Comparison of 2D and 3D RBSM analyses of mortar and concrete on meso scale

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1. Introduction

Authors have carried out a research on simulation of failure of concrete on meso scale where concrete is consisting of mortar and aggregate by 2D and 3D Rigid Body Spring Model (RBSM) which is a suitable method of analysis to present a discrete behavior like fracture [1) 2)]. In this study, comparison of result of 2D and 3D analysis is conducted.

2. Method of analysis and constitutive model [1) 2)]

The RBSM developed by Kawai [3)] is one of discrete numerical analysis method. Analytical model is divided into polygon or polyhedron elements whose phases are interconnected by springs. In 2D analysis, each element has two transitional and one rotational degrees of freedom at the center of gravity. Normal and shear springs are placed between the elements. In 3D analysis, three transitional and three rotational degrees of freedom are given at the center of gravity. One normal and two shear springs are placed at the center of gravity of each phase. Since cracks initiate and propagate along the boundary phase, the mesh arrangement may affect fracture direction. To avoid formation of cracks with a certain direction, a random geometry is introduced using a three-dimensional Voronoi diagram. The Voronoi diagram is the collection of Voronoi cells. Each cell represents mortar or aggregate element in the analysis.

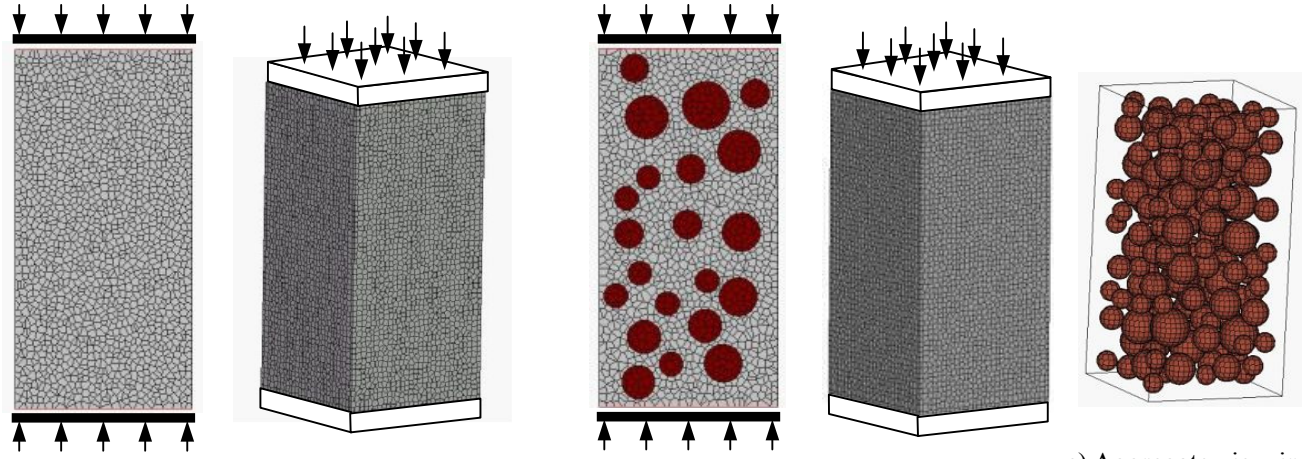
Constitutive model given to the springs between elements are explained in our previous research [2)] in which 3D analysis of mortar and concrete are carried out. The same constitutive model is applied to both 2D and 3D analyses conducted in this study. Elastic modulus and Poisson's ratio are calculated by using developed equations [1) 2)]. In the constitutive model, the normal spring in compression zone always acts elastic and never shows breakage nor softening

Table 1 Specimen overview

	Mortar		Concrete	
	2D	3D	2D	3D
Size	75x150mm	75x75x150mm	75x150mm	75x75x150mm
Aggregate ratio	0%	0%	26.7%	24.9%
Number of element	1,682	48,778	1,740	48,258
Average size of element	2.59mm^2	2.59mm^3	2.54mm^2	2.60mm^3

Table 2 Material properties

Mortar	
Elastic modulus	24,000MPa
Poisson's ratio	0.18
Average tensile strength	4.2MPa
Aggregate	
Elastic modulus	50,000MPa
Poisson's ratio	0.25
Interface	
Average tensile strength	1.6MPa
c	2.7MPa
ϕ	35°



a) 2D mortar b) 3D mortar c) 2D concrete d) 3D concrete e) Aggregate view in 3D concrete

