.2	---	---
LATEX [Kg/m^3]	---	---	36	---
TYRE GRANULES [Kg/m^3]	---	---	---	136
SLUMP TEST [mm] - CLASSE	175 – S4	90 – S2	224 – S5	160 – S4
VIBRATING TABLE [%] - CLASS	66 – FA3	43 – FA2	91 – FA4	60 – FA2
BULK DENSITY FRESH CONCRETE [Kg/m^3]	2,362	2,352	2,022	2,098

Tests On The Concrete Specimens

The following were determined on the 4 types of mixture:

- hygrometric shrinkage;
- compressive strength;
- flexural strength;
- indirect tensile strength;
- dynamic elastic modulus;
- Resistance to initial cracking and ductility index.

Evaluation of the hygrometric shrinkage of the mixture measures the size variations of the concrete over time. After being produced, the specimens were left in the moulds at a constant temperature of 20 ± 2 °C in a moisture saturated environment for 24 hours. The hygrometric shrinkage results are reported in Table 3 and represented in Figure 3.

Tab 3: Hygrometric shrinkage (μm/m)

DAYS	MIXTURE 1	MIXTURE 2	MIXTURE 3	MIXTURE 4
4	-174	-191	-214	-227
7	-234	-247	-313	-320
14	-346	-346	-415	-415
21	-373	-392	-508	-534
28	-439	-458	-564	-594
60	-580	-591	-633	-686

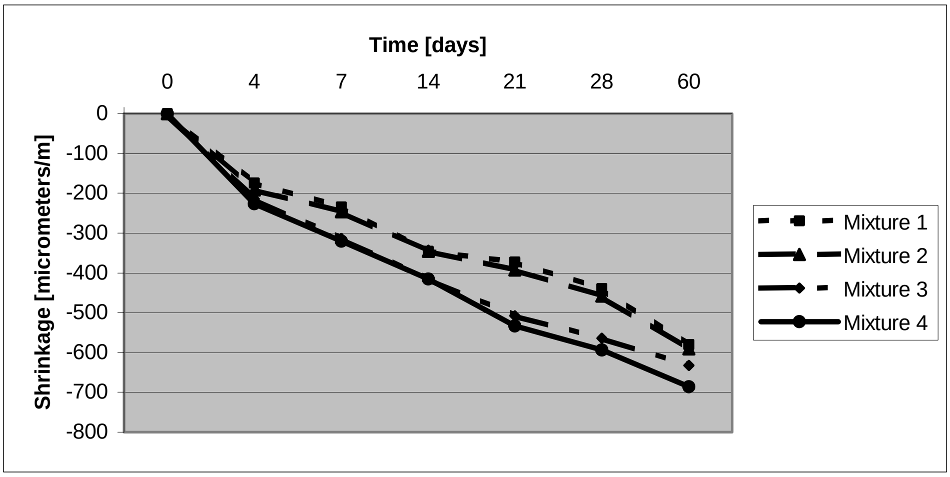

Figure 3: Pattern of hygrometric shrinkage for the 4 mixtures

The results obtained in terms of compressive strength (prEN 12390-4/12390-5), flexural strength (prEN 12390-5) and indirect tensile strength (prEN 12390-6), are reported in Tables 4, 5 and 6 respectively, and graphically represented in Figures 4 and 5.

Tab 4: Compressive strength (N/mm^2)

DAYS	MIXTURE 1	MIXTURE 2	MIXTURE 3	MIXTURE 4
1	32.77	31.00	11.00	7.96
5	56.2	53.00	20.73	19.80
7	58.97	56.83	26.60	20.97
14	62.93	63.40	28.53	22.73
28	66.83	67.50	32.80	22.67

Tab 5: Flexural strength (N/mm^2)

DAYS	MIXTURE 1	MIXTURE 2	MIXTURE 3	MIXTURE 4
7	7.03	6.65	4.13	4.02
28	7.80	7.90	5.20	4.15
60	8.20	8.23	5.45	4.30

Tab 6: Indirect tensile strength (N/mm^2)

