PHYSICAL PROPERTIES OF COLD PROCESS CEMENT

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Abstract

Cold process cement is a mixture of pozzolana and activator. Calcination of raw materials is not required in manufacturing process, thus burning of fossil fuel is avoided. Different chemicals are used to activate the pozzolanic materials. In this work cold process cement was prepared by activating the ground granulated blast furnace slag of Rourkela Steel Plant (RSP) with alkali activator lime and sulphate activator plaster of Paris. Lime content in the raw mixture was varied as 5, 10, 15, 20, 30 and 40% and the plaster of Paris as 1, 1.5, 2, 2.5, 5 and 10% of the dry weight of slag. The consistency, setting times (initial and final) and soundness of mixes were determined and reported. Borax is used as a retarder of setting time. The initial and final setting times of the mixes are found to be lesser than the value prescribed for ordinary Portland cement (OPC). An addition of borax retards the setting time and a borax content of 0.4% by mass gives the setting times that is normally prescribed for OPC. Soundness of this binder varies between 1mm to 3 mm satisfying the prescribed limits. In brief the nature and dosages of activator play a crucial role in setting and hardening process of the mixture and the physical parameters prescribed for OPC can be achieved by proper proportioning of raw material compositions.

Key words: Cold cement, Ground granulated blast furnace slag, Lime, Plaster of Paris consistency.

1. Introduction

Global warming and environmental degradation are major issues related to industrialization. Emission of host of greenhouse gases and its adverse impact on climate has forced the engineers/ scientists to utilize eco-friendly, industrial wastes and conserve the natural resources. The main by-products of the steel plants are blast furnace slag, steel slag, and fly ash. These waste materials create disposal problems and pose threat to the environment. A systematic and engineered use of these waste products in construction industry will solve the disposal problems related to these wastes and in the same time preserve the natural resources. Concrete is the most versatile and environment friendly material for construction industries. But production of cement requires high amount of energy and large amount of CO_2 is emitted into the atmosphere which is unhygienic and harmful for both human beings and environment. This harmful effect can be reduced by reusing above industrial waste/by- products as raw components and admixtures for manufacturing of cement and concrete. This also reduces the cost of disposal and preserves the natural resources. In this context cold process cement is an attractive alternative to Portland cement. This is manufactured from industrial wasted rich in silica and alumina by alkaline activation. These new cementing material is characterized by their nearly equal mechanical strengths and also they don't require high energy in their manufacturing process. Depending on the nature of raw materials to be activated, different reactions have developed which have different microstructure.

The available literature on slag activated by plaster of Paris and lime is very scarce. V. P. Mehrotra (1982) opined that plaster of Paris is a better activator than the conventional hard burnt gypsum (anhydrite) at least for a class of blast furnace slag which is ordinarily considered less than ideal for this purpose. The super sulphated cement was prepared with different activators such as lime, anhydrite, plaster of Paris with the composition of 80% slag, 5-15% plaster of Paris, 5% Portland cement and 5% lime. The result showed that 15% anhydrite, 5% Portland cement gives the optimum result, but with a very short initial setting time. By adding 0.2% of borax, the initial setting time can be raised to a normal range 50-60 minutes. J. Bijen and E. Niel (1981) have investigated the mechanical strength development of super sulphated cement which was prepared by the mixture of (80-85) % blast furnace slag, (10-15) % lime and 2-5% of clinker. Their results indicated that the optimum binder is produced with 83% blast furnace slag, 15% flour gypsum (anhydrite) and 2% clinker (Portland cement). D.K. Dutta and P.C. Borthakur (1990) reported the mechanical properties of super sulphated slag cement prepared by using (70-85) % slag, (10-25) % anhydrite and 5% clinker. The results indicated that the optimum amount of anhydrite to activate the slag is in the range of 15-20%. C. Shi and R.L. Day (1995) and F. Puertes et al. (2003) studied the early strength development and hydration of alkali activated blast furnace slag with sodium hydroxide and water glass. A comparison was made between alkali-activated slag cement and concrete with traditional Portland cement. It is reported that the alkali-activated slag cement and concrete poses higher mechanical strengths, lower heat of hydration and better resistance to aggressive chemicals than compared to traditional Portland cement and concrete. S. D. Wang et al. (1995) reported some disadvantages of alkali activated slag cement (AASC) as quick setting and high shrinkage with micro cracking formation. V. Gluskhoskij et al. (1983), B. Talling (1989), F. Puters (1995) and C. Shi and Y. Li (1989) extensively studied the alkaline activation of slag. Bakharev et al.

