Bauhaus-Universität Weimar

Engineering Geopolymer Composites (EGC)

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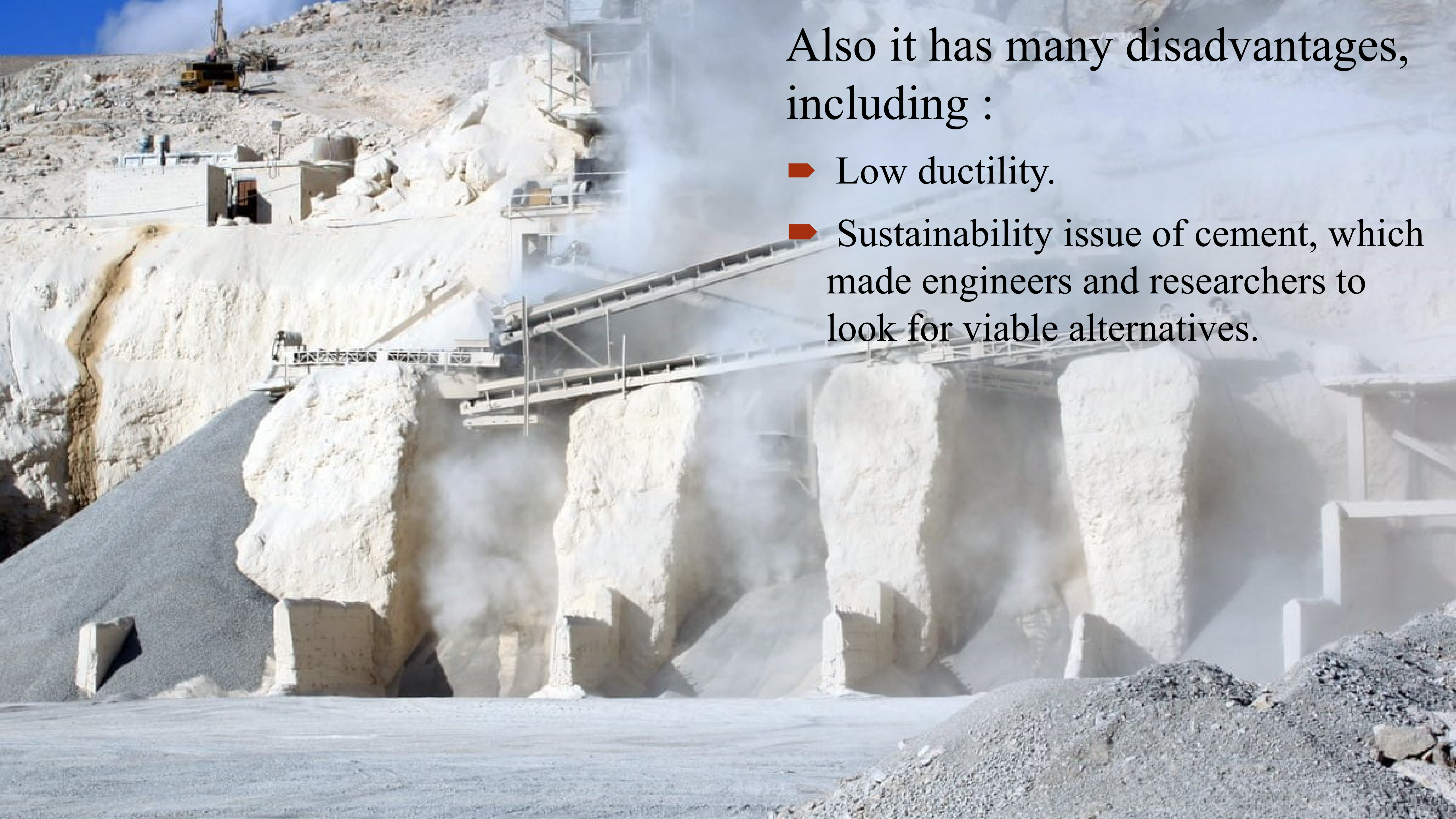
Concrete

Concrete is one of the most widely adopted composite materials in the construction of civil infrastructure

Concrete has many advantages

1. Ability to be Cast.
2. Ability to be molded to different Shapes and sizes.
3. High compression resistance.
4. The raw materials used in cement production are widely available in great quantities.
5.
6.



Also it has many disadvantages, including :

