Combined Effects of Water Film Thickness and Talcum Powder on Flowability of Mortar

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Abstract. To research the effect of talcum powder and water film thickness on performance of mortar, this study measured the flowability and strength of 25 mixes of cement-sand mortar with different water/binder ratio. To reveal the role of WFT in the flowability of mortar, this research measured packing density of 5 different powder mixes with various talcum powder content, calculated the WFT of the 25 mixes of cement-sand mortar. Results proved that addition of talcum powder improve the flow properties of cement mortar. Packing density results showed that with the increase of the amount of talcum powder, the packing density will increase first and then decrease. The flowability was mainly governed by WFT. Talcum content would also affect the flowability of mortar. The increase of talcum content would improve the flowability of mortar.

Introduction

Cement is the main cementitious material used in concrete. In recent years, various kind of fillers have been used in the production of concrete to reduce the use of cement. Wen [1] found that addition of quartz sand would increase the flowability. Tezuka [2] used limestone replacing cement, when the amount of substitution is 5%, workability would not change with a lower W/C ratio. With the wide use of mineral admixtures, various types of high performance concrete can be procuded. However, rheological properties of concrete cannot be ignored [3]. Some researchers found that the flowability of concrete are highly affected by the rheology of mortar [4]. The mortar portion should be designed first. In order to find out the main factors of rheological properties, many scholars at home and abroad have studied it. Schutter and Poppe [5] found water consumption for a given workability was affected by the density of cement particle. Reddy and Gupta [6] found that in order to keep a given flowability, a higher water content should be required if the mortar contain finer sand, the surface area is the main reason. With a lot of researches, some factors have been proved to be the main factors affecting the rheology. The water film thickness (WFT) is a good index to study the flowability of mortar [7].

However, there are few studies on the effect of talcum as admixture on mortar. This study researched the effects of adding talcum powder on the flowability of mortar.

Experimental Program

Materials

In the experiment, the cement used was P.O42.5. Which conformed to the Chinese Standard GB175-2007/XG1-2009, and its density was measured to be 3127 kg/m$^3$; Talcum powder was purchased from Zhengzhou with a density of 2750 kg/m$^3$ and a specific surface area of 1×10$^7$ m$^2$/m$^3$; the fine aggregate was purchased from Xiamen. The density was measured as 2476 kg/m$^3$ and a specific surface area of 13639 m$^2$/m$^3$; The superplasticizer (SP) was liquid polycarboxylic acid high performance water reducing agent. The density was measured as 1030 kg/m$^3$.

Mix Proportion

In order to study the flowability of mortar, twenty-five mixes of talcum powder mortar with various W/C and talcum content were produced for testing. The W/C ratios were varied from 1.0 to 1.4 in
steps of 0.1. The talcum contents were varied from 0% to 20% in steps 5%. All data was reflected in Table 1, where M denotes mortar, X denotes the talcum contents Y denotes the W/C ratios.

**Measurement of Flow Spread and Flow Rate**

Measurement of flowability included static and dynamic flowability measurement. A slump cone with a top diameter of 70mm and a bottom diameter of 100mm was used. To perform the test, the cone was placed at a tile floor, filled up with the mortar, lifted up it slowly. The diameter of the patty formed was considered to be the flow spread of mortar. A V-funnel test was used to measure the flow rate. The V-funnel with a top diameter of 150mm, a bottom diameter of 17mm, a main body length of 120mm and an outlet pipe length of 55mm. Firstly, the paste was poured into the V-funnel with the bottom orifice closed. Then operator opened the orifice when the V-funnel was full and recorded the flow time. All measurements were made within 5 minutes after the mortar was stirred and the temperature of the laboratory was controlled at 20 ±2 ℃ during the whole experiment.

