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**RHEOLOGY OF FRESH CEMENT PASTE CONTAINNING CHEMICAL  
ADMIXTURES MATERIALS**

*By*

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**Abstract:**

Understanding the rheology of cement and water is a not a simple task since, the behavior of complicated system various with time and there is still a great deal of work to be done before it is properly understood. Fortunately, fresh cement paste, mortar, at early ages approximate to the Bingham model , and could be tested at two rates of shear, that is ,they require a two point test. All available tests are either empirical or too expensive and could not be used on site, and measure only one parameter . These tests are a single point tests, this means that in each test only one measurement is made, at one rate of shear or under one set of shearing conditions.

In this study we used a new simple technique based on dropping a needle from a constant height. The penetration depth is measured at different circumstances different w/c ratios, 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). Effect of time of testing after mixing and the effect of agitation of the specimens after 30 minutes as well as the effect of the drop height were also investigated in this study.

This model although simple and cheap and could be performed on site, also proved to be sensitive in monitoring the effect of different water cement ratio, and various percentages of super plasticizer as well as effect of delay of addition of super plasticizer on the penetration depth of the plastic needle.

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## Introduction:

For a full understanding of the flow properties of fresh concrete, first it is necessary to gain a through knowledge of the behavior of pastes consisting of cement and water only.

Cement pastes obviously the most complicated constituent of concrete, consisting as it does of very fine particles under going a chemical reaction, it might be reasonably thought to be primarily responsible for some of the phenomena observed in the concrete behavior. For example, the changes that take place in concrete under vibration might be due to at least partly to a break down of the structure of the paste.

Some of the early work 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.<sup>(1-4)</sup>

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.<sup>(5-8)</sup>

The previous work made by Tattersal on cement paste has indicated , that at low rate of shears, the behavior of cement paste followed a Bingham model with yield values and plastic viscosities that were exponent ional functions of water content.

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.

Several investigations that have taken place that took place to define the different types of flow and define the term Rehology. Further investigations were concerned with rheology of cement pastes<sup>(9-12)</sup> . Further more investigation of the role of fine powder an workability and the effect of partial replacement of cement was and site investigations were also considered in previous studies<sup>(13-17)</sup> . A considerable amount of work has been carried out on the effect of mix design variables up on the two constants (g) and (h) which correspond to the yield and plastic viscosity, on the collection of data on the values necessary for a particular practical job. 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 three phase program using different cement types in paste mixes with four different types of admixtures. This will be followed by their different characteristics, as well as the test set up used and procedure applied supported with figures showing details of testing.

### **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 Fig (1-4). To reach our goal in this phase, 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). Different Plasticizer/Cement ratio were used (0.8%, 0.9%, 1.0%, 1.1%, 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. The effect of water/cement ratios only without addition of any superplasticizer (W/C=0.35, 0.4, 0.45, 0.5, and 0.55)was also considered in this study . 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 flow properties 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 retempering after 30 minutes to initiate a break down structure for the cement paste through manual remixing.

In phase II the effect of delay in addition of super plasticizer with 14% of water to cement paste mix by 5 minutes after initial mixing was also investigated, this procedure was also applied for cement paste mixes with minimum dosage of super plasticizer (0.8%).

### **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. Hence, we will try to find out a relation between potential energy and flow properties of fresh cement paste.

**Table (1) Cement Paste Mix Proportions**

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



Fig ( 1 ) Four types of chemical admixtures used at experimental work



Fig ( 2 ) Measuring Weight of needle.



Fig ( 3 ) Needle and Scale used in experimental work



Fig ( 4 ) Needle Falls in Cement Paste

## RESULTS AND DESCUSSION

In what follows we will discuss the results of penetration depth test method for cement paste mixes under various circumstances. Also we will analyze the scientific test results trying to evaluate those to each others.

### *Phase I (parametric study):*

#### *Effect of percent dosage of admixtures on different types of cement paste mixes:*

##### *Effect of admixtures on OPC type I (Helwan) cement paste:*

In this study we will discuss 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), as mentioned previously ,the percent of admixtures under investigation were (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%, mean while 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 value was of smallest value at P/C of 0.8%, meanwhile the value increased 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). The best result of penetration depth was obtained at 1.2% dosage. See Table (2) and Fig (5).

