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INNOVATIVE SOLUTION FOR MINI-MICRO-TRENCHING SYSTEMS

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ABSTRACT: The excavation techniques for mini-micro-trenches have been in use for years. Currently, due to the development of adoptions such as fiber-to-the-home (FTTH) networks and fiber optic sensors, smaller and smaller dimensions for trenches are required. Thus, trenching systems less than 5 cm wide entail the development of new technologies, both in terms of cutting procedures and backfilling solutions. In this context, an innovative design solution is here introduced. Such technology based on restoring the pavement after micro-trench using a new bi-component grout, the Flowmix Fast, which guarantees both ductility and resistance through the presence into the mixture of a bituminous emulsion and a highly additivated cementitious filler, respectively. The product, compared to conventional techniques that utilize hot sealing, represents a valuable solution to reduce the energy footprint and volatile emissions harmful to the environment and operators. Moreover, a specially designed injection apparatus enables the backfilling operations to be concluded in a single casting, requiring three operators working only. After pouring, the grout restores the pavement surface reaching a solid consistency in about 20 minutes. This assures unprecedented speed of execution, favouring a quick opening to traffic. In terms of performance, laboratory tests were carried out on the material to evaluate properties such as microtexture, macrotexture and adhesion at the interface. The product showed a noticeable bond with the existing structure and ensured high values of skid resistance. Beyond, its fluid consistency allowed the grout to wrap, protect and waterproof the technological networks installed. Another fundamental prerogative is the expansive capacity, which allows a promising sealing of the excavation, preventing water penetration and therefore yielding great durability to the system. Finally, the product is not affected by the softening effect caused by high temperatures.

1. INTRODUCTION

In urban areas several utility lines commonly run parallel to and across road pavements. Utility cuts are then necessary for electricity, fiber optic and telephone lines, water and drainage pipelines (Lemis-Petropoulos, 2012). Among these, the introduction of fiber to connect the central office with the end customer of the telecom access networks is currently in high demand to cope with increasing network request (Tahon, 2014). Fiber To The Home (FTTH) networks are the most future proof solution capable of offering high performance bandwidth and in turn new services to consumers (Evens, 2011).

Over the last decade, the technological development concerning such networks has led to optical fiber cables with greater efficiency and smaller sizes. At the same time, digging technologies for placing them significantly improved.

In this context, no-dig or trenchless technologies are a set of practices ideal for installing, relining and repairing the underground utilities network minimizing the impact on existing road pavements. Unlike the traditional trench, those techniques, such as mini and micro-trenches, have a faster implementation, with a significant lower production of waste material (Cerni, 2020). Thus, time losses for road users and extra-fuel consumption due to congestion are noticeably lowered. Furthermore, the reduced excavation section does not excessively damage the existing pavement, with considerably lower restoration times and costs. An example of mini-trenching technology is the OneDayDig, which is characterized by a 5 cm wide and 30 cm deep trench (Molteni, 2011). This technology based on two different backfilling materials, namely a fast-hardening cement mortar and a hot asphalt concrete patch at the top of the cut. Otherwise, the micro-trenching technologies allow placing cables or conduits inside a trench narrower than 30 mm wide and up to 300 mm deep.

The quality of backfilling plays an important role in the performance of the trench (Corradini, 2020) . Using backfilling materials that are not suitable for the site conditions and not properly installed will lead to premature pavement failures, which can significantly reduce the pavement life (Jensen, 2005). Several studies have been conducted on using different granular, concrete, and bituminous materials for backfilling purposes. Materials used with varying degree of success are cement and fly-ash based grouts (Konczak, J., 2012). Rios et al. noticed that using foamed grouts, freezing and thawing conditioning results in an increase in density, followed by a compressive strength increase after each cycle. (Rios V., et al. 2018). After two different applications where a bottom layer of play sand and an upper layer of either hot bitumen or CMA were used, Hashemian et al. pointed out that using sand to backfill the trench resulted in free conduit movement inside the trench that can be intensified in cold regions with several freeze–thaw cycles. (Hashemian L. et al., 2016). Materials used as backfill must secure the cable inside the trench and be self-compact, quick setting with fluid consistency, stable, properly bond with the existing structure, and prevent water penetration. It is important to note that the cut normally affects more than one layer of the pavement. Therefore, more than one material is usually applied as backfill.

Given this background, the main objective of this research was to evaluate the suitability of a new technology for mini-micro-trenching applications which based on the use of a cementitious-bituminos grout as backfilling material. To the knowledge of the authors, the use of this bicomponent material as mini-micro-trenching backfilling is here addressed for the first time. To this purpose, the performance of the grout was studied through a preliminary campaign of laboratory tests. Then, specific tests were carried out to evaluate the application on road pavements as backfilling material. Hence, macrotexture and microtexture properties of the grout were analysed on laboratory manufactured slabs, while the efficiency of the construction process was investigated through real mini and micro-trenching applications on-site, from which different types of cores were sampled for further laboratory testing. The latter aimed to investigate the existing pavement – mini or micro-trenching (EP-MT) system in terms of adhesion at the interface, which is considered as a crucial aspect to ensure longer lasting systems. The adhesion properties at the interface were evaluated in terms of indirect tensile strengths (ITS) and such values were finally compared with those collected testing the existing layers of the road pavement, namely wearing course and binder course.

