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Rheology Of Cement Paste Containning Chemical Admixtures

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ABSTRACT

Understanding the Rheology of cement and water is a not a simple task since, the behaviour of complicated system varies with time and there is still a great deal of work to be done before, it is properly understood. In this study, we used a new simple and cheap technique to evaluate flow properties of cement paste .This technique is based on dropping a needle from a constant height. The penetration depth is measured at different circumstances, different w/c ratios, different types of super plasticizer, and different percentage of admixture for two types of cement types of cements OPC type V (CEMEX) and OPC type I (HELWAN) were considered in this study. Also, effect of retempering on penetration depth were also considered. Finally effect of variation of needle drop height was also considered. The penetration depth technique proved to be effective in monitoring the effect of superplasticizer/cement ratio percentage, effect of time, manual remixing after 30 minutes and needle drop height on the rheological behavior of different types of cement paste, which further proves the effectiveness of this method in evaluation of cement paste Rheology.

INTRODUCTION

Cement pastes obviously the most complicated constituent of concrete, consisting as it does of very fine particles undergoing a chemical reaction, it might be reasonably thought to be primarily responsible for some of the phenomena observed in the concrete behavior. Some of the early works on cement pastes consist either of experiments with apparatus that had been developed primarily for concretes and mortars or for measurements made by simple empirical methods. [1-5].There are two possibilities; the first is by using the methods of soil mechanics and the second by using techniques that have been established for investigating the rheological properties of suspensions.[6,7].Most recently studies in this field were based on calculating the rheological parameters of cement paste and by using a certain model, the rheological parameters of fresh concrete are measured from that of cement paste, but these were performed by using viscometers or rheometers, which are expensive and could not be used on site.[8,9]. Further investigations were concerned with Rheology of cement pastes. Furthermore investigation of the role of fine powder on workability and the effect of partial replacement of cement and site investigations were also considered in previous studies. It may be possible to assign a single figure to each type of job and to and to present the rest of information necessary for production and control of concrete in the form of tables and graphs. The technique adopted in this study would be very helpful in providing this data very easily for the site engineer.

EXPERIMENTAL PROGRAM

In this section we will discuss the objective and the scope of a two phase program using different cement types, with four different types of admixtures. This is followed by investigation of their different characteristics.

Phase I: This phase focused on the applicability of the needle used in determination of the flow characteristics of two different types of cements, through measurements of penetration depth of the plastic needle on cement paste. See Figures (1-3). As mentioned previously, two types of cement were used OPC type I (HELWAN) and SRC type V (CEMEX). For each type of cement, four different types of super plasticizers were used (Rheobuild 875 type F, Rheobuild 865 type G, Sikament R2002 type G, and Sikament type F). Furthermore different Plasticizer/Cement ratio was used (0.8%, 0.9%, 1.0%, 1.1%, and 1.2%). From the obtained results we can measure the degree of compatibility between different types of super plasticizer. Hence, we can determine the optimum dosage that would provide best flow properties. See Table (1).

Phase II: After the development of the optimum dosage obtained from phase I, for each type of cement with respect to each type of super plasticizer, the objective of the experimental program in phase II was to determine the effect of time at 5& 10 and 30 minutes on penetration depth. Which by the way, shows the sensitivity of the procedure (drop needle) to measure the flow properties of cement paste. This procedure was followed by re tempering after 30 minutes to initiate a break down structure for the cement paste through manual remixing.

Phase III: The objective of the third phase was to study the effect of the height of the needle on the penetration depth of the needle in to cement paste samples; with different W/C (0.35, 0.4, 0.45, 0.5, 0.6) at different needle drop heights (5cm, 10cm, and 15cm) measured from the surface of the cement paste.

Table 1 Cement Paste Mix Proportions

Mix composition	Quantity
Water	70 gm
Cement	200 gm
Admixtures	Based on percent dosage.

