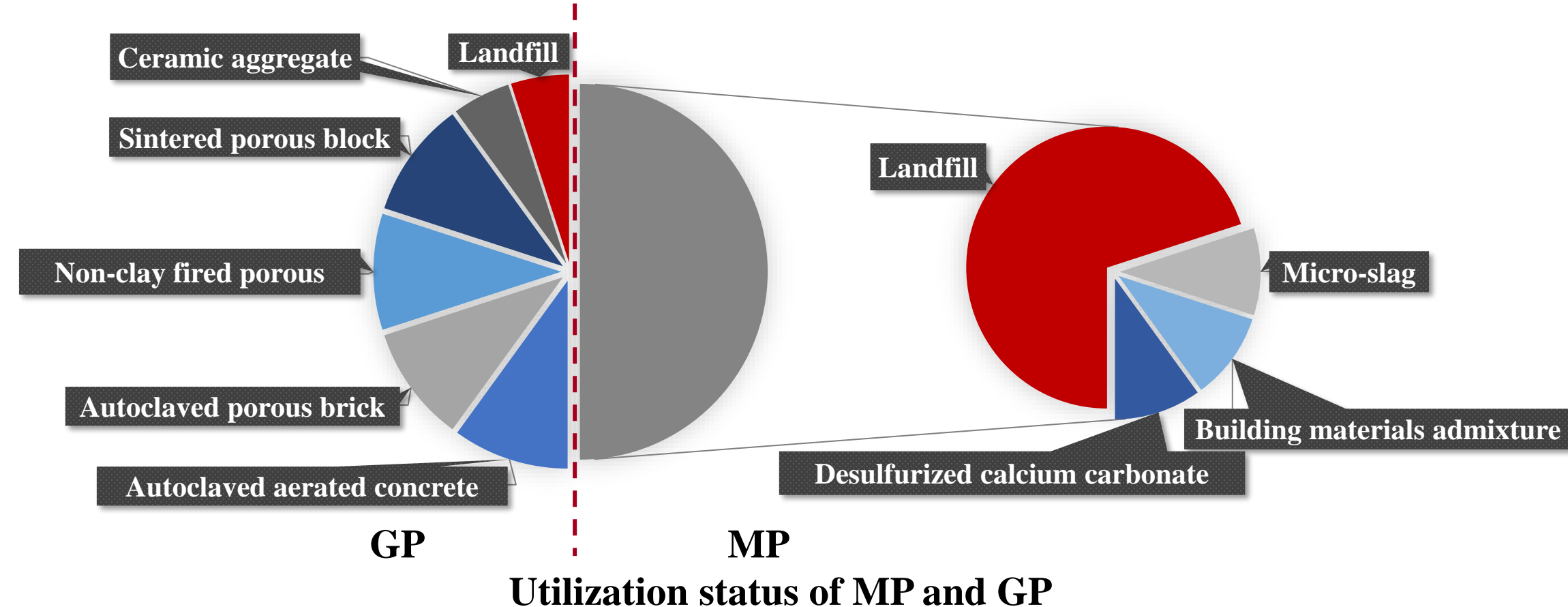


Introduction

- Marble and granite are widely used as building materials worldwide.
- The amount of waste marble powder(MP) and granite powder(GP) produced in the process of mining, cutting and polishing is as high as 25% of the total amount of processed stone.
- Taking Nan 'an, Fujian Province as an example, tons of MP and GP cannot be reused every year, and the common treatment is still landfill, causing severe environmental problems.
- If MP or GP replaces part of cement or are incorporated into concrete as fine aggregate, it can reduce carbon emissions in the cement production as well.



