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SERIES L: ENVIRONMENT AND ICTS, CLIMATE CHANGE, E-WASTE, ENERGY EFFICIENCY; CONSTRUCTION, INSTALLATION AND PROTECTION OF CABLES AND OTHER ELEMENTS OF OUTSIDE PLANT

Optical fibre cables – Guidance and installation technique

Low impact trenching technique for FTTx networks

Recommendation ITU-T L.155

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ENVIRONMENT AND ICTS, CLIMATE CHANGE, E-WASTE, ENERGY EFFICIENCY; CONSTRUCTION, INSTALLATION AND PROTECTION OF CABLES AND OTHER ELEMENTS OF OUTSIDE PLANT

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Recommendation ITU-T L.155

Low impact trenching technique for FTTx networks

Summary

With the miniaturization of the telecommunication infrastructure, i.e., with mini-ducts and mini-cables, it has been possible to use a low impact trenching technique to carry out all the steps of the network construction in a single day, in a less invasive way in terms of time and space, and with a smaller construction site than for the previous trenching technologies. Recommendation ITU-T L.155 describes this trenching technique, which allows the easy installation, in narrow trenches, of underground optical cables and mini-cables in ducts or mini-ducts or directly buried. This type of narrow trench allows the use of reduced dimension machinery in small-sized roads, typically those in cities, producing a lower quantity of waste material and so should be used in urban areas. This technology is mainly characterized by the simultaneous work of a suction machine and a trench saw, which allows for the possibility of opening and closing the work site the same day.

History

Edition	Recommendation	Approval	Study Group	Unique ID*
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Keywords

Environmental low-impact, FTTx network, reduction, urban trenching technique.

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The World Telecommunication Standardization Assembly (WTSA), which meets every four years, establishes the topics for study by the ITU-T study groups which, in turn, produce Recommendations on these topics.

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Low impact trenching technique for FTTx networks

1 Scope

This Recommendation:

- gives advice on general requirements of the main phases in which the work can be divided;
- gives advice on the methods and procedures for performing the work;
- gives some application criteria;
- describes situations where a low impact urban trenching technique is recommended.

2 References

The following ITU-T Recommendations and other references contain provisions which, through reference in this text, constitute provisions of this Recommendation. At the time of publication, the editions indicated were valid. All Recommendations and other references are subject to revision; users of this Recommendation are therefore encouraged to investigate the possibility of applying the most recent edition of the Recommendations and other references listed below. A list of the currently valid ITU-T Recommendations is regularly published. The reference to a document within this Recommendation does not give it, as a stand-alone document, the status of a Recommendation.

[ITU-T L.260] Recommendation ITU-T L.260/L.84 (2010), *Fast mapping of underground networks*.

3 Definitions

3.1 Terms defined elsewhere

None.

3.2 Terms defined in this Recommendation

This Recommendation defines the following term:

3.2.1 urban trenching technique: It is characterized by a width of maximum 5 cm and typically a depth of maximum 30 cm.

4 Abbreviations and acronyms

This Recommendation uses the following abbreviations and acronyms:

FTTx Fiber To The x, where 'x' stands for the final location on the end-user side

GPR3D Ground Penetration Radar 3 Dimensions

NGN Next Generation Network

5 Conventions

None.

6 The urban trenching cable-laying technique

The urban trenching technique should be applied especially in urban areas, where car traffic and shop presence is very high and on routes that generally involve asphalted surfaces such as roads and sidewalks with a base of compact material (asphalt or concrete).

It is not recommended that the technique be used on routes where the soil subgrade is sandy, gravelly or contains medium-sized cobbles (i.e., measuring 10 to 20 cm in diameter).

The main advantages of this technique over traditional cable-laying technologies are the very small obstruction of the road and the low impact on traffic due to the road construction site cleaning, the immediate removal of debris and the quickness of opening and closing the road construction site.