Figure 1 Needle Falls in Cement Paste

RESULTS AND DESCUSSION

Phase I (parametric study):

Effect of admixtures on OPC type I (Helwan) cement paste: In this study the effect of dosage of different types of admixtures (Rheobuild 875, Rheobuild 865, Sikament M, and Sikament R2002) on flow properties of cement paste (penetration depth),was considered as mentioned previously. The plasticizer/cement was (0.8 ,0.9 , 1.0 ,1.1 and 1.2%). For Rheobuild 875 the optimum level of needle penetration was 51 mm at a plasticizer/ cement ratio (P/C) of 1.2%, meanwhile the lowest level of penetration was 41 mm at a P/C ratio of 0.8%. The general trend of this group indicates that the penetration depth started at a minimum value at P/C of 0.8%, the penetration depth started to increase gradually as P/C ratio increased to reach the maximum value at 1.2% .This trend may be attributed to the compatibility of Rheobuild 875 with OPC type I (Helwan). See Table (2). For Rheobuild 865 the optimum level of penetration depth was 39 mm, reached at a plasticizer/ cement ratio (P/C) of 1.2%. Mean while, the lowest level of penetration was 30 mm at P/C ratio of 0.8%. Penetration increased gradually as P/C ratio increased. The general trend of this group indicates compatibility with OPC type I (Helwan). The flow characteristics did not show the high penetration levels achieved in case of Rheobuild 875. Sikament R2002, an optimum level of penetration depth of value 41 mm was reached at a plasticizer/ cement ratio (P/C) of 1.2%. Mean while the lowest level of penetration depth of 28mm was reached at a P/C ratio of 1.0%. This specimen shows a continuous and stable increase in penetration as (P/C) increases. For Sikament M with OPC type I (Helwan). The optimum level of penetration depth was 41 mm, at a plasticizer/ cement ratio (P/C) of 1.1%, and remained constant at 1.2% . Mean while the lowest level of penetration depth was 32 mm, reached at P/C ratio 0.8%. See Table (2). Sikament M was similar in performance to Rheobuild 865, but was more stable and showed a directly proportional relationship with (P/C) ratio but did reach the high levels of penetration achieved in Rheobuild 875.

Table 2 Penetration depth results for various types of plasticizer (Phase I)

	OPC Type I (HELWAN)Penetration depth (mm)				SRC TYPE V(CEMEX) Penetration depth (mm)			
Plasticizer / cement	Rheobuild 875	Rheobuild 865	Sikament R 2002	Sikament M	Rheobuild 875	Rheobuild 865	Sikament R 2002	Sikament M
0.8 %	41	30	34	32	23	20	24	15
0.9 %	43	35	30	34	28	20	29	15
1.0 %	45	34	28	38	25	21	29	20
1.1 %	49	37	40	41	23	26	29	32
1.2 %	51	39	41	41	37	26	29	32
Optimum Dose	1.2%	1.2%	1.2%	1.1%	1.2%	1.1%	1.1%	1.1%

Effect of admixtures on SRC type V (Cemex) cement paste:

For Rheobuild 875 the optimum level of penetration depth (37 mm) was reached at a plasticizer/ cement ratio (P/C) of 1.2%. Mean while, the lowest level of penetration depth of 23 mm was reached at a P/C ratio of 0.8%. This group showed highest penetration levels among all groups. See Table (2). For Rheobuild 865, the highest level of penetration reached was 26 mm at a plasticizer/ cement ratio (P/C) of 1.1% and 1.2% mean while the lowest level of penetration depth of 20 mm was reached at P/C ratio of 0.8% and 0.9%, while the value was 21mm at P/C ratio of 1.0%. The general trend of this group indicates that there is a directly proportional relationship between penetration and (P/C), where the smallest value of 20mm was obtained at P/C ratio of 0.8% and remained constant at P/C of 0.9%, then increased to 21mm at 1.0% .Penetration depth increased suddenly at P/C ratio of 1.1% to reach 26mm and remain constant, while increasing P/C ratio to 1.2%. Although the ultimate penetration level was lower than that encountered when using Rehobuild 875 yet it showed a more stable trend of performance, which indicates that Rheobuild 865 is compatible with SRC type V (Cemex). For Sikament R2002, the optimum level of penetration was 29 mm, reached at a plasticizer/ cement ratio (P/C) of 0.9%, 1.0%, and 1.1%. Mean while the lowest level of penetration depth of 24 mm was reached at a P/C ratio of 0.8%. The general trend for this group, indicates that Sikament R2002 is compatible with SRC type V (Cemex) where the results of penetration depth increased gradually as P/C ratio increased. The ultimate penetration depth though was not as high as in case of Rehobuild 875 and Rehobuild 865. For Sikament M, the optimum level of penetration was 32 mm, reached at a plasticizer/ cement ratio (P/C) of 1.1%. Mean while the lowest level of penetration depth of 15mm was reached at a P/C of 0.8% and 0.9%. The general trend in this group indicates that the penetration depth increased as P/C ratio increased. Sikament M is compatible with SRC type V (Cemex) .The performance of this group showed a directly proportional relationship between penetration depth and (Plasticizer/Cement) ratio. The ultimate penetration level was higher than that encountered Rehobuild 865 and Sikament R2002, and it showed a more stable performance compared to that of Rehobuild 875. The General performance of subgroups using (SRC) cement showed lower levels of penetration compared to specimens using (OPC).

