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Investigation of concrete behaviour containing Metakaolin being exposed by short-term and long –term cycles of melting and freezing

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ABSTRACT: In many parts of the world, climate is such that the daily concrete is exposed to freezing and melting in some seasons of the year. Therefore, the melting and freezing behaviour of concrete in heavy conditions is important. There are different ways for increasing durability and strength against melting and freezing. Adding a pozzolanic material is one of these methods. In this experiment, the effects of the melting and freezing of concrete containing Metakaolin pozzolanic are discussed in the two methods. First, the effect of freezing and melting on the compressive strength of concrete, and second, how far sample degradation goes due to melting. In this study, Metakaolin was added to influence the behaviour of concrete going under melting and freezing. Metakaolin is used as partial replacement of cement in concrete with 6,12,18,24 per cent. According to the results, the resistance increases with increasing the percentage of Metakaolin. In the first cycle of melting and freezing, Metakaolin has got adverse effects in, 7, 14 and 28 day- concrete. In fact, the presence of Metakaolinatyounger ages due to completehardening of concrete at early ages has negative effects. At older ages in which the relative consistency of the concrete as well as hardening are obtained, the effect is positive.

***Keywords*:** Metakaolin,Compressive strength, freezing and melting.

INTRODUCTION

Unfortunately, million- dollar damages are annually reported as a result of freezing during concrete placement, creating a considerable number of problems for fresh and hardened concrete. We need to seek a solution to eliminate this type of damage with proper research. To increase the level of knowledge about highly strong concrete against freezing and melting , it is essential that some researches be conducted in order to decrease lack of practical information regarding concrete being exposed to freezing and melting . The use ofPozzolan as replacement material for concrete not only helps reduce cement and energy consumptionas well as green –house gases but also increases mechanical properties such as compressive strength in older ages as well as concrete durability like permeability (Maleki ,2012) .One of the main reasons of using Pozzolan such as Micro silicain concrete is reaching higher compressive strength ,therefore ,Pozzolanic activity of Micro silica is faster than other ordinary ones.(Ghodousi and Pattersonm, 1997).(Tsivilis and ,2002) Stone powder is another replacement of cement .Using this constructional material because of availability prevents environmental pollution ,leading to cheaper price of concrete .The adding Nono silica material can considerably improve compressive strength of concrete (Malhotra ,1986).In case there are pores in constructional material used in concrete, water will go through the holes and it will be frozen in temperature under zero degree centigrade. Practice of freezing and melting is along with damages and destruction. Cold weather is theoretically increasing hydraulic pressure .If the temperature goes down gradually ,it will create a noticeable number of micron-sized ice pieces in long term .These tiny ice pieces will increase while the weather gets cold leading to destruction .(Setzer,1998 and Setzer 1997) .According to Pozzolanic features of Metakaolin ,it can partially be replaced with cement as the main part of concrete . Metakaolin particles are 10 times smaller than those of cement, thus, using it in concrete leads to denser and more imperviousconcrete against water .Applying Metakaolin increases concrete durability and strength against chemical attacks, sulfates,ASR expansion, and melting and freezing cycles. Metakaolin is also effective on improvement of some mechanical characteristics of concrete such as compressive strength ,short-term features ,and flexural resistance.(Dunste and 1993).It is clear from conducted researches that the maximum speed of increasing the strength in the younger ages of concrete is between one to three days and this phenomenon is related to rapid absorption of water in Metakaolin concrete (Malhotra ,1986) .

In the present study, the mechanical properties of concrete containing Nano-silica and Metakaolin in normal and freezing-melting conditions have been investigated.For this purpose, four samples of each material containing 1, 2, 3 and 4 percentNano-silica, alongwith 6, 12, 24 and 18 percent of Metakaolin as well as a cement control scheme submerged in water, melting, and freezing conditions are maintained.