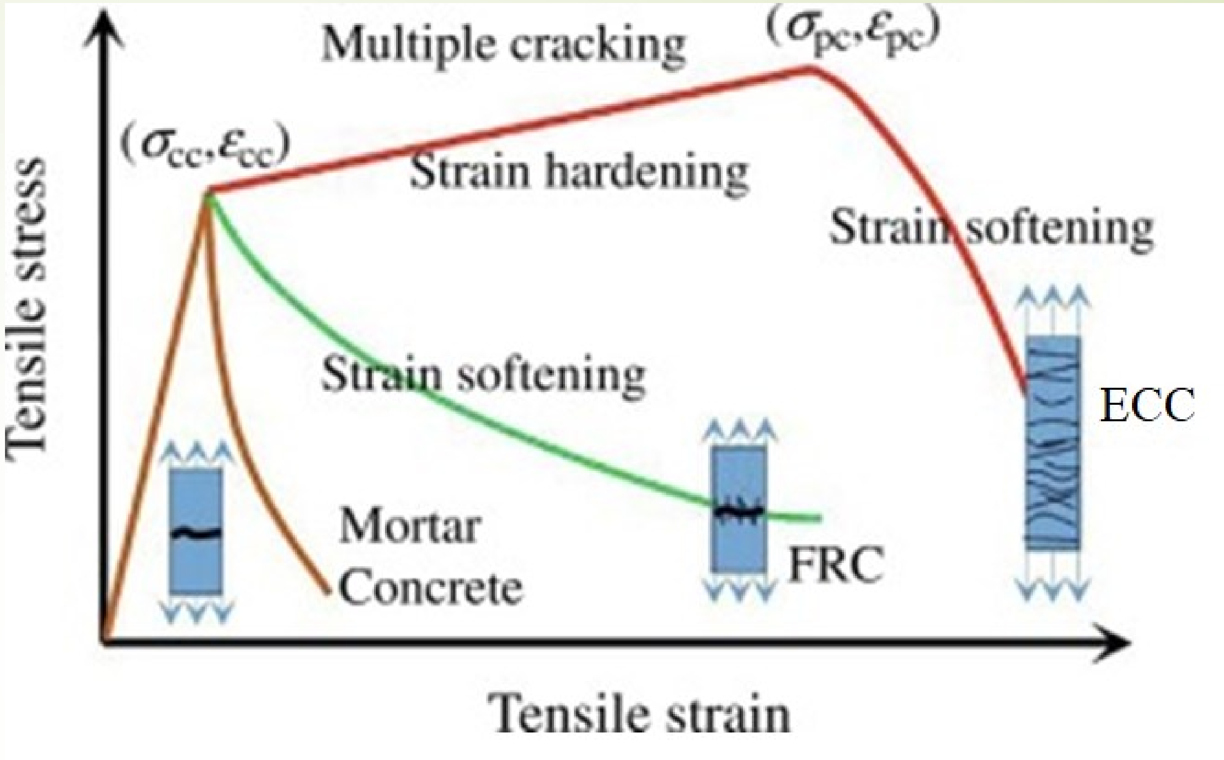
- Low ductility.
- Sustainability issue of cement, which made engineers and researchers to look for viable alternatives.

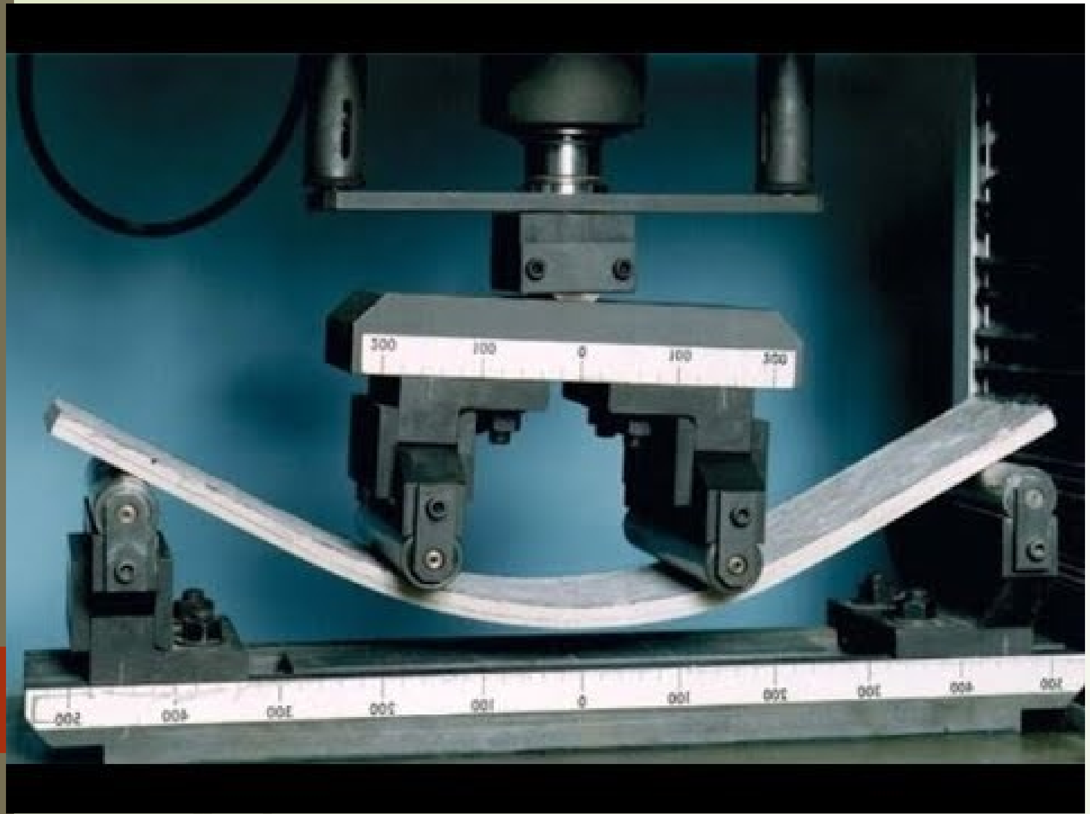
Low ductility of concrete

- What is the maximum usable strain of concrete ?

0.003

Engineering Cementitious Composites (ECC)





- ECC is a type of fiber-reinforced concrete that exhibits:
- high ductility
- energy absorption capacity
- damage tolerance.

