International Journal of Academic Engineering Research (IJAER)
ISSN: 2643-9085
Vol. 3 Issue 12, December – 2019, Pages: 18-21

Review on Effect of Metakaolin on creep and shrinkage of concrete

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Abstract: *The metakaolin is a pozzolona material which is extensively used in concrete as a cementitious material. It is obtained by calcination of kaolinite. Usage of metakaolin enhances the properties of the concrete. The properties of metakaolin can be controlled which is not a property of other mineral admixtures. It acts a filler material and increases the hydration of cement. Creep and shrinkage are the long term defects in concrete which can be controlled by addition of metakaolin. Metakaolin at a dosages of 0%, 5%, 10%, 20%, and 30% were added to cement concrete. In almost all the cases metakaolin has given the good performance, it reduced the autogenous and drying shrinkage and also reduced both the basic creep and drying creep*

Keywords—autogenous shrinkage; creep; metakaolin; water content; dilution effect

1. INTRODUCTION

From the past few years, most of the concrete which we use is being added with cementitious materials. Several cementitious materials like ground granulated blast furnace slag, flyash, silica fume, rice husk, are being extensively used and are majorly known as mineral admixtures. These are all the by-products obtained from the several industries. Nowadays metakaolin is also extensively used in high performance concrete. Metakaolin is the substance obtained by heating the kaolinite at a temperature of 600-800℃. It is also known as calcined clay. The main advantage of metakaolin when compared with other mineral admixtures is that the manufacturing of metakaolin product is controlled, that is we can obtain it by varying the temperatures thereby varying its composition.

Several studies were done extensively to determine the characteristics of creep and shrinkage of concrete. Shrinkage is classified into several types among them, autogenous shrinkage and drying shrinkage are those which creates major problems. The present study deals with changes that will take place in creep and shrinkage by replacing some part of cement with metakaolin in various percentages.

1.1 CREEP AND SHRINKAGE

Creep and shrinkage are the long term effects in concrete. Creep may be defined as the loss of water from the concrete because of stress which is created due to sustained loading.it can be referred as consolidation of concrete. This cannot be recovered. It creates permanent rearrangement of particles.

Creep will happen even when there is no drying. It occurs due to loading. Creep is classified into two types.

1. Basic creep 2.Drying creep.

Basic creep is immediately obtained after loading and it is not majorly dependent on the ambient conditions. Whereas drying creep is creep occurring in dried condition of concrete. It depends on ambient conditions. Like if lesser is the relative humidity and higher is the temperature then drying will be more.

1.2 PROPERTIES OF CREEP

For larger specimens creep in exterior portion of concrete is higher as it is exposed directly to sun and creep in interior portion of concrete will be lower .This creates creep gradient which can lead to large cracking. Creep in concrete can also lead to gradual loss in prestressing force .Creep will be lower for high strength concrete, because as higher is the strength lower will be the deformations and thereby lower will be the creep. It also depends on loading rate, as the loading rate decreases creep strain comes into picture and decreases the strength. Based on research it is identified that more is aggregate content then lesser will be creep. It implies that lower is cement, lower will be creep.

1.3 SHRINKAGE

Depending upon time shrinkage can be classified into:

1. Plastic shrinkage 2. Chemical shrinkage 3. Drying shrinkage 4. Autogenous shrinkage
5. Carbonation shrinkage.

Plastic shrinkage is majorly seen in slabs after pouring reinforcement. If evaporation rate of final finishing of slab is exceeding the bleeding of water surface, then concrete at surface starts drying. Carbonation shrinkage occurs in very less extent.

Not all the cement gets hydrated at a time, unhydrated cement will pull the water which is present, water will pass through the pores creating capillary pressure which causes shrinkage, and this shrinkage is defined as autogenous shrinkage. Membrane curing create shrinkage because water is pulled towards unhydrated cement. It is also known as self desiccation. Drying shrinkage is defined as drying of water or loosing of water due to external temperature.

Fibre effect on shrinkage: fibres will spread the cracks. Smaller cracks will spread over large area, overall crack area is low therefore crack width is low so less is percolation of water.

1.4 METAKAOLIN

Metakaolin is obtained by burning the kaolinite at temperature ranging between 500-800℃. It acts as a pozolonic material. It reacts with the calcium hydrate and produces CSH, C2ASH8 (gehlinite), C4AH13, and C3AH6.
Advantages: it reduces the permeability, increases durability, increases compressive and flexural strength, reduces shrinkage, increases workability, increases the resistance to acid attack and sulphate attack, minimises risk of alkali silica reaction, and reduces the chloride ion diffusivity.

