Full biography of Goangseup Zi[*‡]

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Introduction

Prof. Goangseup Zi is conducting researches on "structural systems" with the application of solid mechanics. Depending on the length scale of interest, the "structural system" may be structures, members, materials, etc. Specifically, he is interested in the failure of the structural systems made of quasi-brittle materials such as concretes, rocks and synthetic composite materials, etc.

Zi's work has spanned several engineering disciplines. He made outstanding advances in computational fracture mechanics, fracture, damage and deterioration of concrete structures, and multi-physics cross-field. He has been honored with numerous awards in recognition of his accomplishments. Particularly in 2018, he received the award of Highly Cited Researcher, which is given by Clarivate Analytics to only top one percent of authors worldwide with most cited publications across all scientific and engineering fields as shown in Fig. 1. He has authored or coauthored two books and more than 100 research articles in internationally refereed journals.

Education

Born and educated in Republic of Korea, Zi received his B. S. and M. S., Ph. D. degrees in civil engineering from the Hanyang University, Seoul, Korea and Northwestern University, Evanston, IL, USA. His Ph. D. advisor was Prof. Zdeněk P. Bažant. During his Ph. D. study, he was awarded Walter P. Murphy honorary fellowship from 1997 to 1998. After his Ph.D., he worked with Prof. Ted Belytschko at the same institute. Both Profs. Zdeněk P. Bažant and Ted Belytschko are

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Figure 1: 2018 Highly Cited Researcher given by Clarivate Analytics.

extremely well-known researchers for their contributions to fracture mechanics and computational mechanics, respectively.

Computational fracture mechanics

Of all of his works in computational fracture mechanics, Zi's contribution to the extended finite element method (XEFM), the extended element-free Galerkin method (XEFG) and the Phantom node method for the simulation of crack growth is well-recognized in the field of computational fracture mechanics. He developed a unique but very simple enrichment scheme as shown in Fig. 2 [41]. It was proposed for the first time to introduce the ordinary step enrichment to only a part of the crack tip element. The enriched displacement field was interpolated by using the same kind of the shape function. This idea greatly simplified the implementation of the enrichment for partially cracked elements, and improved the accuracy and efficiency of the fracture simulation for cohesive cracks. This paper has been cited more than 320 times.

This idea was further simplified into the so-called Phantom node method in which no enrichment is required at all [27, 30]. The standard approximation of the displacement field on was used in each side of the cracked element. The elements were extended to the opposite sides of the crack introducing the local duplication of homologous nodes called phantom-nodes, as shown in Fig. 4. Only the part of the element for the real domain was integrated to construct the variational condition for its implementation. It was shown that,thanks to its conceptual simplicity, this scheme could be combined very freely with other assumed strain-based elements, such as MITC3 and MITC4 [6, 7].

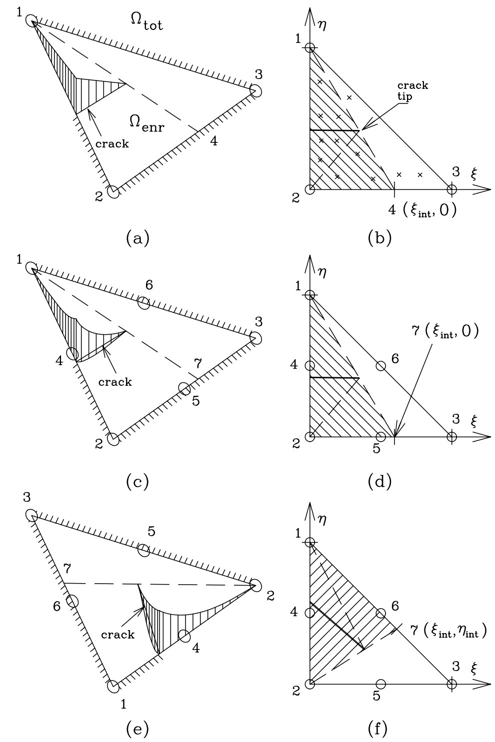


Figure 2: Zi's enrichment scheme for partially cracked elements [41].