(1999, 2001) reported that the AASC had lower resistance to alkali aggregate attack than that of the OPC concrete of similar grade. J.C. Kim and S. Y. Hong (2001) reported that the ion concentration change of liquid phase during hydration was different depending on the activator and the hydration time. F. Collins and J.G. Sanjayan (2000) and A. Fernández et al .(1999) reported that, this new binder has some problems, such as rapid set and high drying shrinkage , which must be resolved before utilizing it in commercial practice. It has been reported that the strength development of AASC depends on the activator type and concentration. A.R. Brough (2000) used phosphate and malic acid as retarders in slag and sodium silicate base mixes and studied the setting and hardening properties of the paste.

2. Experimental Work

2.1 Materials

The blast furnace slag used in this work was collected from Rourkela Steel Plant (RSP). The slag was sun dried and mixed thoroughly to bring homogeneity in the sample. The same was ground in a ball mill to a Baline's fineness of $4100 cm^2/g$. The plaster of Paris and hydrated lime used were procured from the local market. The chemical composition of the slag, lime, and plaster of Paris were determined from EDS tests and the same are given in Table1.

Table 1: Chemical Composition of Raw Materials

Composition (%)	*Slag*	*Plaster of Paris*	*Lime*	*Composition (%)*	*Slag*	*Plaster of Paris*	*Lime*
MgO	*9.52*	*1.92*	*6.47*	Fe_2O_3	*1.37*	*0.552*	*0.381*
Al_2O_3	*21.06*	*1.024*	*0.68*	Na_2O	*0.088*	*1.416*	*4.54*
SiO_2	*30.82*	*0.736*	*2.75*	*MnO*	*0.14*	-	-
K_2O	*1.04*	*0.512*	*0.9*	TiO_2	*1.04*	-	-
P_2O_5	-	*0.256*	-	SO_3	*0.66*	*36.88*	-
CaO	*32.02*	*38.7*	*84.26*	*Loss on Ignition*	*1.81*	*4.54*	*4.54*

2.2 Methods

The physical properties such as consistency, initial and final setting time, and soundness of different mixes of raw materials were determined. The composition of the trial raw material mixes was given in Table 2. The consistency, initial and final setting times of mixes were determined as per IS 4031 -1988 (part 4 & 5) respectively. To measure the excess of free lime and magnesia present in the binder, soundness tests were conducted as per IS 4031 – 1988(part-3).

2.21 Determination of Normal Consistency

The normal consistency of different mixes of the binder were measured by using Vicat apparatus as per IS code 4031 -1988 part (4). For this test, slag was activated with alkali activator lime and sulphate activator plaster of Paris. In this case plaster of Paris was taken as sulphate activator rather than gypsum because it is quick soluble in water than gypsum. The consistency values of slag containing 5, 10,15,20,30 & 40% of lime and 0, 1, 1.5, 2, 2.5, 5 and 10% of plaster of Paris were determined and the same is presented in Table 2.

Table 2: Consistency of Cold Process Cement

Consistency (%)							
Plaster of Paris (%) / Lime (%)	*0*	*1*	*1.5*	*2*	*2.5*	*5*	*10*
5	*28.89*	*28.89*	*29.24*	*29.24*	*29.25*	*29.25*	*29.42*
10	*29.24*	*29.24*	*29.60*	*29.60*	*29.62*	*29.78*	*29.90*
15	*29.60*	*29.96*	*29.96*	*29.96*	*29.96*	*30.32*	*30.5*
20	*29.60*	*30.32*	*30.32*	*30.32*	*30.32*	*30.74*	*31.42*
30	*33.17*	*34.24*	*34.24*	*34.24*	*34.24*	*34.24*	*34.42*
40	*36.20*	*36.90*	*37.10*	*37.10*	*37.20*	*37.20*	*37.4*