2. OVERVIEW ON CEMENT ASPHALT EMULSION COMPOSITE MATERIALS

Cement-asphalt emulsion mixture (CAEM) is a complex composite material with both the flexibility of asphalt concrete and high strength of cement (Zarei, 2022). It mainly consists of cement, asphalt emulsion, fine sand, and several chemical admixtures (Tan, 2013). Based on the concept that cement content controls the elastic modulus, while asphalt emulsion content gives the strain capacity of cement-asphalt emulsion mixture, a combination of optimum cement and optimum asphalt emulsion content would result in better mixture performance (Pichayapan, 2019). Furthermore, types of asphalt emulsion, types of cement, relative humidity, and curing period affect mechanical and rheological properties of the cement-asphalt emulsion composite.

Cement asphalt emulsion composites have wide applications in the industry. In road pavement maintenance, cold recycling process are preferred to hot ones due to the low energy consumption and reduced atmospheric emission. In such process, cement and bituminous emulsion generally act as single components. As grouting solution, CAEM has been greatly appreciated as the elastic cushion layer in slab track of high-speed railway (Ouyang, 2015). The introduction of asphalt emulsion significantly improves the fresh properties as well as hardened characteristics of cement-based materials, such as rheology, flexibility, elasticity, dynamic mechanical properties, fatigue properties and durability. Finally, CAEM has been successfully used in semi-flexible pavements as a grouting material to reduce the significant gap in stiffness among the porous asphalt matrix and the cement-based grouting paste, which is the most common solution as filling material in such pavements. It was observed that the adhesion of CAEM to porous asphalt mixtures is greater than achieved employing cement-based grouts. Moreover, semi-flexible pavements containing CAEM show a higher flexural failure strain at low temperatures and better resistance to frost damage when compared to application containing cement-based grouts (Zarei, 2022).

3. EXPERIMENTAL PROGRAM

3.1 MATERIALS

In this paper a new cement-asphalt emulsion grout is investigated as unique backfilling material for micro-trenching applications. This product is part of the Flowmix technology, which is an innovative solution developed and patented by CVR S.p.A.. The Flowmix based on the collaborating action of a premixed cement grout and a specific bituminous emulsion. Depending on the field of use (building, road, infrastructure), suitable granulometric curves and specific mixing ratios between hydraulic binders, bituminous binder, and aggregates, can be set. The mixture is therefore designed according to the mechanical behaviour and rheological properties required by the possible intended uses. The main binders, namely cements and bituminous emulsion, are complementary and allow adjustable performance based on their proportions into the grout.

In particular, the paper deals with the Flowmix Fast, which borns from Flowmix broad product's line and is specially designed as backfilling solution for mini and micro trenches. Flowmix Fast is a bituminous - cementitious composite material made up of highly reactive hydraulic binders, bituminous binder, fine aggregate, micro silicates with pozzolanic behaviour, expansive agents, specific no segregating and superplasticizers additives. Siliceous and carbonate aggregates with a controlled 0/4 mm gradation are employed. The bituminous binder used is a cationic slow setting bituminous emulsion, whose main properties are listed in Table 1. The main hydraulic binder is an ordinary Portland cement CEM IIA LL 42.5R. According to the producer declaration, the presence of appropriate rheological regulators provide to the composite material adequate viscosity, preventing segregation phenomena.

Table 1. Main properties of the asphalt emulsion used in Flowmix Fast.

Test	Value	Reference Standard
Bitumen content (%)	60	UNI EN 1428
Penetration (dmm)	<100	UNI EN 1426
Softening point (°C)	43	UNI EN 1427
Adhesiveness (%)	>80	UNI EN 13614
Density (Kg/m^3)	1000±50	-

The final product is prepared from a premixed powder of aggregate and hydraulic binders, which roughly account for 72.5% and 27.5%, respectively. Such premixed powder has a density of 1550 kg/m^3. Each 100 parts of the premixed powder, 5 parts of bituminous emulsion and 12 parts of water are added into the fresh grout. The Flowmix Fast guarantees walkability and trafficability in 40 minutes and 50 minutes, respectively, while the opening to traffic occurs in 60 to 90 minutes from casting. Since the material is produced through a "cold" process, there are no seasonal limits for the installation, except for conditions of temperatures close to 0°C or above 40°C. Finally, it eliminates the lowering phenomena due to post-compaction induced by vehicle traffic, typical of systems made with asphalt concrete mixtures (Verhaeghe, 2007).