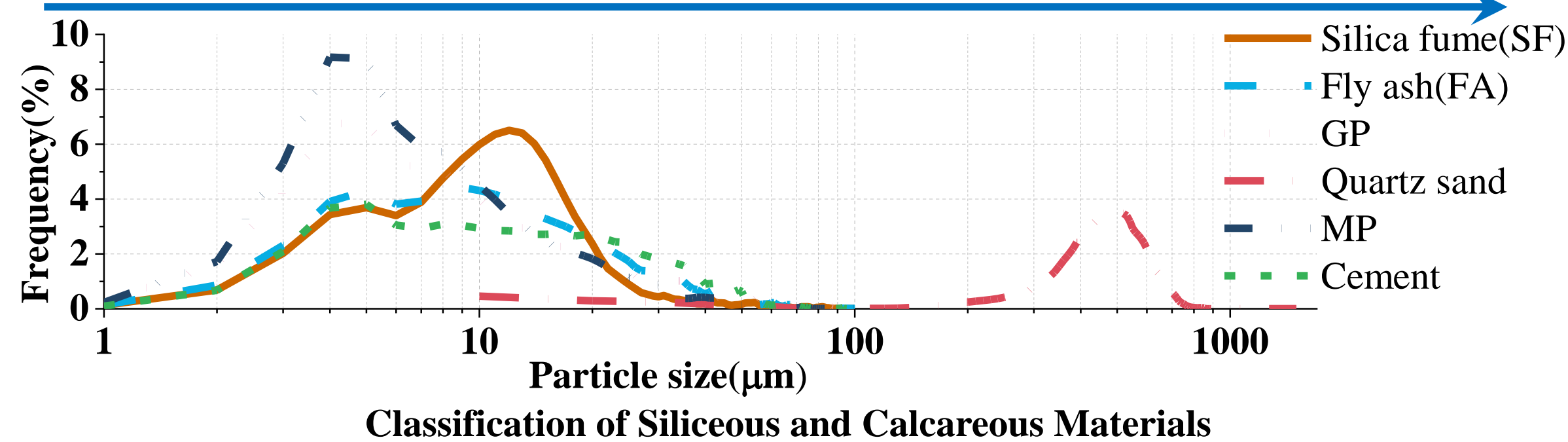
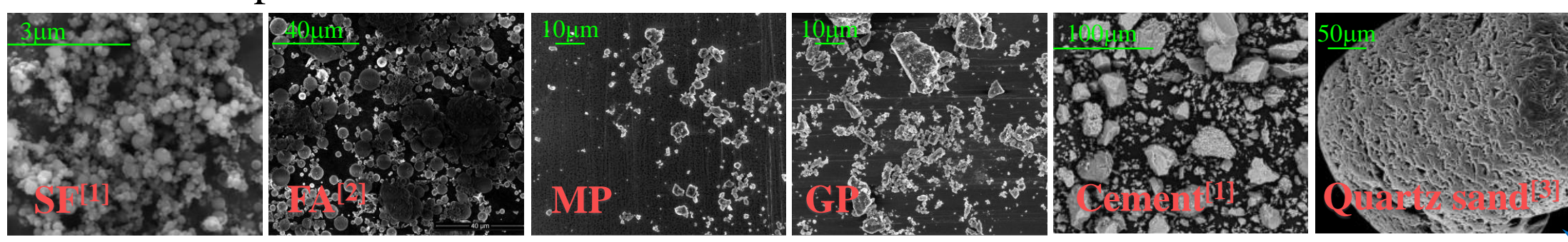
Objectives

- Explore the mechanism of MP and GP on mortar from multiscale levels.
- Find the best mix proportion and analyze the commercial feasibility of waste MP and GP in cementitious materials.

