The Damage of an Asphalt Mortar Highway Rest Area Truck Parking

Christian Paglia *, Michele Paderi, and Cristina Mosca

University of Applied Sciences of Southern Switzerland, DACD, Mendrisio, Switzerland
Email: christian.paglia@supsi.ch (C.P.); michele.paderi@supsi.ch (M.P.); cristina.mosca@supsi.ch (C.M.)
*Corresponding author

***Abstract*—The viscous-elastic, ductile and flexible nature of asphalt pavements promote their extensive worldwide use. Nonetheless, some pavement sections are largely subjected to shear stresses and still loads. Consequently, a higher stiffness of the surface layer is required. In this concern, macro voids enriched asphalt pavements are filled with mortar to increase the rigidity. In this work, a mortar percolated asphalt surface layer was placed in a rest area truck parking to resist the high loads. Visual and optical inspections, compressive strength, freeze / thaw resistance, thermal dilatation and the microstructure were investigated. The lack of percolated mortar complete filling of the asphalt macro voids caused extensive cracking and rutting. Wide crack openings went down through the asphalt layer. The compressive strength and the resistance to frost complied with the normative regulations and exhibited a relatively high resistance, while the lowest tensile strengths and rupture were measured within the poorly percolated mortar layer. The microstructure exhibited variable adhesion at the interfaces, with a frequent presence of porosities also occasionally within the asphalt layer.**

***Keywords*—pavement, asphalt, mortar, cracking, rutting**

I. Introduction

Asphalt pavements are of common use in the construction sector. The riding comfort, the grip and the noise reduction possibilities are only a few advantages of such roadway systems. Nonetheless, the increasing amount of traffic, the load frequency and the chemical changes in the bituminous binders as well as the recycling and the combination of old stiffened bituminous RAP with new soft bituminous materials and rejuvenators [1] makes the durability of asphalt concrete a major issue in the road construction. Fatigue, static, dynamic bearing loads and exposure to the atmospheric conditions, such as wind, sun irradiation, rain, humidity, Oxygen and temperature excursions largely influence the long-term behaviour [2–8].

The resilience of the layered road courses needs a particular attention with respect to the durability. Special roadway structures, such as roundabouts, bus stops and parking lots are subjected to high shear stresses. This also takes place along wide radius curvatures, where the vehicles can maintain a relatively high speed and exercise a high shear on the material.

Consequently, a major stiffness of the surface course is sometimes required to overcome and withstand horizontal shears, deformation and cracking. Vertical static loads are also a major issue with respect to the durability. This is especially observed in parking lots, where cyclic temperature variation and high loads may lead to premature rutting and/or cracking. In this concern, cement asphalt emulsion are investigated [9–11]. Water released form the demulsification may be available for cement hydration [12]. Water repellency and water requirement conflict of the two organic-inorganic materials may find an adequate steady-state [13]. Asphalt pavements produced with mortar filled macro voids are increasingly used to implement the surface durability of such structures. A micro mortar is generally percolated within the asphalt surface course and the rigidity of the surface is increased with respect to the flexibility of conventional asphalt pavements [14]. The surface is supposed to resist the horizontal and vertical shear stresses.

On the other hand, the mixture of cementitious with bituminous compounds must be done with care. The nature of both materials is different and their reciprocal interaction and bond need to be optimized. In addition, a reduction of the interface bond strength between the bituminous material and the stone aggregates may be a cause of damage [15]. Cement asphalt emulsion mortar composites must be applied with care with respect to the interaction between cementitious and bituminous systems and the presence of water [16]. In order to achieve its task with respect to the increased stiffness of the surface layer, an adequate compressive strength of mortar percolated asphalt layers must also attained. This may be reached by keeping the compressive strength properties above a required limit of 6 MPa [14].

In this work a rest area truck parking along a highway was investigated. A mortar percolated asphalt surface layer was applied. A special focus was given to the main mechanical properties and the durability. The cause of damage, i. e. cracking and rutting, was clarified.

Manuscript received February 8, 2024; revised March 2, 2024; accepted March 15, 2024; published November 21, 2024.