The name itself indicates that it is in metastable state which implies it is having high reactivity. Hydration mechanism will depend on the level of reactivity of metakaolin which will in turn depend on the processing conditions and purity of the clay. Metakaolin also decreases the initial setting time because, it retard the dissolution of ions for hydration to occur. Though metakaolin has many advantages, it is releasing more amount of carbon dioxide which is harmful. So its usage should be limited.

2.EXPERIMENTAL STUDIES

2.1 STUDY 1

The test was conducted by adding the metakaolin in dosages of 0%, 5%, 10%, and 15% in concrete. Water to binder ratio and super plasticizer content are maintained constant. The cubes were casted with necessary dimensions. Autogenous shrinkage was measured in two stages. Autogenous shrinkage until 24hours and autogenous shrinkage from 24 hours to 200 days. In the first stage as metakaolin content increases, autogenous shrinkage decreases, this is because of dilution effect created due to reduction in cement. In the second stage until 14 days autogenous shrinkage was increased because of self desiccation which is created due to pozolonic reaction of metakaolin and accelerated hydration. In later day's autogenous shrinkage decreased as metakaolin content in concrete increased. Drying shrinkage contribution for total shrinkage is very less. Major contribution for total shrinkage is given by autogenous shrinkage only.(Brooks & Megat et al.)

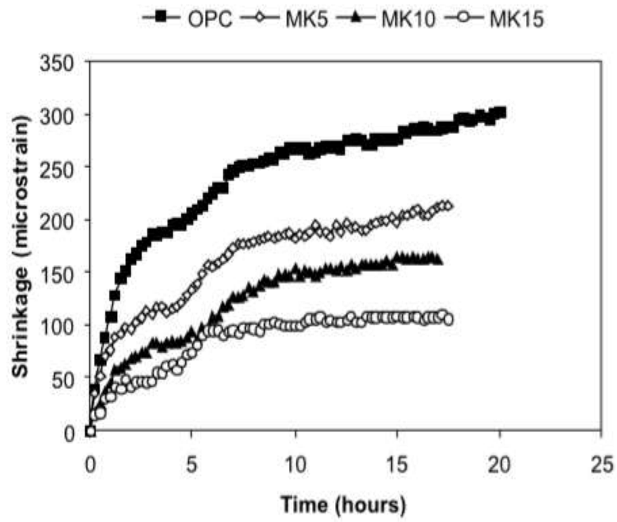

Fig1 Effect of metakaolin on early age autogenous shrinkage of concrete.

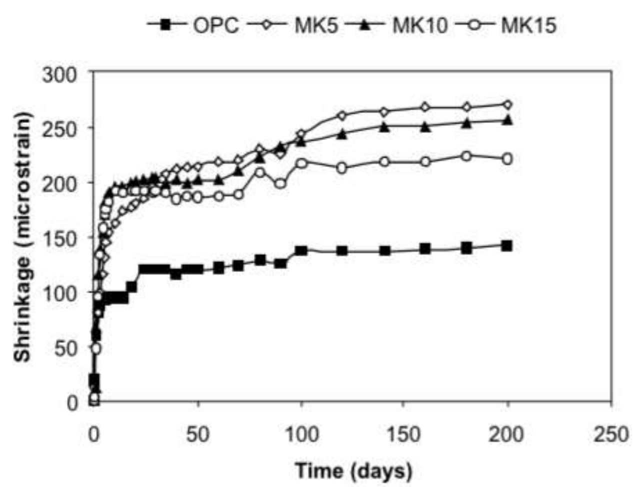

Fig2 Effect of metakaolin on long term autogenous shrinkage of concrete.

From the result, we can infer that the autogenous shrinkage of metakaolin (5%) is lower than OPC in initial 14 days, whereas it increased gradually than OPC after some days.

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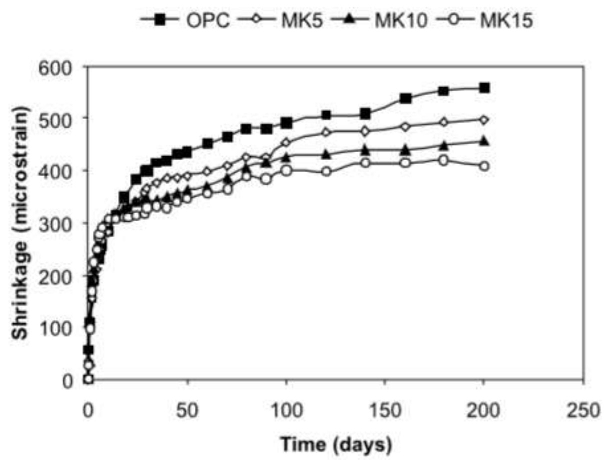

