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A Research About the Concrete Failure Affected by Aggregate

Deliang Meng*, Huijian Li, Lixin Zhang, Pin Cheng
Department of Engineering Mechanics, YanShan University, Hebei province, China
*Corresponding author, e-mail: mengdeliang@ysu.edu.cn

Abstract

Concrete material is one of the wide applications materials in the engineering. There is an important implication on national life safety to research its destruction. And size effect of the concrete also has an important impact on failure mechanism and strain injury of the concrete. There are many influencing factors on concrete size effect. In this paper, we will use the numerical simulation method to research the concrete compression failure from two aspects. One is the arrangement of the aggregate and the other is the aggregate maximum rotation angle. Finally, we got the impact of the law that the two aspects how affected the concrete compression failure. This will provide great guiding significance to the engineering practice.

Keywords: *aggregate, arrangement mode, maximum rotation angle, compression failure, numerical simulation*

1. Introduction

Currently, concrete is the most widely used engineering material. It has become the first choice in the construction industry because it is a broad and an economic material. However, the phenomena of structure collapse which were led by concrete damage often occurred in the actual engineering [1-3]. Therefore, it is very necessary to research the failure mechanism of concrete. The size effect is a recurrent phenomenon in concrete structure when the structure is failure in the actual engineering. And this phenomenon has been noticed by the engineering sector. Especially in recent years, many specified design constructions appeared severe damage under the unexpected disasters such as earthquakes, typhoons and so on. These have caused huge economic and human losses. Related literatures [4-7] and our engineering practice showed that there were big differences in laboratory theories and actual engineering. So the size effect should be a very critical issue. Concrete is a composite material which is composed of aggregate, mortar matrix and interfacial transition zone. Aggregate is a major force part in the concrete. When aggregates arranged in different ways, the transmission paths and transmission ways of force are different when the concrete is loaded. And eventually the failure modes of concrete material are different. In this paper, we will use the numerical simulation method [8-13] to research how the arrangement mode of the aggregate and the aggregate maximum rotation angle to affect the concrete compression failure.

2. Modeling and Research

2.1. Aggregate's Arrangement Mode Factor

We will use ABAQUS software to establish the numerical model. In this paper, we will make two sets of simulation. In the first group of specimens, the aggregates' sizes are all 10mm. And the maximum random rotation angles of aggregate around the x, y and z axes are 45 degrees. In the second group of specimens, the aggregates' sizes are all 15mm. And the maximum random rotation angles of aggregate around the x, y and z axes are also 45 degrees.

We will make four different kinds of aggregate arrangement models. The first mode is regular arrangement. The aggregates which are within each layer and between layers are all arranged in a matrix manner. In the second arrangement, the aggregates within each layer are arranged in a regular matrix manner and the aggregates between layers are arranged in a staggered mode. In the third arrangement, the aggregates within each layer are arranged in a

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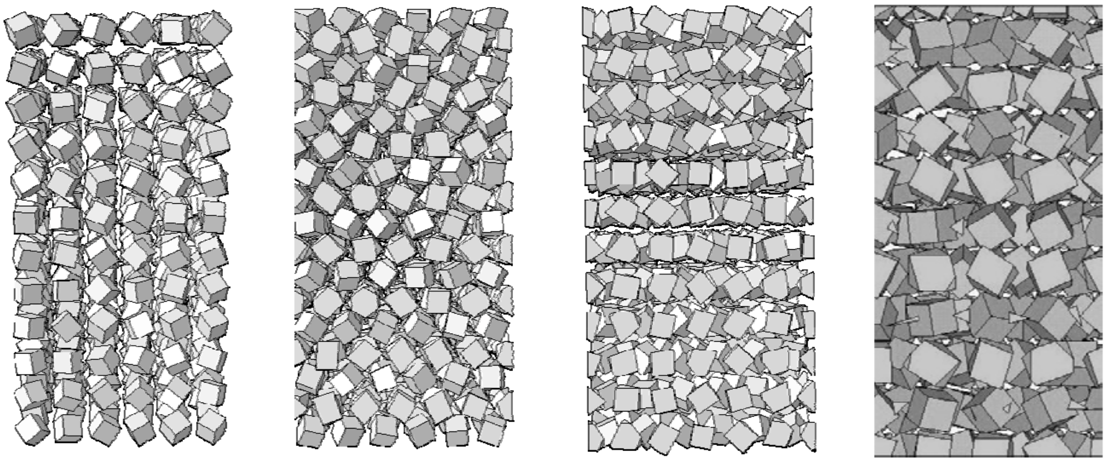
staggered mode and the aggregates between layers are arranged in a regular matrix manner. In the fourth arrangement, the aggregates which are within each layer and between layers are all arranged in a staggered mode. They are shown in Figure 1.