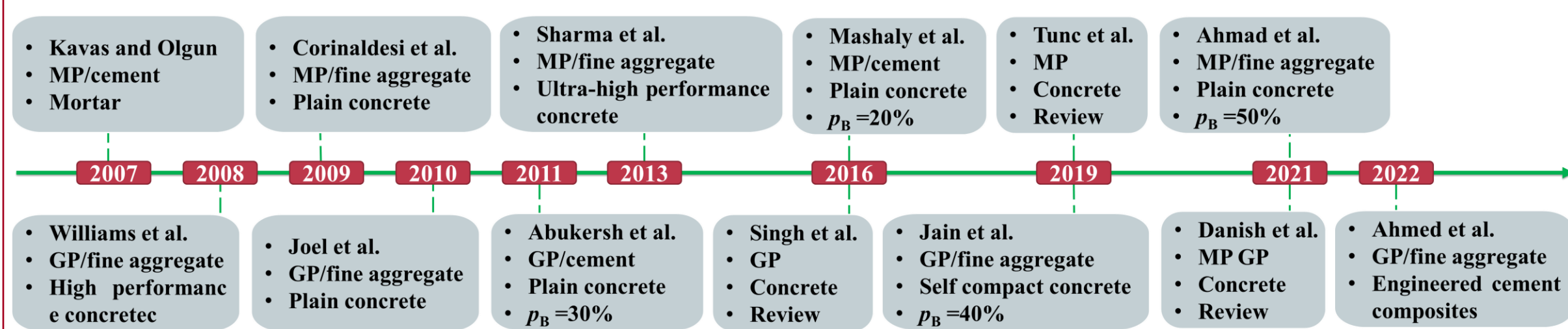
Research Status

Material Properties of MP and GP

- The mineral composition of MP and GP from different producing areas is similar. MP is mainly calcite and GP is mainly quartz.
- The median particle size of MP and GP are 11.5 μ m and 8.9 μ m respectively, which are smaller than cement particles and similar to the particle size of fly ash, and the minimum particle size can reach nanometer scale.