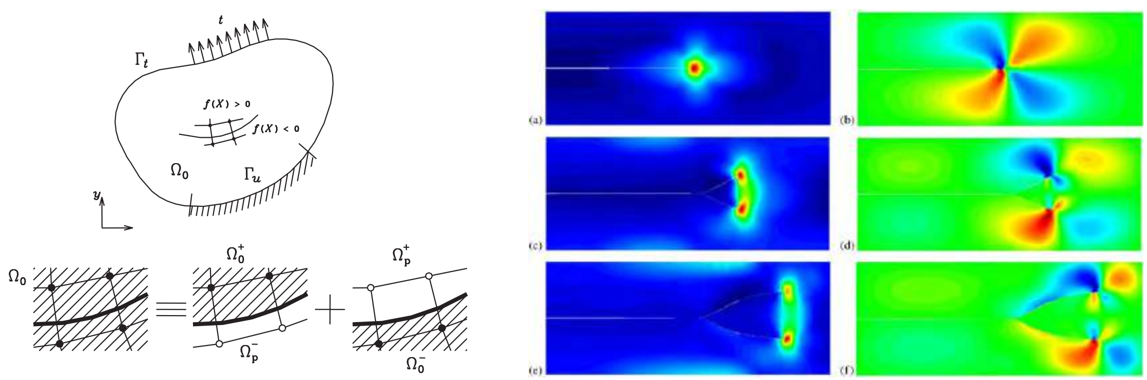


Figure 3: Phantom node method for cohesive fracture [27].

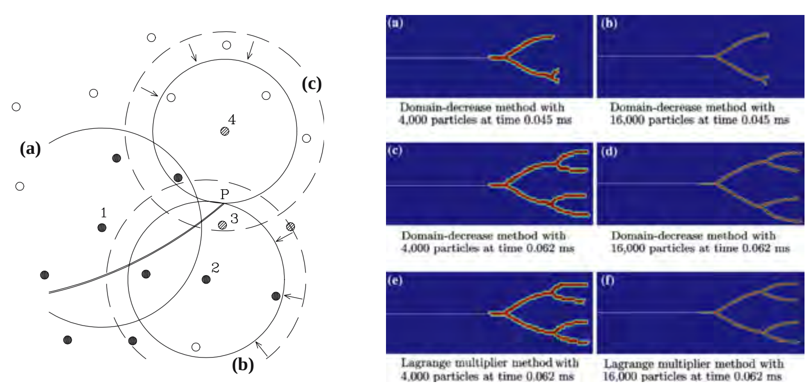


Figure 4: The extended element free Galerkin method for static and dynamic fracture problems [43].

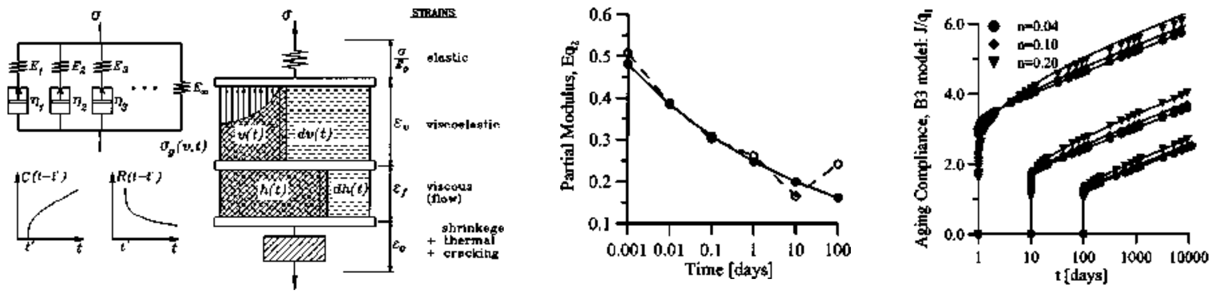


Figure 5: Continuous relaxation spectrum for the simulation of age-dependent concrete creep [38].

Zi applied the idea of XFEM, i. e. the displacement enrichment, to the element free Galerkin method (EFG) to develop the extended element free Galerkin method (XEFG) in close collaboration with Profs. Rabczuk and Bordas [42, 43], as shown in Fig. 4. Because XEFG inherits the advantages of both methods, i. e. the smooth displacement field of EFG and the strong discontinuity of XFEM, this method was very successful in many different kinds of fracture problems including linear [5, 28], nonlinear [24, 26, 31], static [4] and dynamic [25] fracture problems.