In order to perform a comparative analysis among the ITS performance of the EP-MT system and that of traditional hot mix asphalt mixtures, cores from an existing pavement were sampled and trimmed to obtain both wearing course and binder course control specimens. Such samples were subjected to binder extraction test in compliance with UNI EN 12697-1 (European Committee for Standardization, 2020), which revealed a bitumen content of 5.4% and 5.1% to the mixture weight for wearing course and binder course mixtures, respectively. After extraction, the wearing course aggregate mixture showed 0/8mm gradation, while the binder course aggregate blend showed 0/12.5 mm gradation.

3.2. MINI AND MICRO-TRENCHING APPLICATIONS

In this experimental work, mini and micro-trenching applications were executed on a trial area located in Gubbio (Perugia, Italy). Operative activities on-site were carried out through apparatus and personnel provided by New Font S.p.A.. Based on the dimensions of the trench to be realized, different floor sawing machines were employed. Accordingly, floor sawing machines fitted with three 90 cm diameter diamond blades that are coupled to get a cut 2, 5 cm wide and 30 cm deep or with a toothed disc that guarantees a cut 8 cm wide and up to 50 cm deep for micro-trenching and mini-trenching respectively, were used. In Figure 1, the employed sawing machines are shown. Concerning micro-trenching procedures, the reduced contact area among the diamond blades and the existing asphalt concrete layers results in a reduction of friction forces and in turn in a greater directionality, control, and execution speed of pavement sawing. As shown in Figure 2a, the mechanical action of the diamond blades simultaneously removes the waste material and leaves that at the side of the trench. This can be than collected by workers for proper disposal or recycling. Micro-trenching provides clean and precise cuts without damaging the edges of the trench, lowering the risk of detachments and cracks (Figure 2b). While sawing occurs, water is sprayed for dust suppression. Before proceeding, residual dust or mud are removed from the excavation walls through a low pressure water jet, regardless trenching technology.

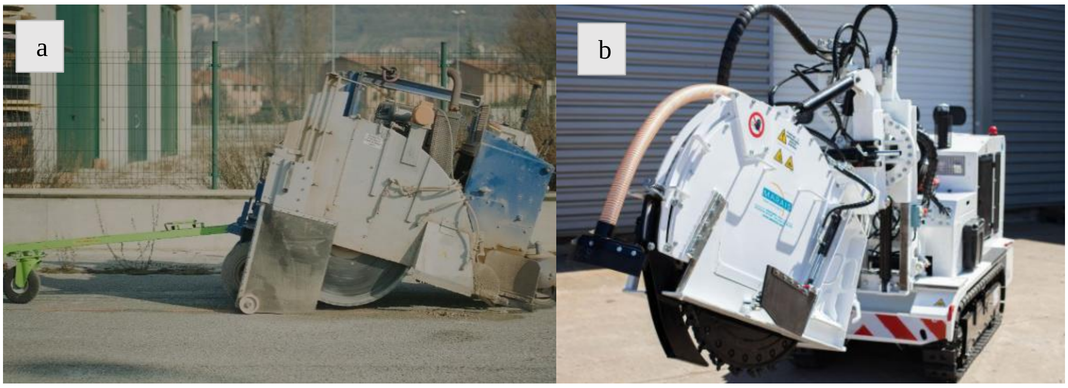

Figure 1. Sawing machine used for micro-trenching (a) and mini-trenching applications (b).

Figure 2. Waste material at the side of the micro-trench after sawing (a); view of the straight and clean edges of the micro-trench (b).

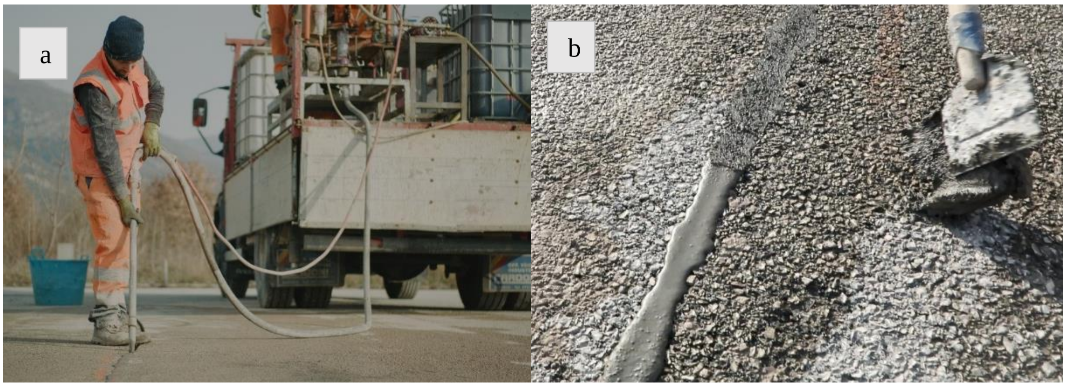

Figure 3. Micro-trench backfilling (a); finishing activities (b).