ECC approximately 6-8 hundred times the ductility of conventional concrete

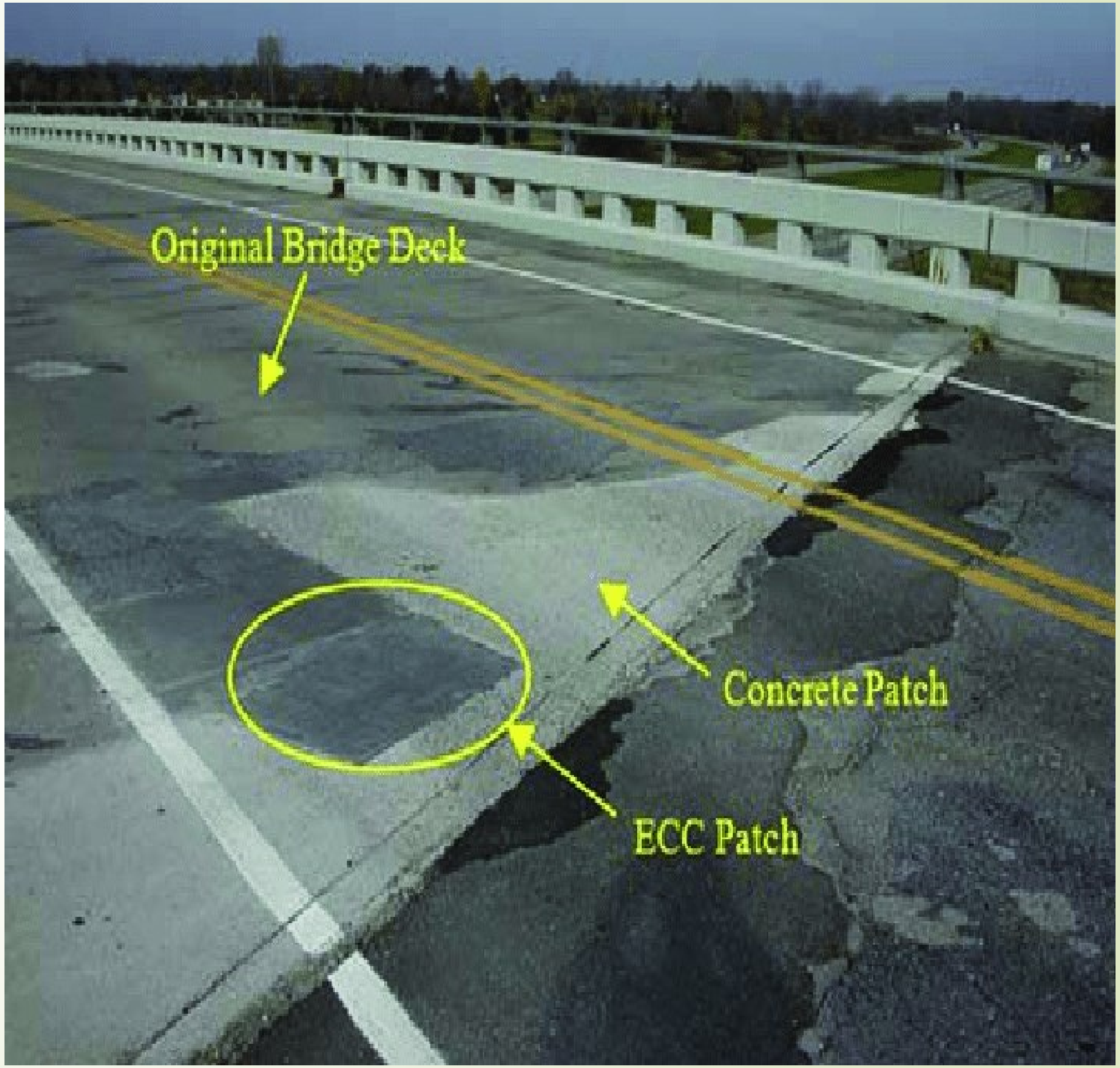
Components of ECC:

- Cement
- Fly ash
- Silica sand : with size less than 0.3mm
- Polyvinyl alcohol fiber (PVA) : 2% Vol.
- Superplasticizer
- Water

Application of ECC

ECC is used in applications where high performance is required such as:

- repair
- bridge decks
- seismic retrofits
- blast-resistant structures
- 3D printing