DAYS	MIXTURE 1	MIXTURE 2	MIXTURE 3	MIXTURE 4
28	4.01	3.69	2.91	1.72

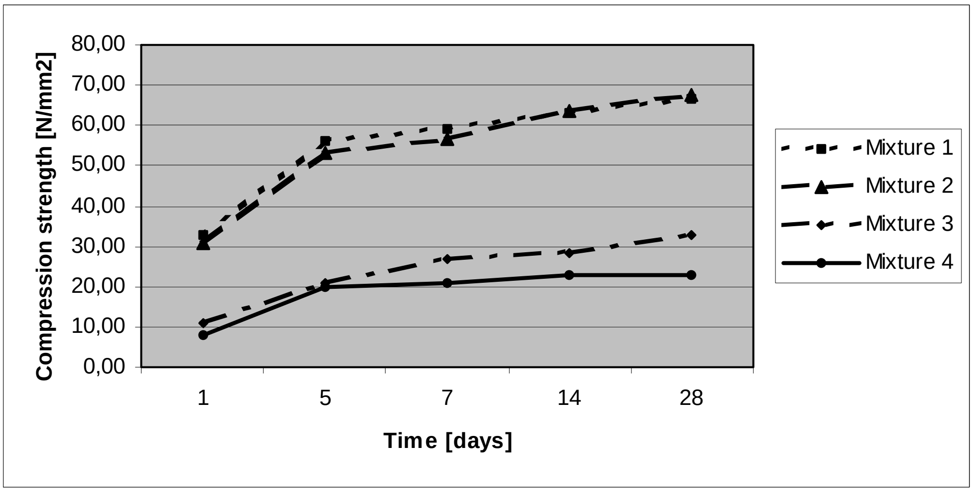

Figure 4: Compressive strength (N/mm^2) vs. mixture and time

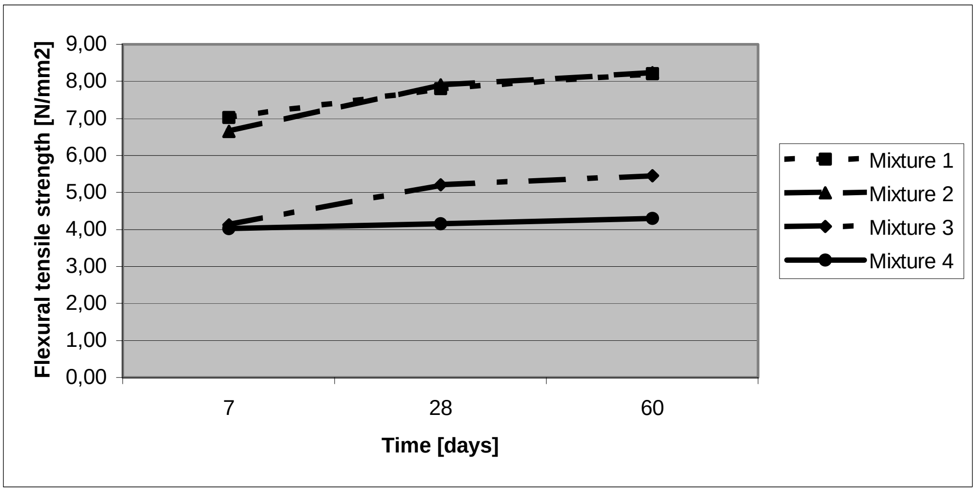

Figure 5: flexural strength (N/mm^2) vs. mixture and time

For the determination of the dynamic elastic modulus (UNI 9771), the elastic characteristics of the concrete specimens were determined starting from the fundamental resonance frequencies for flexural, extensional, torsional vibration modes. For the aims of this study, the elastic flexural moduli were considered of greatest interest. These are reported in Table 7 and represented in Figure 6.