**Table 1. Mix proportions, packing density, WFT and flowability.**

| Mix no | OPC[kg/m^3] | Talcum[kg/m^3] | FA[kg/m^3] | Water[kg/m^3] | SP[kg/m^3] | Packing density | Flow spread [mm] | Flow rate [ml/s] |
|--------|-------------|----------------|------------|----------------|----------|----------------|-----------------|-----------------|
| M-0-1.4 | 205.9       | 0.0            | 1456.5     | 205.9          | 6.1      | 0.039          | 216.5           | 8.5             |
| M-0-1.3 | 221.9       | 0.0            | 1427.1     | 221.9          | 6.0      | 0.124          | 211.5           | 5.3             |
| M-0-1.2 | 237.3       | 0.0            | 1398.9     | 237.3          | 5.9      | 0.797          | 209.0           | 3.0             |
| M-0-1.1 | 252.1       | 0.0            | 1371.7     | 252.1          | 5.7      | 0.294          | 195.0           | 1.0             |
| M-0-1.0 | 266.3       | 0.0            | 1345.7     | 266.3          | 5.6      | 0.379          | 180.0           | 0.0             |
| M-5-1.4 | 205.9       | 28.3           | 1456.5     | 205.9          | 8.5      | 0.078          | 221.0           | 8.8             |
| M-5-1.3 | 221.9       | 27.7           | 1427.1     | 221.9          | 8.3      | 0.140          | 214.5           | 6.5             |
| M-5-1.2 | 237.3       | 27.2           | 1398.9     | 237.3          | 8.1      | 0.809          | 209.0           | 3.8             |
| M-5-1.1 | 252.1       | 26.7           | 1371.7     | 252.1          | 8.0      | 0.263          | 202.0           | 2.7             |
| M-5-1.0 | 266.3       | 26.2           | 1345.7     | 266.3          | 7.8      | 0.325          | 188.0           | 0.0             |
| M-10-1.4| 205.9       | 56.6           | 1456.5     | 205.9          | 10.8     | 0.110          | 221.5           | 9.2             |
| M-10-1.3| 221.9       | 55.5           | 1427.1     | 221.9          | 10.6     | 0.159          | 215.5           | 6.8             |
| M-10-1.2| 237.3       | 54.4           | 1398.9     | 237.3          | 10.4     | 0.824          | 207.0           | 5.0             |
| M-10-1.1| 252.1       | 53.3           | 1371.7     | 252.1          | 10.2     | 0.255          | 212.5           | 2.3             |
| M-10-1.0| 266.3       | 52.3           | 1345.7     | 266.3          | 10.0     | 0.304          | 199.5           | 0.0             |
| M-15-1.4| 205.9       | 84.9           | 1456.5     | 205.9          | 13.2     | 0.164          | 220.0           | 13.5            |
| M-15-1.3| 221.9       | 83.2           | 1427.1     | 221.9          | 12.9     | 0.204          | 220.0           | 10.2            |
| M-15-1.2| 237.3       | 81.6           | 1398.9     | 237.3          | 12.7     | 0.856          | 221.0           | 8.0             |
| M-15-1.1| 252.1       | 80.0           | 1371.7     | 252.1          | 12.4     | 0.284          | 214.0           | 2.2             |
| M-15-1.0| 266.3       | 78.5           | 1345.7     | 266.3          | 12.2     | 0.323          | 209.0           | 0.0             |
| M-20-1.4| 205.9       | 113.2          | 1456.5     | 205.9          | 15.6     | 0.104          | 223.5           | 11.0            |
| M-20-1.3| 221.9       | 111.0          | 1427.1     | 221.9          | 15.3     | 0.138          | 225.0           | 9.0             |
| M-20-1.2| 237.3       | 108.8          | 1398.9     | 237.3          | 15.0     | 0.834          | 223.0           | 7.5             |
| M-20-1.1| 252.1       | 106.6          | 1371.7     | 252.1          | 14.7     | 0.205          | 219.0           | 3.0             |
| M-20-1.0| 266.3       | 104.6          | 1345.7     | 266.3          | 14.4     | 0.239          | 212.5           | 1.0             |

**WFT**

This experiment use the wet packing method to measure the packing density[8]. This method can simulate the tight suspension state of solid particles in mortar, considering the influence of air, water and superplasticizer, which is more accurate than the dry measurement method of packing density. The maximum solid concentration was achieved when the solid particles were wrapped by the water to form a wet mortar. At this moment, the distance between particles were the minimum and the paste was the most compact. When the W/C ratios were relatively large, the compactness of the mortar decreased because the solid particles dispersed and suspended in the slurry. At this time,
reducing the W/C ratios can improve the compactness of the mortar. Likewise, when the W/C ratios were relatively small, there was not enough water to wrap the solid particle to form a mortar. At this time, increased the W/C ratios can improve the compactness of the mortar. According to the \( v \), the voids ratio of the solid particles \( u \) can be obtained as follows:

\[
\begin{align*}
   u &= \frac{1-v}{v} \\
   & \quad \text{The voids ratio is obtained, the excess water ratio } u'_w = u - u_w
\end{align*}
\]

In which \( u_w \) is the water ratio. Then the total specific surface area \( A \) can be calculated as:

\[
A = \frac{M_c}{\rho_c} \times A_c + \frac{M_t}{\rho_t} \times A_t + \frac{M_s}{\rho_s} \times A_s
\]

In which \( M_c, M_t \) and \( M_s \) are the quality of OPC, talcum powder and fine aggregate. \( \rho_c, \rho_t \) and \( \rho_s \) are the density of OPC, talcum powder and sand. \( A_c, A_t \) and \( A_s \) are the specific surface of OPC, talcum powder and sand. The WFT can be calculated by the following formulas:

\[
WFT = \frac{u'_w}{A}
\]