As shown in Figure 3a, the backfilling material is pumped inside the excavation using a MOD. EM – BI2 emulsifying pump designed by New Font S.p.A. and CVR S.p.A. This device ensures adequate blending percentages of water and bituminous emulsion into the premixed powder of aggregates and hydraulic binders. The blending is made in a chamber and then the material, by passing through a rotor/stator and pipe, is laid with the appropriate fluidity, nonetheless requiring minimum processing time. The grout, which results very ductile, fill the whole excavated section together with undesired cavities that however may occur. The device allows the filling operations to be carried out in a single pour, requiring the intervention of three operators only. As showed in Figure 3b, finishing consists in manually spreading out the grout and removing any material excess from the pavement. The pump promotes proper laying and provides a reduction in the reset time of the grout. Furthermore, it allows managing the grout flow rate by replacing the rotor/stator system. Hence, switching from mini-trenching to micro-trenching applications the material flow rate can be lowered so as to avoid grout spillage on existing pavement.
It is to be stressed that both mini and mini-trenching systems ensure a reduced impact on the viability, always guaranteeing the traffic flow of vehicles, even in presence of transversal cuts. Finally, both technologies minimize the moving of heavy vehicles.

3.3 SPECIMEN PREPARATION

Slabs for micro and macrotexture tests

After preparing the Flowmix Fast according to proportions mentioned in Section 3.1, a specific amount of material was poured over a cement concrete plate fitted with a square steel frame which held the grout so as to obtain a slabs 36x36 mm wide and about 10 mm height. The Flowmix Fast slab was allowed to harden to room temperature and after 14 days of curing, the steel frame was removed. Two different slabs were manufactured following such procedure for studying the surface performance of the grout.

Cylyndrical specimens for ITS test

In compliance with the construction procedures described in Section 3.2, mini and micro-trenching installations were performed on a trial area located in Gubbio (Perugia, Italy). Here, after 14 days curing, a first set of samples were cored: CP samples cored from the existing pavement; CMT samples which included the interface between the original pavement and the installed mini or micro-trenches. As shown in Figure 4, CMT cores were sampled with the interface section (one of the two for cores from micro-trenches) as closer as possible to their diameter.

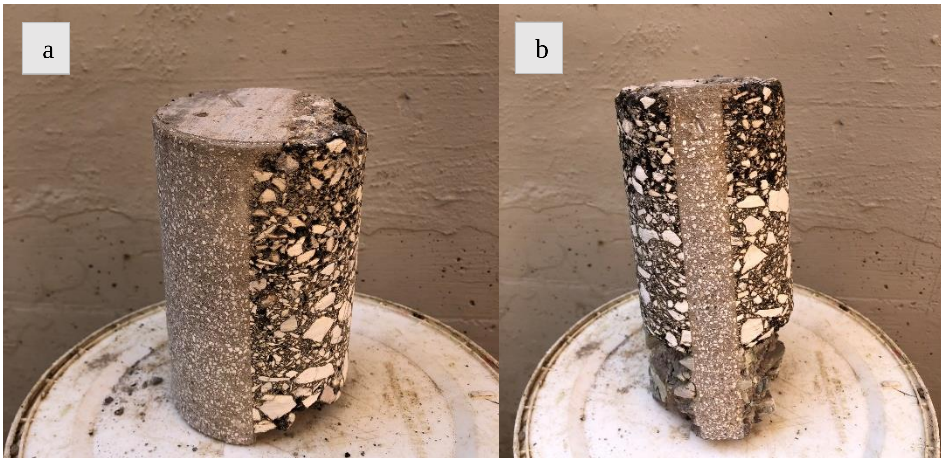

Figure 4. CMT cores sampled from mini-trenching (a) and micro-trenching (b) installations.

The different cores were about 25 cm deep. Hence, by sawing each original core, two specimens were obtained from its upper part and from that immediately underlying. These were about 4.5 cm height and referred to the wearing course and binder course layers of the existing pavement, respectively. Accordingly, the pedis “w” (wearing course) or “b” (binder course) are used in this paper to identify each specimen based on depth of sampling. (i.e. CP_w, CP_b, CMT_w, CMT_b,). The bottom part of the core was instead discarded.

As shown in Figure 5a, a second set of specimens were manufactured using cores sampled from mini-trenches before backfilling was injected. Thus, half-cylinders were obtained, whose cutting section was performed through the same apparatus employed by mini-trenching technology. Then, cores were trimmed to obtain specimens about 4.5 cm height from both the upper part of the sample (wearing course layer) and from that immediately underlying (binder course layer). A shown in Figure 5b, these half cylinders were set up on a baseplate and confined by a plastic tube with the same inner diameter. Using the plastic tube as a mold, the grout was injected to fill the empty volume within the tube up to the same height of the asphalt concrete trimmed part. After 14 days of curing, the plastic tube was removed (Figure 5c). Such set of specimens were identified as MMTw or MMTb if the cored part was from the existing wearing course or binder course, respectively.

