Description of the research work

Laboratory : LMDC (Laboratoire Matériaux et Durabilité des Constructions de Toulouse**)**

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Title:

Homogenization theory and numerical approaches applied to mortar using waste recycled glass: study of its mechanical behavior and durability

Abstract:

Scientific problem - Stakes

For many years, researches are devoted to improve concrete material to obtain better performances and durability, we can refer to High-performance concrete (HPC) and Ultra-high-performance concrete (UHPC). This manufacturing material is one of the most widely used building materials in the world. It is an attractive artificial composite material which can obtain very attractive performances for the building industry needs.

On the other hand, it appears that concrete is a polluting material. Concrete industry which has cost a lot of energy consumption and resources is confronted with the challenges of reducing the CO2 emission. Moreover, intensive exploitation of aggregates rock in concrete creates environmental problems as depletion of natural resources.

Whereas cities needs more and more concrete production, we produce more and more waste glass. Recycling glass waste can be an attractive possibility. Incorporating these into concrete would both divert them from landfills and reduce our CO2 emissions.

The research topic presented here is thus part of the problematic of replacement of natural resources by a recycled and recycled post-consumer product.

So, the proposed research project has for main objective the understanding of the impact of glass particles in concrete on the mechanical behavior and its durability.

Research work plan:

1. Mechanical predictions of mortar containing recycled waste glass

Concrete can be considered as a composite material of two phases: cement paste and aggregates. We can then consider that the mortar is also a material composite of two phases: cement paste and sand. It is implied that the properties of concrete depend on the properties of the two constituents.

If we replace a part of sand by recycled waste particles, the new composite presents new performances, we can refer to experiment studies ([Nguyen, 2013] [Serifou, 2014]). It appears from this studies that the size of inclusion have a deep impact on mechanical and durability performances.

For a better understanding of the link between the components of the new material and its macro performances, we propose a multiscale approach which don't exist in the literature about this kind of material. The thesis proposal focuses then essentially on the theoretical and numerical models. The approach will be based on experimental results from bibliography [Nguyen, 2013] , [Serifou, 2014], [Ling et al.,2011]]and done with the collaboration of Prof. Guoqing Jing from Beijing Jiaotong University in China.

The aim is to study the influence of the type and quantity of aggregates on the properties of concretes recycled and analyze the effect of partial replacement of natural aggregates.

In order to take into account the effects of size and characteristics of this materials, we propose here two approaches:

a) The first one consists on a theoretical micromechanical modeling of the behavior. Micromechanics is able to link physical information at the micro scale ~~and~~ to macro observations. First, it will be necessary to predict the elastic properties as functions of the fractions and size of aggregates. The second part of the approach will consist in predicting the elastic limit of the composites thus constituted. This multi-scale modeling will be based on estimates of the mechanical behavior, we can refer to Mori Tanaka estimations.

b) The second one is based on the finite element approach using a representative volume elementary (RVE). Finite element method is able to take into account the physical characteristics of each components and the influence of the shape and the spatial distribution of aggregates in 2D and/or 3D digital representation. Moreover, the characteristics of the interfaces between mortar and aggregates can be considered and its impact on the overall mechanical characteristics. Finally, with the FE method, the swelling of concrete can be considered and its impact will be analyzed.

It will therefore be interesting to compare multi-scale theoretical modeling with FE approaches. The final objective of this first study is to establish an optimum on the quantity and the geometrical characteristics of aggregates compared with mechanical performances.

2. Micromechanical approaches to predict the ASR on recycled glass mortar

It has often been shown that the addition of glass aggregates in concrete can be reactive see [Shao et al., 2000], [Ling et al., 2011]. At the micro scale, ASR (Alkali Silica Reaction) can cause long term degradation. Reaction between glass aggregates of concrete and the alkalis contained in the cement can provoked swelling of the concrete causing microcracks. It can be noticed that swelling began at the micro level and a better understanding of the link between the aggregates characteristics and ASR can be found at this level. The first step will then consist to understand how the mechanisms began and occupy the pore space and how it increases until causing cracks. We will build a micromechanical modeling of ASR for this kind of new materials based on [Chaplin et al., 2014] and [Lemarchand, 2001] and applied to this new composite.

References

Charpin L., Modèle micromécanique pour l'étude de l'anisotropie de la réaction alcali-silice, Thèse, Université Paris-Est, 2013

Charpin L., Ehrlacher A. Simplified Model for the Transport of Alkali-Silica Reaction Gel in Concrete Porosity. Journal of Advanced Concrete Technology, Japan Concrete Institute, 12, pp.1-6, 2014

Esposito R., Hendriks M.A.N., A multiscale micromechanical approach to model the deteriorating impact of alkali-silica reaction on concrete, Cement and Concrete Composites, volume 70, issue July, 2018

Lemarchand E., Contribution de la micromécanique à l'étude des phénomènes de transport et de couplage poromécanique dans les milieux poreux: application aux phénomènes de gonflement des géomatériaux, Thèse, Ecole Nationale des Ponts et Chaussées, 2001

Nguyen, H., Valorisation du verre dans le béton. Etude expérimentale du comportement de pâte de ciment et du mortier: rhéologie, mécanique et durabilité, 2013

Serifou M., Béton à base de recyclats : influence du type de recyclats et rôle de la formulation , 2014

Shao Y., Lefort T., Moras S., Rodriguez D., Studies on concrete containing ground waste glass. Cement and Concrete Research 30: 91–100, 2000

Ling T.-C., Poon C.-S., Properties of architectural mortar prepared with recycled glass with different particle sizes, Faculty of Construction and Land Use, The Hong Kong Polytechnic University, Materials and Design 32, 2675-2684, 2011