ABSTRACT

The interfacial transition zone (ITZ) between cement paste and aggregate is a weak and porous interface in concrete whose influence on the properties of concrete has been a subject of debate. It was long accepted as the weakest link in concrete, however doubts have also shown on this conventionally accepted concept. In addition to the ITZ, different heterogeneities present at different scales of concrete influence its behaviour at the structural scale. A shift from utilization of natural materials to waste materials such as supplementary cementitious materials, construction and demolition waste, etc. leads to an increase in these heterogeneities. A better understanding of the influence of various heterogeneities on the properties of concrete is crucial for its optimum design.

The objective of this study was to investigate the influence of these heterogeneities on the overall behaviour of concrete. A combination of experimental and analytical modelling studies was carried out to better understand the behaviour of aggregates, interfacial transition zone and fly ash on the properties of concrete. Ultrasonic pulse velocity test and sorptivity test were performed to measure the elastic and transport properties. A new multiscale continuum micromechanics-based approach was developed to model the mechanical and transport properties of concrete incorporating the microstructure of interfacial transition zone. The multiscale nature was incorporated in the approach from the scale of C-S-H gel to the scale of concrete. The microstructure of ITZ around aggregates was simulated using µic, a cement microstructural hydration model. The gradients in the microstructure of ITZ were addressed by homogenizing it in thin layers starting from the surface of aggregate to the bulk cement paste.

The experimental studies demonstrated that the influence of ITZ on elastic modulus, compressive strength and transport properties is complex and that modelling is necessary to distinguish the influence of ITZ from other effects. The experimental study also indicated that the increased presence of fly ash particles in the ITZ leads to an improvement in the mechanical properties of mortars compared to pastes. It was observed that the microstructure of ITZ could be simulated around large particles in a computational volume using the cement hydration model. The modelling studies showed that the large gradients within the microstructure of ITZ is the controlling factor for the compressive strength of concrete. Its influence on the transport properties was found to be higher compared to the influence on elastic properties. The modelling study also demonstrated that why the experimental studies usually conducted to understand the influence of ITZ does not capture the influence of ITZ on the overall behaviour of concrete. The modelling results provide insights into the influence of fly ash on the development of compressive strength. It was seen that pozzolanic reaction of fly ashes leads

to an increase in the C-S-H content in the C-S-H foam, especially in the ITZ, allowing the mortars to gain strengths similar to those without fly ash, despite having a higher total porosity. It was also observed that the changes in the composition of C-S-H, usually observed experimentally, may influence the phase assemblage but its influence on the elastic properties of mortars is little.