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%. The value was increased gradually as P/C ratio increased. The general trend of this group indicates compatible with OPC type I (Helwan) but 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 this specimen did show a continuous and stable increase in penetration as (P/C) was increased.

For Sikament M is a compatible with OPC type I (Helwan). The optimum level of penetration depth of value 41 mm was reached at a plasticizer/ cement ratio (P/C) of 1.1%, and remained constant at 1.2% mean while the lowest level of penetration depth of 32 mm was reached at P/C ratio of 0.8%.. See Fig (5). Sikament M was similar in performance to Rheobuild 865 , but was more stable and showed a directly proportional relation ship with (P/C) ratio but did reach the high levels of penetration achieved in Rheobuild 875.

Phase I

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

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

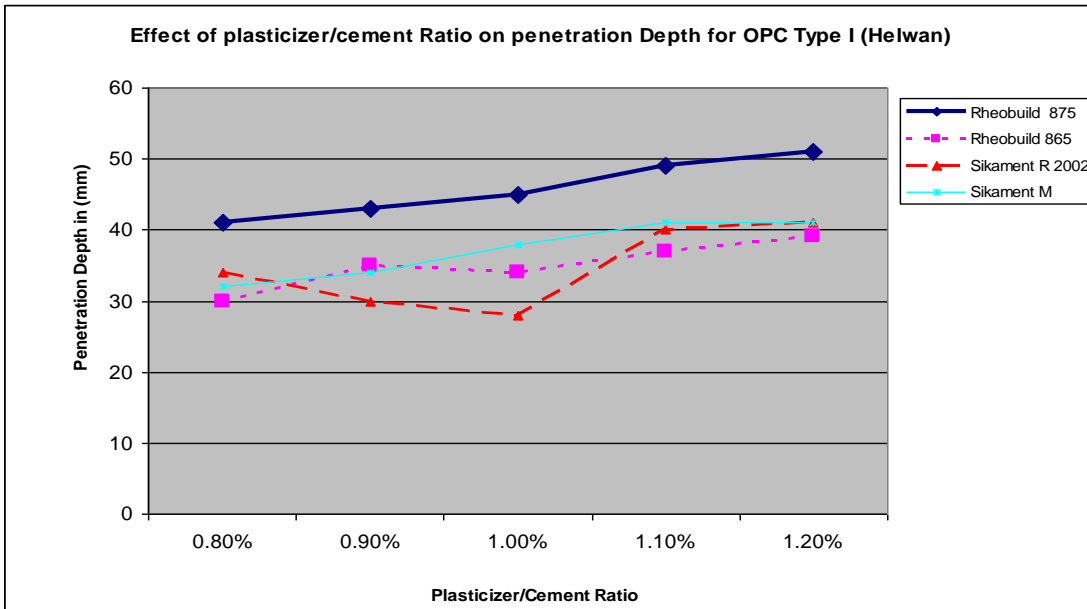


Fig ( 5 ) Effect of plasticizer/cement Ratio on Penetration Depth For OPC Type I (Helwan)