II. Experimental Procedure

The material and pavement type was prepared according to the standard SIA 252 [14] and need to withstand the solicitation type I. A visual and optical investigation was carried out. The main mechanical property, such as the compressive strength was measured on samples with 100 mm diameter and 50 mm height. Four samples of the upper mortar percolated layer and four samples of the underlying asphalt course were tested [17]. A main durability environmental parameter to be tested was the freeze / thaw behaviour. The resistance was measured on three cylindrical mortar percolated asphalt specimens with 100 mm diameter. The specimens were exposed to freeze / cycles up to 28 times in the temperature range from –15ºC to 15ºC [18]. The thermal dilatation was measured on 100 mm diameter whole system samples, by increasing the temperature up to 30ºC, 40ºC and 60ºC for 24 hours. The expansion was registered with a high precision comparator. The tensile strength was measured on samples with a diameter 50 mm for the whole system asphalt and mortar percolated asphalt with steel metal plated glued on the cylindrical specimen edges as depicted in Fig. 1. The microstructure was investigated with optical and scanning electron microscopy SEM.

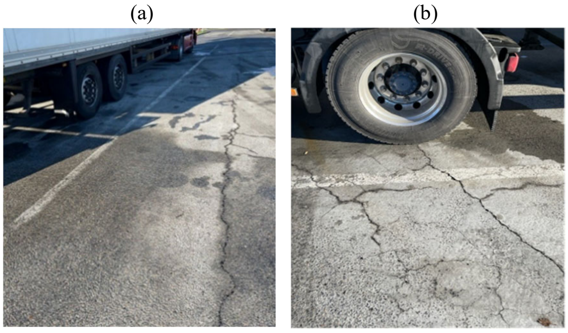
Fig. 1. Tensile test set-up of the whole pavement section.

III. Results and Discussion

A. Macroscopic Visual Inspection

The truck parking area exhibited a relevant amount of cracking. Long cracks with wide opening were observed along the parking marked lines, parallel to the truck parking direction (Fig. 2a). Regions with a more diffuse cracks were also seen along the loaded zones (Fig. 2b). A dishomogeneous presence of cracking and zones with a higher mortar presence (Fig. 2c) correlated with a higher cracking (Fig. 2d). This latter degradation form was mainly due to shrinkage of the mortar-enriched surface and the vehicle loads.

(a) (b)



(c) (d)

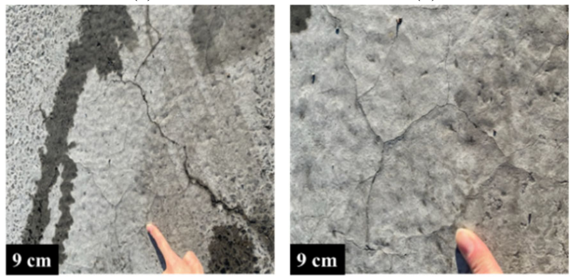


Fig. 2. The truck parking area exhibited a relevant amount of cracking. (a)Longitudinal (b) widespread diffuse cracks on the parking area (c) Mortar enrichments (d) cracks.

Perpendicular cracks are often observed along the main cracks that run parallel to the parking zones marking lines (Fig. 3 a). Transverse cracking with respect to the lanes were also occasionally present (Fig. 3 b). These cracks exhibited wide openings and penetrated in depth down to the asphalt underlying course. A reduced load-bearing capacity of the subbase may be accounted for the damage. Along the truck wheel tracks, the humidity and the enrichments of water indicated the presence of local depressions (Fig. 3 c, d) of the surface.

(a) (b)

(c) (d)

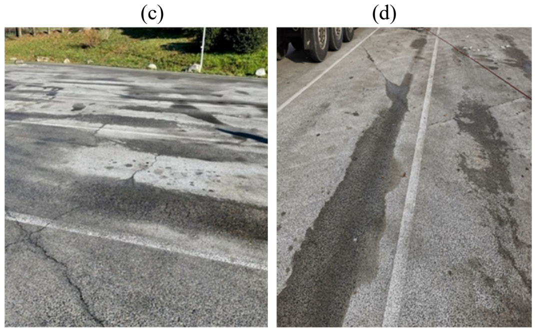


Fig. 3. The truck parking areas: (a) Perpendicular (b) Transverse cracks (c, d) Rutting along the truck wheel tracks.

A more close investigation of the depressions indicates a clear rutting of the percolated asphalt course with alligator cracks (Fig. 4 a). This form of cracking appears in asphalt courses subjected to fatigue [4, 7], while rutting can also be observed in high quality highway surface courses [19]. Material detachment and pot hole formation also occurred (Fig. 4 b). A different mortar filling grade and dishomogeneity of the surface emphasized the difficulties encountered during the application of the material (Fig. 4 c, d). This fact, largely influenced the non-uniform load distribution on the surface and the damages.