Tab 7: Elastic dynamic flexural modulus (MPa)

DAYS	MIXTURE 1	MIXTURE 2	MIXTURE 3	MIXTURE 4
5	40,775	40,316	30,405	19,192
7	41,984	41,446	31,011	19,951
14	43,098	42,667	32,838	20,902
21	44,063	43,017	33,721	21,742
28	44,757	44,290	34,492	21,742
60	45,631	45,571	35,136	22,527

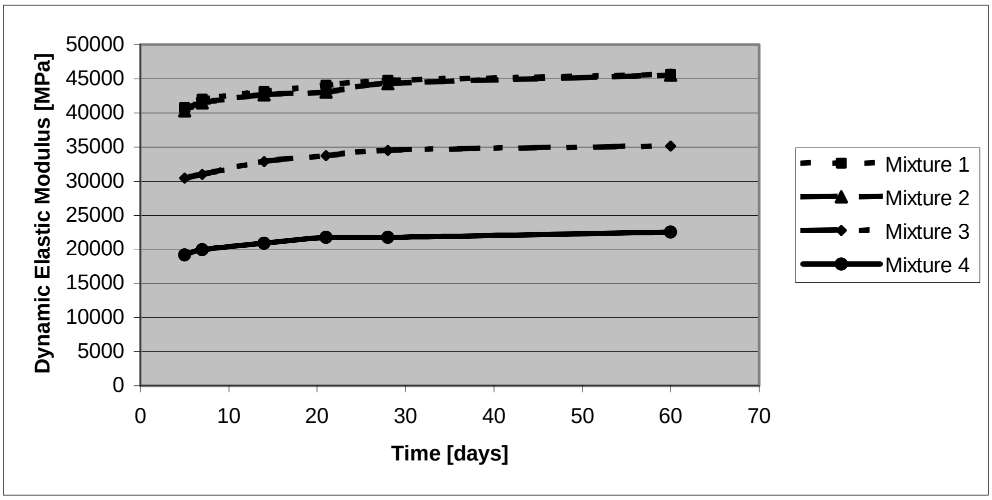

Figure 6: Elastic dynamic flexural modulus (MPa) vs. mixture and time

Lastly, as regards the bending test, for the determination of the resistance to initial cracking and the indexes of ductility of the 4 mixtures, the CMOD (Crack Mouth Opening Displacement) and CTOD (Crack Tip Opening Displacement) were both checked.

It should be noted that ductility expresses the capacity of the specimen to conserve its mechanical resistance characteristics with the progression of the cracking process and the ductility index must always be between 0 and 0.6 mm.

The results are reported in Table 8.

Tab 8: Resistance to initial cracking (MPa) and ductility index

	MIXTURE 1	MIXTURE 2	MIXTURE 3	MIXTURE 4
RESISTANCE TO INITIAL CRACKING (MPa)	3.75	3.69	2.70	2.40
CLASS	$F_{3.7}$	$F_{3.7}$	$F_{2.5}$	$F_{2.5}$
DUCTILITY INDEX	0.28	0.33	0.56	0.48
CLASS	D_{SO} Soft.	D_{SO} Soft.	D_{S1} Soft.	D_{SO} Soft.

Analysis Of The Results

The results obtained during the laboratory tests on the concrete specimens show that the values of compressive strength are higher for mixtures 1 and 2 (30 N/mm^2 after 24 hours) than for mixtures 3 and 4 (10 N/mm^2 after 24 hours). The addition of polypropylene fibre (mixture 2) had no affect on the compressive strength of the concrete.

The addition of latex and the partial substitution of the aggregate with tyre rubber granules penalizes the compressive strength, but notably reduces the elastic modulus of the material (after 7 days, the dynamic elastic modulus for mixtures 1 and 2 was around 40 N/mm^2, for mixture 3 around 30 N/mm^2 and for mixture 4 around 20 N/mm^2). Therefore, the aim of reducing the fragility of the concrete can be achieved through the addition of tyre rubber or latex granules. This latter addition to the mixture, although reducing the performances in absolute terms, increases the flexural/compressive ratio.

It emerges from the experimentation that adding latex is the best way to improve the performances of cement concretes to be used for UTW. The addition of latex to the mixture appears, probably because of the rate, to penalize the mechanical performances of the mixture.

Examination of the results has permitted a possible formulation of concrete suitable for UTW to be identified, in which the additives that reduce the water/cement ratio react jointly so that the concrete develops high mechanical resistance, the polypropylene fibres to reduce the risk of initial micro-cracking, the latex to reduce the fragility of the concrete slabs.