2.22 Determination of Initial and Final Setting Time

In order that concrete be placed in position conveniently it is necessary that the initial setting time of the binder is not too quick and after it has been laid, hardening should be rapid so that the structure can be made as possible. For determine the setting time 300g of binder was taken and 85% of normal consistency of water added to prepare the paste within 3 minutes. The paste was filled in Vicat mould immediately after 3 minutes and finished the surface smooth within 5 minutes. The initial time was determined the period elapsed between the time when water was added to cement and time at which the needle fail to pierce the test sample about 5mm from bottom. The final setting time was determined the time period elapsed between the time when water was added to the mix and time at which the annular attachment of needle fails to pierce the test sample. The setting times were determined by mixing the slag with 5, 10,15,20,30 & 40% of lime and 1, 1.5, 2, 2.5, 5, 10% of plaster of Paris. Initial and final setting time of different mixes is presented in Table 3 and 4 respectively. In addition to this, the effect of borax on setting time was studied by adding 0.2, 0.4, 0.6, 0.8, and 1% borax to the mixes containing 20% lime and different percentage of plaster of Paris. The test results are presented in Tables 5 and 6.

Table 3: Initial Setting Time of Cold Process Cement

Initial setting time (min)							
Plaster of Paris (%) / Lime (%)	*0*	*1*	*1.5*	*2*	*2.5*	*5*	*10*
5	*271*	*269*	*47*	*47*	*24*	*18*	*13*
10	*270*	*236*	*30*	*29*	*20*	*17*	*12*
15	*239*	*150*	*26*	*24*	*16*	*16*	*12*
20	*235*	*109*	*21*	*21*	*14*	*14*	*11*
30	*214*	*35*	*20*	*20*	*14*	*13*	*11*
40	*163*	*19*	*19*	*18*	*12*	*12*	*10*

Table 4: Final Setting Time of Cold Process Cement

Final setting time (min)							
Plaster of Paris (%) / Lime (%)	0	1	1.5	2	2.5	5	10
5	540	495	480	470	310	270	79
10	533	470	450	430	290	266	74
15	493	441	424	410	251	236	72
20	478	370	350	320	219	230	72
30	442	361	320	310	218	181	71
40	375	275	230	280	205	170	55

Table 5: Effect of Borax on Initial Setting Time

Plaster of Paris (%) / Borax (%)	1	1.5	2	2.5	5	10
0	109	21	21	14	13	11
0.2	119	54	37	30	21	19
0.4	155	106	100	96	27	23
0.6	160	130	121	109	89	63
0.8	171	164	153	150	100	67
1.0	291	199	187	185	118	99

Table 6: Effect of Borax on Final Setting Time

Plaster of Paris (%) / Borax (%)	1	1.5	2	2.5	5	10
0	370	350	320	230	219	71
0.2	376	370	361	345	262	209
0.4	382	375	367	354	279	245
0.6	398	379	372	366	289	279
0.8	406	393	388	370	307	287
1	415	398	390	375	314	295

2.23 Determination of Soundness

To measure the excess of free lime and magnesia present in the binder soundness tests were conducted on different mixes as per I.S 4031 part-3. For each mix 3 tests were done and the average of these values presented in Table 7.

Table 7: Soundness of Cold Process Cement

Soundness(mm)							
Plaster of Paris (%) / Lime (%)	0	1	1.5	2	2.5	5	10
5	2	2	2	1.5	1	1	1
10	2	2	2	1.5	1	1	1
15	2	2	2	1.5	1	1	1
20	2	2	2	1.5	1	1	1
30	2	2	2	2	1	1	1
40	2	2	2	2	2	2.5	3

3. Result and Discussion

3.1 Consistency

The consistency values of the mixes were determined by varying the lime content as 5, 10,15,20,30 & 40% and plaster of Paris as 0, 1, 1.5, 2, 2.5, 5, and 10% in the mix. The test results are presented in Table 2. The relationship between normal consistency and percentage of lime is presented in Figure1. It is seen that the normal consistency increases with either increase in lime or plaster of Paris contain. The consistency values of the mixes of slag, lime and plaster of Paris varies from 28.89 to 37.7 % compared to the value of about 30% for ordinary Portland cement (OPC).

