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ESTIMATION OF VIRTUAL THICKNESS OF MORTAR LAYER OVER AN AGGREGATE IN FRESH CONCRETE BY EXCESS PASTE THEORY

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1. INTRODUCTION

In shotcrete, the particle rebound is highly affected by the paste (cement paste in case of mortar shotcrete and mortar paste in case of concrete shotcrete) either surrounding fine aggregates (or coarse aggregates) or appearing freely in the interstitial space between them, respectively. In DEM simulation of shotcrete, the effect of mortar or paste comes through the thickness of it around an aggregate, its cohesiveness, and stiffness and dashpot parameters [1]. So, it is of extreme necessary to quantify these parameters to real mix proportion variables for quantitative simulation of shotcrete. In this research, the thickness of mortar layer is going to be quantified by the theory of excess paste [2] and W/C ratio has been found as an important index to stimulate it and some shotcrete simulation has been presented along with.

2. EXCESS PASTE THEORY

Dry aggregate assembly incorporates interior void on it due to non-conforming surface of aggregate at their collision. The fresh concrete, if one see from two-phase view, he will end up with coarse aggregate and mortar. The volume of mortar being sufficient to fill the interstitial space in the compacted aggregate, plus an increment that causes a certain dispersion of the aggregates particles. That is to say, there is excess of mortar that produces a certain distance of separation between points that would be in contact in the dry compacted state. This imagined situation is illustrated in Fig. 1 (a) representing the dry compacted state and (b) the state when the aggregate is dispersed in fresh concrete. Each particle seems to have acquired a thin coating of mortar that maintains the dispersed state and the interstitial space must also be filled. In the fresh concrete, the volume of mortar is always augmented by a certain amount of air. Authors have published many papers on numerical simulation of shotcrete by DEM [1, 3]. As assumed in this model, fresh concrete is a two-phase material, mortar surrounding coarse aggregate. Author now gives a way to determine the thickness of mortar layer from the excess paste theory. Considering the distance of dispersion being relatively small to diameter of particle the average distance can be estimated by dividing the volume of excess mortar by the total area of aggregate surface which makes contact to [2]. Fig.2 idealized the change of T with W/C ratio. It shows that with increasing W/C ratio, T first increases and then stabilizes at some where and start decreasing.

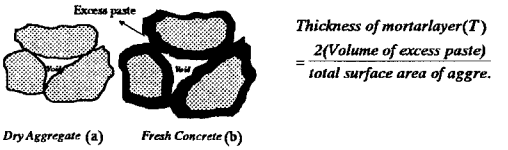

Fig. 1 Excess paste theory for fresh concrete

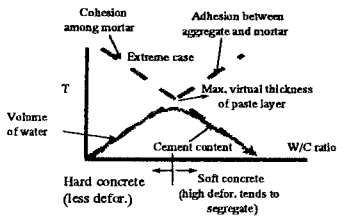

Fig. 2 Idealization of the presence of virtual thickness of mortar layer in fresh concrete

3. FLOW CHART OF CALCULATION

In this research, this theory is applied in a little different way as explained below. The thickness of mortar layer can be directly found from the designed mix proportion. For the designed mix proportion, the addition of water (W), cement (C), and sand (S) gives the volume of mortar in the fresh concrete. So, from any mix proportion, the amount of mortar volume containing certain amount of coarse aggregate can be picked up. After deducting the interstitial voids and air content, the excess volume of mortar that disperses the aggregate is obtained. Random radius was found out from fixed amount of aggregate from its weight by random variables generated (old radii). Now, these random radii were equally magnified by a constant thickness of mortar (assuming that all coarse particles are equally surrounded by mortar) which is

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Table 1 Typical mix proportions of concrete (for shotcrete)

Mix. no.	W/C by wt. ,%	S/A %	Amount in kg per m^3				Ex. Mortar cm^3	T mm
			Cement	Water	Sand	Gravel		
1	58.6	62	360	211	1065	677	5100.79	2.64
2	53.6	62	360	193	1094	698	4933.49	2.56
3	48.6	62	360	175	1123	714	4803.09	2.50

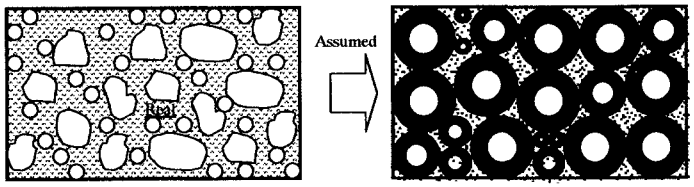

Fig. 3 Real situation versus assumed situation

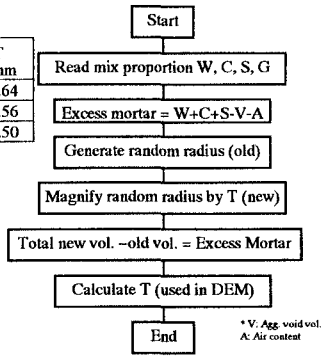

Fig. 4 Calculation flow chart

new sizes as shown in Fig. 3. By equating the total volume of new particle size minus old size particle to the excess volume of mortar, the mortar layer thickness can be quantified. The flow chart of entire calculation is shown in Fig. 4. Accordingly, the mortar thickness for three mixes (mix design for shotcrete experiment in our Lab.) has been calculated and shown in Table 1. The mix proportion with varying W/C ratio and the corresponding T shows that as the W/C ratio increases T also increases.

A DEM investigation was done with this two different thickness (no.1 and 2) of mortar layer and its effect in terms of rebound. The detail explanations of simulation principle can be found in references 1 or 3. In this calculation, author changes only the thickness of mortar with the change of mix proportion, but the result clearly does not show the effect of W/C ratio on the rebound loss. It is of opinion that mix proportion determines the constitutive behavior of fresh concrete and should be fully reflected in the stiffness and dashpot parameters of the simulation, which is still our research concern.

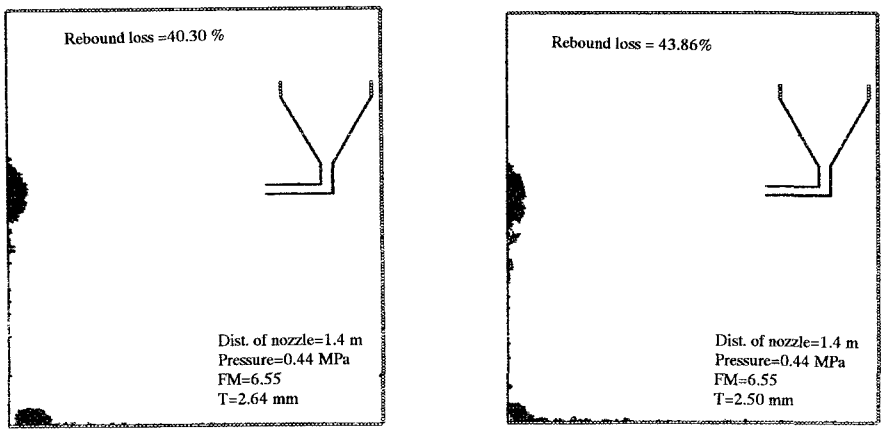

Fig. 4 Shotcrete with higher and lower W/C ratio

4. CONCLUSIONS

1.) The excess paste theory gives a partial explanation for thickness of mortar layer over an aggregate. However, more precise way of describing it, might give closer to reality.

2.) W/C ratio plays a direct role to define a certain amount of virtual thickness of mortar over an aggregate. The thickness of the mortar layer greatly reduces the amount of rebound in shooting.

5. REFERENCES

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