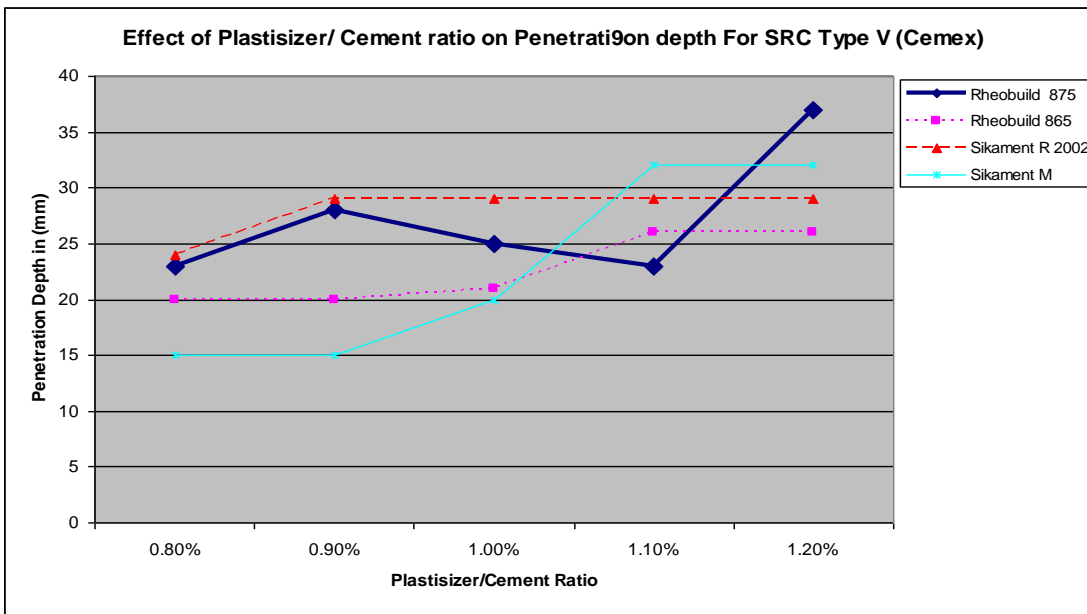


Fig (6) Effect of Plastisizer/ Cement ratio on Penetration depth For SRC Type V (Cemex)

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

In this study we will discuss 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), as mentioned previously, the percent of admixtures under investigation were (0.8 ,0.9 , 1.0 ,1.1 ,and 1.2%).

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 yet it showed a high degree of instability at levels of P/C ratio 1.0% and 1.1%. This is contrary to the case of using Rheobuild 875 with (OPC) type I Helwan. See Fig (6) and 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 relation ship between penetration and (P/C), where the smallest value of 20mm was obtained at P/C ratio of 0.8% and remain constant at P/C of 0.9%, then increased to 21mm at 1.0% and the value was 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 depth of value 29 mm was 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 of 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 depth of value 32 mm was 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 0.9% . The general trend of this group indicates that the penetration depth value increased as P/C ratio increased. Sikament M is compatible with SRC type V (Cemex) .The performance of this group showed a directly proportional relation ship 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 Rehobuild 875.

The General performance of subgroups using ( SRC ) cement showed lower levels of penetration compared to specimens using (OPC).



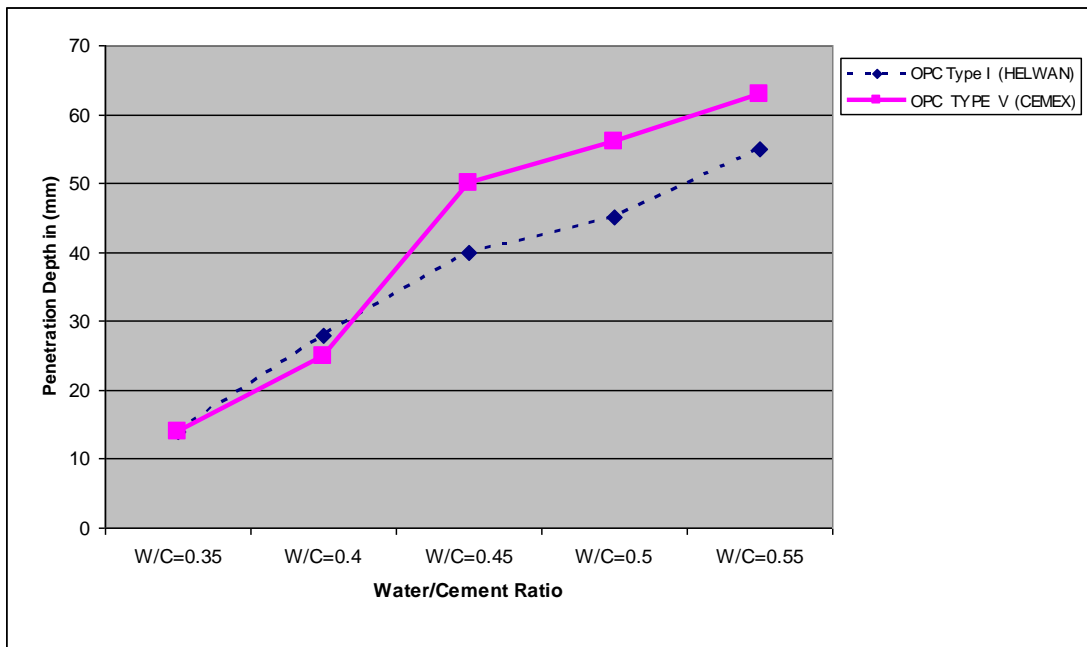
***Effect of W/C ratio on flow properties of cement paste:***