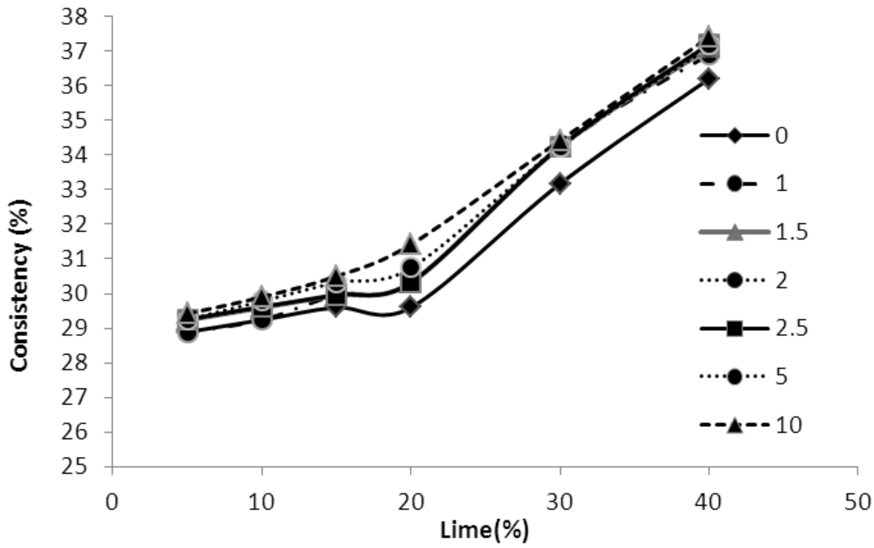

Figure1: Consistency values for cold process cement

3.2 Setting Time

The relationship between initial &final setting time and percentage of lime is presented in Figures 2 and 3 respectively. These figures show that the both initial and final setting times decrease with increase in lime contain. The quick setting of the mix upon addition of lime is due to increase in cation concentration and increase in pH value of the mix. Further, it is observed that at a given lime content an increase in plaster of Paris reduces the setting time. This quick setting action is attributed to the high concentration of sulphate ions in solution which reacts quickly with aluminium rich slag forming hydrated products. Similar trend was also observed by V. P. Mehrotra [1982]. In general it is observed that the initial and final setting times of the mixes are lower than the value prescribed for ordinary Portland cement. In order to ward off or overcome this problem the borax was adding in theses mixes. By adding the borax the initial and final setting times get changed.