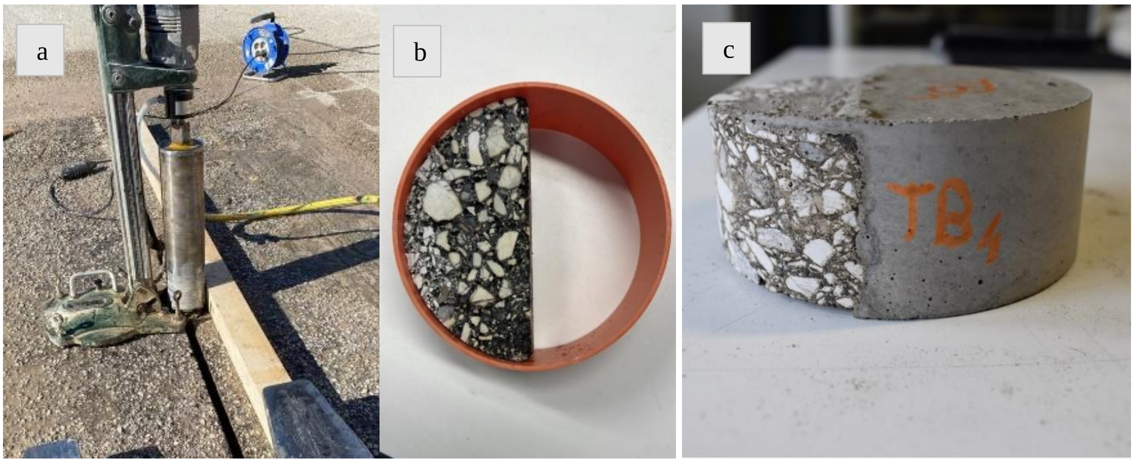

Figure 5. Sampling on empty micro-trench (a); half specimen confined by a plastic tube (b); hardened MMT specimen (c).

3.4 EXPERIMENTAL METHODS

Indirect Tensile Test

The indirect tensile test was carried out to evaluate the indirect tensile strength (ITS) of tested specimens in accordance with UNI EN 12697-23 (European Committee for Standardization, 2018) ITS was measured by means of a electro-mechanical press, imposing a constant rate of deformation of 50 ± 2 mm/min until specimen failure occurred. The testing temperature was set to 25 °C, in compliance with Italian Technical Standards (Centro Sperimentale Interuniversitario di Ricerca Stradale, 2001). Therefore, samples were maintained in an environmental chamber at the set temperature for 3 h before testing. During the test, load and vertical displacement were continuously measured and recorded. Failure occurred by splitting along the vertical diametrical plane. Based on the acquired measurements, the ITS was calculated as follows:

$$ITS = \frac{2 \cdot F_{max}}{\pi d t} \qquad [1]$$

where Fmax is the maximum vertical force (N), d is the specimen diameter (mm), and t is the specimen thickness (mm).

British Pendulum Test

The British pendulum test allowed skid resistance of road pavement to be determined in compliance with UNI EN 13036-4 (European Committee for Standardization, 2012). The slip or skid resistance of a surface is measured by means of a device called Pendulum Tester. The apparatus incorporates, at the end of its pendulum arm, a spring-loaded slider made of a standard rubber that slides on the surface to be measured. The arm, after being locked in a horizontal position, is then released in order to swing freely. Once it has reached its maximum height, the operator manually stops the backswing. The maximum height of the pendulum rise is identified by a needle positioned in front of a scale directly graduated to show readings of pendulum test value (PTV). Each test based on 5 measurements, gathered re-wetting the surface just before releasing the pendulum. The PTV value is calculated as the mean of five swings.

Volumetric patch test

The test procedure used for evaluating the macrotexture properties of the Flowmix Fast was in accordance with UNI EN 13036-1 (European Committee for Standardization, 2010). The principle is that the greater the texture, the more the glass spheres will be taken up by it and the smaller the circle that can be achieved pouring a standard quantity of these on the pavement surface. In this study a known volume of glass spheres was spread evenly over the surface of the bicomponent grout to form a circle, thus filling the surface voids with glass beads. The diameter of the circle was measured on four axes and the value averaged. This value was used to calculate the Mean Texture Depth (MTD) as follows:

$$MTD = \frac{4V}{\pi D^2} \qquad [2]$$

where V is the exact volume of glass spheres in ml, D is the average diameter of the sand patch in mm.