Evaluation Of The Adhesion Between The Bituminous Pavement And Concrete Resurfacing

The composite pavement obtained by resurfacing the bituminous concrete layer with a concrete slab was subjected to pull-off tests to verify the adhesion in correspondence to the interface between the layers. Prior to testing, the slabs were left out of doors to season for 28 days.

The pull-off test consisted of causing the composite pavement to break, by the application of a vertical force, i.e. the detachment of a section previously glued to the pull-off tester.

For mixture 1, the average adhesion tension was 0.45 N/mm^2, for mixture 2 it was 0.20 N/mm^2, for mixture 3, 0.27 N/mm^2 and for mixture 4, 0.135 N/mm^2. As might be expected, detachment occurred because of a break of cohesion in the bituminous support, because of its poor tensile strength. The values obtained allow the claim to be made that the adhesion between support and concrete reinforcement is purely mechanical and that it is enough to guarantee sufficient adhesion between the layers.

ON-SITE EXPERIMENTS

In the light of the results obtained in the laboratory, the research focussed on on-site experiments, which involved reinforcing an existing flexible pavement with thin concrete slabs.

The study was split into the following phases:

- identification and characterisation of the existing bituminous pavement;
- choice of the cement concrete mixture and design of the UTW;
- conducting bearing-capacity tests on the composite pavement;
- analysis of the results.

Identification And Characterisation Of The Existing Bituminous Pavement

For the application of UTW resurfacing, an experimental stretch of bituminous pavement was chosen, 10 m in length and 5 m wide. The surface of the entire pavement was well-maintained, with occasional patching. Because it had been demonstrated during the laboratory trials that the mechanical behaviour of the UTW is closely correlated to the type and maintenance state of the supporting bituminous pavement, it was necessary to characterise the pavement.

Core samples showed that the pavement was composed of a 15-20 cm thick unbound road base (40/71 gravel) and a 2 cm thick wearing course in bituminous concrete (with a residual voids percentage of between 3% and 5%).

In order to define the bearing capacity, plate-bearing tests were done on the pavement. These provided a Md Modulus of 214 N/mm^2.

Choice Of The Concrete Mixture And Design Of The UTW

The composition of the mixture adopted for the on-site experiments is reported in Table 9.

Tab 9: Composition of the mixture on site

CEMENT CLASS	CEM II/A-L 42.5 R
CEMENT RATE [Kg/m^3]	450
RATIO w/c	0.39
TOTAL WATER [l/m^3]	175
AGGREGATES [Kg/m^3]	1,784
SUPERPLASTICIZER [% of cement weight]	1
POLYPROPYLENE FIBRE [Kg/m^3]	1
LATEX [Kg/m^3]	30

The use of CEM II/A-L 42.5 R cement was considered necessary as it guarantees that high resistance is reached within 24 hours after laying. The mixture was produced with the following additives:

- styrene-butadiene latex, at a rate of approx. 30 l/m^3. Compared to laboratory mixture 3, a much lower amount of latex was added to the mixture;
- polypropylene fibre at a rate of 1 kg/m^3.

Mechanical characterisation was carried out on the mixture thus defined, determining the compressive strength and flexural elastic modulus. The results obtained are reported in Table 10 and in Figures 7 and 8.