***Effect of w/c ratio on OPC type I (Helwan) cement paste:***

In this study we will discuss the effect of w/c ratio on flow properties of cement paste (penetration depth), as mentioned previously, the w/c ratios under investigation were (0.35, 0.4, 0.45, 0.5, and 0.55) no plasticizer was used in this group. For OPC type I (Helwan), the smallest value of penetration depth of 14mm was obtained at w/c ratio of 0.35 which is the minimum ratio used in the test, while the largest value of penetration depth of 55mm was reached at w/c ratio of 0.55. The general trend of this group indicates that the penetration depth value was increased as the w/c ratio increased. This trend may indicate that there was a direct relation between w/c ratio and value of penetration depth and the relation was approximately linear. See Fig (7).

***Effect of w/c ratio on SRC type V (Cemex) cement paste:***

The general trend indicates the existence of the same proportionality mentioned above. For SRC type V (Cemex), the smallest value of penetration depth of 14mm was obtained at w/c ratio of 0.35 which was the minimum ratio used in the test, while the largest value of penetration depth of 63mm was reached at w/c ratio of 0.55. The general trend of this group indicates that the penetration depth value was increased as the w/c ratio increased. Comparison between SRC and OPC indicates that at low levels of W/C 0.35-0.4 the performance of both groups was very similar, but at high levels of W/C OPC was more sensitive to the increase in W/C, reaching higher levels of penetration which indicates higher levels of flowability.



**Fig (7)Effect of w/c on the penetration depth for different types of cement**

**Phase II (parametric study):**

**Effect of time (5min, 10min, and 30 min) on penetration depth:**

**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, this value was decreased as the time increased. After 5minutes of initial mixing and penetration value decreased to 29 mm and maintains decrease till it reaches 16mm after 10minutes. after 30 minutes, penetration depth decreased to a minimum value of 4 mm at 30minutes.

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, where the penetration depth reached 10mm after 5minutes and 3mm after 10 minutes of initial mixing and reaching a minimum value of 0mm at 30minutes. See Table (3) and Fig (8).

For Sikament R2002, the optimum P/C ratio was 1.1% which corresponded to penetration depth value of 41mm at initial testing, this value was decreased as the time increased, where the value was equal 34mm after 5minutes of initial mixing and still decrease till reaches 22mm after 10minutes of initial mixing and reaches the minimum value of 6mm at 30minutes 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 5minutes of initial mixing and continues to decrease till it reaches 16mm after10minutes and reaches a minimum value of 9mm after 30minutes. The rate of decrease in penetration depth (flowability) 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 increase, the hydration process increase, also loss of water due to evaporation and chemical reaction which result in decrease in flow ability of cement paste mix, in addition to the fact that temporary effectiveness of super plasticizer starts to disappear.

**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 5minutes of initial mixing and reaches 7mm after10minutes. After 30 minutes penetration depth reaches 1 mm . See Table (3) and Fig (9).

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 30minutes. 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 was equal 22mm after 5minutes of initial mixing and still decreases till reaches 4mm after10minutes of initial mixing and reaches the minimum value of 1mm at 30minutes after initial 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 still decreases, till it reaches 7mm after10minutes of initial mixing and reaches a minimum value of 3mm after 30minutes 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**

Time	OPC Type I (HELWAN)				SRC TYPE V (CEMEX)			
	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 + Retemixing	14	10	18	21	9	8	7	9