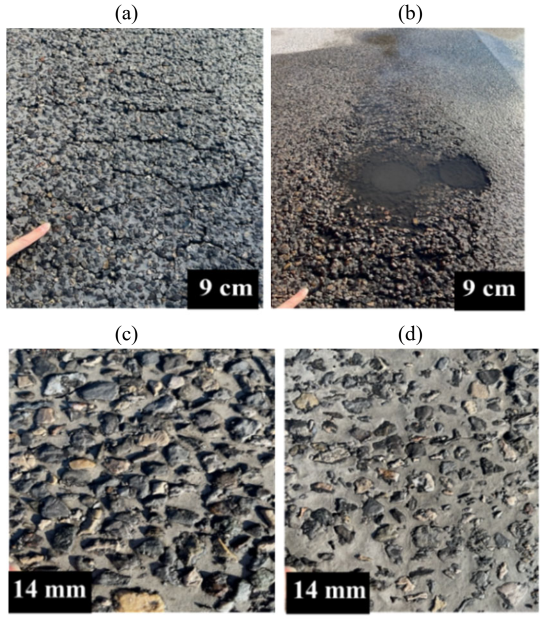


Fig. 4. The truck parking areas: (a) Rutting and alligator cracking (b) Material detachment and pot hole formation (c; d) Dishomogeneous mortar filling

The cracks occurred along the junctions asphalt concrete and mortar filled asphalt and along different mortar filled surfaces (Fig. 5a). Cracks were usually present in the upper part of the pavement, but with wide openings, the cracks propagated in the underlying asphalt course. Cracking was a main result of a bad mortar filling of the asphalt macro voids (Fig. 5b), while rutting occured with less pores in the asphalt and a porosity in the mortar percolated asphalt layer (Fig. 5 c). The cored specimens exhibited a mortar percolated macro void asphalt surface layer with variable thickness of 55 mm–70 mm. For an asphalt concrete with an aggregate size ranging from 0 to 22 mm, a minimum mortar percolated thickness of 60 mm is required [8]. This thickness was generally reached, except for two cored specimen locations.

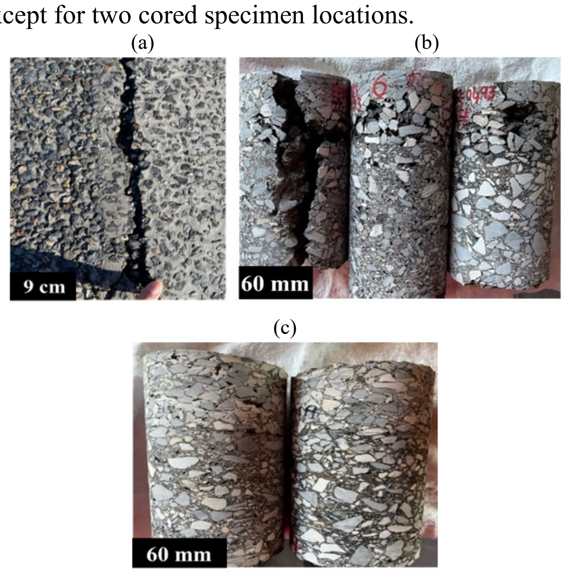


Fig. 5. The cracks (a) Cracking by different mortar enrichment placing junctions (b) Poor macro voids mortar filling (c) Specimens in the rutting areas with pores in the mortar percolated layer.

B. *Compressive Strength*

The compressive strength showed variable values (Fig. 6a). This was especially observed for the mortar percolated samples, due to the different filling of the macro voids with mortar. A slightly strength increase was measured in the mortar filled zones as compared to the asphalt underlying course. The mean strength value of the percolated mortar layer was 12.9 MPa (Fig. 6b) and exceeded the standard requirement. The compressive strength was higher than 6 N/mm^2 [14]. This in spite of the partial poor filling grade. Therefore, this mechanical parameter can be considered as indicative and largely depended of the mortar penetration. It cannot be directly taken as a direct reliable durability requirement.