The urban trenching technique is normally carried out by simultaneously cutting through the paving and digging a trench whose depth and cross-section vary in accordance with the number of ducts to be laid: depth is ≤ 30 cm, while cross-section can be ≤ 5 cm. In order to guarantee a protection against impact resulting from road-repairing, the depth of the laid infrastructure should be maintained constant at a known level that should be 5 cm deeper than the foreseen asphalt cutting depth normally specified for road surface repair works. Figure 1 shows some possible duct and mini-duct installation configurations that can be used.

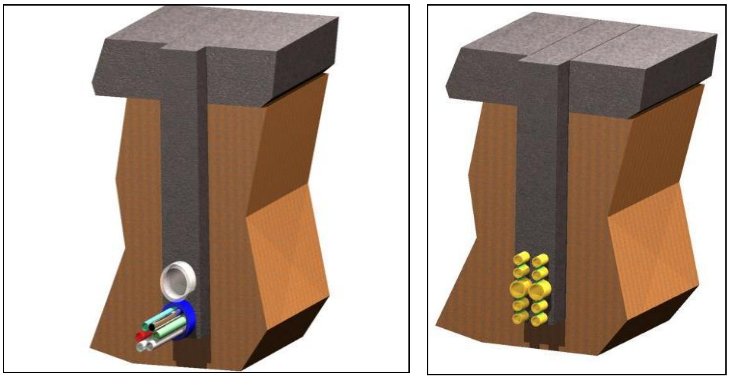

Figure 1 – Examples of urban-trenching duct installation configuration

Any crossings through unpaved sections (which should in any case have a compact subgrade) should be carried out using the same technique.

6.1 Preparatory step

Generally, a detailed survey of the route should be carried out, the purpose of which is to identify the work required to be done before starting cable installation operations. Such work could include, for instance, the preparation at bridges, or at road or rail crossings. Further, it is necessary to determine closure locations and section ends.

The location of all underground utilities should be determined in order to establish the correct route for the trench. This is normally accomplished by means of cartographic documentation provided by the administrations that own the road or by the utility company, and/or through instrumented field surveys. The detailed utilities investigation should be made with the ground penetration radar 3 dimensions (GPR3D) fast solution technique [ITU-T L.260].

The designed route should be free from sharp changes in direction. Where such changes are unavoidable, they should be made by means of cuts angled so as to comply with the minimum bend radii specified for the ducts and cables.

Where necessary, the contractor can take core samples along the planned route to determine the type of subsoil or as a further method of checking for obstacles. A GPR3D fast solution should be used in order to detect ground characteristics [ITU-T L.260].

6.2 Excavation requirements

The following requirements should be observed in cutting while applying the urban trenching technique:

- comply with all provisions and regulations established by the administrations involved as regards excavation permits, schedules, etc.;
- place the barriers and road signs required by current legislation, regulations and the administrations involved, in clearly visible locations around the excavation site.

Generally, the site is opened and closed during the same day, so the excavation should not remain open during the night.

6.3 Working phases for laying the infrastructure or cables

All the construction activities should be split in separate operational steps involving subsequent phases (Figure 2). This synergism should allow:

- flexible use of smaller machines;
- reductions of time and space occupancy.