Fig 3 Total shrinkage of drying concrete specimen

However total shrinkage in concrete is less with increased addition of metakaolin, this can also be possible because of less amount of water available for evaporation, since most of the water is consumed in hydration and pozzolonic reaction

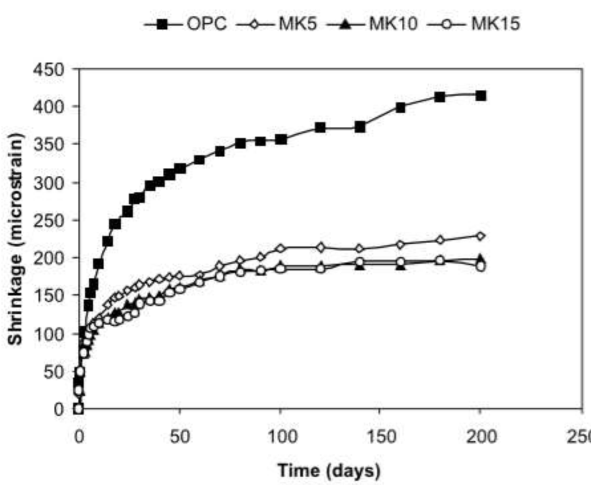

Fig4 metakaolin effect on drying shrinkage(Brooks&Megat et al)

2.2 STUDY 2 EFFECT OF WATER BINDER RATIO ON SHRINKAGE

It was assumed that Metakaolin effect on autogenous shrinkage might be possible because of:

1) Heterogeneous nucleation of hydration products on surface of metakaolin.
2) Dilution effect that is more is replacement of cement with metakaolin less cement is available so less will be the production of hydration products resulting in less shrinkage.
3) Pozolonic reaction of metakaolin with calcium hydroxide.(gleize et al)

Considering the above points, w/b ratios 0.3, 0.5 were considered with metakaolin dosages as 5%, 10%, 15%, and 20%. It was observed that early autogenous shrinkage is more w/b 0.3 than for 0.5. This is basically because of increase in metakaolin content in w/b ratio of 0.3. Increase in metakaolin indicate that there will be acceleration in hydration and pozzolonic reactions, so more is the possibility of shrinkage. (Gleize et al.)

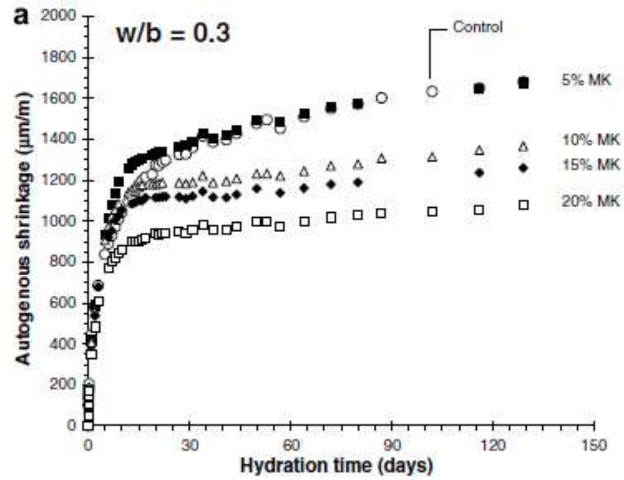

Fig5 metakaolin effect on shrinkage for w/b ratio of 0.3

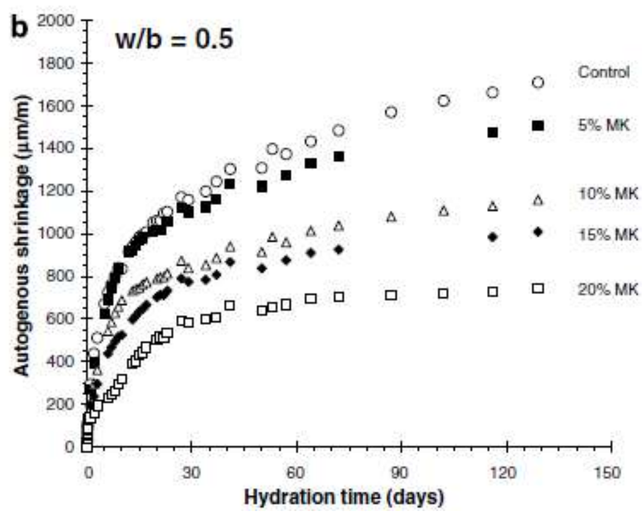

Fig6 metakaolin effect on shrinkage for w/b ratio of 0.5(Gleize et al)