Phase II (parametric study)

Effect of time (5min, 10min, and 30 min) on penetration depth : In this section only optimum specimens within each group with highest flow values were selected.

Effect of time on OPC Type I (Helwan) cement paste: For Rheobuild 875, the optimum P/C ratio for this subgroup was 1.2%. Penetration depth value of 51mm at initial testing was registered; After 5 minutes of initial mixing with water penetration decreased to 29 mm and maintained to decrease till it reached 16mm after 10 minutes. After 30 minutes, penetration depth decreased to a minimum value of 4 mm. For Rheobuild 865, the same trend mentioned previously for Rheobuild 875, was observed for this subgroup as well. The optimum P/C ratio was 1.2%, which corresponded to penetration depth value of 39mm at initial testing, this value decreased as the time increased, reaching a minimum value of 0mm at 30 minutes. See Table (3) and Figure (2). For Sikament R2002, the optimum P/C ratio was 1.1%, which corresponded to penetration depth value of 41mm at initial testing, where penetration depth reached 34mm after 5 minutes of initial mixing and still decreases till it reaches 22mm after 10 minutes of initial mixing and reaches the minimum value of 6mm at 30 minutes after initial mixing. For Sikament M, the optimum P/C ratio was 1.2%, which corresponded to penetration depth value of 41mm at initial testing, this value decreased as the time increased, where the value was equal to 21mm after 5 minutes of initial mixing and continues to decrease till it reaches 16mm after 10 minutes and reaches a minimum value of 9mm after 30 minutes. The rate of decrease in penetration depth for this group was the lowest among all groups. The general trend indicates that, the value of penetration depth decreases as the time increases, this may be attributed to the fact that as the time increases, the hydration process increases, also loss of water due to evaporation and chemical reaction result in decrease in flow ability of cement paste mix.

Effect of time on SRC Type V (Cemex) cement paste:

For Rheobuild 875, the optimum P/C ratio was 1.2%, which corresponded to penetration depth value of 37mm at initial testing; this value decreased to 28mm after 5 minutes of initial mixing and reached 7mm after 10 minutes. After 30 minutes penetration depth reaches 1 mm. See Table (3) and Figure (3). For Rheobuild 865, the optimum P/C ratio was 1.0%, which corresponded to penetration depth value of 29mm at initial testing, this value decreased as the time increased, and reaches a minimum value of 1mm at 30 minutes. The general trend for this group was similar to that of Rheobuild 875, but with lower levels of penetration. Sikament R2002, had an optimum P/C ratio 0.9%, which corresponded to penetration depth value of 30mm at initial testing, this value was decreased as the time increased, where the value reached 22mm after 5 minutes of initial mixing and continued to decreases till it reached 4mm after 10 minutes of initial mixing and reached a minimum value of 1mm after 30 minutes of water mixing. For Sikament M, the optimum P/C ratio was 1.1% which corresponded to penetration depth value of 32mm at initial testing, this value was decreased as the time increased, where the penetration value was equal 12mm after 5minutes of initial mixing and continued to decrease, till it reached 7mm after 10 minutes of initial mixing and reached a minimum value of 3mm after 30 minutes after. Rate of decrease in penetration depth for this group was the lowest among all groups.