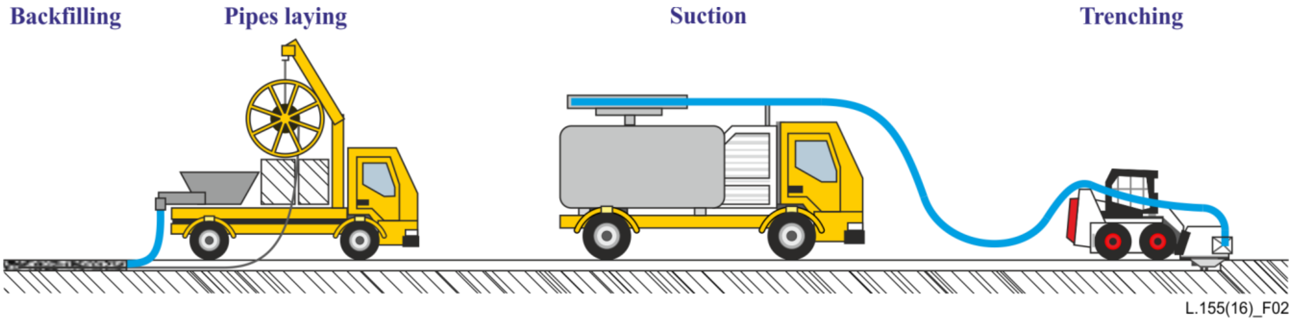

Figure 2 – Daily reduced trenching technique logical scheme

6.3.1 Simultaneous trenching dig phase and cleaning phase

It is recommended that the urban trenching technique be characterized by the simultaneous work of the trench saw and the suction machine. This combined action should allow the waste material to be collected while produced by the saw, leaving the site clean immediately after the end of the trenching phase and completely removing dust problems.

6.3.1.1 Trenching dig phase

The urban trench should be made using a small size saw disk, mounted on small dimension operating machines. The trenching cut should not damage the urban road pavement near the dig section. The saw should be inside a protective carter connected via a flexible tube to a vacuum pump installed on the suction machine.

6.3.1.2 Spoil suction phase

The debris suction and the digging phase should be performed simultaneously in order to accelerate the trench cleaning action.

Spoil should be transported to authorized disposal sites in accordance with current local laws. The trench cleaning shall be made with automated methods in order to avoid or limit troubles to people and environmental pollution.

At the end of this phase, the trench cross-section should be completely free of stones and the bottom of the trench should be clean. The trench and the near zones should be completely clean of debris that could reduce the backfilling material features.

6.3.2 Ducts or cable laying

The reel can be mounted aboard a machine subsequent to the saw, so that the duct(s) or cable can be automatically fed into the trench, via a suitably shaped guide integrated into the ploughshare, as the excavation proceeds.

The equipment and procedures used for this purpose should guarantee that:

- initial duct or cable configuration and position in the urban trenching technique are maintained along the entire route unless special circumstances dictate otherwise;
- if obstacles or situations are encountered which make it impossible to proceed with the urban trenching technique, the reel (and thus the ducts or the cable) can be removed from the machine without having to cut the ducts, thus ensuring that cable deployment can be continued using conventional methods without performing splices that are unnecessary from the technical standpoint.

6.3.3 Backfilling phase

After the ducts, mini-ducts or cables are installed, the trench should be backfilled with a highly resistant and fast-hardening material. The trench backfilling shall be made with rapid cement mortar casting. The mortar should be quick setting, with fluid consistency, containing cement with high strength, selected aggregate and special additives. Bitumen material shall be avoided. The backfilling material should have particular features in order to assure vehicle traffic restoration within two to four hours and it shall present high compatibility with mechanical and visual characteristics of existing pavement surface.

6.3.3.1 Mortar features

The cement mortar should have the following features:

- high compressive strength (> 50 N/mm^2), better than jet concrete (30 N/mm^2) and similar to precast concrete, in order to protect the infrastructure below;
- slip resistance similar to that of asphalt (60) – [b-BS EN 1340:2003];
- it should undergo controlled shrinkage in order to adhere to trench walls with sufficient coupling ("silos" effect);
- intrinsic fluidity of the material in order to fill completely the trench;
- high resistance to thermal variation, above all to frost and thaw cycles;
- easily removable, in case of pavement resurfacing, without causing damage to the infrastructure.

6.4 Identification

The urban trenching technique should not need any kind of identification, because the backfilling material laying is just an identification element for the new infrastructure.