Drawbacks of ECC

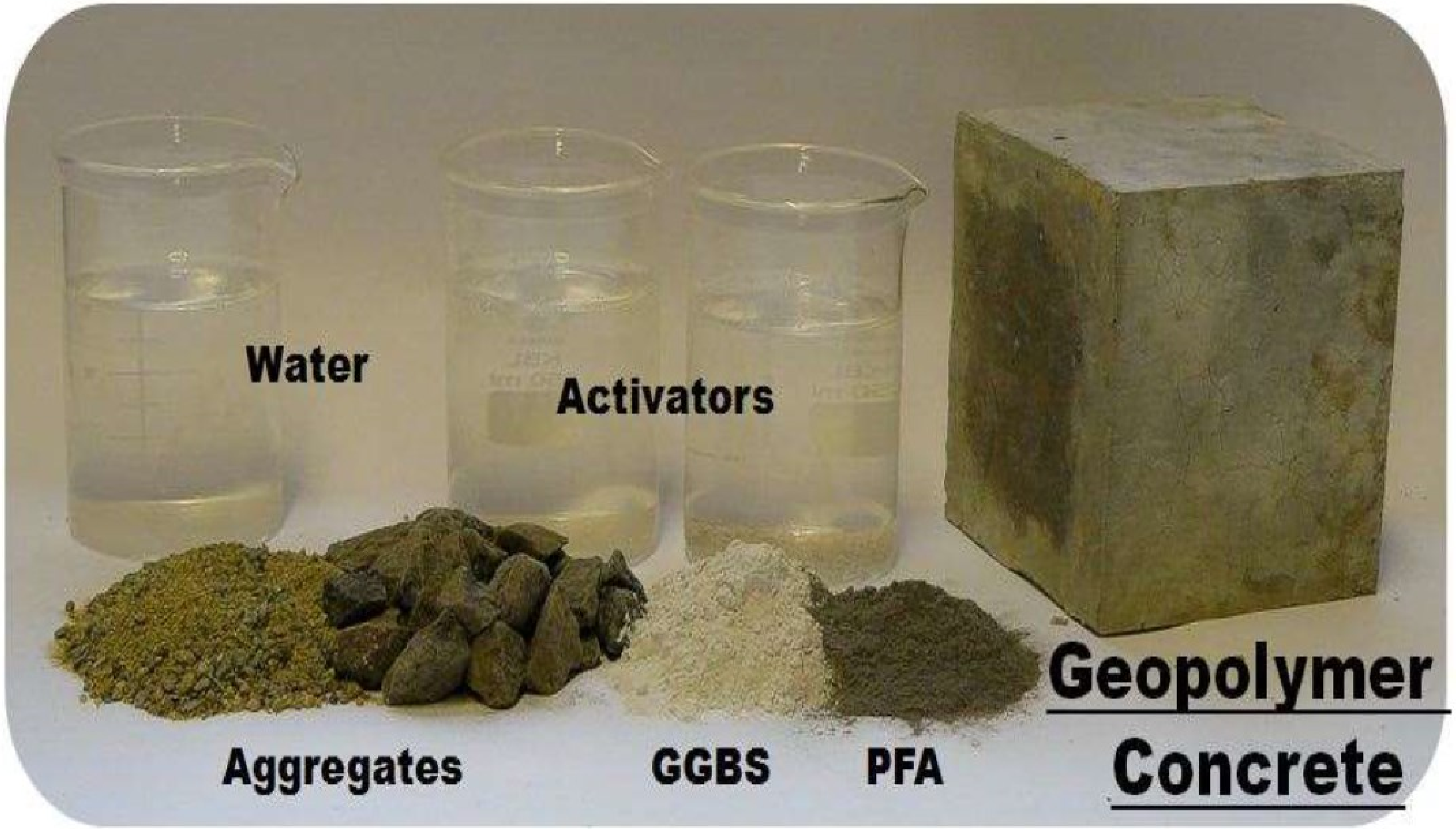
- ECC consumes cements 2.5 to 3 times of normal concrete
- The cost $$$

WHY NOT OPC?

- Global warming has become a major concern in recent years, and CO_2
- emissions from cement manufacture are estimated to account for around 8% of all gas emissions globally, approximately 1 ton of CO_2 is produced for every 1 ton of cement.

To address this environmental concern, other binder must be employed instead of OPC concrete.

Recently, a new type of environmentally-friendly **geopolymer concrete** becomes popular and it gives a chance to replace cement by appropriate alumina-silicate source such as fly ash.

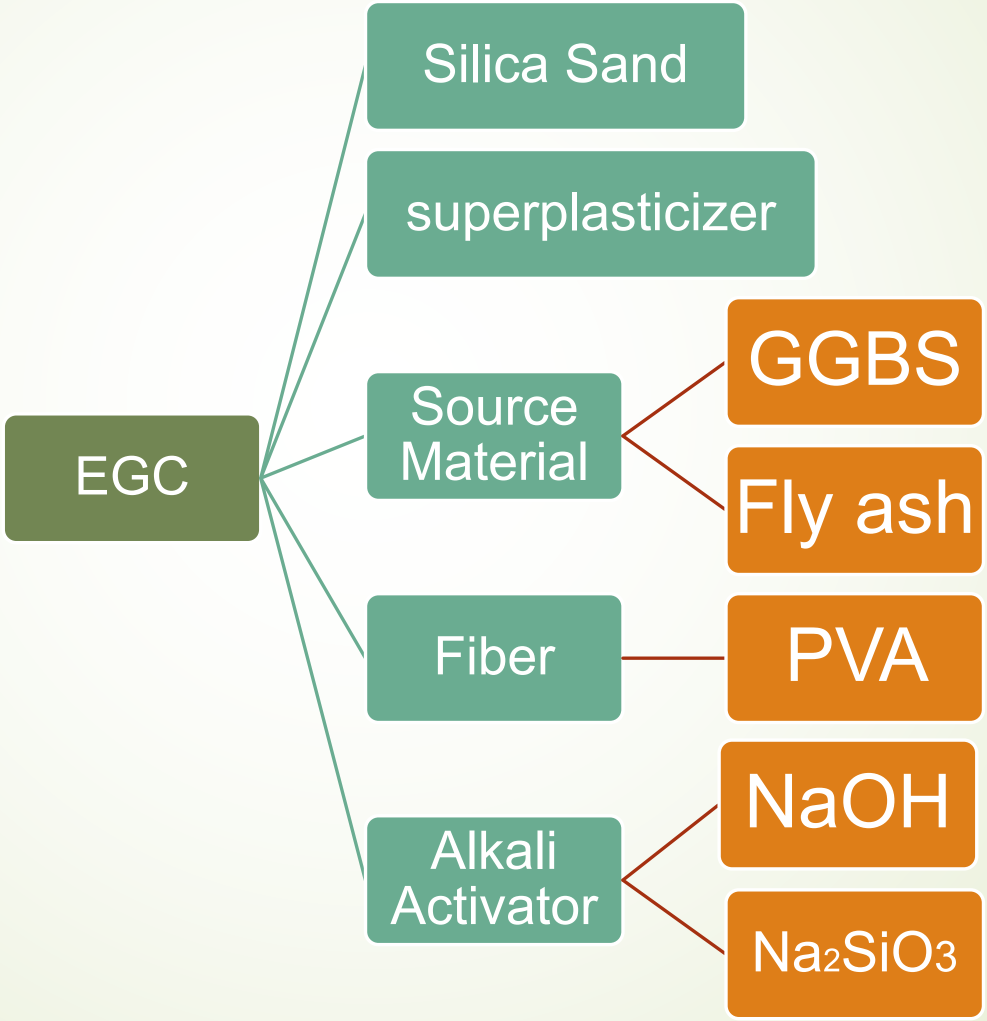


WHY GEOPOLYMER CONCRETE?

