Functional Artificial Aggregates for Sustainable Construction

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Background

- Shortages of natural aggregates (sand and gravel) gradually cannot meet the increasing construction demand nowadays, which has become a critical problem for concrete industry. In addition, the large scale excavation of natural aggregates is not sustainable, which can impose a threat onto the natural environments.
- The increase of discarded industrial by-products/wastes has forced modern society to face the challenges of landfill shortage and environmental pollution. Although several grain-like waste materials can be directly used as aggregates (shown in the below figure), they cannot meet the high demand of construction work as aggregates can occupy 60–70% volume of concrete.

- Therefore, the approach of recycling waste materials to produce artificial aggregates through cold-bonding technology is a one-stone two-bird solution for the aforementioned issues, which is more cost-effective and less energy-consuming than sintered aggregates.

Objective and Scope

Objective: to explore the feasibility of the application of waste-based artificial aggregates in cementitious materials and evaluate the overall performance

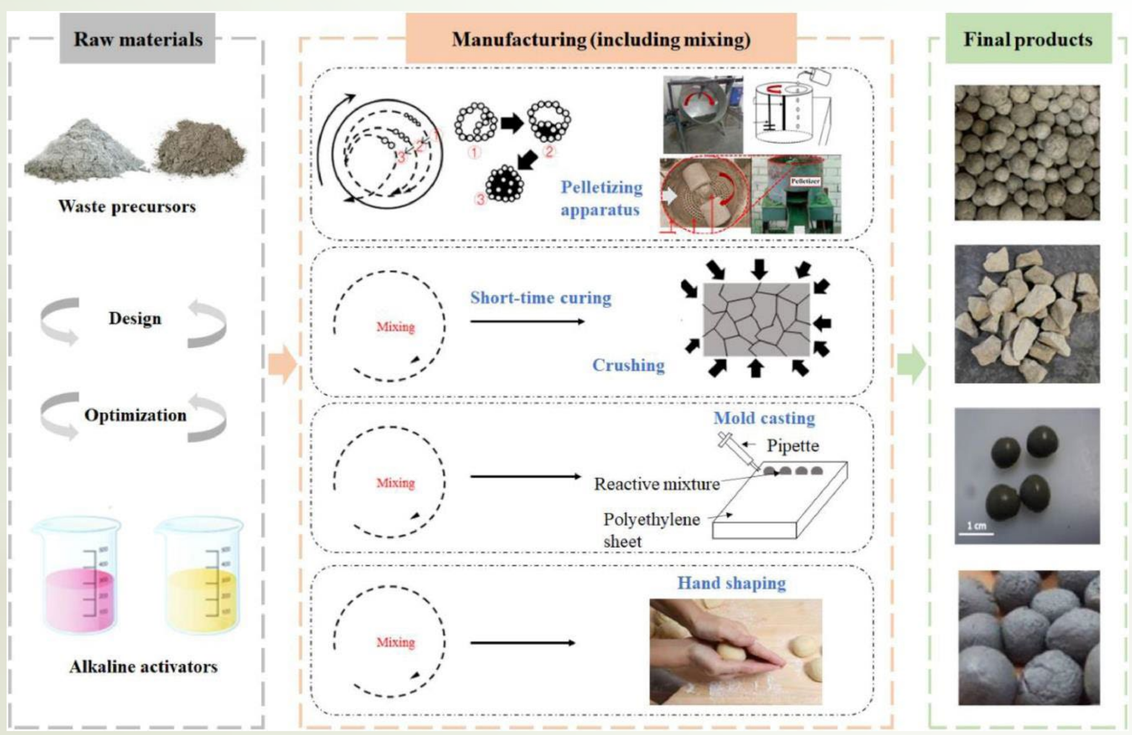
Scope:

- **Ordinary concrete:** Physical and mechanical performance
- **High-performance cementitious composites:** Mechanical performance, cracking behavior and microscopic characterization

Artificial aggregate technology and properties

Artificial aggregate technologies:

- Pelletization, crushing, mold casting and hand shaping

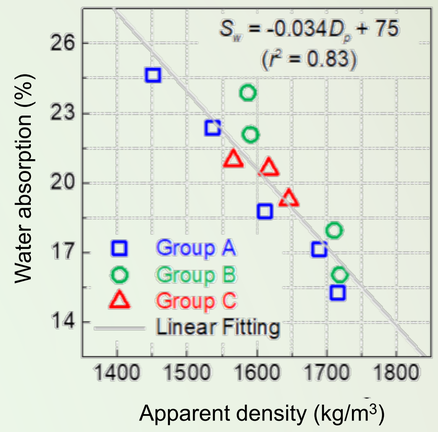


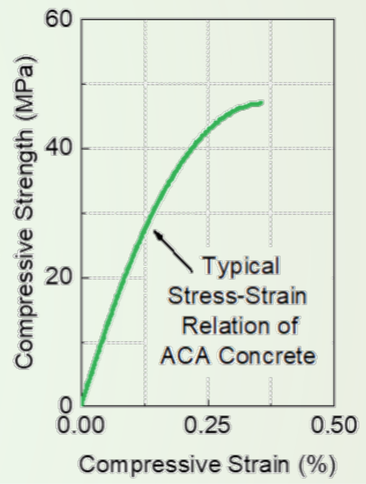
Artificial aggregate properties

- Artificial aggregates can be produced from different materials (left: fly ash & right: red mud).
- The produced crushed artificial coarse aggregates have similar shapes to natural aggregates.
- The water absorption values are generally larger than 15%.