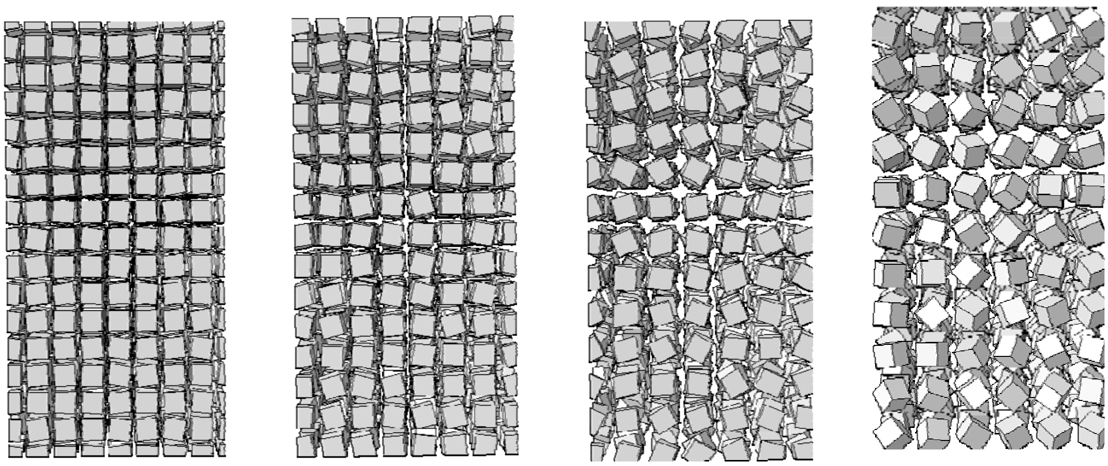


(a) the First arrangement (b) the Second arrangement (c) the Third arrangement (d) the Fourth arrangement

Figure 1. Diagram of Aggregate Arrangement

2.2 The Maximum Rotation Angle of the Aggregate Factor

In this paper, the maximum rotation angles have four levels. They are 10 degrees, 15 degrees, 30 degrees and 45 degrees. The aggregate modes are shown in Figure 2.



(a) 10 Degrees (b) 15 Degrees (c) 30 Degrees (d) 45 Degrees

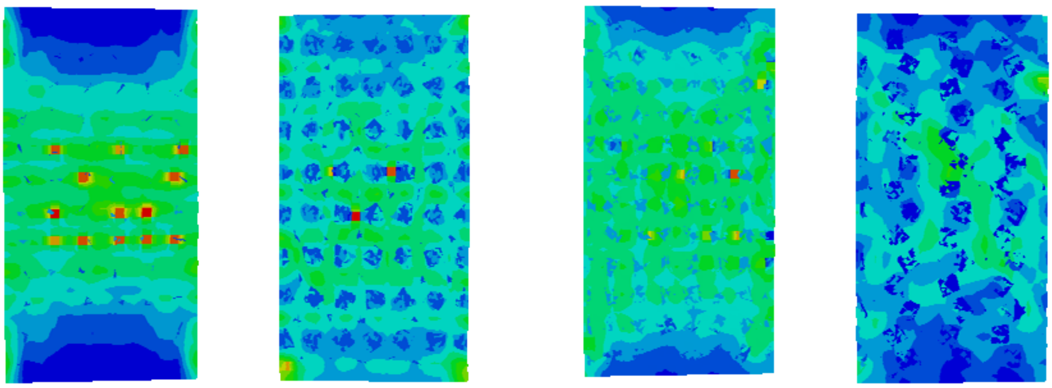
Figure 2. Diagram of Different Maximum Rotation Angle of the Aggregate Model

We will make three groups of numerical simulation. In the first group, the aggregate size is 10mm. And the aggregate is the first arrangement mode. In the second group, the aggregate size is 10mm. And the aggregate is the second arrangement mode. In the third group, the aggregate size is 10mm. And the aggregate is the third arrangement mode. When the maximum rotation angle of the aggregate is small, it corresponds to the fully dense and vibration compacting concrete in the actual project. When the maximum rotation angle of the aggregate is big, it corresponds to inadequate vibration and there are many void defects in concrete in the actual project.