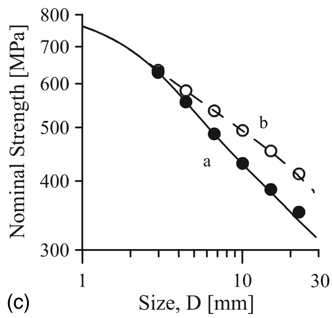
Fracture, damage and deterioration of concrete structures

Because of the multiscale nature of concretes, Zi worked in various length scales, i. e. from material scales to structure scales, for this subject. He tried to provide a universal framework for both structural concretes and asphalt concretes used in pavements. The continuous relaxation spectrum method shown in Fig. 5 would be a good example which is useful for structural concretes [38] and asphalt concretes as well [22]. By using this method, the age-dependent rheological model can be determined uniquely. It had been a ill-conditioned problem to determine a rheological model corresponding to a creep behavior using the widely-used least square fitting method.

Zi has developed various tools to study the nonlinear fracture and damage behavior of concrete materials. One of the most important consequences of fracture mechanics is the size effect; the nominal strength depends on the size. If the effect of nonlinear fracture is important, as observed in most of structural concretes and also, asphalt pavement, a nominal strength may be determined only after the calculation of the full load-displacement curve. He formulated an eigenvalue relation between the nominal strength of a structure and the cohesive law mathematically [39]. It was shown that the nominal strengths at different sizes could be determined without the calculation of full load-displacement curves as shown in Fig. 6a. He also showed that the cohesive nonlinear crack could be represented by the sum of infinitely many linear elastic cracks as shown in Fig. 6b [1].

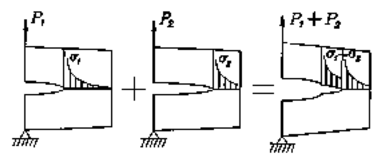
One of the test methods devised by Zi has been accepted as an international standard, ISO

$$\overline{\sigma}_{\rm N} = \frac{\int_{\alpha_0}^{\alpha} \bar{w}_{,\alpha}(\xi)\left\{\overline{\sigma}_{,\bar{w}}(\xi)\bar{w}(\xi) - \overline{\sigma}(\xi)\right\}\mathrm{d}\xi + \overline{D}\overline{\sigma}_0 \int_{\alpha_0}^{\alpha} \overline{C}^{\sigma 0}(\xi)\overline{\sigma}_{,\bar{w}}(\xi)\bar{w}_{,\alpha}(\xi)\mathrm{d}\xi}{\overline{D}\int_{\alpha_0}^{\alpha} \overline{C}^{\sigma \mathrm{N}}(\xi)\overline{\sigma}_{,\bar{w}}(\xi)\bar{w}_{,\alpha}(\xi)\mathrm{d}\xi}$$



(a)

$$\sigma_N = \frac{K_c}{\sqrt{D}} \int_0^1 \frac{q(\rho)\,\mathrm{d}\rho}{k[\alpha(\rho)]}$$



(b)

Figure 6: (a) Zi and Bažant's eigenvalue method [39] and (b) the smeared-tip method [1] to determine the nominal strengths.

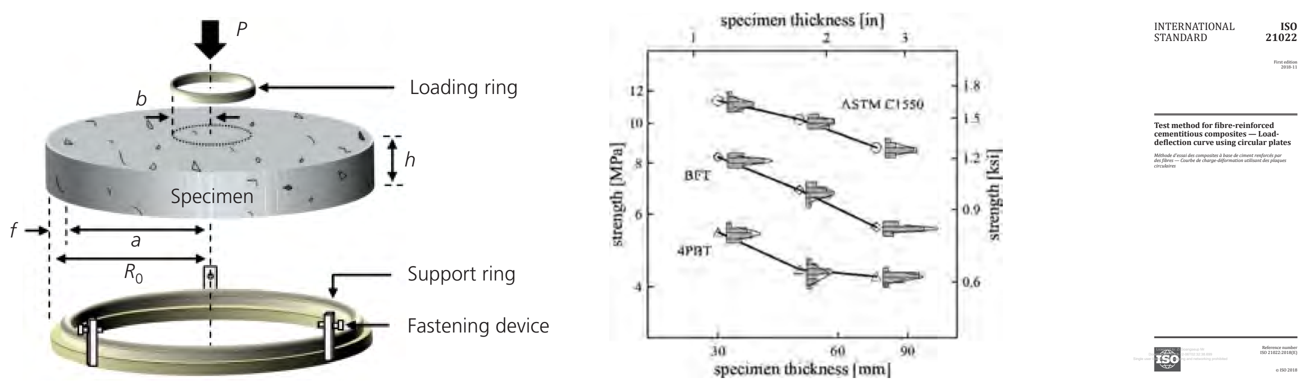


Figure 7: The biaxial flexure test (BFT) to measure the biaxial tensile strength of concretes [11, 44].