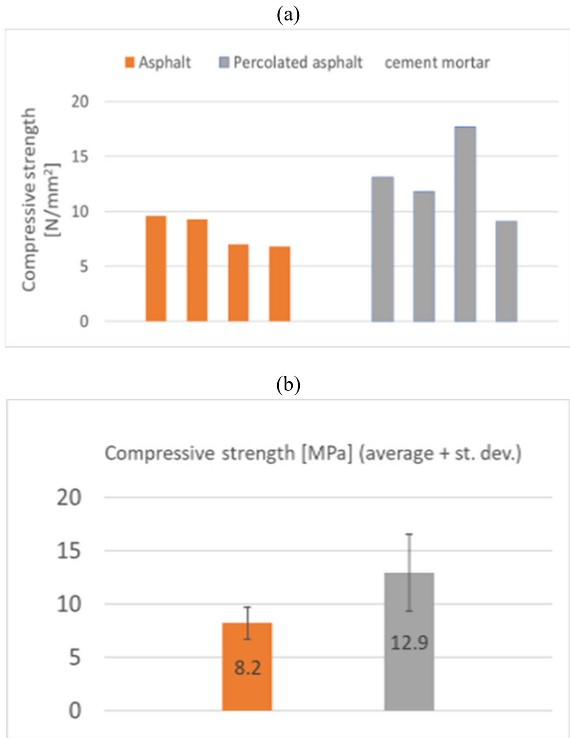
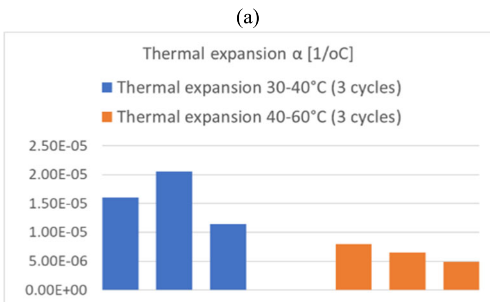


Fig. 6. Compressive strength of the mortar percolated asphalt and the underlying asphalt course. (a) Single measurements (b) Mean and standard deviation

C. *Thermal Expansion*

The thermal expansion of the whole system was relatively high on the first thermal cycle with a mean value of 1.00×10^{-5} 1 / °C and was reduced on the second cycle down to 0.7×10^{-5} 1 / °C (Figs. 7. A and b). This accounted for a relatively reduced capability to adapt to the environmental thermal excursions with time.



(b)

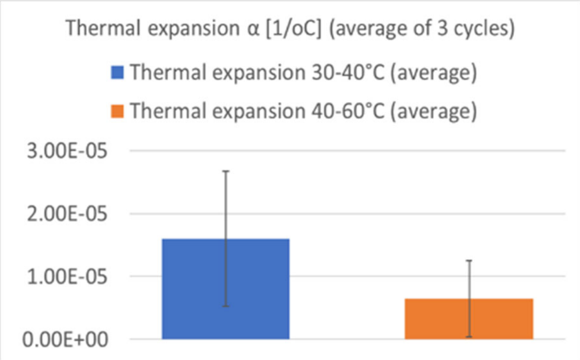


Fig. 7. Thermal expansion data of the whole system after both thermal cycles. (a) Single measurements (b) Mean and standard deviation.

D. Freeze / Thaw Resistance

Pavements across the alpine region need to have a particular resistance to frost action. The viscous-elastic behaviour of asphalt may partially reduce the susceptibility from a physical dimensional point of view, but the chemical interaction with the atmosphere, such as the oxidation and ageing of the bituminous materials decrease the resistance and increase the cracking of the asphalt [1, 4, 6]. In this regard, the ductility component of the bituminous material may contribute to some extent to the increased capability of the pavement system to adapt to the dimensional variation induced by the cyclic temperature. Consequently, the relatively low ageing of the bituminous binder (< 3 years) allowed to maintain an acceptable deformability during the severe freeze / thaw testing. On the other hand, the filling of asphalt macro voids with the more rigid mortar did not adversely affect the scaling propensity of the surface. In fact, the mortar percolated surface layer showed a good resistance to freeze and thaw of 100 g/m^2, despite some variable values (Table I). The limit of 300 g/m^2 set by a standard [14] was not reached.

