Simulation and Research on Dynamic Crushing of Rod Concrete

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Abstract. The dynamic mechanical properties of waste glass powder concrete are studied, and the dynamic compressive strength, peak strain, stress-strain curve and dynamic enhancement factor change with strain rate and waste glass powder content are analyzed. Based on the HJC model of concrete, the SHPB test was simulated by ANSYS / LS-DYNA software. With the increase of impact pressure, the phenomenon from block spalling to aggregate crushing appears. When the impact velocity is low, several radial through cracks appear in the test block, and the test block is separated into several blocks with larger volume. With the increase of impact velocity, multiple cracks develop simultaneously.

Keywords: Finite element method, modeling, crushing, concrete.

1. Introduction

The research of dynamic compression mechanical properties of concrete materials is to study the influence of strain rate on the strength and strain of concrete through compression or tensile tests under uniaxial stress, and to observe the change rules of dynamic strength, dynamic strain, toughness and dynamic enhancement factor of concrete materials under different strain rates [1]. ABAQUS or ANSYS / LS-DYNA software is often used to simulate the SHPB test of concrete. In the process of numerical simulation, the selection of constitutive model of concrete material directly affects the simulation results.

2. Numerical simulation methods and related settings

2.1. Analysis scheme.

ANSYS is a commonly used finite element analysis software in engineering field. The LS-DYNA program is developed for nonlinear stress analysis of structures subjected to impact pressure [2]. Now it has been developed into a multi field analysis program with good parallel processing ability, which can be used for nonlinear dynamic analysis, quasi-static analysis, structure thermal coupling analysis, etc. In SHPB test simulation, there are two kinds of materials: Hopkinson bar and waste glass powder concrete test block. Among them, the Hopkinson bar is made of metal, and the linear elastic model can better reflect its mechanical properties, but there are many models for concrete, which is a brittle material.
2.2. Meshing and boundary setting.
In the process of numerical simulation, the structure of the model is composed of grid elements and nodes. Good grid quality can ensure the accuracy of numerical simulation. In meshing, due to the inconsistency of the structure shape, it is obviously not appropriate to let the program mesh according to the default size or intelligently, so it is necessary to manually set the number of cells on each line [3]. When meshing, the first thing to consider is the number of meshes. If the number of meshes is too small, the calculation accuracy is poor, which can not reflect the real mechanical properties of materials. If the number of meshes is too large, the calculation time will be doubled, which is not conducive to repeated simulation. Therefore, it is necessary to control the number of grids properly, so that the calculation time will be slightly prolonged and the calculation accuracy will be greatly improved with the increase of the number of grids in a certain range. In special parts such as different section size, different material properties and complex stress, the grid should be appropriately densified. In the parts with the same material properties and uniform stress distribution, the number of low-density grids should be adopted. The form of alternate density can not only reduce the total number of grids, but also ensure the accuracy of the calculation results [4].

When defining the contact surface and the target surface, the two end faces of the test block with high grid density are defined as the contact surface, and the end faces of the incident bar and transmission rod in contact with the test block are defined as the target surface. The rod fixing device under the actual test condition is simplified as the constraint on X and Y axis to limit the displacement of the bar in this direction.

![Fig. 1 Mesh refinement method](image1)

![Fig. 2 Loading direction](image2)

2.3. Contact properties.
Because the rods of SHPB test device are cylindrical bars with the same diameter and the contact surfaces of the rods are parallel, single-sided contact or face-to-face contact are used when selecting the contact type. Single side contact is used to deal with self-contact and part to part contact, which does not need to define the contact surface. The algorithm will automatically find all the external surfaces and detect whether the contact surfaces are penetrated. Compared with face-to-face contact, this step of contact surface setting can be omitted. Therefore, it can be used to deal with the impact test simulation with unknown contact area. Face to face contact can be used to deal with the problem of large contact surface, which needs to set contact surface and target surface. When selecting the contact surface and the target surface, because the surface contact algorithm is symmetrical, the target surface and contact surface can be selected arbitrarily. In practical operation, the part end face with high mesh density is generally defined as the contact surface.