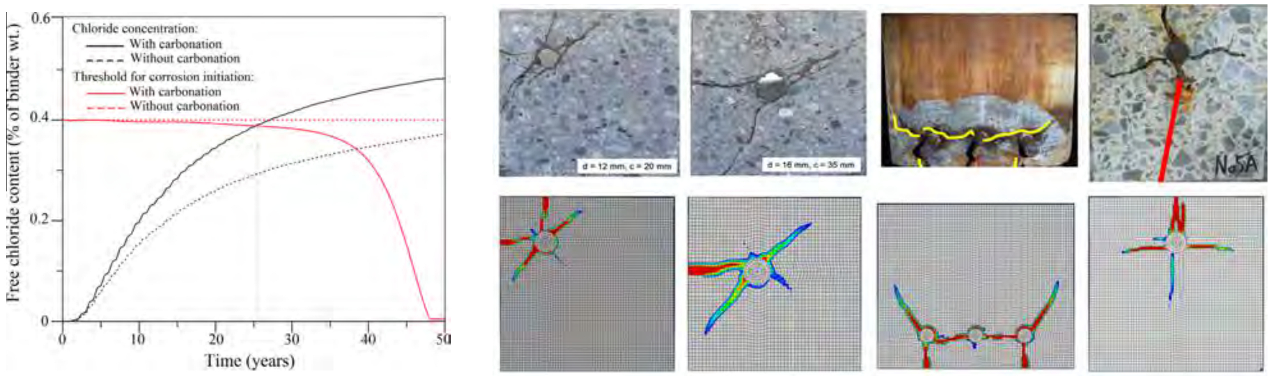


Figure 8: The reduction of durability life under combined durability attacks [35] and an example of chemo-physical model for the entire process of corrosion [34].

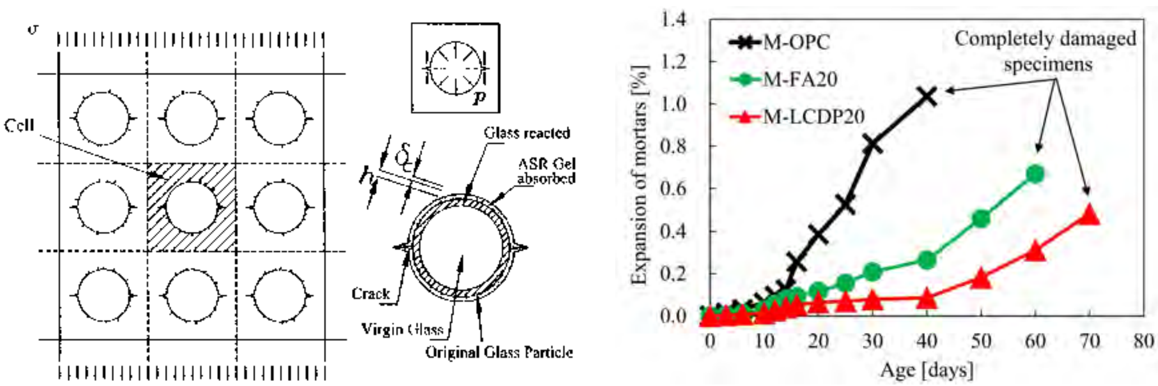


Figure 9: The chemo-fracture model to explain the ASR of glass particles [3] and the improvement of ASR resistance with glass powder [17, 18, 33].

21022, in ISO/TC71/SC6 as shown in Fig. 8 [11]. This is an axisymmetrical generalization of the four-point bending test to measure the biaxial tensile strength of concrete by using only one actuator [16, 19, 20, 32, 44]. Using this new test method, he proved that the size effect in the biaxial condition is stronger than the uniaxial condition [45]. This characteristics was also studied by the recently developed microplane model M7 [21] as well.

Currently, his research group has shown interest toward the subject of the combined durability of concrete structures in which more than one durability issue are coupled to drive the loss of the durability resistance. He showed that the durability life could be reduced significantly when carbonation and migration of chloride ions were considered simultaneously [35–37]. That reduction was more than 50% of the durability life when they were considered separately. He also developed a fine chemo-physical model to simulate the entire corrosion process of the reinforcement [34]. This model reproduced various experimental data reported in the literature successfully.