TABLE I. FREEZE AND THAW RESISTANCE OF THE MORTAR PERCOLATED UPPER ASPHALT COURSE

Freeze-Thaw test		
Sample	**Density [Kg/m^3]**	**Freeze-Thaw Resistance [g/m^2]**
2 S/N	2224	60
3 S/N	2238	30
6 S/N	2207	200
7 N/S	2155	100
	average	100.0
	st. dev.	85.5

E. Microstructure

The microstructure showed locally a relatively good adhesion between the mortar and the aggregates (Fig. 8a), although clear porosities were often seen along the mortar-bituminous aggregate interfaces (Fig. 8b and c). The pores were occasionally round and aligned along the interfaces, but in some areas, continuous capillary pores were seen.

(a) (b) (c)

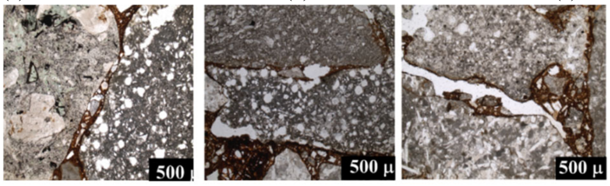


Fig. 8. Microstructure of the mortar percolated asphalt surface layer. (a) Local good (b) Pore enrichments (c) Along the bituminous-mortar interface.

(a) (b) (c)

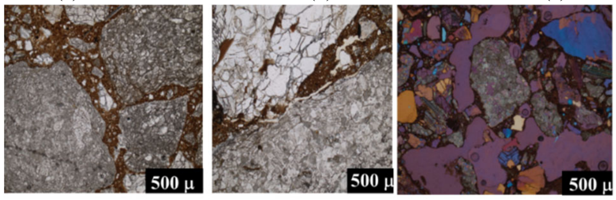


Fig. 9. Microstructure of the underlying asphalt course. (a) Good adhesion between the aggregates and the bituminous layers (b) Local pore discontinuities along the interface (c) Pores within the bituminous matrix.

A good adhesion was observed between the aggregates and the bituminous layers (Fig. 9a). In these areas of adequate material compaction, a tight bond with no discontinuities was detected. Furthermore, in the zones with lack of mechanical compaction, porous discontinuities were present, especially along the interfaces (Fig. 9b). The micropores were occasionally present within the bituminous layer around the aggregates (Fig. 9c). Sometimes the porosity exhibited an interconnected network, that negatively influenced the load bearing capacity of the pavement system.

F. Tensile Strength

TABLE II. TENSILE STRENGTH OF THE WHOLE SYSTEM. TYPE OF RUPTURE: A = WITHIN THE MORTAR PERCOLATED ASPHALT LAYER; B = ALONG THE INTERFACE MORTAR PERCOLATED ASPHALT LAYER AND ASPHALT LAYER; C = WITHIN THE ASPHALT LAYER

Sample	L [mm]	Dimension Φ [mm]	Load [KN]	Tensile Strengh [N/mm^2]	Rupture type
4 N/S	102	50	1.72	0.9	20% type B - 80% type C
5 N/S	106	50	2.52	1.3	**100% type B**
12 N/S	119	50	0.52	0.3	100% type A
7 S/N	110	50	2.48	1.3	**100% type B**
8 S/N	108	50	2.08	1.1	100% type C

The tensile strength of the whole system exhibited variable values and rupture location. The bond strength between the layers is a main issue in the asphalt pavements. In this particular system, a trend to fail along the interface mortar percolated asphalt layer-asphalt layer was detected. The slightly different material properties, such as the compressive strength, makes this contact zone a potential weak region. Nevertheless, the tensile values of 1.3 Mpa cannot be considered very low (Table II). The rupture within the underlying asphalt layer tended to a value around 1.0 MPa. On the contrary, the lower values were measured with cohesive rupture within the mortar percolated asphalt layers. This was accounted for the lack of mortar filling and the presence of mortar unfilled macro spaces within the surface layer.

IV. CONCLUSIONS

The lack of percolated mortar complete filling of the asphalt macro voids caused cracking and rutting. Transverse wide crack openings were observed down to the asphalt layers. The values of the compressive strength and resistance to frost complied with the normative regulations and exhibited a relatively high resistance. Nonetheless, significant damage was observed due to the voids presence. The lowest tensile strengths and ruptures were measured within the poorly mortar percolated asphalt layer. The microstructure exhibited variable adhesion at the mortar-bituminous and aggregate-bituminous interfaces, with the presence of porosities also within the asphalt layer.

CONFLICT OF INTEREST

The authors declare no conflict of interest.

