Research on 3D Meso-structure Modeling Method and Penetration Simulation of Concrete Target

Fuqiang Li[1], Ronghui Wang[1], Zhanyang Chen[2], Shuhu Li[1], Danyong Wang[1], Huamin Jia[1], Huazhen Wei[1]

[1] Shandong Non-metallic Materials Research Institute, Jinan, 250031, China.

[2] Beijing Institute of Technology, Beijing, 100081, China.

Abstract: This paper presents a new three-dimensional(3D) meso-structure modelling method, the anti-penetration performance of concrete target with aggregate is studied. Firstly, the shape, size and characteristics of random distribution of concrete aggregates are considered, a new meso-model generation algorithm is proposed, which is in accordance with the actual gradation and actual volume ratio of aggregates. Then, the finite element model was generated using a mapping algorithm. Finally, the influence of aggregate volume ratio on the anti-penetration performance is analyzed by simulating different concrete target models.

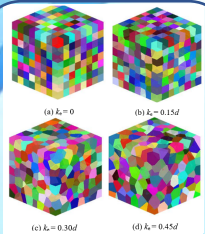

Figure 2. 3D Voronoi partition map

Figure 3. A cell with its minimum bounding box

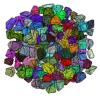

Figure 4. Scaled cell model

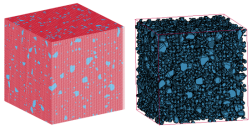

Figure 7. Finite element model of concrete meso-structure

Model Algorithm Flow

Step 1. Determine the aggregate volume ratio, gradation and shape parameters required for the concrete target model;
Step 2. Determine that n coordinate points are uniformly dropped, according to the gradation of aggregate;
Step 3. Generate randomly the seed point coordinates by using the Monte Carlo method;
Step 4. Divide Voronoi cells based on seed points by the 3D Voronoi algorithm;
Step 5. Scaling each cell equally;
Step 6. Select randomly the cells to form cell model, according to the single gradation requirements;
Step 7. Judge whether there is a next gradation. If "yes", execute step 2-6. If "no", execute step 8;
Step 8. Merge the cell model generated;
Step 9. Generated concrete aggregate by spatial mapping method.

After the random aggregate is generated and placed, a 3D hexahedral concrete background grid is established. The background grid is mapped to the aggregate grid based on the positional relationship between the background grid and the geometric outline of the aggregate.

Material Model

Table 1. Parameters of the RHT material for mortar.

ρ_0/(g/cm³)	2.314	D_1	0.04
A_f/GPa	35.27	D_2	1
G/GPa	16.7	A	1.6
f_c/GPa	0.035	N	3.0
f_s/f_c	0.1	α_0	1.1884
f_t/f_c	0.18	ε_p^{co}	0.01

Table 2. Parameters of the RHT material for aggregates.

ρ_0/(g/cm³)	2.7	D_1	0.042
A_f/GPa	86.71	D_2	1
G/GPa	24.17	A	1.6
f_c/GPa	0.119	N	4.0
f_s/f_c	0.1	α_0	1.1
f_t/f_c	0.38	ε_p^{co}	0.012

Numerical Simulation

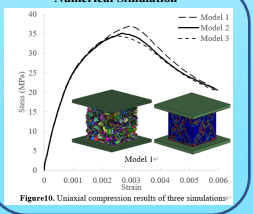

Figure10. Uniaxial compression results of three simulations[4]

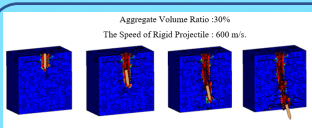

Figure11. Penetration process of rigid projectile

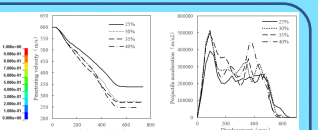

Figure 12. Curve of penetration velocity and acceleration of projectile with displacement

Conclusion

Under the premise that the aggregate gradation of the concrete is continuous gradation and randomly distributed, the penetration velocity of the projectile decreases with the increase of penetration displacement, the residual velocity and acceleration of projectile decreases with the increase of aggregate volume ratio. When the aggregate volume ratio increases from 25% to 30%, the residual velocity of the projectile decreases the most, with 19%. The analysis results can provide reference for the design of concrete protective structure.