His expertise on mechanics was also very useful for finding the pozzolanic aspect of glass powder as a partial cement substitute. During his Ph. D., he developed a chemo-fracture theory to explain the influence of the particle size on the alkali-silica reaction (ASR) damage [3]. He suggested that

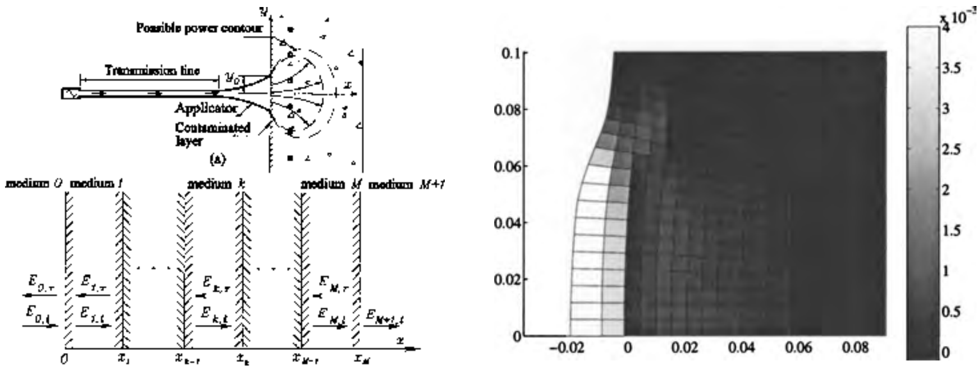


Figure 10: Decontamination of the radionuclides from the concrete surface by using microwave power [2, 40].

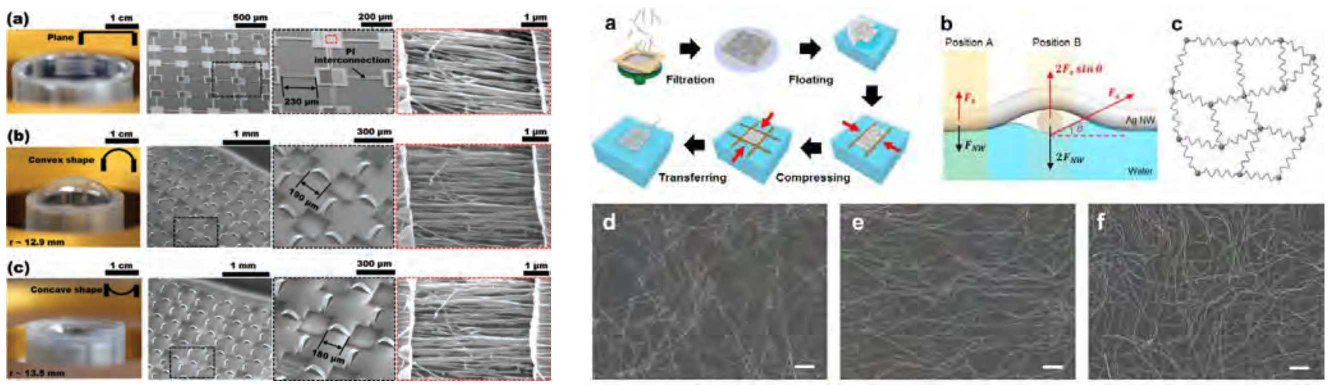


Figure 11: Mechanics for the design of various stretchable devices.

when glass was a form of fine powder, there would be no ASR damage. Later, he developed a series of mix design in which 10 to 20% of cement was replaced by glass powder. His mix-design containing glass powder showed excellent resistance to various kinds of durability attacks, such as chloride ion penetration, freeze-thaw, ASR damage, etc. [17, 18, 33]; see Fig. 9.

Multi-physics cross-field

Driven by the synthetic nature of modern engineering, as pointed out by M. A. Biot, Zi tries to consider problems from the view point of multi-physics rather than posing an extreme specialization. His first multiphysics project was decontamination of radionuclides from concretes by using microwave power as shown in Fig. 10. He developed a unified model in which all of electromagnetic field, heat and mass transfer, fracture and damage were coupled to simulate what happened in the real practice of the technology [2, 40].

His research activity is not limited to the boundary of the construction field although he is most active in the field of civil engineering. His research group is in a close collaboration with a chemical engineers group for the subject of stretchable electronic devices, such as semi-conductors, supercapacitors, etc. [8–10, 12–15, 23, 29]. Two examples are shown in Fig. 11. Such devices should be designed suitably to work in function within a specified range of deformation. The mechanical analysis and prediction are essential in this new type of devices.

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