AUTHOR CONTRIBUTIONS

C. Paglia wrote literature, data analysis, microstructural investigation, paper writing; C. Mosca, M. Paderi worked on data measurements, laboratory investigations; all authors had approved the final version.

ACKNOWLEDGEMENT

The authors thank G. Corredig for the investigation of the microstructure and the technicians of the Institute of materials and construction Supsi for sampling, the mechanical and the durability testing.

REFERENCES

[1] W. Sorociak and B. Grzesik, *IOP Conf. Ser.: Mater. Sci. Eng.*, vol. 603, 052058, 2019.

[2] Y. Hu, W. Si, X. Kang, Y. Xue, H. Wang, T. Parry, and G. D. Airey, "State of the art: Multiscale evaluation of bitumen ageing behaviour," *Fuel*, vol. 326, 2022.

[3] Y. Li, J. Feng, S. Wu, A. Chen, D. Kuang, T. Bai, Y. Gao, J. Zhang, L. Li, L. Wan, Q. Liu, Z. Chen, and D. Gu, "Review of ultraviolet ageing mechanisms and anti-ageing methods for asphalt binders," *Journal of Road Engineering*, vol. 2, no. 2, pp. 137–155, 2022.

[4] R. Bonaquist, "Critical factors affecting asphalt concrete durability," WisDOT ID nr. 0092-14-06, August 2016.

[5] H. Soenen, X. Lu, and O. Laukkanen, "Oxidation of bitumen: Molecular characterization and influence on rheological properties," *Rheol Acta*, vol. 55, pp. 315–326, 2016.

[6] R. Tauste, F. Moreno-Navarro, M. Sol-Sánchez, and M. C. Rubio-Gámez, "Understanding the bitumen ageing phenomenon: A review," *Construction and Building Materials*, vol. 192, pp. 593–609, 2018.

[7] W. G. Buttlar, A. Chabot, E. V. Dave, C. Petit, and G. Tebaldi, "Mechanisms of cracking and debonding in asphalt and composite pavements," *State of the Art of the Rilem TC 241-MCD*, vol. 28, Springer, 2018.

[8] S. Pirmohammad and M. R. Ayatollahi, "Fracture behaviour of asphalt materials," *Structural Integrity 14*, Springer 2020.

[9] P. Ayar. "Effects of additives on the mechanical performance in recycled mixtures with bitumen emulsion: An overview," *Constr. Build. Mater.*, vol. 178, pp. 551–561, 2018.

[10] S. Du, "Influence of chemical additives on mixing procedures and performance properties of asphalt emulsion recycled mixture with reclaimed cement-stabilized macadam," *Constr. Build. Mater.,* vol. 118, pp. 146–154, 2016.

[11] S. Du, "Effect of curing conditions on properties of cement asphalt emulsion mixture," *Constr. Build. Mater.,* vol. 164, pp. 84–93, 2018.

[12] W. Yang, J. Ouyang, Y. Meng, B. Han, and Y. Sha, "Effect of curing and compaction on volumetric and mechanical properties of cold-recycled mixture with asphalt emulsion under different cement contents," *Constr. Build. Mater.,* vol. 297, 123699, 2021.

[13] C. Zhu, H. Zhang, H. Guo, C. Wu, and C. Wei, "Effect of gradations on the final and long-term performance of asphalt emulsion cold recycled mixture," *J. Clean. Prod.,* vol. 217, pp. 95–104, 2019.

[14] Swiss standard SIA 252, Cement, magnesia, resin and bituminous pavements, 2012.

[15] M. Fakhri, S. A. Siyadati, M. R. M. Aliha, "Impact of freeze–thaw cycles on low temperature mixed mode I/II cracking properties of water saturated hot mix asphalt: An experimental study," *Constr. Build. Mater*., vol. 261, 2020.

[16] H. A. Umar, X. Zeng, X. Lan, H. Zhu, Y. Li, H. Zhao, and H. Liu, "A review on cement asphalt emulsion mortar composites, Structural development, and performances," *Materials*, vol. 14, no. 12, p. 3422, 2021.

[17] European Standard EN 12504-1, Testing concrete in structures, 2019.

[18] Swiss standard SIA 262 / 1 appendix C, Actions of infrastructures, complimentary specifications, 2020.

[19] C. Paglia and M. Paderi, "The asphalt rutting within a highway tunnel," in *Proc. International Conference on Advances in Civil Engineering ICACE*, 20–22 December, India, 2022.