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Numerical Simulation of Construction Process of Large Building Project Based on Discrete Element Method

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Abstract: Assembling integrated concrete cutting construction technology is a kind of construction engineering means commonly used in large stadiums at present. The advantage of this method lies in that it is connected by reinforcing bars, connecting pieces or applying prestress and pouring concrete members on site, which significantly enhances the mechanical resistance of construction engineering. And milling and planing machine as a large stadium assembly integrated concrete cutting construction indispensable important engineering machinery, its demand continues to grow, domestic independent research and development of high-performance milling and planing machine is urgent. Based on three-dimensional discrete element method model conforms to the macroscopic mechanical properties of the road, establish milling planer operation simulation model of quantitative stadium assembled monolithic concrete construction process of milling planer cutting resistance, using uniaxial compression and splitting tensile test to determine the compressive modulus of asphalt concrete pavement and tensile modulus, obtain the macro level check micro contact connection parameters. Discrete element specimens with coarse aggregate of irregular shape are generated by using the algorithm of 3d discrete element software PFC3D. Through the establishment of kinematics model, the critical condition expression of vibration planer is deduced, and the improvement of the working process force by adding different vibration modes is studied, so as to calculate the optimal combination value of vibration planer amplitude and vibration frequency, and obtain the better vibration mode of milling planer.

1. Introduction

Assembled monolithic concrete is a multi-phase composite with pores consisting of coarse aggregates and tar sands. Because of its advantages in viscosity and elastoplasticity, assembled monolithic concrete is widely used in large stadium construction. The milling machine is an important construction equipment for assembling integral concrete cutting construction, and the demand is increasing. The milling tool is the executing part of the milling operation. The change of the working parameters of the milling machine directly affects the force and wear of the milling tool.

At present, vibration theory is widely used in the field of engineering machinery. Theoretically, it can reduce the resistance of milling, thus reducing the thermal energy loss and tool wear caused

by milling operations. It is a new direction for the research and development of milling machines. In the theory and experimental research of vibration cutting, many domestic and foreign scholars have done a lot of work. Rajan Varadarajan (2018) and other scholars proposed the elliptical vibration cutting method, and verified by experiments that the vibration cutting can effectively reduce the frictional resistance between the rake face and the chip, which can effectively reduce the cutting force and energy consumption. Andrea Schenker‐Wicki (2017) verified by theoretical analysis and glass processing experiments that vibration cutting can reduce noise and chatter during machining. Indrek Ibrus (2018) uses vibratory cutting to machine hard-to-machine hardened steels, demonstrating that vibration cutting can improve machined surface quality and tool life. Robert J. Allio (2018) studied the influence of vibration cutting on the brittle-plastic transition mechanism in glass processing. Under the influence of vibration cutting, the force will be significantly reduced and the critical depth of cut will increase significantly. The increase amplitude is related to the ratio of workpiece speed and maximum vibration speed. When the ratio is small, the increase is large. Niels Ketelhöhn (2018) study found that the vibration cutting formed a mesh-like microstructure on the surface of the workpiece, and the scratched surface and roughness of the machined surface obtained under vibration cutting were superior to those of conventional cutting [1].

With the rapid development of computer technology, numerical simulation provides new ideas and methods for studying milling and vibration milling operations. In recent years, domestic and foreign scholars have done a lot of research on the analysis of asphalt concrete cutting process. Thuc Uyen Nguyen Thi (2018) uses the three-dimensional discrete element method to simulate the axial compression test of the mixture. The static stress distribution indicates that the shape and angle of the coarse aggregate have a significant effect on the overall performance of the mixture. Håkan Håkansson (2017) used the discrete element method (DEM) to simulate the uniaxial compression test. The effects of various microscopic parameters on the overall macroscopic properties of the material were obtained through experiments, and the Burger's model was validated for the simulation of asphalt mixture. Bang-Ning Hwang (2018) uses the algorithm to generate a coarse aggregate particle set with angular shape and grading characteristics in PFC3D, and fills the asphalt sand rubber particles to form an asphalt mixture. Through various loading tests, the factors affecting the anisotropy of the mixture are obtained. Pierre Loewe (2018) uses DEM to simulate the skeleton of SMA aggregate asphalt concrete. It is proved by experiments that DEM can greatly help to realize grading visual design, analysis of skeleton strength and mixture deformation and failure mechanism. In the discrete element method to study the engineering problems of the bulk processing class.