6.5 Resurfacing

The urban trenching technique should not need pavement resurfacing. That should be achieved with backfilling material, both on the road and on the sidewalk. At the end of the activity there should not be cracks, steps or smear. The new pavement colour should be similar to the current one.

6.6 Maintenance

The maintenance of buried cables and ducts should be performed with the same techniques and tools as for normally buried infrastructures because the backfilling concrete mortar should be easily removable.

7 Daily urban trenching methods and procedures

The debris suction phase and the cutting phase should be executed at the same time. All phases described in clause 6.3 should be subsequent, but if the environmental conditions, like urban traffic, are very hard, or because of administration prescriptions allowing only limited site lengths, suction/digging phases and pipes laying/backfilling can be made at different times.

8 Daily urban trenching application criteria

Some criteria for specific applications of the urban trenching technique are given in the following clauses.

8.1 Entry to existing manholes or chambers

Connection to an existing prefabricated structure such as a manhole, pit or chamber should be accomplished by means of a conventional excavation approximately 2 m long and dropping gradually from the urban trenching technique to points of access to the prefabricated structure in such a way as to comply with minimum duct or cable bend radii requirements. Ducts and cables should enter the prefabricated structure at a suitable distance (e.g., 20 cm) from the structure's interior floor. Ducts should be secured with cement mortar on both the internal and external sides of the prefabricated structure. Inside the prefabricated structure, individual ducts should be separated and located at a horizontal distance of some centimetres (e.g., 3-4 cm from each other) and they should protrude (e.g., 15-20 cm) inside the prefabricated structure. Once ducts have been terminated in the prefabricated structure, the latter should be surfaced and smoothed.

8.2 Road crossings

New road crossings should be cut using the same methods envisaged for lengthwise excavations. Where existing conventional type road crossings are used (e.g., with ducts located at a depth of approximately 1 m from the road surface), the two different depths should be joined by an excavation which drops gradually for a length of at least 2 m, complying with the minimum bend radii (see clause 8.1). In case of crossing, any cables should be protected with appropriate ducts along the whole crossing length.

9 Practical rules for the correct realization of micro-trenches

The following practical rules for the correct realization of micro-trenches within the road pavements are recommended:

- in general road pavements designed and constructed using standard practices ensure better performance of the system, in terms of the stress levels induced by the vehicles in transit both on the micro-trench filling material and at the micro-trench/pavement interface;
- heavy vehicles in transit may induce stress variations on the micro-trench filling material and at the micro-trench/pavement interface only when the wheels of the vehicles are located within a zone of impact within 0.5 m of the micro-trench. Therefore, the most recommended position for the micro-trench is the one that maximizes the distance between the micro-trench itself and the vehicle tire tracks. In practice, this translates into the following options:
  1) positioning the micro-trench at the centerline of the lane;
  2) positioning the micro-trench on the lateral margin of the outer driving lane (often under the line marking the outer edge of the driving lane) if the lane is wide enough to ensure an adequate distance between the outer wheels of the vehicle and the edge of the carriageway (at least 0.5 m). This option limits the visual impact of the micro-trench. If the roadway is on an embankment, this solution allows use of the micro-trench filling material as a containment element at the outer side of the embankment.

These options are illustrated in Figure 3.

Figure 3 – Examples of micro-trench positioning

Appendix I

Italian experience regarding "one day" reduced mini trench

(This appendix does not form an integral part of this Recommendation.)

The capabilities of realizing new infrastructures with lower environmental impact, and the tendency to use digging technologies less invasive in terms of time and space of road occupation and restoration, have driven network construction technologies towards the miniaturization of primary elements. In Italy, an innovative approach is developed to carry out all steps of the network construction, for fiber to the x, where 'x' stands for the final location on the end-user side (FTTx) applications, in a single day, with big advantages in terms of environmental and social costs.