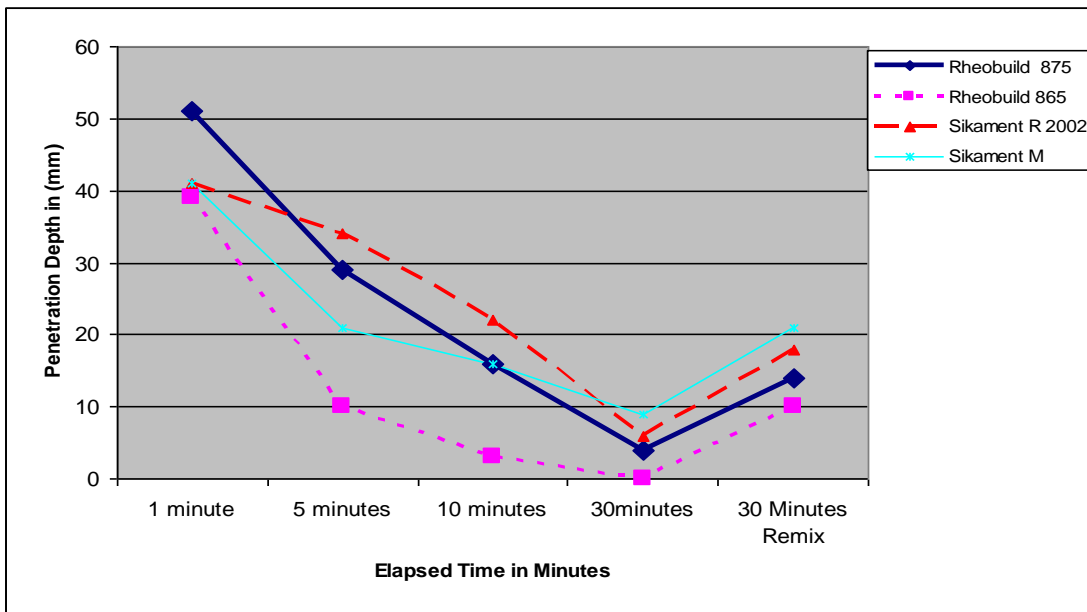


Fig ( 8 ) Effect of Time on penetration depth for OPC Type I (HELWAN)

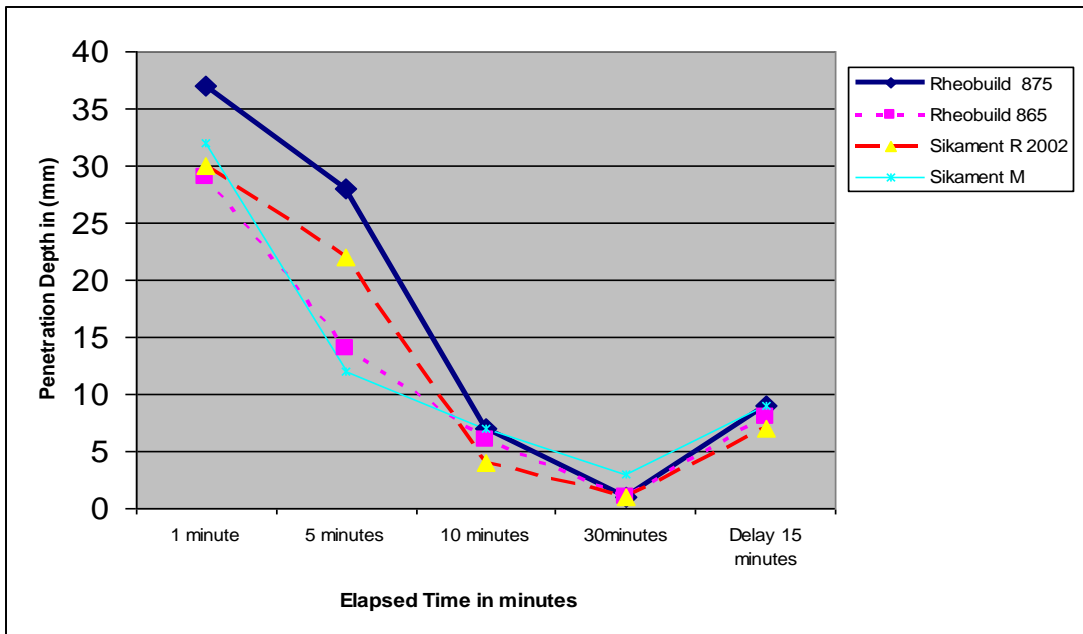


Fig ( 9 ) Effect of Time on penetration depth for SRC TYPE V (CEMEX)  
**Effect of Retempering on penetration depth:**