3. Analysis and Results

3.1. Aggregate's Arrangement Mode Factor

The simulation results of the first group samples are shown in Figure 3.

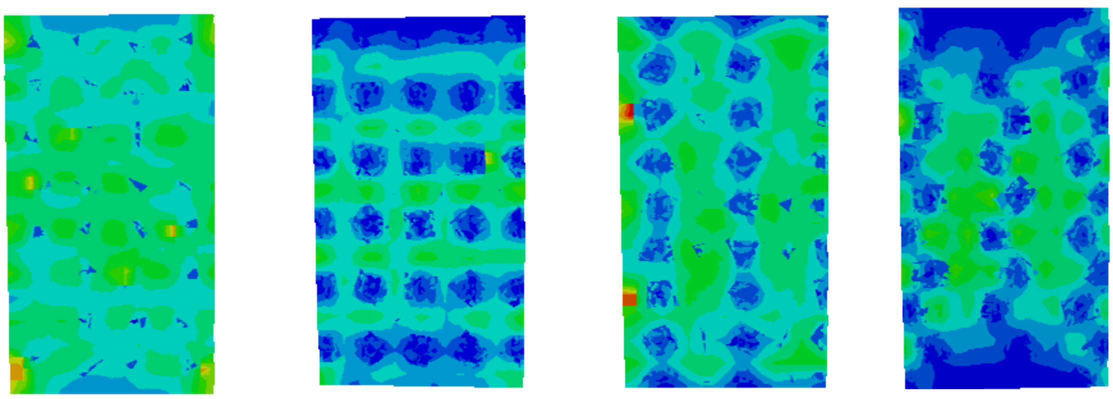


(a) the First arrangement (b) the Second arrangement (c) the Third arrangement (d) the Fourth arrangement

Figure 3. Strain Maps of the First Group Samples

From the Figure 3, we can easily find that different aggregate arrangement mode will lead to different strain distribution field in cross section when concrete was compressed. The aggregate's arrangement will impact the result of the high strain gathered of the sample. And it will further result in a different degree of localization. Finally, concrete material's different destructions will occur. Generally they are asymptotic destructions and sudden catastrophic ruptures.

The simulation results of the second group samples are shown in Figure 4.



(a) the First Arrangement (b) the Second Arrangement (c) the Third Arrangement (d) the Fourth Arrangement

Figure 4. Strain Maps of the Second Group Samples

From the Figure 4, we can find something. When the aggregate in sample is the fourth arrangement mode, the average strain gathered in localization area is the largest. When the aggregate in sample is the third arrangement mode, the average strain gathered in localization area is the least. When the aggregate in sample are the first and the second arrangement modes, the average strain gathered in localization area is in center. And moreover, the second is higher than the first in some sort. In regard to the area ratio of the localization area to the entire cross-sectional area, the fourth arrangement mode is the least and the first arrangement mode is the largest. The third is higher than the second.