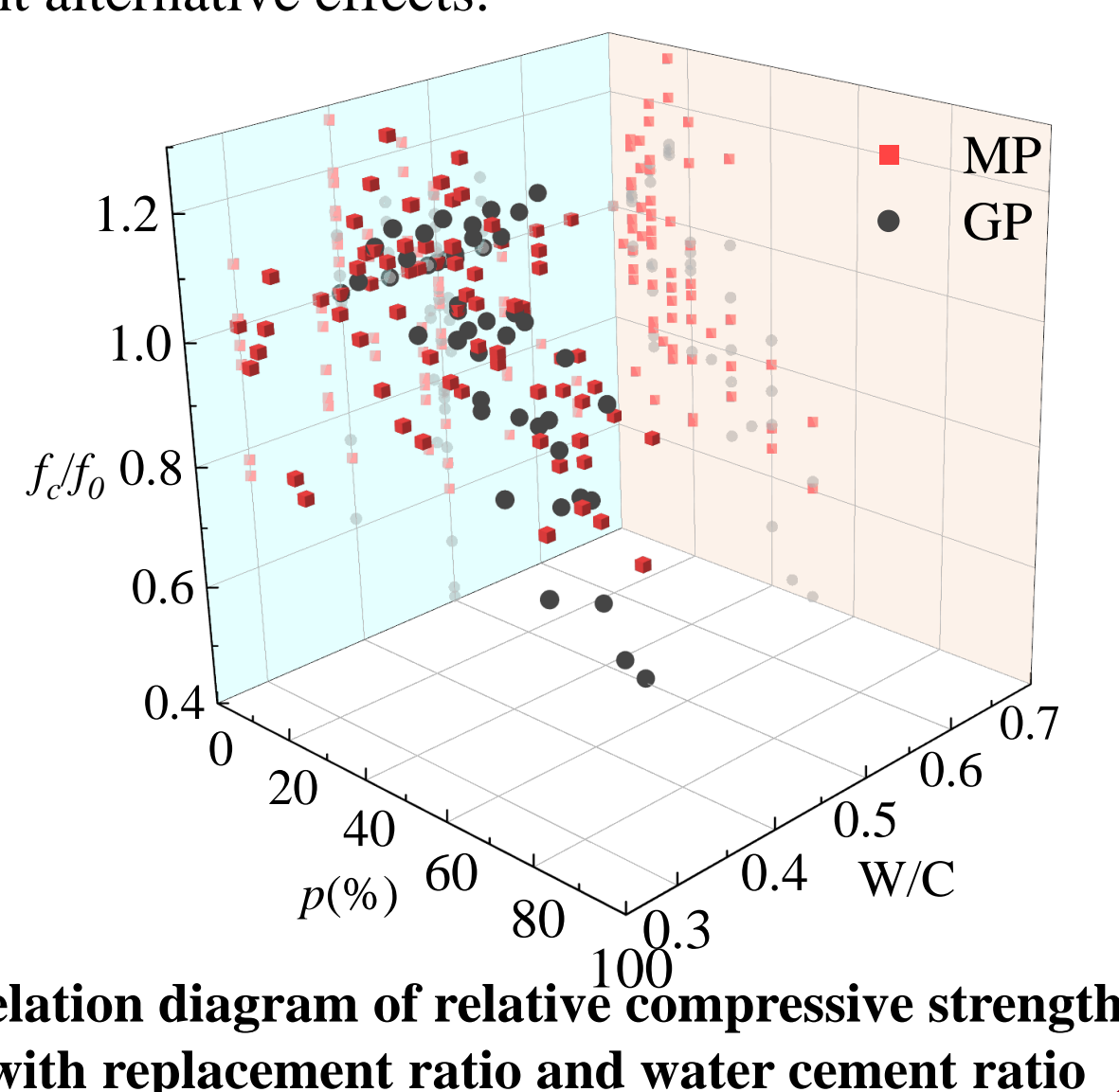


Application in Cementitious Materials



- GP and MP mainly have two alternative modes in ordinary concrete or mortar, that is, replacing cement of the same quality or fine aggregate of the same quality. Since these two alternative modes will cause the actual water-cement ratio to change and remain unchanged, they will also produce different alternative effects.

- After the addition of MP or GP, it can reduce the porosity, improve the strength and durability of concrete, but it may also have the opposite effect. Its effect is influenced by the coupling factors of mixing method, water-cement ratio and admixture.
- There are relatively few researches on the hydration dynamic characteristics, hydration mechanism and multi-scale pore structure of cementitious materials after the addition of MP and GP, which leads to a large dispersion of properties after the addition.