Table 3 Penetration depth for various types of cement at different time intervals

	OPC Type I (HELWAN)				SRC TYPE V (CEMEX)			
Time	Rheobuild 875	Rheobuild 865	Sikament R 2002	Sikament M	Rheobuild 875	Rheobuild 865	Sikament R 2002	Sikament M
1 minute	51	39	41	41	37	29	30	32
5 minutes	29	10	34	21	28	14	22	12
10 minutes	16	3	22	16	7	6	4	7
30minutes	4	0	6	9	1	1	1	3
30 minutes + Remixing	14	10	18	21	9	8	7	9

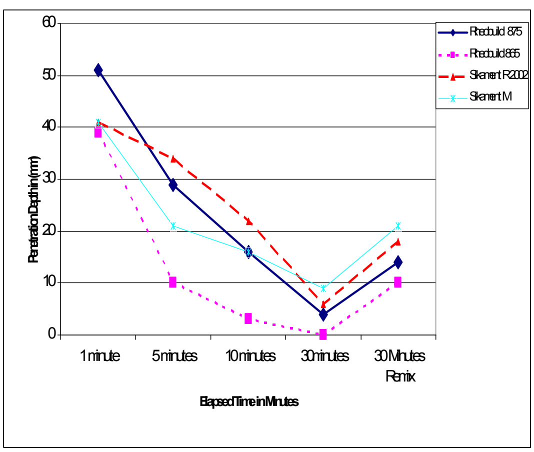

Figure 2 Effect of Time on penetration depth for OPC Type I (HELWAN)

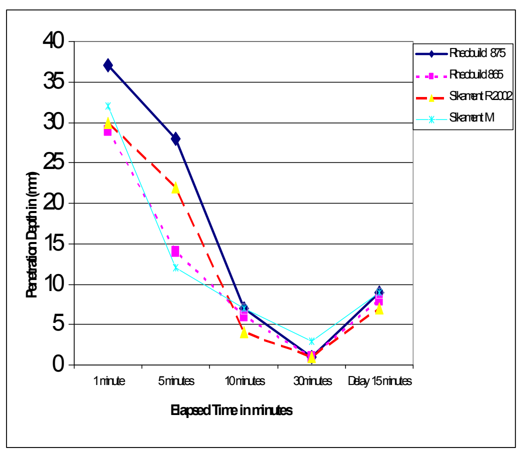

Figure 3 Effect of Time on penetration depth for SRC TYPE V (CEMEX)

Effect of Retempering after 30minutes on OPC Type I (Helwan) cement paste

After 30 minutes from initial mixing re-tempering or agitation of cement paste mix by 25 revolution by a metal rod was performed. The general trend indicates that, the value of penetration depth increases again as cement paste is subjected to agitation; the reason for this is the break down structure of the cement paste. The value of penetration depth after agitation for most of the cases was more than the value of penetration at 10 minutes after initial mixing.

Effect of Retempering after 30minutes on SRC Type V (Cemex) cement paste

The general trend for all specimens in this group indicates that after remixing of the cement paste after 30 minutes, penetration of the needle increased from 1-3 mm to 7-9 mm. It was evident that the penetration depth for specimens in this group after remixing, were less than those achieved when type I cement.

Phase III: Effect of height of needle on penetration depth

For all subgroups in this study, the effect of drop height of the needle on different types of admixtures (Rheobuild 875, Rheobuild 865, Sikament M, and Sikament R2002) on flow properties of cement paste (penetration depth) was considered in this study, with variation in W/C (0.35 ,0.4 , 0.45 ,0.5 ,and 0.55) no plasticizer was used in this study.

Effect of height of needle on penetration depth of OPC Type I (Helwan)

For w/c ratio 0.35, at 4cm drop height of needle from surface of cement paste, the penetration depth was 14mm; this value increased to 16mm as the height increased to 9cm and reached a maximum value of 25mm at height of 14cm. See Figure (4). For w/c ratio of 0.4, at 4cm height of needle from surface of cement paste, the penetration depth was 28mm, this value increased to 34mm as the height increased to 9cm and reached the maximum value of 42mm at height of 14cm. For w/c ratio of 0.45, at 4cm height of needle from surface of cement paste, the penetration depth was 40mm, this value increased to 47mm as the height increased to 9cm and reached the maximum value of 62mm at height of 14cm. For w/c ratio of 0.5, at 4cm height of needle from surface of cement paste, the penetration depth was 45mm, this value increased to 53mm as the height increased to 9cm and reached the maximum value of 64mm at height of 14cm. For w/c ratio of 0.55, at 4cm height of needle from surface of cement paste, the penetration depth value was 55mm, this value increased to 64mm as the height increased to 9cm and reached the Maximum value of 69mm at height of 14cm. The general trend indicates that, for the same w/c ratio, as the height of needle increases, the penetration depth of needle increases, also at the same height of needle, as the w/c ratio increases the penetration depth value. The relation between penetration depth and height of needle approximately a straight.