Based on the PFC3D discrete element analysis software, this paper aims to assemble the integrated concrete cutting and separating construction process for large stadiums. It uses the grading and irregular polyhedral shape coarse aggregate generation algorithm to establish the coarse aggregate with irregular polyhedron shape and tar sand. A discrete element model of a particle. The uniaxial compression and splitting tensile test were used to determine the compressive strength, compressive modulus, tensile strength and tensile modulus of the integrated concrete building components assembled in large stadiums, and the macroscopic parameters of the microscopic parameters of the cutting construction model were obtained. On this basis, the vibration milling operation model is established, the critical conditions of vibration milling are derived, and the influence of vibration mode and amplitude vibration frequency combination on the milling process is quantitatively analyzed.

2. Three-Dimensional Discrete Element Modeling of Integrated Concrete for Large Stadiums

2.1 Random Generation Algorithm for Irregular Polyhedron rough Aggregate

(1) Fill the discrete element spheres that are regularly arranged. In a regular hexahedron space with a side length equal to the coarse aggregate particle size, a discrete element sphere with a regular arrangement and a particle radius of 1 mm is filled, and a regular hexahedron composed of a regularly arranged sphere is formed (regardless of the pores between the regularly filled spheres).
(2) Randomly cut regular hexahedrons. The process of generating a random plane by using several random planes to cut a regular hexahedron is as follows:

① A sphere having a radius smaller than the radius R of the regular hexahedron is generated by centering the center XXX of the regular hexahedron.

② The coordinates of several points are randomly selected on the spherical surface generated in step 1) [2].

2.2 Single-Axis Compression Discrete Element Test Piece Modeling

Use the ball command in the specimen area to generate discrete element sphere particles with a regular arrangement and a radius of 1 mm. The algorithm is used to divide the particles into groups of coarse aggregate particle clusters. When generating coarse aggregates of different granularity irregular polyhedron shapes, there are repeated divisions between the discrete element particles filled between different coarse aggregates, so the number of discrete element particles of the coarse aggregate will be the final sample. It will change; considering the existence of pores in asphalt concrete, the porosity of the compressed specimen is set to 4%; the density of the discrete aggregate particles is set to 2.9×103 kg/m3; and the density of the tar pitch colloidal particles is set. It is 2.5×103 kg/m3; there may be repeated division of particles between coarse aggregates in each grade; considering the overlap of particles [3]

3. Mechanical Properties Testing and Determination of Contact Connection Models

3.1 Mechanical Performance Test of Integral Concrete Cutting Construction in Large Stadiums

The destruction of the concrete mix follows the Mohr Coulomb formula, ie no damage occurs when is met. As shown in Fig. 2, this equation takes the equal sign when it corresponds to the oblique line tangent to the molar circle; in order to determine the cohesive force C and the internal friction angle φ on the right side of the discriminant, two molar stress circles need to be drawn. The compressive strength is determined by a uniaxial compression test, and the splitting tensile strength is determined by a splitting tensile test. The cohesive force C and the internal friction angle φ obtained from the mechanical properties test can be used as criteria for checking the simulation results and criteria for judging failure failure in the subsequent milling operation simulation.