Experimental Process



Ultrasonic dispersion
Curing

① Workability

- Consistency

② Setting time

- Initial and final setting time

③ Micro structure

- Hydration products

④ Pore structure

- Pore size, porosity

⑤ Mechanical strength

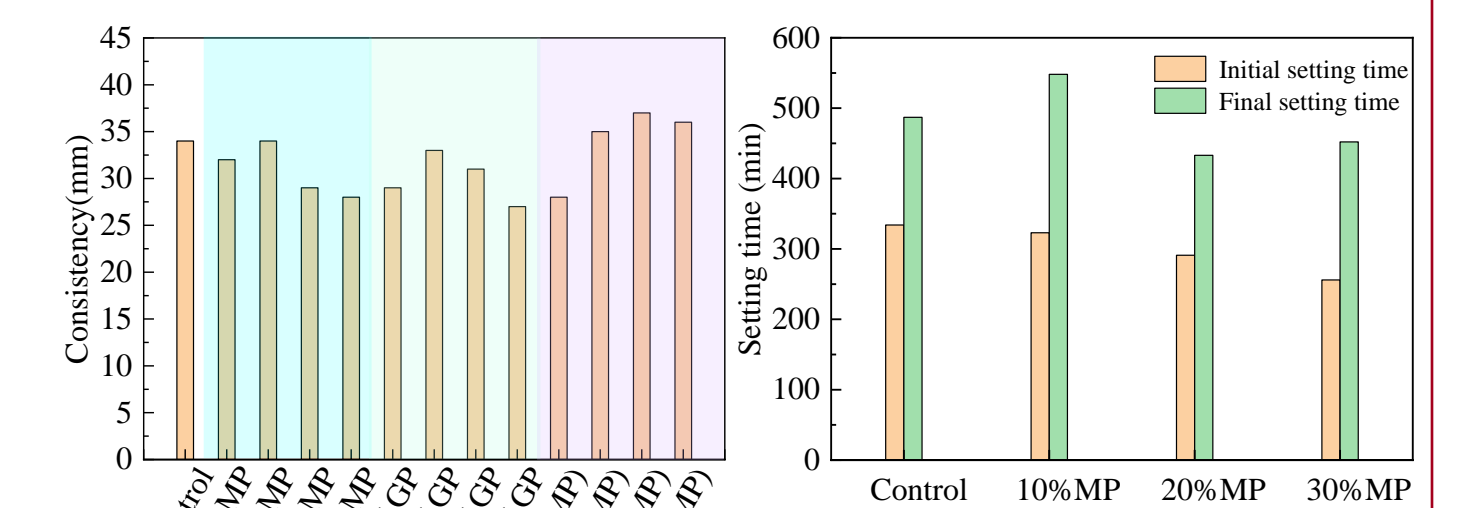
- Compressive strength



Results and Discussions

Workability and Setting time

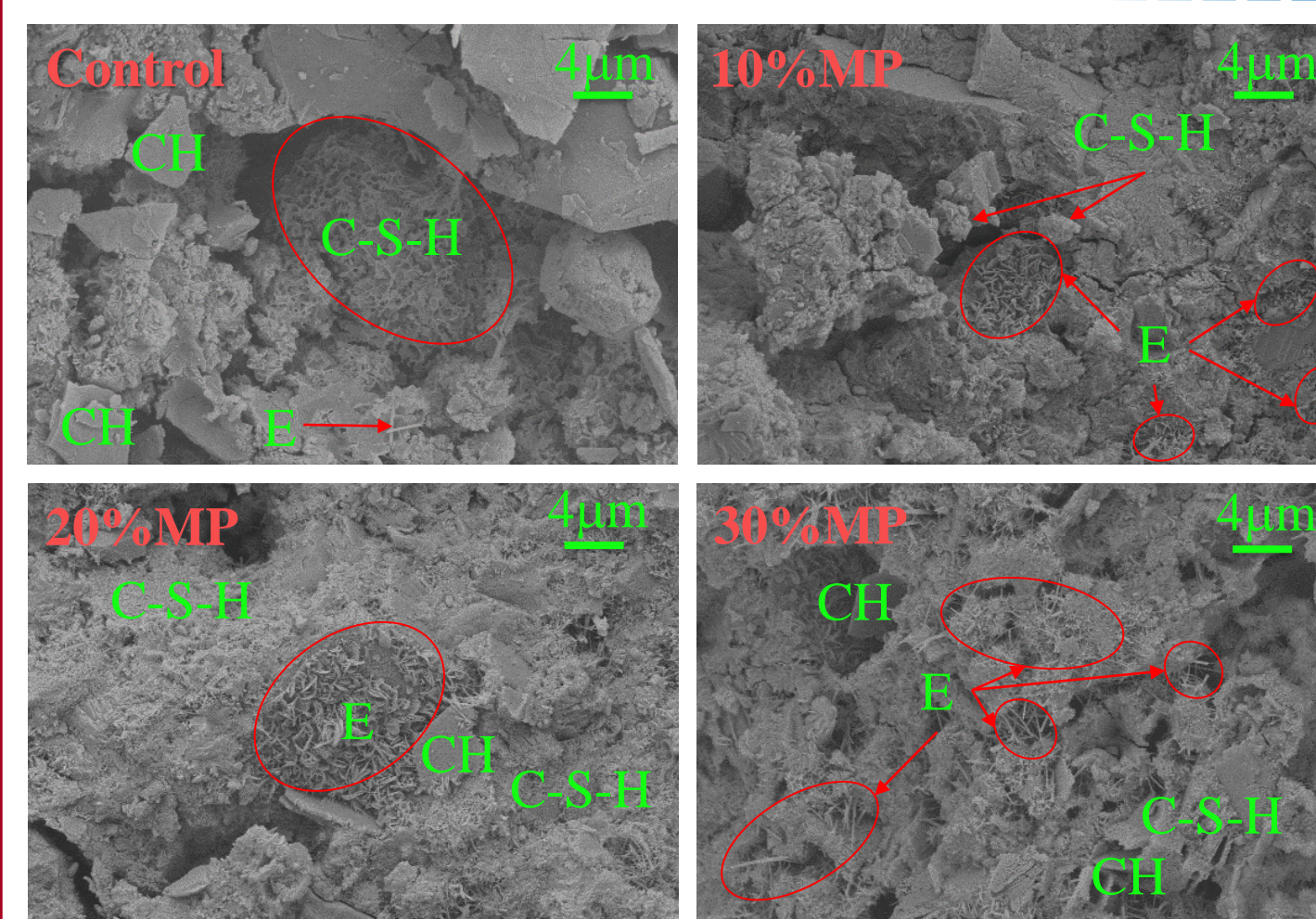
- As the replacement rate increasing from 5% to 30%, the consistency of mortar first increases and then decreases, but is lower than that of the control group.
- When MP and GP are added more than 5% respectively, the consistency of mortar is higher than control group.
- With the increase of MP content, the initial setting time of mortar gradually decreases, and the final setting time increases first and then decreases and then increases.