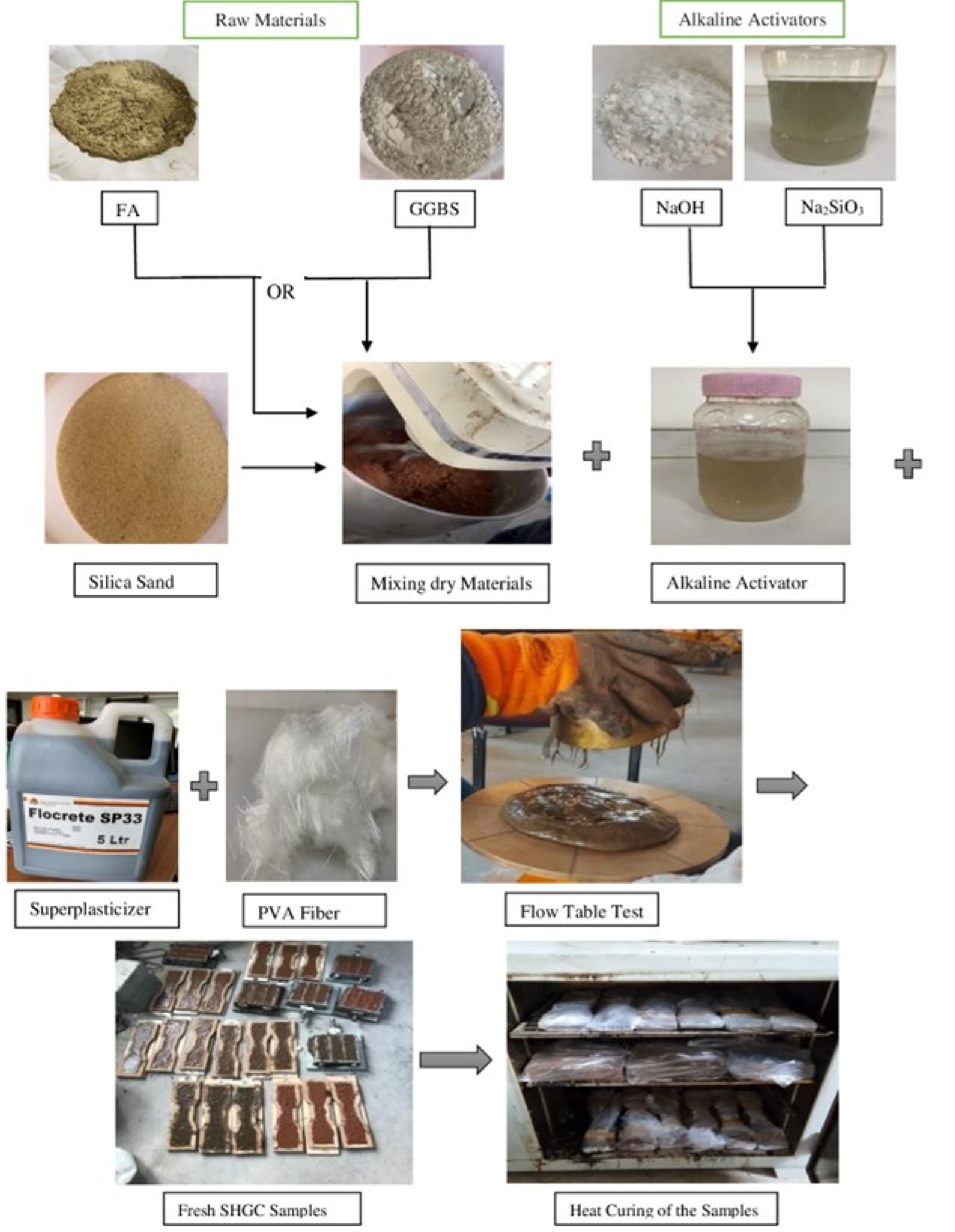
- Ecofriendly and sustainable construction material.
- reduces the CO_2 emission by (80-90%)
- Fire resistance and acid resistance
- 60 % less energy than OPC in production process

Is it possible to produce ECC by geopolymer ??

Engineering Geopolymer composites (EGC)