Tab 10: Mechanical characteristics of the concrete on site

DAYS	COMPRESSIVE STRENGTH [N/mm^2]	FLEXURAL DYNAMIC ELASTIC MODULUS [MPa]
1	29.10	24,332
2	33.75	27,719
7	37.90	31,326

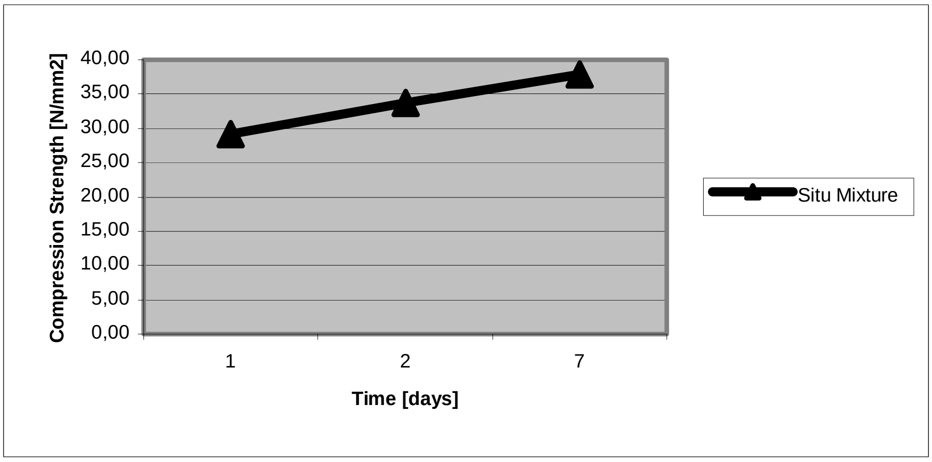

Figure 7: Compressive strength of the concrete on site vs. time

A comparison between the values obtained for the mixture on site and those obtained for mixtures 2 (addition of polypropylene fibre) and 3 (addition of latex) in the laboratory, demonstrates that:

- the compressive strength of the mixture used on site, after 1 day, is quite similar to that of laboratory mixture 2, obtained by the addition of polypropylene fibre (29 N/mm^2 and 31 N/mm^2, respectively);
- the elastic modulus reached, after 7 days, by the mixture adopted on site (31,000 MPa), is rather lower than that of mixture 2 (41,000 MPa), having values like those for mixture 3 (31,000 MPa).

Furthermore, the mixture used on site presents an already high dynamic elastic modulus after 24 hours (25,000 MPa), so that the pavement can be used by traffic less than two days after laying.

The mixture adopted on site therefore unites different requirements, i.e. it is a mixture that offers an adequate response to the compressive stresses to which it is subjected, it has values of dynamic elastic modulus that can guarantee a not excessive rigidity to the pavement, plus high resistance together with fast hardening that allows the transit of traffic just a few days after being laid.

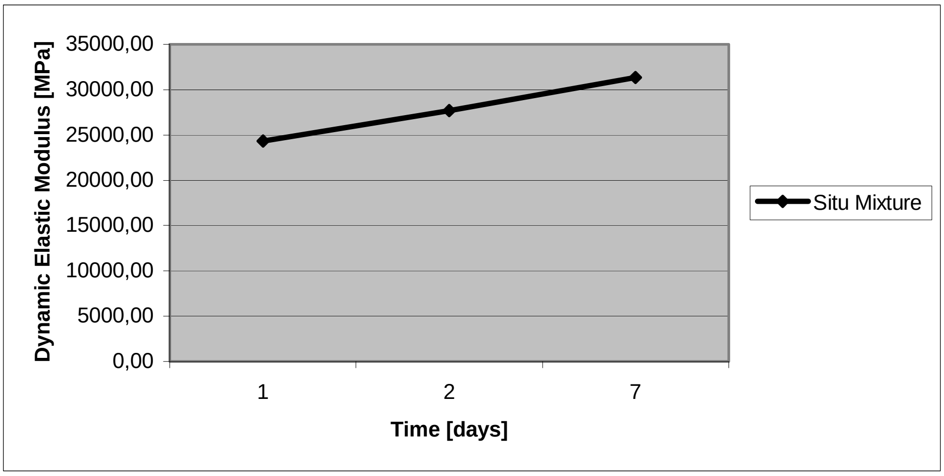

Figure 8: Dynamic elastic modulus of the concrete on site vs. time

The design of the concrete slabs was done in accordance with the regulations of the A.C.P.A. (American Concrete Pavement Association). The slabs were 1 m square and 8 cm thick. Special attention was paid to the ideal length of seasoning for cutting the slabs: this was done when the concrete had reached a compressive strength of not less than 25-35 MPa. Fine blades 3-4 mm thick were used for cutting to a depth of 25 mm, i.e. approx. 1/3-1/4 of the thickness of the resurfacing. The joints thus formed were not sealed.