Mortar consistency values with different replacement rates Effect of MP content on setting time of mortar

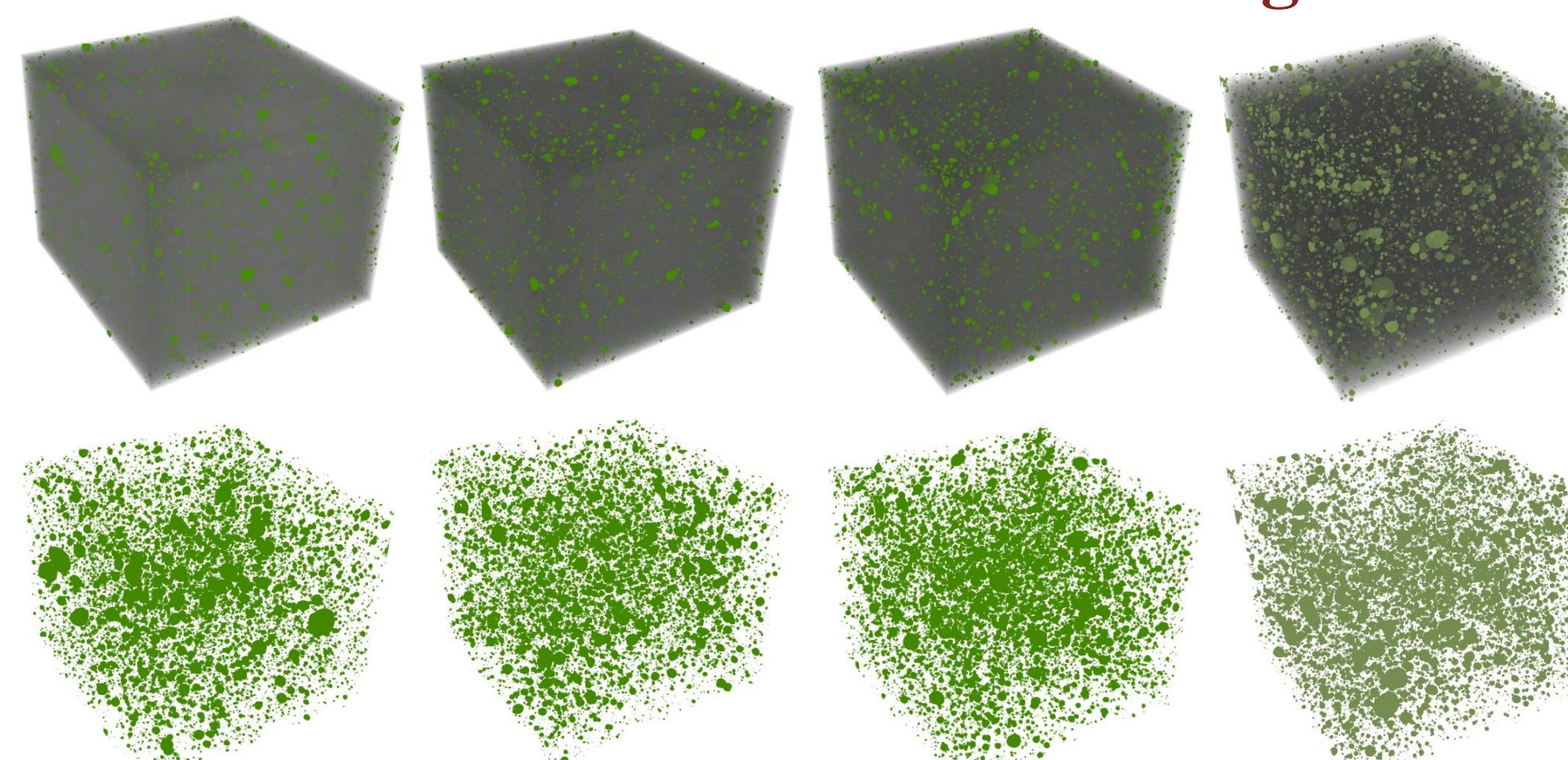
Microstructure

- Calcium silicate hydrate(C-S-H) is mainly mesh and gel, ettringite(E) is mainly flake and needle, calcium hydroxide(CH) is mainly multilateral crystal.
- C-S-H is the main product of cement hydration, which can fill the pores in the matrix, so as to make the structure denser and improve the properties of mortar.
- Ettringite can make cement provide early strength and compensate for early shrinkage of concrete, but the presence of a large amount of ettringite will cause concrete expansion and cracking.
- As the increase of MP, the content of reticular C-S-H decreases gradually, while the content of flake and acicular ettringite increases gradually, which leads to the gradual decrease of mortar strength.