Application in ordinary concrete

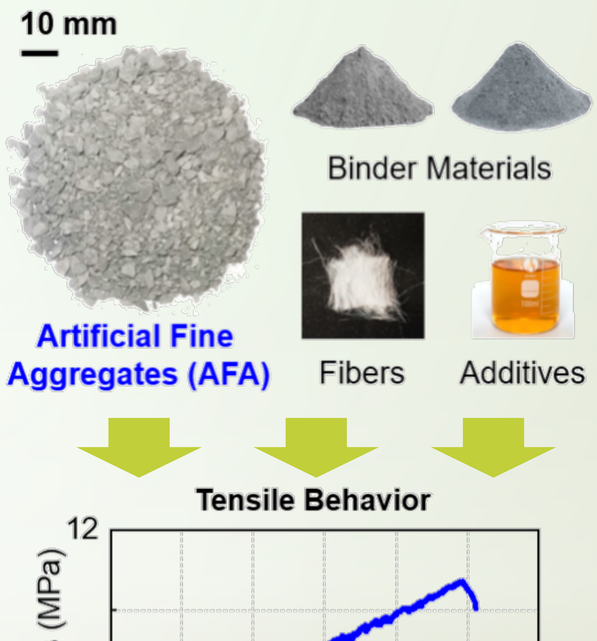
- **Target:** Artificial coarse aggregates (ACA)
- **Overall physical properties:**
  - ➢ As ACA are generally lightweight, the ACA concrete mass (around 2100 kg/m^3) can be lower than natural aggregate concrete (around 2400 kg/m^3) .
  - ➢ ACA have high water absorption, and therefore can be used as internal curing agent in ordinary concrete.
  - ➢ Both the density and water absorption of ACA can be adjusted by changing the raw materials and mix proportions of ACA.
- **Mechanical properties:**
  - ➢ The ACA concrete inevitably has lower strength than natural aggregate concrete.
  - ➢ The current highest compressive strength of ACA concrete is around 48 MPa.
  - ➢ The failure mode of ACA concrete depends on the ACA strength as well as the matrix strength.
  - ➢ The feasibility of the application of ACA in ordinary concrete is demonstrated.

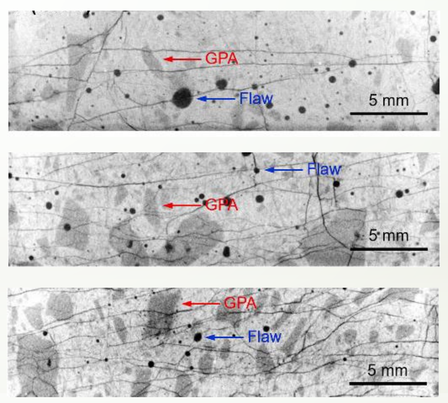


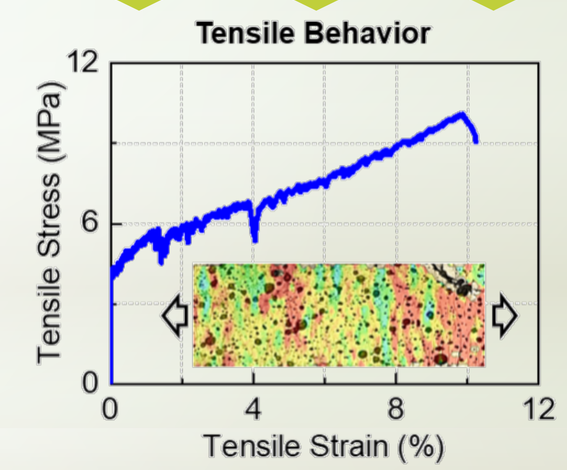


Application in high-performance cementitious composites

- **Target:** Artificial fine aggregates (AFA)
- **Overall Mechanical properties:**
  - ➢ Compressive strength > 110 MPa
  - ➢ Tensile strength > 6 MPa
  - ➢ Tensile strain > 6%
- **Cracking behavior:**
  - ➢ Saturated multiple cracking
  - ➢ Average crack width < 65 μm
- **Microscopic characterization:**
  - ➢ Enhanced AFA/binder bonding
  - ➢ Crack-inducing effect of AFA







Summary and Findings

- It is feasible to use waste materials to develop artificial aggregates, and their applications in ordinary concrete and high-performance cementitious composites are demonstrated.
- Artificial coarse aggregates are effective to reduce the self-weight of the produced ordinary concrete, but the concrete strength is inevitably lower than that of natural aggregate concrete. However, the current highest artificial aggregate concrete strength is around 48 MPa, which can satisfy most of the construction work.
- Artificial fine aggregates are suitable for the production of high-performance cementitious composites with high compressive strength over 110 MPa and high tensile strain over 6%. The lower strength of artificial fine aggregates than matrix can help induce more microcracks, which facilitate saturated multiple cracking and excellent tensile ductility.

Acknowledgement

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