Three-Dimensional Analysis of Flow of Fresh Concrete as Two Phase Model by MPS

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1. Back Ground

Recently, as the amount of steel bars in buildings increases, it is getting more difficult to compact fresh concrete to the congested area of steel bars such as beam-column joint part. As one of the approaches to solve this problem, numerical simulations of flow of fresh concrete have been conducted where the concrete properties are modeled by Rheology model, for example. Although several analysis methods have been proposed to simulate the workability of fresh concrete based on DEM, FEM etc. [1),2)], flow of fresh concrete as the two phase model (aggregate and mortar) and the stuck of aggregate between reinforcement bars have not been simulated reasonably yet. To achieve it, two phase model simulation with multidirectional arrangement of reinforcement are necessary to be conducted. The aim of this paper is to analyze the flow and stuck behavior of fresh concrete under multidirectional bar arrangement condition by three dimensional MPS (Moving Particle Semi-implicit) method[3)], one of particle methods. Particle method software Particleworks was used for the simulation. Bingham Model is applied as the constitutive law. This research is a basic research to assess the workability of concrete and flow characteristic.

2. Analysis Model

This study attempts to reproduces the experiment of workability with high workable concrete by Fujiwara and others[4)]. As shown in Fig. 1, fresh concrete was set in the rectangular box (680×300×300mm) and placed above the single or multidirectional arrangement of reinforcement bar. The parameters of the test were the arrangement of reinforcement bar (one direction or cross), clearance of rebar, and volume of aggregate of concrete (Table. 1 and Fig. 1). Concrete starts to flow when the gate at the bottom is opened. Workability and stuck behavior were observed. For the analysis, concrete was modeled by two phase material, aggregate and mortar. The aggregates were model as rigid spheres those diameters were varied with 2mm based on the size distribution. The maximum size is set 20mm. In this study the aggregates smaller than 6mm were removed due to the difficulty of mesh in the analysis. Mortar is modeled by assembles of particle elements and the Bingham Model is applied to the particle element (Fig. 2). Considering the computational time, the size of the analysis model is smaller than that of in the experiment that was 400×200×200mm(Fig. 3, Fig. 4). For the

Table. 1 Analysis cases

Analysis Case	Single or multidirectional bar arrangement	Clearance between bars[mm]	Aggregate volume (%)	Result of the experiment	Number of elements in analysis	Number of coarse aggregate in analysis
No.1	Cross	47	35.0	Pass	859,107	3,502
No.2	Cross	27	17.5	Stuck	859,107	1,752
No.3	Cross	27	35.0	Stuck	859,107	3,502
No.4	One direction	27	35.0	Pass	859,107	3,502

Table.2 Rheology model of mortar

Yield value(Pa)	19.8
Plastic viscosity(Pa・s)	6.7
Density of coarse aggregate(kg/m^3)	2,640
Density of mortar(kg/m^3)	3,150

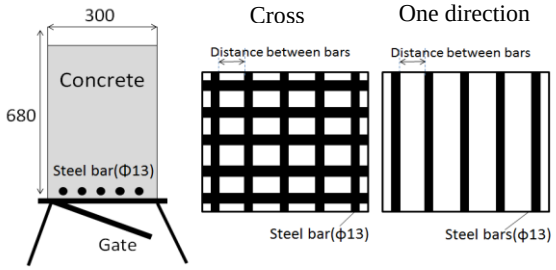

Fig. 1 Experimental setup

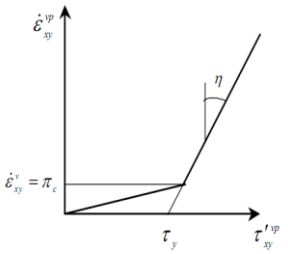

Fig. 2 Bingham model

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Rheology model of mortar, the values were set from those observed in the experiment that were 19.8(Pa) for yield value, 6.7(Pa・s) for plastic viscosity, 2,640(kg/m^3) for density of coarse aggregate, and 3,150(kg/m^3) for the density of mortar (Table.2). Steel is modeled as rigid round shape bars. Friction coefficient between steel and mortar or aggregate is set 0.1.