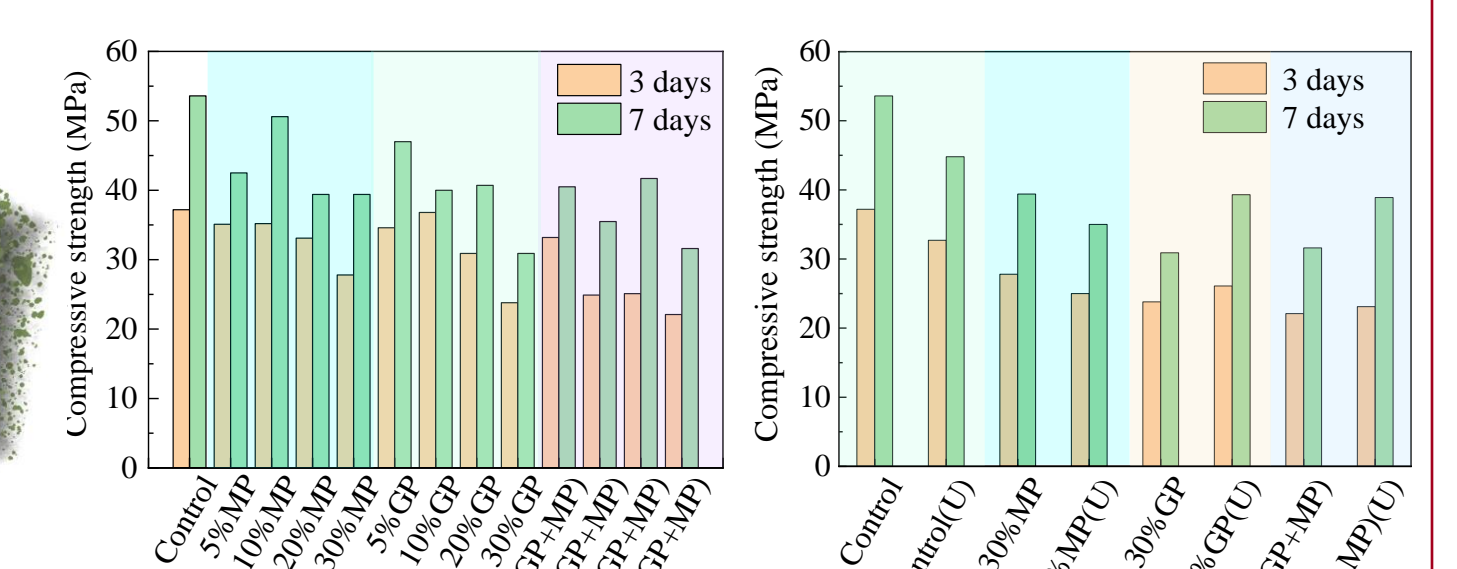
SEM images of mortar with different replacement rates

Pore structure and Mechanical strength



Control (porosity:1.38%) 10%MP (porosity:1.29%) 20%MP (porosity:1.42%) 30%MP (porosity:1.59%)
CT images of pore structure of mortar (7 days) with different MP replacement

- With the increase of MP replacement rate, the porosity of mortar decreases first and then increases, and the average pore size increases, but most of the holes are closed holes, and the connected holes are less.



Influence of stone powder content on compressive strength of mortar Ultrasonic treatment of stone powder and cement on compressive strength of mortar

- As the replacement rate increasing from 5% to 30%, the compressive strength of mortar first increases and then decreases, but is lower than that of the control group.
- Ultrasonic dispersion can reduce the compressive strength of the mortar in the control group and 30%MP group, but increase that of 30%GP group and the mixed group.

Conclusions and Reference

- Effect of fine particles and composition of MP and GP on mortar: filling effect, nucleation effect, volcanic ash effect.
- With the change of hydration products and the deterioration of pore structure, the strength of mortar gradually decreases.
- Ultrasonic dispersion may have adverse or positive effect on compressive strength, this needs to be further studied.
- In terms of strength, the content of 20% MP and GP is acceptable, which is helpful in the fight against climate change.

Ref. [1] Ramos et al, 2013. [2] Saafi et al, 2013. [3] K. Vos et al, 2014.