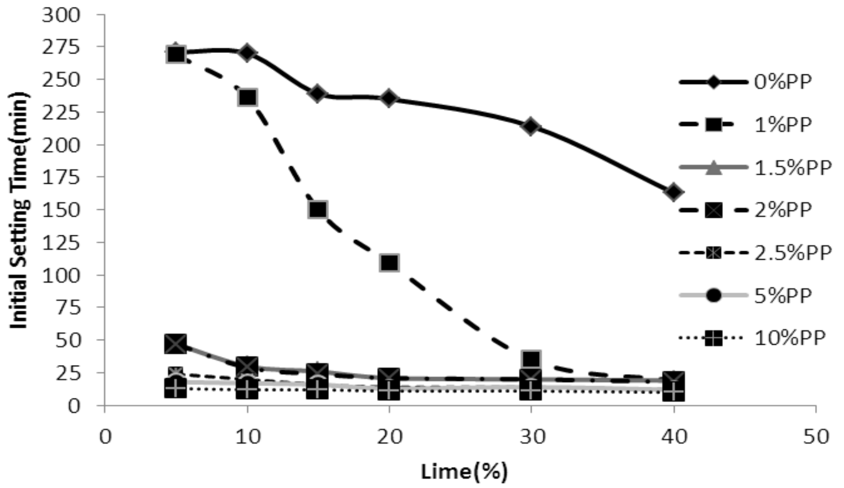

Figure 2: Initial Setting Time of Cold Process Cement

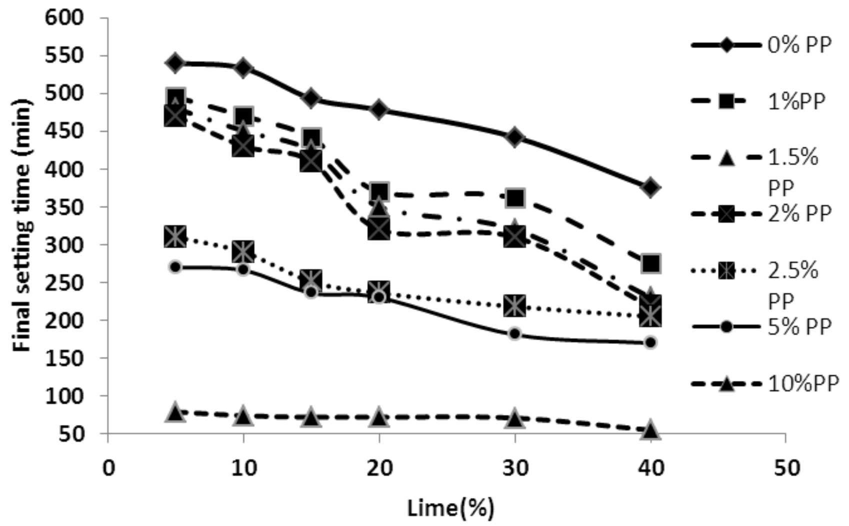

Figure3: Final Setting Time of Cold Process Cement

The initial setting time of mixes increase with increasing in borax content. Borax content of 0.4 percent is sufficient to increase the initial setting time from 11 minute to workable range of 23 minute and higher borax contents further delays the initial setting than that prescribed for OPC. The relationship between initial &final setting time and percentage of lime is presented in Figures 4 and 5 respectively. The final setting time also increase with increase the borax content. The final setting time with 0.4% borax dosages was 245 minutes or more than 6 hours, which was the sufficient time to set the structure. In some literature it is reported that the 0.2 % borax was sufficient to retarder this type of cement. But in this work 0.4 %borax was require due to more quantity of lime present in the mixes.