In order to overcome all the problems caused by traditional digging technologies, each step of the process has been analysed. Thanks to the simultaneous and synergic use of a trench saw and a suction pump, the digging work can be completed very quickly, with reduced-dimension machinery, and with no residual material to be removed. The last element of this solution is the innovative material used to fill in the trench, with a very fast hardening time to allow to complete the work in a few hours, restoring the pavement to the previous state. This technique allows opening and closing digging works in only one day.

With a global approach, the problem of working downtown is traduced into an effort of reducing whole critical dimensions related to the usual trenching machines, beginning with trench dimensions.

This kind of new trenching technique is characterized by a maximum width of 5 cm and a maximum depth of 30 cm.

The true innovation during the trenching phase is the simultaneous operation of a powerful suction machine and a trench saw, as shown in Figure I.1.

Figure I.1 – Trench saw combined with suction machine

This combined action allows the waste material to be collected as it is produced by the saw, leaving the site clean immediately after the end of the trenching phase and completely removing dust problems. Figure I.2 shows clearly the cleaning of the site and inside the trench.

Figure I.2 – Cleaning of the site and inside the trench

Another important innovation is related to pavement re-establishment. According to traditional techniques, the trench is normally filled with excavated material and binder on top, and finally a layer of pavement is posed. With traditional technologies, pavement can be restored only after the backfilling material is ready and usually it takes at least 24 hours.

With the new Italian trenching system, thanks to an innovative material which has mechanical and esthetical characteristics similar to the pavement, the trench is completely filled in one operation and with just one material. Moreover, the fast hardening time, main characteristic of this material, allows the closure of the working site in just a few hours (Figure I.3).

Figure I.3 – Innovative material before and after hardening completed

Due to the behaviour of this innovative material, the site can be opened to the traffic just a couple of hours after the filling. Its physical and mechanical characteristics, combined with the esthetical result, avoid laying of the asphalt carpet, reducing operating phases and troubles for citizens.

A new mixing machine adapted to the type of material has been developed (Figure I.4). The mixing machine features, which can be installed on ordinary trucks, several solutions optimal for trench filling while keeping the site clean.

Figure I.4 – The mixing machine

The whole system can thus be divided into two different modules: the first, which will perform the trenching phase, is composed by the saw and the suction machine; the second, which will perform re-establishing phase, is composed by one truck with the mixing machine. These two modules can work in line or at different times/places, allowing major flexibility, but anyway guaranteeing a better solution.

The new Italian reduced trenching technique has introduced a new point of view on trenching techniques, turned into a less invasive way. Due to the combined use of innovative instruments and materials, the construction site (of very reduced dimensions) can be opened and closed in a single day of work, thus minimizing the impact for the community. Examples of these new trenching sites, on the road and on the sidewalk, are shown in Figures I.5.a and I.5.b, respectively. In these pictures a site in an urban area of Milan is shown, as well as the advantages of the new digging technique with respect to the traditional one, as discussed above.

Figure I.5 – The new digging technique at a worksite in an urban area of Milan

Appendix II

Effect of micro-trenches on road pavements

(This appendix does not form an integral part of this Recommendation.)

II.1 Scope

The goal of this work is to present a proposal to define the best technological characteristics and features for micro-trenches in terms of the location of the micro-trench with respect to the road layout and types of filling materials. This proposal is based on a specific numerical analysis study to evaluate the stress changes that may occur on the road pavement upon construction of the micro-trench structures.

II.2 Study for the optimization of the performance of micro-trench/pavement system

The effect of the realization of a micro-trench on the roadway can be optimized by taking into account three aspects that affect the performance of the micro-trench/pavement system:

1) type of the road pavement;

2) position of the micro-trench with respect to the vehicle tire tracks;

3) type of micro-trench filling material.

In the following clauses, they are separately described.