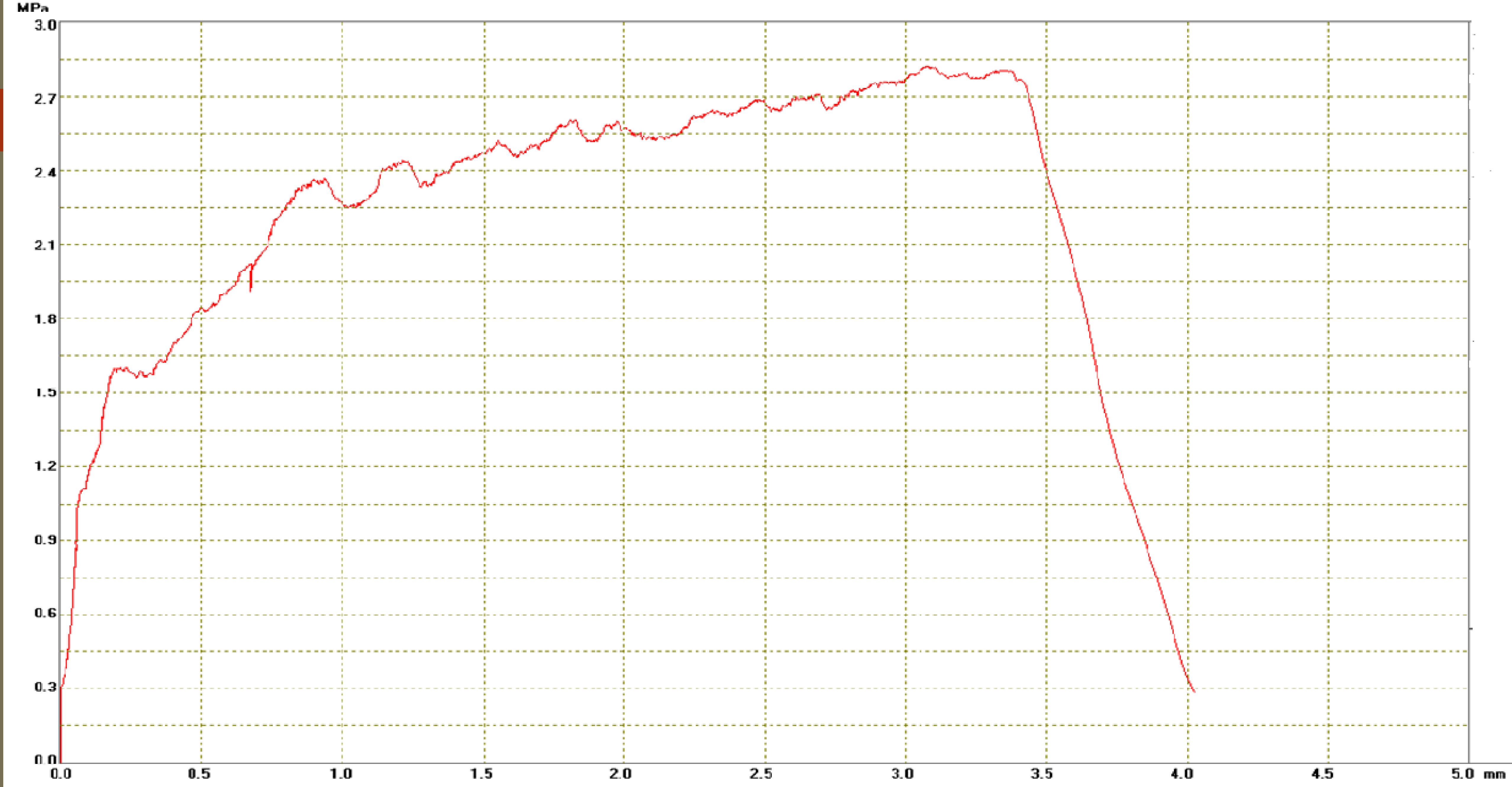


Mixing, Pouring, and Curing Procedures of Engineered Geopolymer Composites Samples