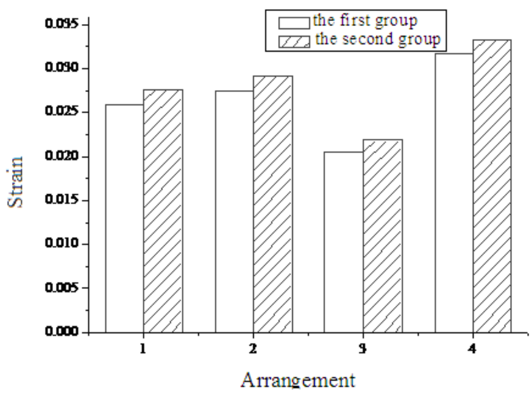


Figure 5. Diagram of the First Principal Strain

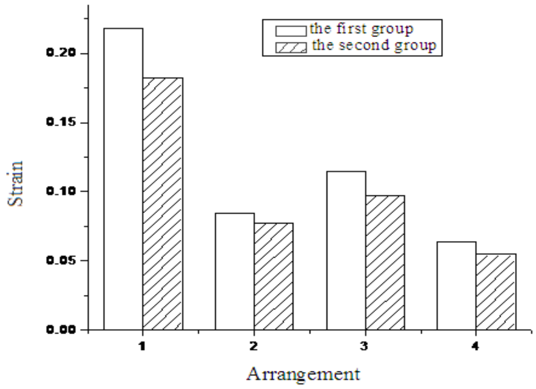
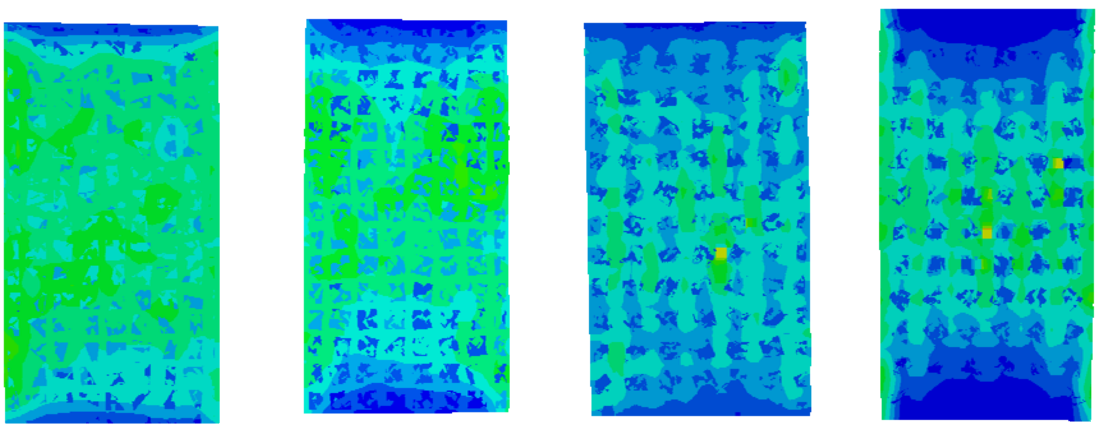


Figure 6. Ratios of the Localization Area to the Entire Cross-sectional Area

When the aggregate in sample is the fourth arrangement mode, there will easily take place sudden catastrophic damage. And when the aggregate in sample is the first arrangement mode, there will easily take place progressive destruction. The destructions of the second and the third arrangement modes are in the middle of the former two modes. The results of the average first principal strain of the two groups of samples in the localization area of strain gathered are shown in Figure 5. The area ratios of the localization area to the entire cross-sectional area are shown in Figure 6.

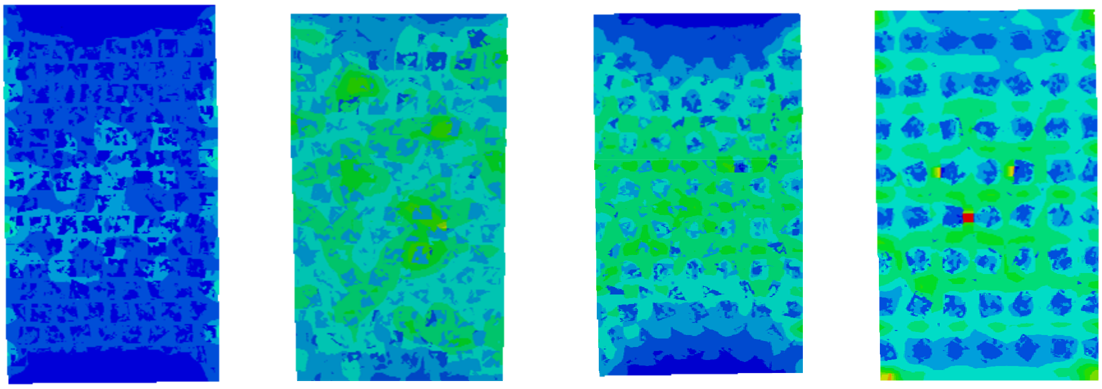
3.2. The Maximum Rotation Angle of the Aggregate Factor

The results of the strain localization of the first, the second and the third groups are respectively shown in Figure 7, Figure 8 and Figure 9.



