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The two-component grout in the tunnelling applications

The object of this thesis concerns the currently main used technology for the tunnelling backfilling: the two-component grout. During the advancement of a shielded machine, an annular void is continuously created due to the difference in diameter between the machine head and the extrados of the precasted assembled rings. The filling of this void, called also annulus, is an operation of paramount importance. A backfilling correctly performed ensures the locking of rings in the designed position, the bearing of the the back-up load, an immediate support to the excavated medium (strongly reducing subsidence) and the improving of the waterproofing. The two-component grout technology is based on two fluids that once mixed together give rise to a gel in a few seconds. The two components are commonly named component A and component B. The first one is a cement mortar, made up of cement, bentonite, water and retarding/fluidifying agent while the second one is an accelerator.
Despite its intensive use all around the word, this material is not completely known. Furthermore international standard for the grout characterization are not available. Consequently, with a view to the real needs of all stakeholders working in the tunnelling filed, from designers to the common workers, the research path at the base of this work has been drawn.
After describing the central role of the mix design for the whole backfilling process, the first step of the research has been the writing of a standard procedure able to reproduce at the laboratory scale a component A similar to the one produced in the construction site. In order to perform a comparison, a testing procedure has been established and applied at the laboratory scale and at the real scale (at the construction site). More in detail, the component A characterization has been based on the main well-established tests (unit weight, flowability, bleeding) while its interaction with the component B has been assessed by an experimental procedure, able to provide the "gel time". Conclusively, the hardened grout has been studied by assessing the uniaxial compression strength, at short and at long curing time. The good overlapping between the laboratory results and the construction site ones has permitted to fix a cornerstone, i.e. the procedure for producing two-component grout sample, that has been used for all the further experimentation.
As second step of the research, mechanical parameters of the grout never studied or not known in deep have been deepened in the context of the grout hardening, i.e. after the jellification process. The surface compression strength (SCS), the elastic parameters, the shear strength and the tensile strength have been investigate. The SCS has been defined using the pocket penetrometer, the base instrument needed for the strength assessment. The Young's modulus has been studied by a double approach: the first one, according to the classic approach (the two-component grout has been considered as standard mortar), while the second one, according to the geophysics approach. Geophysics permitted also to investigate, absolutely for the first time, the dynamic moduli and the Poisson's ratio, in a context of a fast and continue evolution of the material. The shear strength evolution in function of the curing time has been studied according to the Mohr-Coulomb criterion. The "widening" of the area recognized by the envelope criteria is a clear graphically representation of the fast hardening process of the material. Concerning the tensile strength, the indirect methods highlighted a certain independence from the curing, with values substantially stable in time after the 28 days of curing.
The obtained values, even if surely important as order of magnitude for the studied parameters, should be considered as an added value to the main outcomes, i.e. the drawn procedures. If values are also important, it must be underlined that they are strictly function if the used mix design, while the procedures can be applied to every mix.
The third part of the research has been focused on the durability. Three different actions have been considered and their effect on the two component grout, i.e. the time (the ageing), the air and the water. Furthermore, in the context of the durability, a new mix design and a new construction site have been introduced, in order to verify the effect of the "real curing condition" (i.e. the curing in the construction site). Results highlighted that the weakness of the hardened grout is the air action, able to completely powder the material in some days, while the properties are saved in time if a certain moisture in ensured by the curing environment. The study of the new mix design related to the new construction site have permitted to highlight the importance of the curing condition that in situ are potentially different from the laboratory one.

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The last part of the research concerned the study of the bentonite in the two-component grout applications. The activation process (the hydration process of the bentonite accelerated mechanically) can increase the component A performance in terms of a bleeding reduction and in terms of a SCS increasing. It has been underscored that not all bentonites are equally suitable for the two-component grout technology: the performances are function of the kind of bentonite and the swelling index (SWI) has been recognized as the main parameter responsible of good performance in terms of stability and SCS. The Atterberg's Liquid Limit helps in the case of more products with the same SWI, being linked to the bleeding phenomenon.

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