4. RESULTS AND DISCUSSION

4.1 Preliminary tests

The mechanical properties of the Flowmix Fast were preliminary investigated through a wide series of experimental tests, which were carried out on both fresh and hardened grout. These results are summarized in Table 2.

Table 2. Results of laboratory tests carried out on Flowmix Fast

Test	Value	Reference Standard
FRESH GROUT		
Air	≤10%	UNI EN 1015-7
Spreading	165 mm	UNI EN 1015-3
Setting start time	15 minutes	UNI EN 196-3
End of grip time	25 minutes	UNI EN 196-3
Fresh grout density	2050 kg/m^3	UNI EN 1015-6
HARDENED GROUT		
Hardened grout density	1900 kg/m^3	UNI EN 1015-10
Average flexural strength at 2 hours	≥ 1,0 N/mm^2	UNI EN 1015-11
Average compressive strength at 2 hours	≥ 4,0 N/mm^2	UNI EN 1015-11
Average flexural strength at 28 days	≥ 3,5 N/mm^2	UNI EN 1015-11
Average compressive strength at 28 days	≥ 18,0 N/mm^2	UNI EN 1015-11
Average resistance to adhesion after 28 days on concrete “f_u”	≥ 0,80 N/mm^2 - A	UNI EN 1015-12
Characteristic value of the initial shear strength "f_{v0k}"	≥ 0,30 N/mm^2	Tab.11.10.VIII NTC DM 17/1/2018
Water absorption by capillarity coefficient “C_m”	≤ 0,20 kg/(m^2 min^{0,5})	UNI EN 1015-18
Modulus of elasticity in compression “E”	≥ 16 GPa	UNI EN 13412
Shrinkage at 28 days	≤ 300 µm	UNI 8147 – B method

From the results shown in Table 2, It can be noted that the composite grout reveals a particularly fluid consistency, which is promising for use as monolithic backfilling of mini and mini-micro-trenches, ensuring adequate protection of the telecom infrastructure. Furthermore, by quickly setting and hardening, the product might assure fast repairs on road pavements, making possible the opening to traffic within 2 hours from casting. Accordingly, are to be stressed also the great mechanical performance achieved in two hours from casting, both in terms of compressive and flexural strengths. Low values of water absorption by capillarity are likely due to the presence of the bituminous binder into the grout. Finally, Flowmix Fast shows an expansive behaviour to ensure compensated shrink.

4.3 Microtexture and macrotexture tests

In accordance with UNI EN 13036-4 (European Committee for Standardization, 2012), two laboratory manufactured slabs were tested to evaluate the skid resistance of the Flowmix Fast. The experimental program based on a wide series of pendulum tests carried out on each slab following the same testing pattern. As shown in Figure 6a, skid resistance tests were executed about 5 cm far from each edge of the slab, setting the pendulum tester to half of its width. The same sliding direction (“A”) was followed testing each edge. After testing all the edges, the opposite sliding direction (“B”) was investigated, shifting few centimetres the pendulum setting position so as to avoid testing the same contact area repeatedly. Results of five swings and PTV value are summarized in Table 3 at each test position.

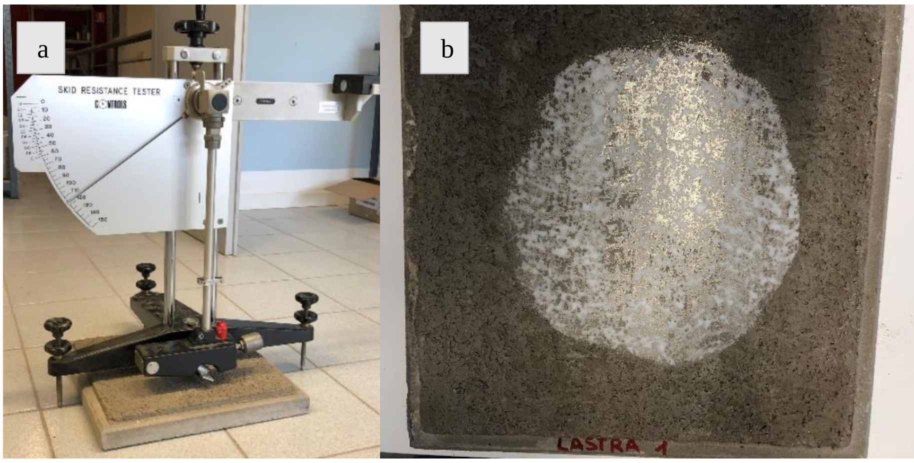

Figure 6. British pendulum test set up (a); MTD measurement (b).