II.2.1 Type of the road pavement

A typical asphalt road construction is multi-layered in form, comprising bitumen-bound and unbound materials. However, In Italy, the experience gained working on site with completed micro-trenches, showed that in urban areas, road pavement could vary significantly. The effect of the presence of a micro-trench on the pavement response depends on the type of roadway layers. In particular, the following were considered, as all of them have been found during the construction of micro-trenches in urban areas: P1) consists of an asphalt layer of 5 cm above the natural soil; P2) consists of an asphalt layer of 5 cm over an unbounded road base of 25 cm, above the natural soil; P3) consists of an asphalt layer of 5 cm, over a binder asphalt of 10 cm, over an unbounded road base of 15 cm, above the natural soil.

The goal was to identify the most vulnerable roadway types during the construction of micro-trenches and to minimize the potential extent of damage on them.

II.2.2 Position of the micro-trench with respect to vehicle tire tracks

Due to different stiffness of road pavement materials and of the micro-trench filling mixtures, the presence of the latter can give rise to stress concentrations in the vicinity of the vertical surfaces at the contact surface between the pavement and micro-trench, during vehicles' transit. Such concentrations are identified as the possible cause of the progressive deterioration of the road surface and of the filling material. The magnitude of these effects is related to the geometrical relationship between the depth of the micro-trench and the distance of the micro-trench from the load application on the road surface (i.e., wheel-pavement contact area). If the vehicles are circulating sufficiently far from the micro-trench, or if the area of influence of the moving load is located outside the excavation area, then, the variations of the stress state are negligible. It is important to assess quantitatively the extent of the area of impact of the loads transmitted by vehicles driven on the roadway, alongside the amount of stress concentrations produced at the micro-trench/pavement contact surface.

The goal was to establish practical rules for the correct positioning of the micro-trench with respect to the road lanes, and therefore to the distance of the micro-trench from the vehicles' tires. In particular, three possible positions of the micro-trench were considered (see Figure II.1): G1) micro-trench placed at the centerline of the lane; G2) micro-trench placed under the tires of vehicles in transit; G3) micro-trench placed in proximity of one of the tires of the vehicles in transit.

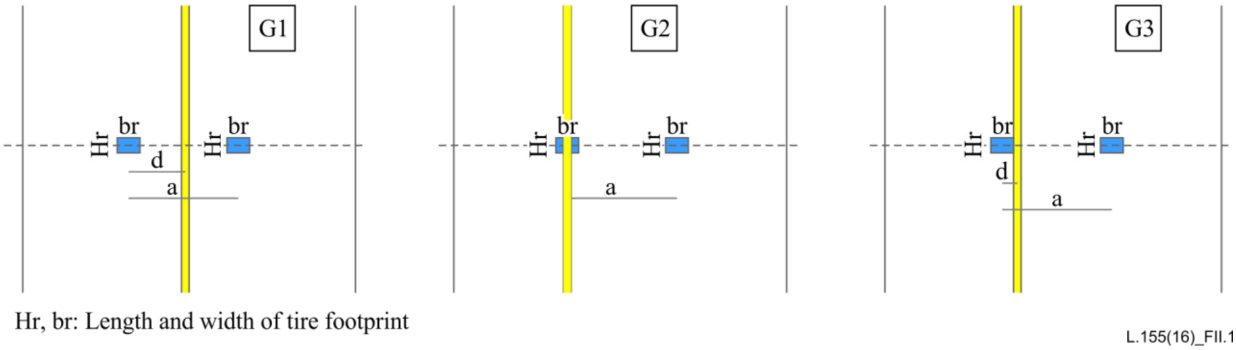

Figure II.1 – Positions considered for the construction of a micro-trench

II.2.3 Types of micro-trench filling material

Stiffness variations between the micro-trench filling materials and the road paving materials may produce stress concentrations at the micro-trench/pavement contact interface.

The goal was to identify the type of filling material that minimizes such stress concentrations on the roadway, and, therefore, minimizes the potential extent of damage. In order to achieve this goal, four types of filling materials for micro-trenches were considered: R1) micro-trench entirely filled with special mortar; R2) micro-trench filled with special mortar and with modified asphalt for the remaining 5 cm to the road surface; R3) micro-trench entirely filled with modified asphalt; R4) micro-trench filled with gravel and with modified asphalt for the remaining 5 cm to the road surface.