Experiment plan

In this study, the meta-kaolin is used to replace part of the cement. Determining compressive strength is done according to (BS 1881-Part116)standard, freezing according to ASTM-C666 (method B) freezing against the air and melting against water. Up to 4 of experiment al cycles are 6-hour cycle. Concrete is exposed to freezing during this 6-hour period and then submerged in 4.5-t0-5.5 ° c water for the same amount of time. Melting operation was performedin 7,14,and 28 days(14,28,56 cycles) after submerging fresh concrete in water for one day for short –term cycles as well as 30,60,,and 90 days (60,12,180 cycles) after submerging fresh concrete in water for 28 days .Mixing plan of samples was done considering ACI-Regulation using weight –volume method as table (1) (Nezhad,2007).

Table 1. Mixing plan

$\frac{W}{C}$	Cement (kg)	Granule particles(kg)	fine-grained particles(kg)	Water (w)
$\frac{0}{457}$	350	820	1080	160

In these tests, the largest aggregate size is 37.5 mm and weight of the concrete- volume unit is2410$\frac{kg}{m^3}$.Granule constructional materials have been selected considering softness coefficient of 3 mm and coarse ones have been taken from the mine. Cement type is Portland type 2. Four main mixing plans were obtained by replacing Metakaolin according to different percentages of cement weight. Following strategy was taken in to consideration to build mentioned plans. First, a third of water enters the mixer in order to make concrete mixture, then, fine-grained and coarse particles areadded, mixing one to two minutes. After that, cement and water are added .Finally,Metakaolin and remaining amount of water areadded, mixing for 6 minutes. After preparing the concrete , it is molded in three layers containing 35-hit hammer in each layer .Samples are taken out from frame after 24 hours and they are submerged in the first container for 24 hours .Samples selected for passing the first predicted melting and freezing cycles are taken in to the freezer after being submerged for 24 hours in the water .In terms of long-term cycles, these samples are taken in to the freezer after being submerged for 28 days in the water in order to pass freezing and melting cycles.

RESULTS AND DISCUSSION

In this research, $M_O$is used to describe concrete without additives, M for Metakaolin concrete, and MF for concrete passing freezing and melting cycles. Numbers next to M show weight percentage of replacing material of Metakaolin with cement .For instance, M12 indicates 12 per cent Metakaolin .Compressive strength based on kilogram on square centimetres ,two controls (Control A as sample without Pozzolanic material and the other one is replacing material) have been listed in table 2 for sample comparisons .

Table 2. Compressive strength of samples and control groups $\frac{kg}{cm^2}$

No.	Sample name	No. of Cycles	Compressive strength of control	Compressive strength of Sample A	Compressive strength of control A	Compressive strength of Metakaolin sample
1	$M_1 = 7$	14	238	238	166.5	163
2	$M_2 = 7$	14	227	238	166.5	169.5
3	$M_3 = 7$	14	216	238	166.5	157.5
4	$M_4 = 7$	14	211	238	166.5	154
5	$M_1 = 14$	28	247	242	220	139
6	M_2=14	28	231	242	220	171.5
7	M_3=14	28	228	242	220	133
8	M_4=14	28	228	242	220	121
9	M_1=28	56	320	265	222	75.5
10	M_2=28	56	306	265	222	169
11	M_3=28	56	260	265	222	54.5
12	M_4=28	56	252	265	222	63

As it can be seen from graph1,Metakaolin controlgroup,Metakaolin up to one per cent increases strength in which M12 is the best sample according to results of experiment. $M_1 = 7$ Where 7 and 1 show the number of days and Metakaolin percentage, respectively.