**Experimental Results**

**Flow Spread and Flow Rate**

The experiment results are listed in the ninth and tenth columns of Table 1 and the W/C ratio of different talcum content are plotted in Figs. 1 and 2. It is obvious that the flow spread would increase with the increase of talcum content. From the Fig. 1, it can be seen that at a lower W/C ratio, the addition of talcum powder had more obvious effect. From the Fig. 2, it is obvious that the improve of talcum content can increase the flow rate of mortar. At a talcum content of 15%, the flow rate increased most obviously. This phenomenon may be explained that the talcum particles are spherical in shape.
Packing Density and WFT
The results of packing density are listed in the seventh columns, it is reveal that as the increased of talcum content from 0% to 15%, the packing density increased from 0.797 to 0.856. The packing density decreased from 0.856 to 0.834 as the talcum content increased from 15% to 20%. The phenomenon are reasonable, the particle diameter of the talcum powder is smaller than the particle diameter of the cement. When the talcum content is low, the talcum powder would fill the voids between the cement and aggregate particles to increase the packing density, but when the talcum content is high, the talcum powder would lead the packing density decreased.

Roles of WFT

Roles of WFT on Flow Spread
As shown in Fig. 3, the flow spread against the WFT was plotted, the flow spread increased with the increase of WFT. As WFT continues to increase, the increase in flow spread slows down. The figure show that at the same WFT, a higher talcum content would lead to larger flow spread. This phenomenon indicated that the flow spread also affected by talcum content. Through multi-variable regression analysis, the best fitting curves of flow spread-WFT relationship under different talcum powder content has been obtained. The best-fit curves are plotted alongside the date points, and their equations and $R^2$ values are printed in the graph. It is obvious that the best-fit curves shifted downward with the talcum content decreasing which indicating the flow spread increased with the talcum contents increased when the WFT was a constant. A fairly high $R^2$ value of 0.938 has been achieved, indicating that the flow spread is governed by both the WFT and talcum content.

Roles of WFT on Flow Rate
As shown in Fig. 4, the flow rate against the WFT was plotted, the flow rate increased with the increased of the WFT. The WFT could be considered as the main factor. From the figure, when WFT is a fixed value, a higher talcum content would lead to larger flow rate. This is due to the lubricating effect of talcum powder. The talcum powder could lubricate the interaction of fine aggregate. The best fitting curves of flow rate-WFT relationship under different talcum powder content has been obtained. It can be seen that the value of $R^2$ reached 0.841. This means that WFT and talcum content affect the flow rate of mortar together.
Conclusions
The main conclusions of this study are as follows: through measure the packing density of twenty-five talcum powder mortar mixes. The WFT of mortar mixes were calculated. Twenty-five mortar mixes were made to measure the flowability. The test results show that with the increase of the amount of talcum powder, the packing density will increase first and then decrease. The effects of the W/C ratio and talcum content are complex. With the change of W/C ratio and talcum content, the packing density and specific surface area of mortar would also change. These factors could be assessed by WFT and talcum content. The WFT and the talcum content determines the flow spread and flow rate. However their importance is not equal. The WFT is the most important factor to determine the flowability of mortar. The talcum content also play a role in mortar in flowability of mortar, but is not the main factor.

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References
[1] Wen Mendan, Chen Jiajian, Gao Yushen. Experimental study on effect of quartz sand on properties and water film thickness of cement paste[J]. Journal of Shantou University (Natural Science), 2018, 33(1):63-72.
[2] Tezuka Y, Gomes D, Martins JM, Djianikian JG. Durability aspects of cements with high limestone filler content,[C] Proceedings, 9th International Congress of the Chemistry of cement, New Delhi, India, 1992:53-59.
[3] Li Yunhua, Xie Yonujun Long Guangcheng. Progress of research on self-compacting concrete[J]. Journal of the chinese ceramic society, 2007, 35(5):671-678.
[4] Ng I.Y.T., Ng P.L., Kwan A.K.H. Rheology of mortar and its influences on performance of self-consolidating concrete[J]. Key Engineering Materials, 2009, 400-402:421-426.
[5] Schutter G.D., Poppe A.M. Quantification of the water demand of sand in mortar[J]. Construction & Building Materials, 2004, 18(7):517-521.
[6] Reddy B.V.V., Gupta A. Influence of sand grading on the characteristics of mortars and soil–cement block masonry[J]. Construction and Building Materials, 2008, 22(8):1614-1623.
[7] Kwan A.K.H., Li L.G. Combined effects of water film thickness and paste film thickness on rheology of mortar[J]. Materials and Structures, 2012, 45(9):1359-1374.
[8] Li L.G., Kwan A.K.H. Packing density of concrete mix under dry and wet conditions[J]. Powder Technology, 2014, 253:514-521.