Before laying the concrete, strain gauges were positioned on the pavement to measure the lengthwise and transversal deflections of the slabs. The same type of strain gauges were buried in the upper part of the layer of concrete, in symmetrical positions with respect to the strain gauges set on the bituminous surface.

To measure the vertical displacement of the slabs, LVDT (Linear Voltage Displacement Transducers) were placed on top of the resurfacing in opportune positions.

Execution Of Static Tests On The Composite Pavement

The tests on the pavement with UTW were done through the application of a load caused by a heavy three-axled vehicle, with twinned central and single external wheels, weighing a total of 25.4 tons.

The vehicle was moved to various positions on the slabs. The deformations and deflections of the slabs were measured by a multi-channel strain gauge exchange.

The positions of the vehicle on the pavement referred to the central axle with the twin wheels. In particular, the two most critical cases were studied, divided into sequence A and sequence B, which regard the position of the twin wheels in proximity to the slab joints.

Sequence A involved positioning a pair of twin wheels in correspondence to the slab axle and the other pair tangent to the two joints, lengthwise and transversal. In sequence B, a pair of twin wheels was instead positioned tangential to the two joints, and the other pair astride the joint lengthwise and at a tangent to that transversal. See Figure 9.

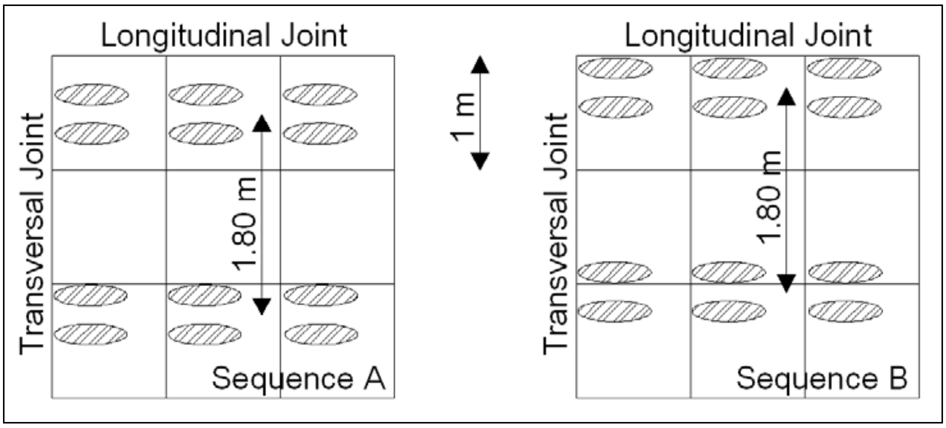

Figure 9: Positions of the vehicle's central axle on the slabs of the experimental section

The lengthwise, transversal and vertical deformations were referred to the initial position of the slabs prior to the transit of the vehicle.

With sequence A, the lengthwise and transversal deformations measured at the maximum had a value of around 250 μm, whereas for sequence B the maximum values reached were around 100 μm.

For the vertical deflections, the values were between 0.25 mm and –0.27 mm for sequence A, and between 0.25 and –0.15 mm for sequence B. The vertical deformations of the slabs were between 0.12 mm and –0.39 mm for sequence A and between 0.001 mm and –0.007 mm for sequence B.

The readings taken from each instrument showed that, after application of the load, the slabs sustained such minor lengthwise, transversal and vertical deformations as to be considered insignificant.

CONCLUSIONS

For various reasons, the use of cement mixes in road pavements is infrequent in Italy, and the few applications have been in specific fields (airport, industrial and intermodal container depot pavements).

The technique of Ultra-Thin Whitetopping (UTW) for the rehabilitation of the structural and functional characteristics of a damaged flexible pavement involves its resurfacing with thin concrete slabs. This technique can be applied on roads with an average-low volume of traffic, or else on areas which degrade rapidly, such as road intersections and parking areas.

This research, by means of systematic laboratory and on-site characterisation of the materials used and through a series of static and dynamic tests on the mixtures produced, has demonstrated that the use of concrete resurfacings for flexible pavements is indicated wherever maintenance is required to rehabilitate a damaged pavement, with the new composite pavement guaranteeing an adequate response to mechanical stresses, high resistance shortly after being laid and long-lasting durability.

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