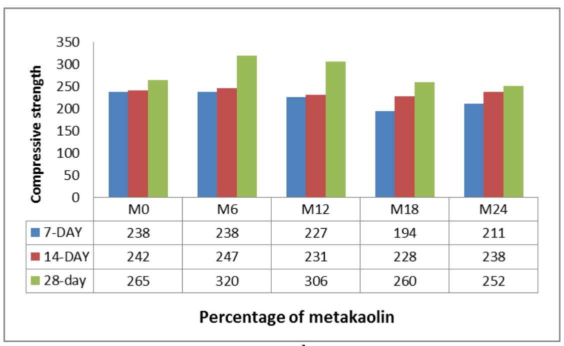


Figure 1. Compressive strength ($\frac{kg}{cm^2}$) of Metakaolin controlgroup

Picture 2 shows Metakaolin group for freezing and melting cycles. Since concrete passes freezing and melting cycles after 24 hours and it has not yet been hardened, destruction occurs. Therefore, Metakaolinincreases compressive strength in long term, although it reduces compressive strength in short term. According to the results, the most destruction is for sample M18 in cycle 56. In picture 3 , it shows compressive strength of samples containing Metakaolin which have passed melting and freezing cycles after being submerged for 28 days in water.Compressive strength of samples containing Metakaolin increases along with increasing Metakaolin percentage in older ages. According to the effects of melting and freezing on concrete, compressive strength decreases slightly due to destruction. Slight reduction of strength in the second cycle shows the effect of melting and freezing on compressive strength of not completely hardened concrete. It is also clear that increasing Metakaolin in older ages increases concrete strength which is showing the effect of Metakaolin on concrete strength.

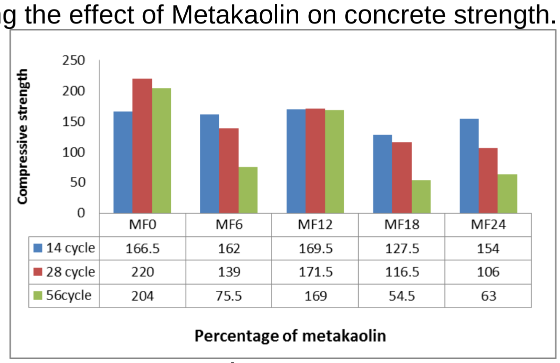
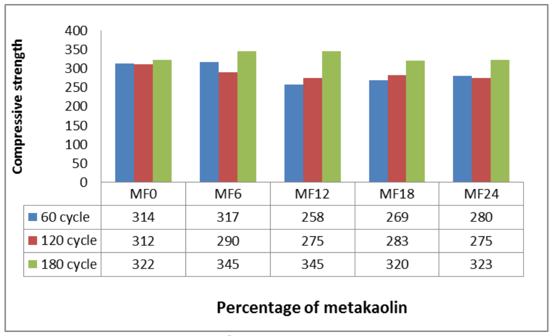


Figure 2. Compressive strength ($\frac{kg}{cm^2}$) of Metakaolin group of short-term cycles



	MF0	MF6	MF12	MF18	MF24
60 cycle	314	317	258	269	280
120 cycle	312	290	275	283	275
180 cycle	322	345	345	320	323

Figure 3. Compressive strength ($\frac{\text{kg}}{\text{cm}^2}$) of Metakaolin group of long-term cycles

CONCLUSION

The effect of melting and freezing on concrete containing Pozzolanic material of Metakaolin was investigated using two methods. First, the impact of melting and freezing on compressive strength of concrete is investigated and, second, how much the sample destruction is due to melting and freezing. In Control group ofMetakaolin, we will see compressive strength by increasing the material up to one percent, since concrete is submerged in the water .Increasing the percentage of Metakaolin, strength rises up. Metakaolin has adverse effects on the first cycle of melting and freezing of 7, 14, and 28 –day concrete against melting and freezing .In fact, presence of Metakaolin in younger ages has an adverse influence due to completely hardened concrete .This effect turns to positive one in older ages when concrete has completely been hardened .In the second cycle of melting and freezing, concrete is submerged in the water for 28 days and then it passes melting and freezing cycles. This causes a noticeable reaction of Metakaolin leading to increasing the concrete strength against melting and freezing cycles. Destruction happens faster while increasing the material among samples containing Metakaolin in which the concrete has not been hardened and it is exposed to melting and freezing cycles.

Conflict of interests

The authors declare that there is no conflict of interests regarding the publication of this paper.

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