# Fresh properties of Concrete using Ultra-Fine Fly Ash and Metakaolin (Alccofine)

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**ABSTRACT-** *In this research program, high volume ultra-fine fly ash concrete mixes produced with OPC 53 grade cement for higher grade M40, M50 and M60. Initially control mix was produced with 100 % OPC cement. Further 40% of cement content was replaced with ultra-fine fly ash with Alccofine (Metakaolin) and fresh properties were found. The Metakaolin (alccofine) were used in 5, %, 10%, 15% and 20 % to enhance the concrete properties and to reduce cement content for M40, M50 and M60. In such a way overall cement content was reduced up to 60 %. Replacement of cement by UFFA with Metakaolin results in more improved and economical concrete. Workability, density and water absorbtion of produced concrete were determined in the laboratory. Combination of UFFA and Metakolin shows use of Metakoline reduces the workability of concrete and density of concrete. In comparison to control mix, concrete containing fly ash and Metakoline shows less segregation, a lower rate of waster absorbtion and greater cohesion.*

**Keywords**: Ultra-fine fly ash, metakaolin, ordinary portland cement, workability, density, water absorbtion.

## I. INTRODUCTION

Cement both in mortar and concrete, is the most essential element of the infrastructure and has been known as a long-lasting construction material [16, 17]. Reuse of recycled or waste materials for the construction of civil structures is an issue of great importance in this century. Mixing of mineral admixtures in concrete and mortar improves compressive strength, pore structure and permeability. Some of this materials, known as pozzolana, which by themselves have no cementitious properties, however, when used with portland cement reacts to form cementitious materials. Partial replacement of portland cement in concrete reduces the volume of portland cement. This reduction in cement volume further reduces the construction cost, energy loss and waste emissions such as carbon dioxide ($CO_2$) emission. This also, reduces the energy consumption and thus, reduces the rate of global warming [17, 18, and 19].

The use of supplementary cementitious material in high strength concrete and high performance concrete is common now a days. Providing alternative material to reduce cement consumption in concrete is quite challenging task. Although a no of studies have been conducted on use of SCM such as class c fly ash in HVFA concrete [1, 3, 5, 14] and in high strength concrete [4], class F fly ash [13], Fly ash in HVFA concrete [2, 6, 8, 11], to provide economical, ecological , green concrete and to minimize environmental problem. These studies shows excellent properties such as workability, density and compressive strength, flexural strength, split tensile strength, abrasion resistance etc. Among all the SCM in concrete fly ash plays an important role in reducing cost and providing alternative supplementary cementitious material to construction industry. The performance of fly ash can further be improved using mineral admixture such as GGBS and silica fume in concrete [11,13] and alccofine in ultra HPC [12]. Use of alccofine with UFFA shows improved performance of concrete. Previous research do not show much literature in this regard and there is a research gap in use of UFFA in construction application especially using alccofine. Therefore it can be said that there is a need of research and investigation in this particular area to understand the most beneficial and economical features of the UFFA with metakaolin (alccofine) in concrete for cement replacement.

## II OBJECTIVE OF THE STUDY

The research was aimed to investigate effect of fresh properties of concrete using ultrafine fly ash with alccofine (metakaoline) for cement replacement.

## III MATERIALS AND THEIR PROPERTIES

**Cement**

OPC 53 grade cement of Ultra tech was used for this research program.

**Natural Sand**

Locally procured natural sand was used as fine aggregate in concrete. Locally available Narmada sand (zone-II) was used

**Aggregate**

A combination of 20mm nominal size aggregate and 10mm nominal size aggregate is used as coarse aggregate in this experimental program. Both types of coarse aggregate were locally procured.

**Water**

The water used was ordinary tap water from the Bhopal city.

**Ultra-Fine Fly ash**

Fly ash used in this study was collected from Sarni thermal power plant.

**Metakaolin**

Commercially available Bags of Metakaolin were used in various proportions in this study.

## IV. EXPERIMENTAL PROGRAM

To conduct experimental program various trials were prepared using metakaoline and ultrafine-fly ash and metakaolin for grade M40, M50 and M60.