From the above two graphs, It can be inferred from the results that more is the water content, more is the reduction in shrinkage. As the metakaolin percentage increases, shrinkage is reducing. It is because lesser is the amount of possible water content, so less will be the shrinkage

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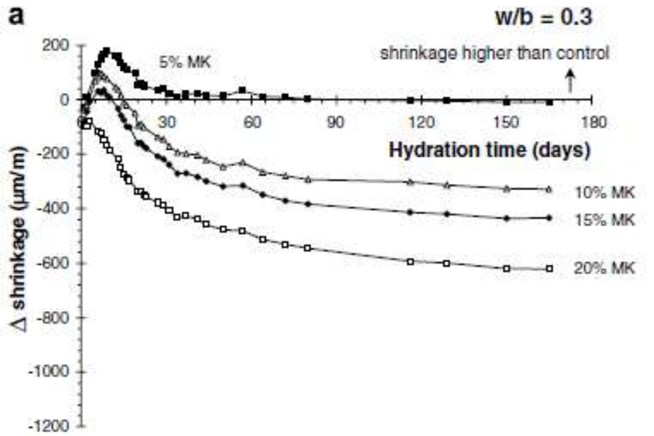

Fig 7 representing the increase of shrinkage for metakaolin dosage 0f 5%.(Gleize et al)

The shrinkage is increased for 5% of metakaolin. This is possible because of heterogeneous nucleation of hydration products on metakaolin which accelerates the formation of CSH and thereby increasing the autogenous shrinkage. Whereas for water binder ratio of 0.5, it showed a general trend of decreasing in the shrinkage.

2.3 CREEP

For measurement of creep concrete cubes with metakaolin in varying percentages of 5%, 10%, 15% are considered. They are cured for 28 days and are subjected to creep testing. As usual it was observed that as percentage of metakaolin increases, creep is decreasing. This could be possible because of improving the density (metakaolin acts as a filler material). Creep reduction is also related to autogenous shrinkage. As autogenous shrinkage is increasing which implies that more amount of water is consumed in hydration, so less water is available to pass through the pores thus reducing the capillary tension and indirectly reducing the initial creep.(Brooks&Megat et al)

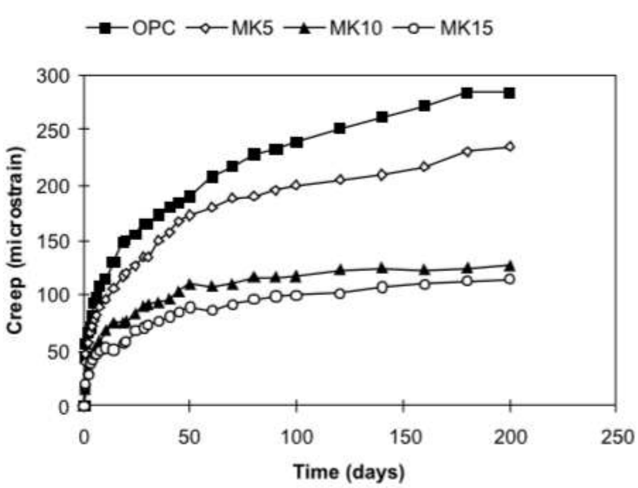

Fig 8 metakaolin effect on creep of concrete

3.CONCLUSION

- From the above studies, it is observed that different studies adopted have resulted in different solutions. Many advantages were seen by adding metakaolin into concrete. Characteristics will differ based on percentage of addition of metakaolin.
- We cannot replace metakaolin with cement in higher quantities because it may reverse the properties that is less will be the cement, so less hydration products are generated and functioning of metakaolin creating pozzolonic reaction with concrete will also reduce.
- Since metakaolin is obtained from burning of kaolinite. It may result in huge emission of carbon dioxide which is harmful. So even though metakaolin is having many advantages, it cannot be used up to maximum extent.
- Cost of metakaolin product is also very high. It can only be used in countries where there is availability of plenty of clay minerals.

4.FURTHER STUDIES

- Temperature effect on metakaoline has not been analysed. Its variations with respect to temperature and its effects on properties of concrete can be further studied.
- Usage of two or more mineral admixtures in combination with metakaolin is also being studied.
- Metakaolin based geopolymer concretes.

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