Table 3. British pendulum test results

SLAB “1”														
Edge	**Sliding direction**	**Swing**					**PTV**	**Sliding direction**	**Swing**					**PTV**
		1	**2**	**3**	**4**	**5**			**1**	**2**	**3**	**4**	**5**	
1	A	69	67	68	67	68	**68**	B	64	64	67	64	64	**65**
2	A	70	67	65	65	65	**66**	B	66	66	65	65	65	**65**
3	A	71	70	70	69	69	**70**	B	64	67	63	63	67	**65**
4	A	68	66	65	64	64	**65**	B	67	66	65	65	65	**66**
SLAB “2”														
Edge	**Sliding direction**	**Swing**					**PTV**	**Sliding direction**	**Swing**					**PTV**
		1	**2**	**3**	**4**	**5**			**1**	**2**	**3**	**4**	**5**	
1	A	72	71	71	70	70	**71**	B	73	73	70	70	70	**71**
2	A	66	66	65	65	64	**65**	B	66	65	64	64	64	**65**
3	A	71	71	70	70	70	**70**	B	74	71	70	70	70	**71**
4	A	70	69	68	68	68	**69**	B	72	71	69	69	69	**70**

The overall data reveal a great homogeneity in PTV values with reference to tested slabs, positions, and directions. Such values ranged from 65 to 71. In order to perform a comparative analysis among manufactured slabs, mean PTV values were calculated based on sliding direction. Accordingly, the first slab shows PTV mean values equal to 69 and 67 along A and B sliding directions, respectively, while the second slab provids the same PTV mean value of 71 along both directions. Thus, both replicates yield similar results. With reference to PTV minimum values (PTV≥60) on wearing course layers according to Italian technical standard (Centro Sperimentale Interuniversitario di Ricerca Stradale, 2001), results gathered on Flowmix Fast are satisfactory.
As shown in Figure 6b, on the same slabs MTD values were calculated through Eq. 2 in compliance with UNI EN 13036-1 (European Committee for Standardization, 2010). Measurements were carried out both before and after the British pendulum test campaign. Thus, the possible wearing effect provided by the pendulum slider was investigated as well. MTD results are summarized in Table 3.

Table 4. Volumetric patch test results

Slab ID	MTD 1st test	MTD 2nd test	Decrease (%)	MTD Mean value
1	0.57	0.50	12	0.54
2	0.51	0.50	2	0.51

Experimental results highlight a reduced effect of the British pendulum test campaign on MTD values, which show a decrease of 12% and 2% on slab 1 and 2, respectively. The overall results are comparable among tested replicates and are greater than macrotexture requirements (MTD≥ 0.4mm) provided by Italian technical standard for wearing course layers (Centro Sperimentale Interuniversitario di Ricerca Stradale, 2001).

4.3 Indirect tensile strength test

The indirect tensile test was carried on all investigated samples. When the procedure was applied to CMT or MMT specimens, the vertical loading direction was set along the interface between asphalt concrete and Flowmix Fast. Testing set up is shown in Figure 7.

Figure 7. ITS set up for MMT sample.

Tables 5, 6 and 7 summarize ITS results and specimens' dimensions (i.e., thickness and diameter) for CP, CMT and MMT samples, respectively. The tables report the results with reference to the type of asphalt concrete mixture which made up the sample, namely wearing course or binder course blends.

Table 5. ITS results on CP specimens.

ID	t (mm)	d (mm)	ITS (MPa)	ID	t (mm)	d (mm)	ITS (MPa)
CPu-1	45.54	123.30	1.00	CPb-1	42.98	123.30	0.69
CPu-2	45.31	123.30	0.98	CPb-2	45.78	123.30	0.75
CPu-3	42.91	123.30	0.94	CPb-3	45.73	123.30	0.78
CPu-4	43.74	123.30	1.12	CPb-4	44.78	123.30	0.72
CPu-5	45.62	123.30	1.10	CPb-5	42.03	123.30	0.64
CPu-6	44.25	94.70	1.00	CPb-6	46.70	94.70	0.76
CPu-7	48.19	94.70	1.14	CPb-7	41.33	94.70	0.85
CPu-8	44.92	94.70	1.15	CPb-8	44.80	94.70	0.83

Table 6. ITS results on CMT specimens.

ID	t (mm)	d (mm)	ITS (MPa)	ID	t (mm)	d (mm)	ITS (MPa)
CMTu-1	47.27	94.70	0.47	CMTb-1	46.41	94.70	0.7
CMTu-2	44.99	94.70	0.45	CMTb-2	47.54	94.70	0.57
CMTu-3	44.82	94.70	0.75	CMTb-3	46.99	94.70	0.56
CMTu-4	45.34	94.70	0.69	CMTb-4	47.55	94.70	0.62
CMTu-5	47.63	94.70	1.12	-	-	-	-

Table 7. ITS results on MMT specimens.