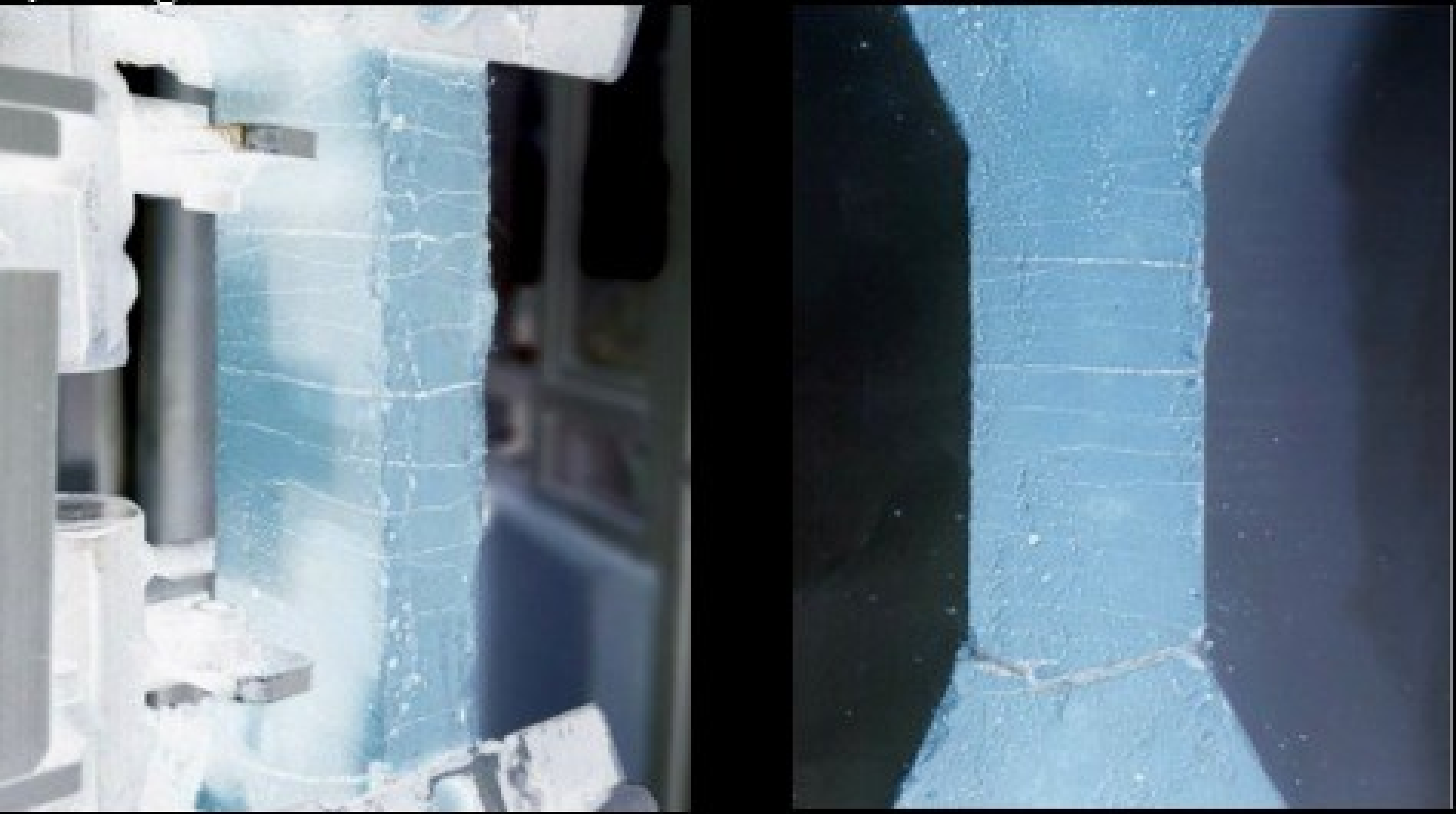


Mechanical properties EGC-FA

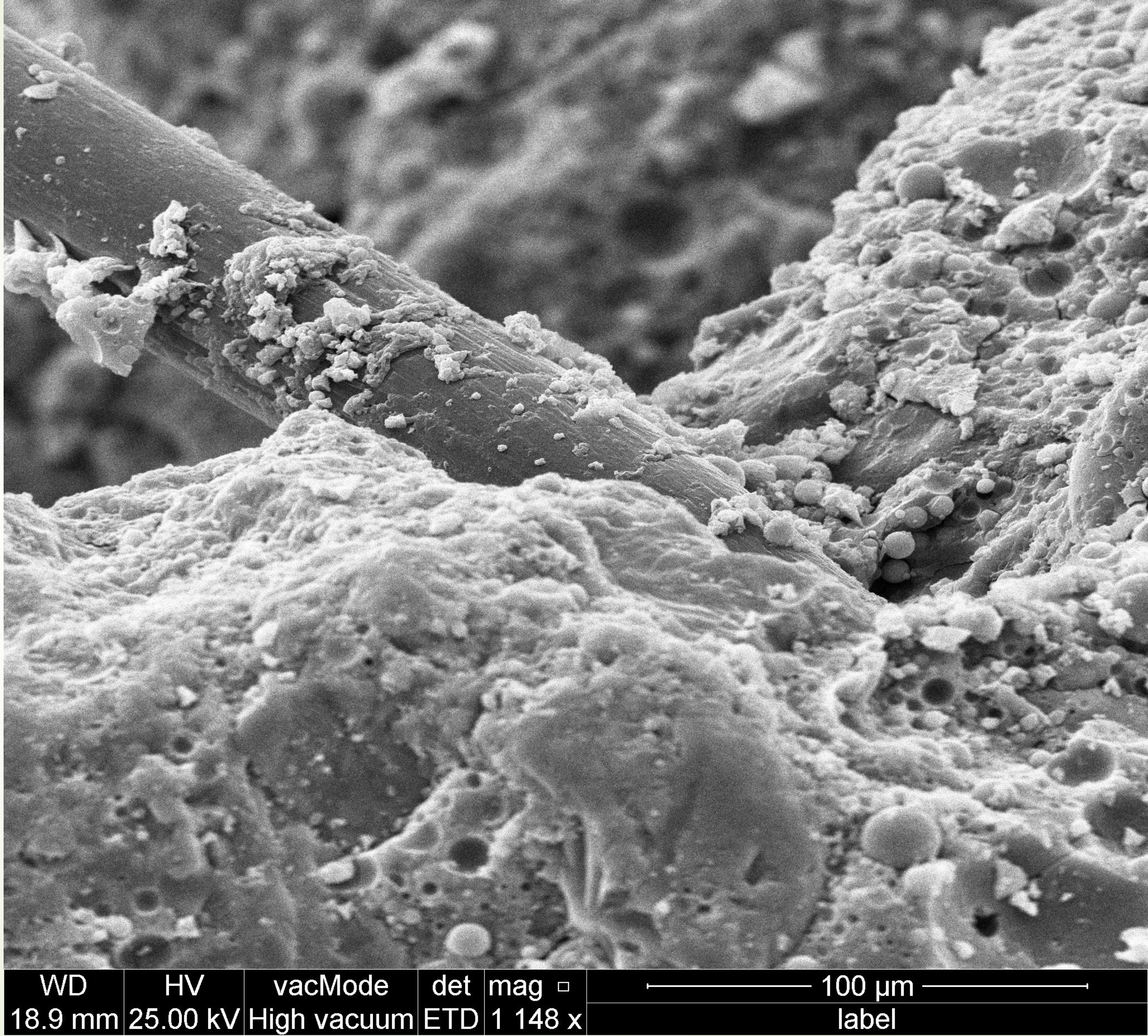
- **Compressive strength: 34.5** MPa
- **Flexural properties :**
- Load : 4108 N
- Deflection : 1.6 mm
- **Direct Tensile strength performance :**
- First-crack strength : 1.59 MPa
- Ultimate Tensile strength : 2.8 MPa
- Tensile Strain capacity : 4.19 %
- **Density : 1830 Kg/m^3**



Elongation (mm)



Microstructural analysis by using scanning electron microscopy (SEM)