II.2.4 A 3D finite element model for evaluating the performance of the micro-trench/pavement system

In order to evaluate the performance of the roadway pavement after the realization of a micro-trench, a 3D finite element modelling study was carried out, considering a portion of a roadway lane with known mechanical and geometrical characteristics (Figure II.2).

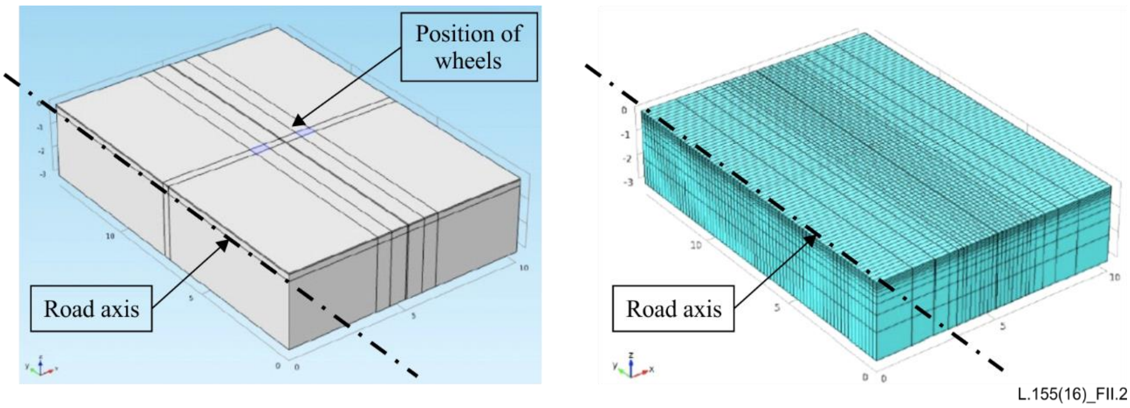

Figure II.2 – Portion of roadway lane considered and meshed domain

For the traffic loads, the following variables were considered: ordinary vehicles and heavy vehicles (e.g., trucks); speed conditions within the limits required by traffic laws; straight and curved roadway geometries; ascent and descent conditions (simulating acceleration and deceleration).

The numerical analyses were focused on identifying the design strategies in the realization of micro-trenches to minimize the probability of failures and cracking of the road surface.

Examination of the results enabled identification of the most critical conditions for the road pavement according to the type of road material layers, type of filling materials and trench positions relative to the location of the vehicle tire tracks.

II.2.5 Summary of results

The effects of the various conditions considered in the numerical analysis study are summarized in the following clauses and reported in Table II.1.

II.2.5.1 Types of road pavement

Considering the three types of road pavement layers (P1, P2 and P3), the micro-trench entirely filled with the R1 material (special mortar), and the three geometrical conditions for the position of the micro-trench (G1, G2 and G3), the general performance of the micro-trench/pavement system was found to improve from the pavement type P1 to P3. Therefore, it was concluded that roadways with pavement layers that are similar to the standards imposed by Italian Technical Regulation are less vulnerable, as might be expected.

II.2.5.2 Position of the micro-trench with respect to the vehicle tire tracks

The areas of impact of the load transmitted from the tires to the roadway are relatively narrow, only a little wider than the actual areas of the tire footprint; consequently, the stress increments are concentrated in the immediate vicinity of the tire itself.

Thus, the geometry G2 (micro-trench under the wheel) can be indicated as the most critical one for the possible phenomenon of failure involving the filling material. The geometry G3 (micro-trench next to the lateral border of the load area) can be indicated as the most critical one for the phenomenon of detachment along the vertical contact plane between the pavement and the micro-trench. It is possible to conclude that the most recommended position for the micro-trench is G1, in which the micro-trench is located sufficiently far from the vehicles' wheels.