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

For Rheobuild 875, the optimum P/C ratio was 1.2% which corresponded to penetration depth value of 51mm at initial testing, this value decreased as the time increased till it reached a minimum value of 4 mm at 30minutes after initial mixing. After this stage as we performed retempering or agitation for cement paste mix by 25 revolution by a metal rod then the value of penetration depth increases again to a value of 14mm. See Fig (10)  
 For Rheobuild 865, the optimum P/C ratio was 1.2% which corresponded to penetration depth value of 39mm at initial testing, this value reached a minimum value of 0mm at 30minutes after initial mixing after this stage as we made retempering or agitation for cement paste mix by 25 revolution by a metal rod then the value of penetration depth increases again to a value of 10mm.

For Sikament R2002, the optimum P/C ratio was 1.1% which corresponded to penetration depth value of 41mm at initial testing, this value was decreased as the time increased till reach the minimum value of 6mm at 30minutes after initial mixing after this stage as we made retempering or agitation for cement paste mix by 25 revolution by a metal rod then the value of penetration depth increases again to a value of 18mm.

For Sikament M, the optimum P/C ratio was 1.2% which corresponded to penetration depth value of 41mm at initial testing, this value was decreased as the time increased till reach the minimum value of 9mm at 30minutes after initial mixing, after this stage as we made retempering or agitation for cement paste mix by 25 revolution by a metal rod then the value of penetration depth increases again to a value of 21mm .

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:***

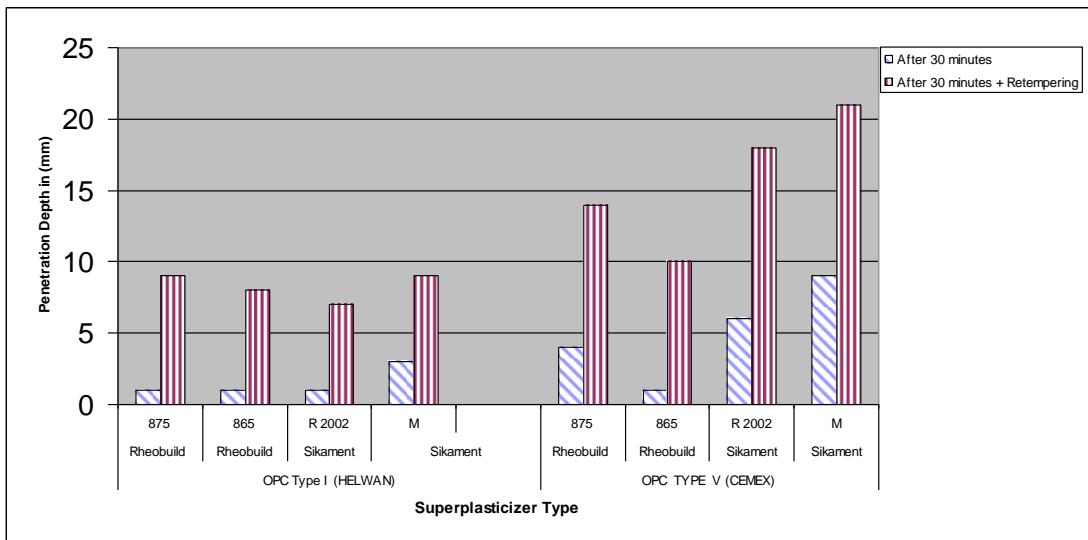
For Rheobuild 875, the optimum P/C ratio was 1.2% which corresponded to needle penetration depth of 37mm at initial testing, this value decreased as the time increased to reach a minimum of 1 mm at 30minutes after initial mixing. After retempering or agitation for cement paste mix by 25 revolution by a metal rod, then the value of penetration depth increased again upto 9mm. See Fig (10). See Table (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, to reach a minimum value of 1mm at 30minutes after initial mixing. Retempering increased the value of penetration depth increases again to a 8mm.

For Sikament R2002, the optimum P/C ratio was 0.9% which corresponded to penetration depth value of 30mm at initial testing, this value was decreased as the time increased till reaches the minimum value of 1mm at 30minutes after initial mixing after

this stage as we made retempering. the value of penetration depth increased again to a value of 7mm.