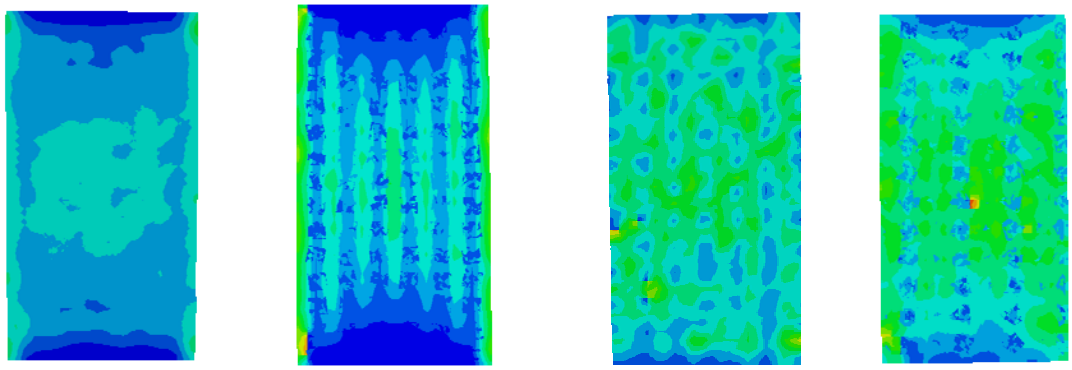
(a) 10 Degrees (b) 15 Degrees (c) 30 Degrees (d) 45 Degrees

Figure 7. Strain Localization Schematic Diagram of the First Group Samples



(a) 10 Degrees (b) 15 Degrees (c) 30 Degrees (d) 45 Degrees

Figure 8. Strain Localization Schematic Diagram of the Second Group Samples



(a) 10 Degrees (b) 15 Degrees (c) 30 Degrees (d) 45 Degrees

Figure 9. Strain Localization Schematic Diagram of the Third Group Samples

The average strains in localization area of sample are shown in Figure 10. The area ratios of the localization area to the entire cross-sectional area are shown in Figure 11.

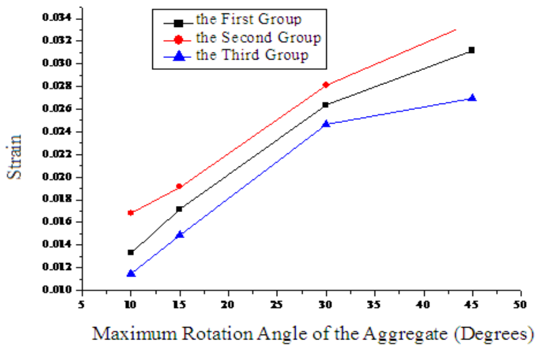


Figure 10. Average Strain Value within a Localization Area Diagram

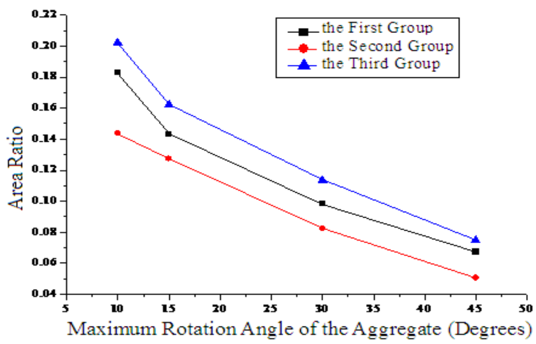


Figure 11. Area Ratios of the Localization Area to the Entire Cross-sectional Area Diagram

From the Figure 11, we can find these laws. The bigger the maximum rotation angle of aggregate is, the smaller the average strain in localization area is. And the area ratio of the localization area to the entire cross-sectional area is smaller. So there will easily take place sudden catastrophic ruptures. Therefore, in the actual concrete pouring process, we must ensure that concrete was full vibration. And only in this way, we can ensure the material to reach the design of the bearing capacity and to meet the requirements of normal use.

4. Conclusion

In this paper, we analyzed that how the aggregate arrangement modes and the maximum rotation angle of the aggregate to impact the concrete compression failure by using the numerical simulation method. Different aggregate arrangement modes and different maximum rotation angles of the aggregate will all exert a great influence to concrete failure. When the arrangement is the fourth mode, namely, the interlaced arrangement, the average strain gathered in localization area is the largest. And the area ratio of the localization area to the entire cross-sectional area is the least. Moreover, there will easily take place sudden catastrophic damage. When the arrangement is the first mode, namely, the regular arrangement, the area ratio of the localization area to the entire cross-sectional area is the biggest. And there will easily take place progressive destruction. The bigger the maximum rotation angle of aggregate is, the smaller the average strain in localization area is. And the area ratio of the localization area to the entire cross-sectional area is smaller. So there will easily take place sudden catastrophic rupture. And these rules we have got are more important and valuable to the engineering. They also can guide the engineering practice.

Acknowledgements

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