II.2.5.3 Type of micro-trench filling material

The problems related to the increase of shear and tensile stresses are located in a very shallow area of the micro-trench (with a thickness lower than 5 cm). The replacement of the first 5 cm of excavation with filling material characterized by a more ductile and deformable behavior (such as modified asphalt) allows the reduction of stress concentrations on the micro-trench, with a positive effect on the overall behavior of the system.

Table II.1 – Technical recommendations for minimizing the impact of micro-trench construction on a roadway

	Considered Condition	Highly Recommended	Recommended	Not Recommended
Pavement layers	P1: Asphalt above natural soil		X	
	P2: Asphalt layer (5 cm)+unbounded road base (25 cm)+natural soil		X	
	P3: Asphalt layer (5 cm)+binder asphalt (10 cm)+ unbounded road base (15 cm)+natural soil	X		
Filling material	R1: Special mortar		X	
	R2: Modified asphalt + special mortar	X		
	R3: Modified asphalt	X		
	R4: Modified asphalt + gravel	X		
Micro-trench position	G1: Centerline of the road lane	X		
	G2: At the bottom of a vehicle's wheel			X
	G3: Close to a vehicle's wheel			X

II.3 Effects of thermal strains on the performance of the micro-trench/pavement system

It is well known that in the presence of significant temperature variations on the pavement surface, the roadway is subject to phenomena associated with thermal expansion/contraction. Therefore, a specific study has been devoted to understand if the presence of an inclusion of material within the pavement, with different thermo-mechanical behavior, can give rise to differential deformation at the contact interface between micro-trench and the pavement, and, thus the onset of tensile stresses that can eventually cause cracks and damage on the road surface.

To quantitatively assess the extent of these effects, a series of numerical analyses have been conducted in parametric form at the variation of the thermal conditions imposed on the surface of the pavement and of the characteristics of conductivity and thermal expansion of the materials. In particular, this was obtained by varying the relationships between: i) the coefficient of thermal expansion of the pavement and of the micro-trench filling material; ii) thermal conductivity of the pavement and of the micro-trench filling material; iii) stiffness of the pavement and of the micro-trench filling material.

II.3.1 Technical guidance to minimize thermal effects

In the presence of a micro-trench entirely filled with material of R1 type (special mortar), differential thermal strains were observed, due to the higher stiffness of the mortar with respect to the one of the pavement materials. However, this effect was localized at the most superficial part of the pavement for a depth that does not exceed 5 cm.

The substitution of the first 5 cm of the filling material with modified asphalt (which is characterized by mechanical characteristics more similar to those of the pavement upper layers) allowed complete elimination of the horizontal stress increments due to the differential thermal strains.

II.4 Effects of the micro-trench on the drainage conditions of the roadway

In principle, a micro-trench installed parallel to the roadway, on the outer side, could be a barrier to water drainage towards the outside of the carriageway. This phenomenon may be significant in the presence of pavings realized with draining pavement, where the layer of draining asphalt is characterized by a hydraulic conductivity greater than that of the mixtures used as filling materials.

To quantitatively assess the impact of the presence of a micro-trench on the pore pressure regime and on the velocity of seepage within the road pavement, a specific study was performed by varying: i) the relationship between the depth of the micro-trench and the surface of the drainage layers; ii) the relationship between the hydraulic conductivity of the micro-trench filling materials and of the drainage layers; iii) the boundary conditions imposed at the road surface (e.g., rainfall rate).

II.4.1 Technical guidance to improve drainage conditions

The results of the study demonstrated that positioning the micro-trench on the outer side of the lane did not induce any appreciable change in the conditions of drainage of the pavement, even for the case of fully waterproof filling material for the entire thickness of the micro-trench since the seepage takes place predominantly in the vertical direction.

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