Refer to the standard proposed by Mary Lacity (2019) to obtain a larger concrete block in the assembly of integral concrete building components in a large stadium that needs to be renovated, and cut the concrete block by using a cutter × width × height 40 mm × 40 mm × 40 mm 10 sets of hexahedral asphalt concrete specimens and 10 sets of hexahedron specimens of length × width × height 80 mm × 40 mm × 40 mm. The specimen was axially loaded to the specimen with a loading speed of 1 mm/min. When the load force dropped from the peak to 80% of the peak value, the loading was completed and the test was completed; the failure of the specimen.

3.2 Determination of Microscopic Parameters of Contact Connection Model in Integral Concrete Discrete Element Specimens for Large Stadiums

Large-scale stadiums are equipped with three kinds of media: coarse aggregate, tar sands and pores. The discrete element model needs to consider four types of contact, which are between the interior of the coarse aggregate and the discrete particles of the asphalt sand. The contact between the contact, the coarse aggregate edge discrete element particles and the tar pitch edge discrete element particles, the contact between the coarse aggregate edge discrete element particles and the other coarse aggregate edge discrete element particles. For the contact of these four assembled monolithic concrete discrete element particles, the corresponding contact type and connection model matching were selected.

3.3 Microscopic Parameter Checking of Contact Connection Model in Assembly Monolithic Concrete Discrete Element Specimens

After preliminarily setting the microscopic parameters of the contact and connection of each group, in order to make the macroscopic parameters of the assembled integral concrete model material consistent with the actual test results, it is necessary to establish a virtual test pair of uniaxial compression and splitting tensile force in PFC3D. The existing model parameters are checked. The judgment condition shown in the flow is the fit of the stress-strain curve recorded by the test and the virtual test. When the two are attached to each other and the peak stress is close, the result can be considered reasonable.

(1) Simulated assembly of monolithic concrete uniaxial compression and splitting tensile test. The micro-parameter assignment is performed on the uniaxial compression virtual test model and the split-shock virtual test model built in the PFC3D; and two walls are established on the upper and lower surfaces of the two test pieces; the lower surface position is fixed, and the upper surface wall is fixed Load at a given speed v=0.05 m/s, and record the force of the test piece; stop loading until the axial compressive stress of the test piece is 80% of the peak stress, at which time the test piece is destroyed.

Comparing the two sets of simulation data and experimental data in Figures 8 and 9, it can be seen that the uniaxial compression and splitting tensile stress-strain curves of the simulation and test are not a single linear relationship before the peak, and reach the peak value. After a certain resistance, it will be invalid; this phenomenon reflects the partial viscoelasticity of the stadium-assembled monolithic concrete.

(2) Data sorting. Comparing the experimental determination and simulation calculation data, the error value of the two groups of data is less than 10%, and the micro-parameter data check is successful.

4. Conclusions

(1) A three-dimensional discrete element model of integrated concrete for large stadiums was established. FIF language programming was used in PFC3D. The irregular coarse aggregate generation algorithm was used to build large scales with irregular polyhedral shape coarse aggregate and concrete sand rubber. The stadium is equipped with a monolithic concrete test piece model.

(2) Through the uniaxial compression and splitting tensile test, the compressive modulus and tensile modulus of the integrated concrete building components assembled in large stadiums are measured, and the macroscopic criteria for checking the microscopic parameters of the contact connection of the discrete element building component models are obtained. The uniaxial

compression test and the splitting tensile test were simulated in PFC3D, and the microscopic parameters in the contact connection were checked according to macroscopic criteria. An integrated concrete cutting model for large stadiums with actual pavement macroscopic mechanical properties is established using the corrected microscopic parameters.

(3) Deriving the critical condition expression of vibration milling, adding vibration on the established 3D discrete element milling operation model to study the improvement of the working parameters of the vibration milling process. It is found that the additional X-direction vibration milling can significantly improve the milling. Planing resistance, X-direction average milling resistance and peak resistance after additional vibration is about 1/3 of ordinary milling; quantitative analysis of 4 sets of amplitude vibration frequency combination, select better combination of amplitude and vibration frequency as A1=4 mm and f1=150 Hz.

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