ID	t (mm)	d (mm)	ITS (MPa)	ID	t (mm)	d (mm)	ITS (Mpa)
MMTu-1	45.51	123.30	0.77	MMTb-1	46.93	123.30	0.98
MMTu-2	48.44	123.30	0.85	MMTb-2	45.89	123.30	0.91
MMTu-3	46.04	123.30	0.66	MMTb-3	46.72	123.30	0.35
MMTu-4	47.59	123.30	0.85	MMTb-4	48.90	123.30	0.63
MMTu-5	46.15	123.30	0.78	MMTb-5	49.11	123.30	0.67
MMTu-6	42.50	123.30	0.73	MMTb-6	47.23	123.30	0.41

Results provided by different samples and assessed based on reference layer (i.e. wearing course or binder course) generally show satisfactory repeatability, as testified by coefficients of variation (CV) lower than 0.1. Great CV values for CMTu and MMTb samples are determined. In particular, CV values equal to 0.39 for both these samples were computed.

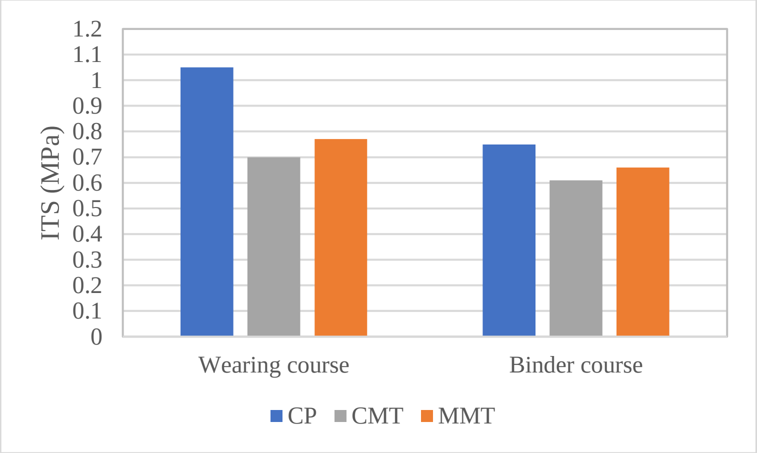

Figure 8. ITS average values for tested samples

In order to provide a comparative analysis among investigated samples, ITS values were averaged as shown in Figure 8. From the figure it can be noted that CMT and MMT samples, as expected, reveal lower ITS values at the interface than CP ones. With reference to wearing course layer, the percentage decreases of CMT and a MMT samples in comparison with CP samples are equal to 34% and 26%, respectively. Similarly, when the binder course application is considered, these percentage decreases result equal to 19% and 13%, respectively. Thus, composite samples from the binder course layer, show a small decrease of ITS values in comparison with those provided by the existing pavement. Concerning the greater ITS reduction observed on composite samples from the wearing course layer, it is to be stressed that ITS average values of CMTu and MMTu samples however comply with minimum requirements of Italian technical standard (ITS≥0.60) for asphalt concrete pavements (Centro Sperimentale Interuniversitario di Ricerca Stradale, 2001).

Finally, it is to be observed that MMT samples yield higher ITS values than CMT ones. Such occurrence might be due to the coring activities on mini and micro-trenching systems, whose adhesion at the interface might be affected by the noticeably vibrations induced by the coring process.

5. CONCLUSIONS

In this paper, a new technology for mini-micro-trenching applications, was studied. These applications, which do not need to disrupt traffic, lower both social and environmental impacts in comparison with standard trenching systems. The investigated technology based on the use of a bituminous-cementitious grout (Flowmix Fast) as backfilling material. This composite material combines the prerogatives and peculiarities of the two components, providing semi-flexible behaviour and strength. The following conclusions can be drawn from the presented results:

- The bituminous-cementitious grout shows a fluid consistency, which is promising for use as monolithic backfilling of mini and micro-trenches, ensuring adequate protection of the telecom infrastructure. Furthermore, by quickly setting and hardening, the product might assure fast repairs on road pavements. Such behaviour is confirmed by noticeably mechanical performance after two hours from casting, both in terms of compressive and flexural strengths.
- Surface performance of the material results valuable both in terms of microtexture and macrotexture. Accordingly, PTV and MTD experimental values higher than 65 and 0.50 respectively, were obtained. Based on reference values provided by Italian technical standard for asphalt concrete wearing courses, collected data are satisfactory.
- The adhesion properties at the interface of the existing pavement – mini and micro-trenching systems were evaluated in terms of ITS on both CMT and MMT samples. Samples from binder course layer, show a slight decrease of ITS in comparison with existing pavement performance. Otherwise, the decreases observed with reference to the wearing course layer range from 34% to 26% based on type of tested sample. However, ITS values gathered testing CMTu and MMTu samples comply with minimum requirements of Italian technical Standard for asphalt concrete pavements.

In conclusion, from this study on Flowmix Fast as backfilling material for mini-micro-trenching applications, promising surface and interface adhesion properties were observed. Future development of the research will focus on the adhesion properties of the grout, testing the interface under repeated dynamic loads.

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