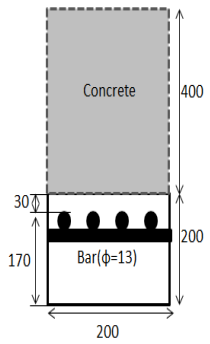


Fig. 3 Size of analysis model

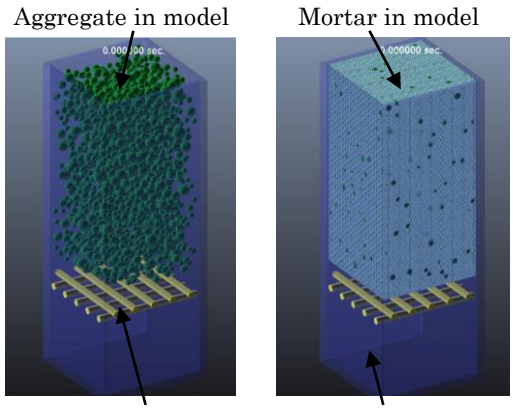
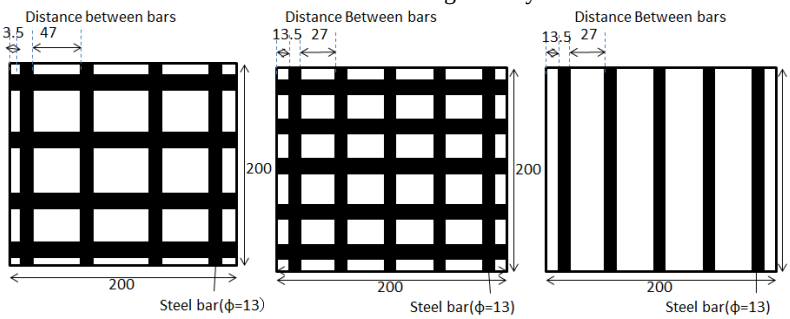


Fig.4 Analysis model

3. Result of Analysis

In the cases No.1 and No.4, all aggregate passed the bars, while in No.2 and No.3, some aggregate were stcuked at the bars (Fig. 6 and Table. 3). Exactly speaking, on No.2 case, only a few aggregate were stucked at only 2 points, and on No.3 case, so many aggregates were stucked. So the results of No.2 and No.3 are same as that of the experiment, but on the other hand, the resutl of No.1 and No.4 is different from that of the experiment. Although there is some difference between the results of the experiment and that of this analysis, this MPS analysis simulated stuck of fresh concrete on three dimensions analysis depending on the arrangements of steel bars and aggregate volume.



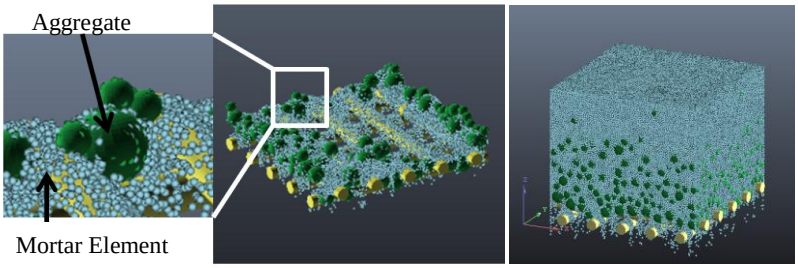
No.1 No.2, No.3 No.4

Fig. 5 Arrangement of bars

Table. 3 Result of analysis

Analysis Case	Result of the Experiment	Result of the Analysis	Accordance
No.1	Stuck	Pass	×
No.2	Stuck	Stuck	○
No.3	Stuck	Stuck	○
No.4	Stuck	Pass	×

There are 3 things as tasks to be solved next. 1st one is to include the model for thin layer on surface of aggregates. 2nd one is to change the Rheology on Bingham model depending on the situation of fresh concrete. 3rd one is to check the validity of friction coefficient between materials.



No.2 No.3

Fig. 6 Stuck of fresh concrete

4. Conclusions

MPS method on three dimensions was applied to the analysis of the workability of fresh concrete and then compared with the previous experiment. The accordance is not perfect yet, so the tasks to be solved next were also pointed out.

References

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