Effect of height of needle on penetration depth of SRC Type V (Cemex)

For w/c ratio of 0.35, at 4cm height of needle from surface of cement paste, the penetration depth value 14mm, this value increased to 17mm as the height increased to 9cm and reached the maximum value of 22mm at height of 14cm. See Figure (4). For w/c ratio of 0.4, at 4cm height of needle from surface of cement paste, the penetration depth value was 25mm, this value increased to 29mm as the height increased to 9cm and reached the maximum value of 35mm at height of 14cm. For w/c ratio of 0.45, at 4cm height of needle from surface of cement paste, the penetration depth value was 50mm, this value increased to 55mm as the height increased to 9cm and reached the maximum value of 60mm at height of 14cm. For w/c ratio of 0.5, at 4cm height of needle from surface of cement paste, the penetration depth value was 56mm, this value increased to 63mm as the height increased to 9cm and reached the maximum value of 67mm at height of 14cm. For w/c ratio of 0.55, at 4cm height of needle from surface of cement paste, the penetration depth value was 63mm, this value increased to 68mm as the height increased to 9cm and reached the maximum value of 72mm at height of 14cm. The general trend indicates that, for the same w/c ratio, as the height of needle increases, the penetration depth value of needle increases, also at the same height of needle, as the w/c ratio increases the penetration depth value increases where the maximum penetration depth of value 72mm was obtained at w/c ratio of 0.55 and height of 14cm, also the relation between penetration depth and height of needle was approximately a straight line.

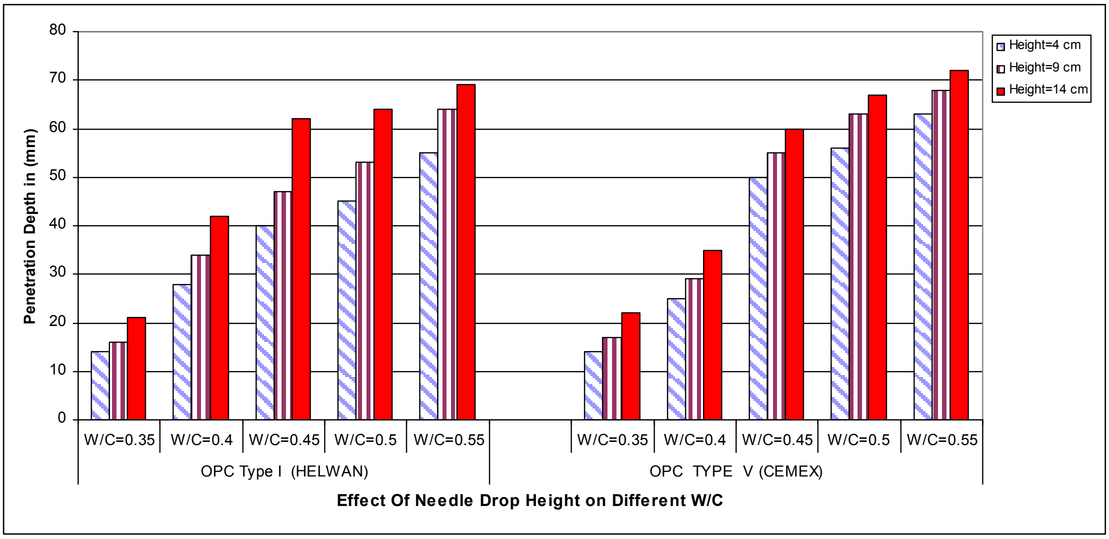

Figure 4 Effect of needle drop height on different types of cement

CONCLUSION

In what follows a conclusion of the study on rheological behavior of fresh cement paste containing chemical admixtures for several types of cement will be discussed.

1- It was evident that the penetration depth technique adopted in this study was successful in determining the optimum point, where penetration reaches the maximum value. For all subgroups

2- The penetration depth technique, proved to be effective in monitoring the effect of percent dosage of chemical admixtures on the rheological behavior of different types of cement paste.

3- The technique proved to be successful in monitoring the effect of time on the rheological behavior of different types of cement, it was noted that as the time increases, the penetration depth decreases.

4- Agitation of cement paste manually after 30 minutes of water addition, proved to be effective in the break down structure of the cement paste and increasing the penetration depth once more.

5- It was noted that as the height of the needle increases, the penetration depth for all types of cement increases.

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