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 to reach a minimum value of 3mm at 30minutes after initial mixing after this stage as we made retempering or agitation for cement paste mix by 25 revolution by a metal rod then the value of penetration depth increases again to a value of 9mm.



**Fig ( 10) Effect of Retempering After 30 Minutes Retempering On OPC type(I) and SRC type (V)**

***Effect of 5 minutes delay in addition of super plasticizer on penetration depth:***

For all subgroups at this stage, the penetration depth value at P/C ratio of 0.8% was measured as we delayed addition of 14% by volume of mixing water with super plasticizer by 5 minutes after initial mixing.

***Effect of 5 minutes delay in addition of super plasticizer on penetration depth of OPC Type I (Helwan) cement paste:***

For Rheobuild 875, the penetration depth value at P/C ratio of 0.8% was 32mm . This value increased up to 46mm as we added super plasticizer with 14% of mixing water after initial mixing which was less than the value of 51mm at optimum dosage 1.2% incase of normal way of mixing. See Fig (11).

For Rheobuild 865, at P/C ratio of 0.8% was 26mm. Delay in addition of 14% by volume of the mixing water by 5minutes resulted in increase in the penetration depth to 35mm, this value less than the 39mm penetration value at optimum dosage 1.2% .

For Sikament R2002, the penetration depth value at P/C ratio of 0.8% was 26mm .This value increased to 35mm as we added super plasticizer with 14% by volume, of the mixing water after initial mixing which was less than the value of 41mm at optimum dosage 1.2% incase of normal way of mixing.

For Sikament M, the penetration depth value at P/C ratio of 0.8% was 27mm while this value increased to 41mm as we added super plasticizer with 14% of mixing water after initial mixing which was equal to the value of 41mm at optimum dosage 1.1% incase of normal way of mixing.

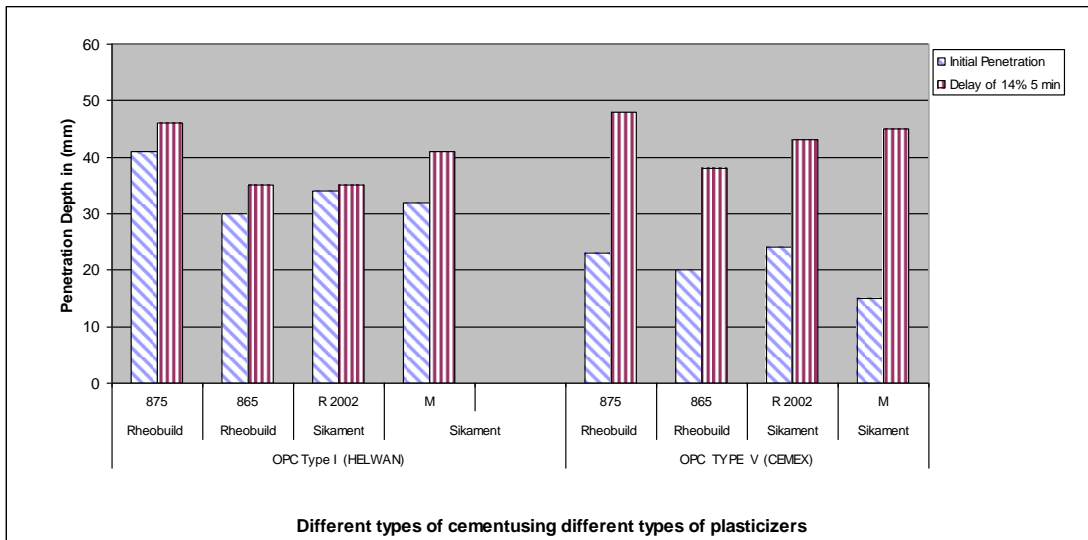
***Effect of 5 minutes delay in addition of super plasticizer on penetration depth of SRC Type V (Cemex) cement paste:***

For Rheobuild 875, the penetration depth value at P/C ratio of 0.8% was 23mm . This value increased to 48mm as we added super plasticizer with 14% of mixing water which was more than the value of 37mm at optimum dosage 1.2% incase of normal way of mixing. This was contrary to the case where OPC was used. See Fig (11).