Fig. 1 View of specimens

Keywords RBSM, meso scale analysis, 2D and 3D comparison, Voronoi geometry
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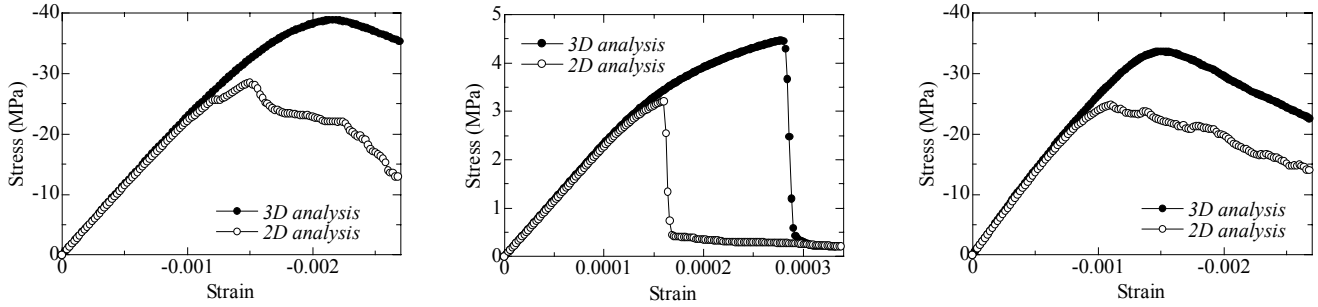


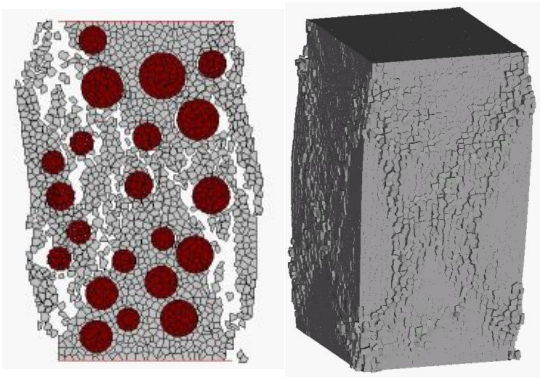
a) Compression test of mortar b) Tension test of mortar c) Compression test of concrete

Fig. 2 Predicted stress strain curves

behavior. It means that the compression failure of specimen in macro scale is presented by meso scale tensile and shear failures between elements.

3. Specimen of analysis

Fig.1 and Table 1 show the view of mortar and concrete specimens and details of the specimens, respectively. Distribution of aggregate in concrete specimens is determined based on JSCE code [4] which is mentioned in previous research [2]. Uni-axial compression and tension test of mortar and compression test of concrete are carried out. Loading boundary is fixed in lateral direction in compression analyses. Table 2 shows the material properties of mortar, aggregate and interface. The *c* and ϕ for interface are the value for Mohr-Coulomb type criterion.



a) 2D concrete b) 3D concrete

Deformation x *10*

Fig. 3 Deformation at axial strain of -2,500μ

4. Result of analysis

Stress strain curves in Fig. 2 show the results of analyses. The results of the 3D analyses are discussed in detail in previous research [2]. In all cases, strength in 3D analysis shows the higher strength than that in 2D. It is because 2D analysis cannot present the three-dimensional propagation of crack. Generation of a crack in 2D analysis means a full penetration of the crack in depth direction in specimen because the plane stress condition is assumed. In 3D analysis, propagation of crack in depth direction is simulated in analysis so that the process of fracture propagation becomes more complicated than that in 2D. As a result, 3D analysis shows the higher resistance. Especially in compression test, three-dimensional complex propagation of crack cannot be presented by 2D analysis even though the 2D analysis can simulate the macro-scopic shear crack at failure as shown in Fig.3. The difference of 2D and 3D analysis of existence of aggregate will be examined in the future.

5. Conclusion

In meso scale analyses of mortar compression and tension test and concrete compression test by RBSM, 3D analysis shows higher strength than that in 2D.

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