After the model is established, the model is imported into the post-processing software LS pre post, and the stress-strain curves of each group of waste glass powder concrete in the model are obtained. The reliability of the HJC model was verified by comparing with the test results, observing the failure of the test block and the waveforms of incident wave and transmission wave. According to the crushing condition of the test block, the initial crack position, crack development and stress distribution of waste glass powder concrete at different speeds were observed, and the mechanical properties of waste glass powder concrete under high strain rate were studied.
3. Results analysis and discussion

3.1. Analysis of stress-strain curve.

The error between numerical simulation and experimental results is within 10%. The biggest error is the strength of concrete under 1.1MPa impact pressure, and the error is 7.5%. The results of numerical simulation are consistent with the experimental results, and the reliability of the model is confirmed, as shown in Fig.3. In the LS pre post software, the surface elements in the middle of the incident rod and transmission rod are selected, which are consistent with the position of the test strain gauge. The stress-strain curves of each group of waste glass powder under different impact pressures were calculated and compared with the test results. Concrete is composed of coarse and fine aggregate, mortar and interface layer between aggregate and mortar. In this simulation, concrete is considered as uniform material instead of non-uniform meso model. Therefore, in the damage stage after the stress-strain curve reaches the peak strain, there will be greater error between the test results and the numerical simulation, so it is no longer considered.

Under the same amount of waste glass powder, the strength of concrete increases with the increase of strain rate. Compared with the test results, the dynamic compressive strength of waste glass powder concrete is generally consistent, and the error at low strain rate is larger than that at high strain rate. Except for the results of 1.1MPa air pressure load, the results of numerical simulation are more consistent with the change law of strength compared with the concrete with other waste glass powder.

Mechanical properties of concrete with different content of waste glass is shown in Fig.4. It can be inferred that with the increase of impact pressure, the concrete block gradually develops from fracture to fragmentation. When the strain rate is low, several axial cracks appear after impact. The test block breaks with the development of the crack, and the broken block remains relatively intact. With the increase of strain rate, the impact stress of aggregate is greater than that of mortar, and the aggregate bonded into block is separated. However, due to the strength of the aggregate itself, the impact stress will not make the aggregate broken. However, at higher strain rate, the diameter of concrete block is smaller after crushing. The larger diameter aggregate will be broken into several pieces, and the mortar block will be broken into powder.
3.2. Analysis of crushing process.
Observe the impact of impact air pressure on the concrete crushing, select the concrete test block with 10% waste glass powder content under different strain rates for analysis. The final failure mode of the numerical simulation test block is shown in Fig. 5. When the impact velocity is low, a radial through crack appears. With the increase of impact velocity, many cracks develop simultaneously. Under the influence of crack development, the central part of the test block tends to be crushed gradually, and the edge of the test block is broken up into smaller size blocks. The stress wave has been transmitted to the concrete block. With the increase of incident wave, cracks appear at the edge of the block and develop to the center of the test block, and the test block is broken. Before the initial crack appears, the dark part of the block diameter indicates that the change should be low, that is, the location of the crack. The brighter the color, the greater the strain, that is, the failure part of the element. With the transmission of stress wave, the radial expansion deformation of the specimen occurs under impact compression.

The results of static compression test on concrete with different amounts of waste glass powder show that the strength of concrete decreases gradually with the increase of waste glass powder content. The decrease range of strength in the stage of 5% to 15% of waste glass powder is smaller than that of 15% to 25% of waste glass powder. With the increase of strain rate, obvious strain rate strengthening effect appears in each group of concrete blocks. In multiple groups of tests, the dynamic compressive strength of concrete blocks with 10% content is the highest, reaching 58.45 MPa, and the relative static compressive strength is increased by 166%.

4. Conclusion
The dynamic stress-strain curves of each group of concrete were analyzed. With the increase of strain rate, the slope of rising section of stress-strain curve of concrete block with the same content increased slightly, and the stress-strain curve became fuller. The dynamic compressive strength of waste glass
powder concrete is generally consistent, which verifies the reliability of the model. Some of the peak strains deviated from the test results, but the overall variation was between 0.0035 and 0.0045, and the correlation between peak strain and strain rate was weak, which was consistent with the test results.

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