For Rheobuild 865, the penetration depth value at P/C ratio of 0.8% was 20mm. This value increased up to 38mm as we added super plasticizer with 14% of mixing water after initial mixing which was more than the value of 26mm at optimum dosage 1.1% incase of normal way of mixing.

For Sikament R2002, the penetration depth value at P/C ratio of 0.8% was 24mm . This value increased to 43mm as we added super plasticizer with 14% of mixing water after initial mixing which was also less than the value of 29mm at optimum dosage 1.1% incase of normal way of mixing.

For Sikament M, the penetration depth value at P/C ratio of 0.8% was 15mm. This value increased to 45mm as we added super plasticizer with 14% of mixing water after initial mixing which was more than the value of 32mm at optimum dosage 1.1% incase of normal way of mixing.



**Fig (11) Effect of 5 minutes delay penetration depth**

**Phase III**

**Effect of height of needle on penetration depth:**

For all subgroups in this study we will discuss the effect of different types of admixtures ( Rheobuild 875, Rheobuild 865, Sikament M, and Sikament R2002) on flow properties of cement paste (penetration depth), as mentioned previously, the water/cement under investigation was (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 Fig (12).

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



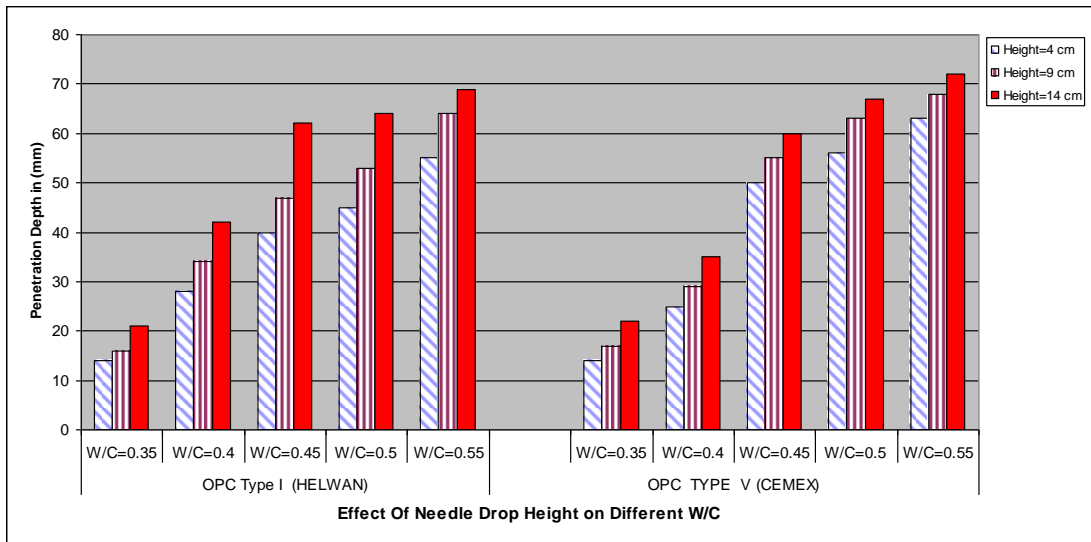
maximum value of 69mm at height of 14cm. The general trend indicates that , for the same w/c ratio, as the height of needle increases, the penetration depth value of needle increases, also at the same height of needle, as the w/c ratio increases the penetration depth value. The relation between penetration 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 was 14mm, this value increased to 17mm as the height increased to 9cm and reached the maximum value of 22mm at height of 14cm. See Fig (12). 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 approximately a straight line.



**Fig (12) Effect of height of needle on penetration depth**

## Conclusion

### Introduction:

In this study the rheological behavior of fresh cement paste containing chemical admixtures and cement replacement materials for several types of cement was discussed, this was followed by a briefing on the experimental program & the testing techniques, finally presentation and analysis of results will be discussed to conclude in this work.

### Phase I

- 1- It is evident that the penetration depth technique adopted in this study was successful in determining the optimum point where penetration reaches the maximum value.
- 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- Investigation of the effect of w/c ratio on the rheological behavior of different types of cement showed that as the w/c ratio increases, the penetration depth increases,

### Phase II

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

6- The effect of delay in addition of chemical admixture with 30% of the mixing water proved to be very effective in increasing the penetration depth in all subgroups.

### Phase III

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

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