Recent Research and Development of Concrete in Vietnam

Summary

Concrete is the key and major material in the construction industry in Vietnam. In recent years, concrete has been commonly used over 200 million cubic annually for various products comprising ready-mixed, cast-in-place and precast concrete structures and components. The demand of using concrete in practice needs more efficient products towards more sustainable with limiting the use of natural resources. Recent research and development of Ultra High Performance Concrete (UHPC), High-strength Lightweight concrete, Sustainable concrete using cementitious and aggregate replacements such as fly ash, GGBS and sea sand, and a new 3D concrete showed promising results in experiments as well as application in practice.

Ultra High Performance Concrete (UHPC) or Ultra High Performance Fibre Reinforced Concrete (UHPFRC) with very high compressive strength (150–200 MPa) and flexural strength (typically 20–45 MPa) has been being successfully developed in Vietnam. The research results confirmed that up to 50% fly ash (FA), 30% ground granulated blast furnace slag (GGBS), 30% rice husk ash (RHA) could effectively replace the cement content in the UHPC composition to help improve the sustainability of the concrete. The addition of fibres is proved to enhance the loading capacity, reduce shrinkage, and prevent cracking effectively to UHPC. This leads to confidently apply the UHPC for real structures in Vietnam. Recently, the application of UHPC in Vietnam has been implemented for various structures from septic tanks, rural bridges, sheet piles, etc. to retrofitting a large bridge (use of 2000 m^3 UHPC) and this shows very promising and potential for more popular use in the near future.

High strength lightweight concrete (HSLWC) using hollow fly ash microspheres (FAC) with unit weight of 1300-2000 kg/m^3 and compressive strength of 40-70 MPa has been successfully produced. When using FAC to replace 100% of sand for producing high-strength lightweight concrete, with W/B of 0.4, binder content of 750 kg/m^3, density of concrete reduced from 2180 to 1367 kg/m^3, at the same time reducing dry shrinkage of concrete by about 26% at 6-month age. Similar to conventional concrete, increased binder content increases dry shrinkage of HSLWC. Adding polypropylene fiber at 0.3-0.5% volume of concrete mixture reduces dry shrinkage of concrete, although reduction rate is not so high about 4.3 to 7.3%. Dry shrinkage of HSLWC with density about 1342-1376 kg/m^3 in the range of 754 – 940 $\mu\varepsilon$, is generally larger than that of conventional concrete (with coarse aggregates), but lower than that of fine aggregate concrete (without coarse aggregates). This feature will affect deformation properties and crack resistance of concrete structure. The concrete has been used to fabricate a number of real scale slabs and beams and then the flexural test results showed that the structures worked very well even compared with the ordinary weight concrete structures.

A number of research on the sustainable concrete using cementitious and aggregate replacements such as fly ash, GGBS and sea sand have also been studied thoroughly. The use of fly ash in combination with local aggregate materials namely crushed sand and sea sand for concrete structures in marine environments showed that 20 - 40% fly ash could minimize the disadvantages of these two types of sand such as poor workability, high mixing water demand when using crushed sand and reducing durability and protection of reinforcement from corrosion when using sea sand with high chloride ion content.

Several research focused on using GGBS to replace cement for conventional concrete with compressive strength from 30 to 60 MPa. Two types of GGBS with different fineness, one with a specific surface area (Blaine fineness) > 4000 cm^2/g and one > 5000 cm^2/g, with GGBS ratios up to 70%. The studies show that using GGBS with Blaine surface area > 5000 cm^2/g gave higher compressive strength, flexural strength, split strength, and elastic modulus of concrete at the age of 7 days and the late ages of 28 and 91 days than using GGBS with Blaine surface area > 4000 cm^2/g. Also, using GGBS can improve chloride ion penetration resistance, impermeability, and aggregate alkali reaction resistance and improve sulfate resistance via decreased expansion mortar bars immersed in sulfate solutions (Na_2SO_4 and $MgSO_4$).

Due to rapidly high demand of construction sand and the limitation of river sand resources in Vietnam, the issue of alternative sand sources for river sand is a matter of concern. Vietnam has a long coastline of more than 3200 km with a large sea area, so sea sand resources are very potential. The research results showed that sea sand is mainly fine sand with a fineness modulus from 0.6 to 3.15, of which the major is from about 1.0 to 2.16. Chlorine ion content in sea sand depends on the water absorption and mining location, ranging from 0.023-0.16%, of which major in the range > 0.05%-0.1%, which is higher than the threshold (not more than 0.05%) of the chlorine ion content specified in the current national Vietnam standards on aggregates for concrete and mortar. Concrete using sea sand with a chlorine ion content of 0.375% gave the greatest reduction in workability and loss of workability compared to the original sea sand and other samples. The strength development of concrete using sea sand at the age of 7 and 28 days was higher than that of river sand and washed sea sand but strength at later ages 28, 91, and 365 days tended to decrease. The compressive strength after 365 days of sea sand containing 0.15% chlorine ion content (original sand) and 0.375% decreased by about 5.4-7.1% and 7.4-10.8% for concrete grades of 30 and 40 MPa, respectively. The chloride ion penetration resistance and impermeability of concrete using sea sand also decreased as the chloride salt content in sea sand increased.

Since 2019, a 3D printing concrete technology has been tested and developed using a 3D concrete XYZ gantry printer with overall dimensions of 4.92x2.53x2.53 m that can print objects with dimensions up to 1.8x1.8x2.5 m. A high performance concrete having good extrudability, buildability, open time and over 50 MPa compressive strength, over 8MPa flexural strength and less than 0.2% drying shrinkage has been developed and be usable effectively for 3D printing. The material and the 3D concrete printer have been deployed to print successfully architectural objects, a set of curvy table & chair and a 1.8x1.8x2.5 m sentry box. In 2022, another research using larger concrete printer has successfully completed two 3D concrete printed houses with the areas of 70 m^2 and 120 m^2 and one 15 m^2 bungalow. These are the lively evidence for the rapid development of this latest concrete technology in Vietnam.