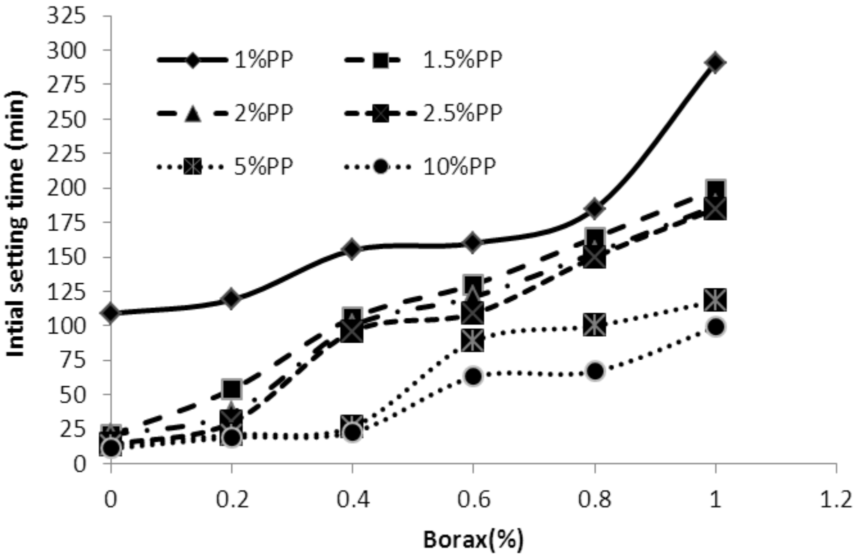

Figure 4: Effect of borax on initial setting time

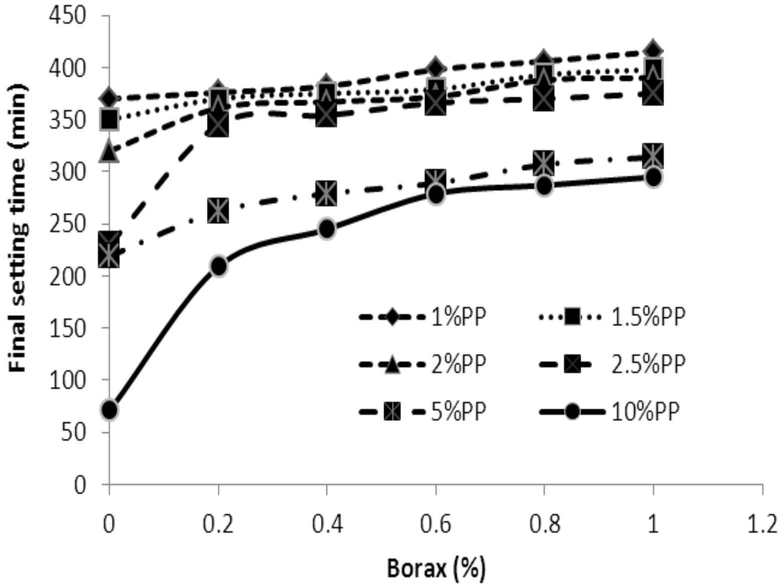

Figure 5: Effect of borax on final setting time

The result obtained in this work highlights the influences of the activators on the setting time and workability or consistency of cold process cement. The physical properties of alkali activated slag cement or cold process cement depend upon the type of activator used and their dosages. It is observed that both the type and dosage of the activator are significant factors influencing the properties fresh mixtures. The nature and dosages of activator play a crucial role in setting and hardening process of the mixture. The result shows that the setting time of mixtures are very quick and the paste stiffened quickly as the dosages of plaster of paris increases. Similar results were also reported in literature where, plaster of Paris and anhydrites are used as activators [V.P. Mehrotra 1982 & D. K. Dutta 1990]

3.3Soundness

The soundness of cold process cement was determined by varying the lime content as 5, 10,15,20,30 &40% and plaster of Paris as 0, 1, 1.5, 2, 2.5, 5 and 10% in the mix. The test results are presented in Table 6. The relationship between soundness of cold process cement and percentage of lime is presented in Figure 6. It is seen that the soundness of cold process cement is constant values that is 1mm in 0 and 5% of plaster of Paris. But in case of 10% of plaster of Paris it is increases 1mm to 3 mm with percentage of Lime contains increase. It may be due to excess amount of free calcium present in plaster of Paris and lime. But these values are acceptable which are within the range of 1to 3mm.The Soundness of cold process cement is increase up 40% Lime and at the plaster of paris content to0, 1 and 1.5%. After that the value of soundness is decrease and at that proportions 10% plaster of paris and 40% lime gives the highest value. This is due to excess amount of CaO present in plaster of paris. According to Bureau Indian Standard the soundness of cement shouldn't exceeds 10 mm. So this cement is not in sound and it is used as build material.

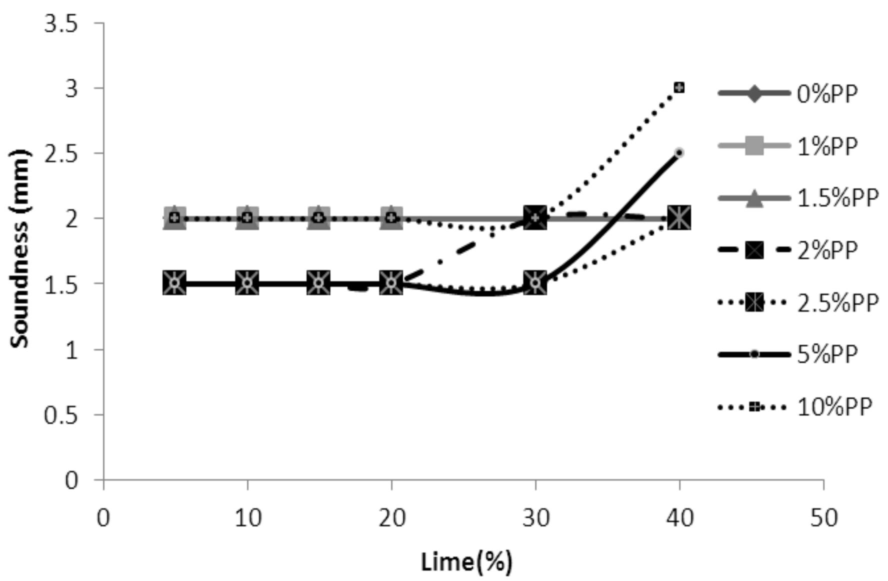

Figure 6: Soundness of cold process cement

4. Conclusions

The physical properties of cold process cement were studied in this work. Based on the experimental findings, the following conclusion can be drawn:

The consistency of cold process cement increases with either increase in lime or plaster of Paris content. The consistency values for raw material mixes considered in the present study varies from 28.89 to 37.7% compared to the value of about 30% for ordinary Portland cement (OPC).

The initial and final setting times of the mixes decrease with either increase in lime and plaster of Paris content. In general the initial and final setting times of the mixes are lower than the value prescribed for ordinary Portland cement.

An addition of borax retards the setting time and a borax content of 0.4% by mass gives the setting times that is normally prescribed for OPC.

Soundness of this binder varies between 1mm to 3 mm which is lower than the value prescribed for ordinary Portland cement.

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