Reference

- 1. Emissions., C.C. *Supplemental Data of Global Carbon Project 2021 (1.0)*. Our World in Data Based on the Global Carbon Project 2021; Available from: https://ourworldindata.org/co2-emissions.
- 2. Nematollahi, B., J. Sanjayan, and F.U.J.J.o.M.i.C.E. Ahmed Shaikh, *Tensile strain hardening behavior of PVA fiber-reinforced engineered geopolymer composite.* 2015. **27**(10): p. 04015001.
- 3. Teixeira, E., R. Mateus, A. Camões, F.J.C. Branco, and B. Materials, *Quality and durability properties and life-cycle assessment of high volume biomass fly ash mortar.* 2019. **197**: p. 195-207.
- 4. Tosti, L., A. van Zomeren, J.R. Pels, R.N.J.R. Comans, Conservation, and Recycling, *Technical and environmental performance of lower carbon footprint cement mortars containing biomass fly ash as a secondary cementitious material.* 2018. **134**: p. 25-33.
- 5. Li, V.C. and H.-C. Wu, *Conditions for pseudo strain-hardening in fiber reinforced brittle matrix composites.* 1992.
- 6. Yu, K.-Q., J.-T. Yu, J.-G. Dai, Z.-D. Lu, and S.P. Shah, *Development of ultra-high performance engineered cementitious composites using polyethylene (PE) fibers.* Construction and Building Materials, 2018. **158**: p. 217-227.
- 7. Zhang, Z., Q. Zhang, and V.C. Li, *Multiple-scale investigations on self-healing induced mechanical property recovery of ECC.* Cement and Concrete Composites, 2019. **103**: p. 293-302.
- 8. Xu, L.-Y., B.-T. Huang, J.-G.J.C. Dai, and B. Materials, *Development of engineered cementitious composites (ECC) using artificial fine aggregates.* 2021. **305**: p. 124742.
- 9. Wang, S. and V.C.J.A.M.j. Li, *Engineered cementitious composites with high-volume fly ash.* 2007. **104**(3): p. 233.
- 10. Zhang, Z., S. Liu, F. Yang, Y. Weng, and S.J.J.o.C.P. Qian, *Sustainable high strength, high ductility engineered cementitious composites (ECC) with substitution of cement by rice husk ash.* 2021. **317**: p. 128379.
- 11. Adesina, A., S.J.C. Das, and B. Materials, *Influence of glass powder on the durability properties of engineered cementitious composites.* 2020. **242**: p. 118199.
- 12. Yu, K., M. Lin, L. Tian, and Y. Ding. *Long-term stable and sustainable high-strength engineered cementitious composite incorporating limestone powder.* in *Structures*. 2023. Elsevier.
- 13. Nematollahi, B., *Investigation of Geopolymer as a Sustainable Alternative Binder for Fiber-Reinforced Strain-Hardening Composites*. 2017, Faculty of Science, Engineering and Technology, Swinburne University of ….
- 14. Fakhrabadi, A., M. Ghadakpour, A.J. Choobbasti, S.S.J.C. Kutanaei, and B. Materials, *Influence of the Non-Woven Geotextile (NWG) on the engineering properties of clayey-sand treated with copper slag-based geopolymer.* 2021. **306**: p. 124830.
- 15. Li, Z., Z. Ding, and Y. Zhang. *Development of sustainable cementitious materials*. in *Proceedings of international workshop on sustainable development and concrete technology, Beijing, China*. 2004.
- 16. Duxson, P., J.L. Provis, G.C. Lukey, J.S.J.c. Van Deventer, and c. research, *The role of inorganic polymer technology in the development of 'green concrete'*. 2007. **37**(12): p. 1590-1597.

Reference

- 17. Zhang, P., K. Wang, J. Wang, J. Guo, S. Hu, and Y.J.C.I. Ling, *Mechanical properties and prediction of fracture parameters of geopolymer/alkali-activated mortar modified with PVA fiber and nano-SiO2*. 2020. **46**(12): p. 20027-20037.
- 18. Gao, Z., P. Zhang, J. Guo, and K.J.C.I. Wang, *Bonding behavior of concrete matrix and alkali-activated mortar incorporating nano-SiO2 and polyvinyl alcohol fiber: Theoretical analysis and prediction model*. 2021. **47**(22): p. 31638-31649.
- 19. Pan, Z., J.G. Sanjayan, and B.V.J.M.o.c.r. Rangan, *Fracture properties of geopolymer paste and concrete*. 2011. **63**(10): p. 763-771.
- 20. Nguyen, K.T., N. Ahn, T.A. Le, K.J.C. Lee, and B. Materials, *Theoretical and experimental study on mechanical properties and flexural strength of fly ash-geopolymer concrete*. 2016. **106**: p. 65-77.
- 21. Fakhrabadi, A., M. Ghadakpour, A.J. Choobbasti, S.S.J.B.o.E.G. Kutanaei, and t. Environment, *Evaluating the durability, microstructure and mechanical properties of a clayey-sandy soil stabilized with copper slag-based geopolymer against wetting-drying cycles*. 2021. **80**(6): p. 5031-5051.
- 22. He, P., D. Jia, T. Lin, M. Wang, and Y.J.C.I. Zhou, *Effects of high-temperature heat treatment on the mechanical properties of unidirectional carbon fiber reinforced geopolymer composites*. 2010. **36**(4): p. 1447-1453.
- 23. Alomayri, T., F. Shaikh, and I.M.J.J.o.m.s. Low, *Thermal and mechanical properties of cotton fabric-reinforced geopolymer composites*. 2013. **48**(19): p. 6746-6752.
- 24. Gomes, R.F., D.P. Dias, F.J.T. de Andrade Silva, and A.F. Mechanics, *Determination of the fracture parameters of steel fiber-reinforced geopolymer concrete*. 2020. **107**: p. 102568.
- 25. Zhang, P., Z. Gao, J. Wang, and K.J.C.I. Wang, *Numerical modeling of rebar-matrix bond behaviors of nano-SiO2 and PVA fiber reinforced geopolymer composites*. 2021. **47**(8): p. 11727-11737.

سوباس

thank you
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gracias
merci
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