## V. CASTING OF SPECIMENS

Various concrete mixes were produced in the lab using ultra-fine fly ash (40 to 45 %) in combination with metakaolin (5%, 10 %, 15% and 20%) for M40, M50 and M60. Control mix with 100 % OPC and concrete mix with 50%UFFA were casted and tested in the laboratory. Fresh properties were determined and compared with controlled 100%OPC concrete and 50%UFFA concrete.

## VI. RESULTS AND DISCUSSION

Table (6.1, 6.2 and 6.3) shows workability, (6.4, 6.5 and 6.6) density and (6.7, 6.8 and 6.9) water absorption for grade M40, M50 and M60.

**Table 6.1 Workability of UFFA modified concrete M40**

| Mix | W/C Ratio | Cement + UFFA (%) | Meta-kaolin (%) | Slump value (mm) | Decrease in slump value (%) as compared to OPC concrete |
|---|---|---|---|---|---|
| M40 (Control mix) | 0.38 | 100 % OPC | 00 % | 40 | -- |
| M40UFFA50MK0 | 0.32 | 50% OPC+50% UFFA | 00 % | 45 | +12.5 |
| M40UFFA45MK5 | 0.30 | 50% OPC+45% UFFA | 05 % | 38 | 5.26 |
| M40UFFA40MK10 | 0.30 | 50% OPC+40% UFFA | 10 % | 36 | 11.11 |
| M40UFFA45MK15 | 0.30 | 40% OPC+45% UFFA | 15 % | 34 | 17.64 |
| M40UFFA40MK20 | 0.30 | 40% OPC+40% UFFA | 20 % | 32 | 25 |

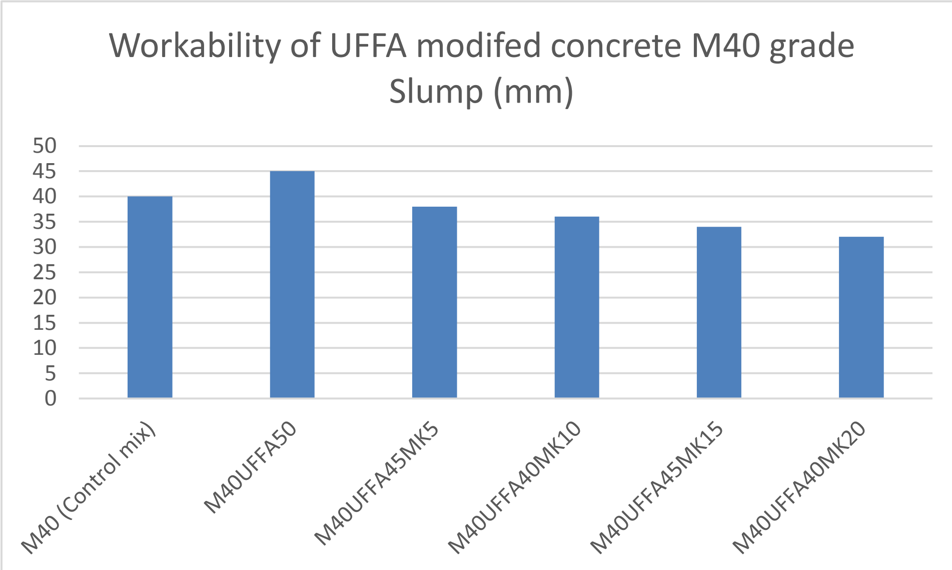


Fig. 6.1 Workability of UFFA modified concrete M40 grade

It is clear from the above chart that workability of concrete in combination with UFFA and Metakaoline decreases as compared to OPC concrete as well as UFFA concrete for grade M40. Workability of 50% UFFA concrete is found to be 12.5% more as compare to OPC concrete. Maximum reduction in slump 25 % is found at 40%UFFAand 20%MK. The decrease of workability could be interpreted due to the high surface tension of Metakoline, while the quantity of cement plays a reverse role, due to the amount of paste in the batches, which increases the consistency of concrete by its gelatinous property.

**Table 6.2 Workability of UFFA modified concrete M50**

| Mix | W/C Ratio | Cement + UFFA (%) | Meta-kaolin (%) | Slump value (mm) | Decrease in slump value (%) as compared to OPC concrete |
|---|---|---|---|---|---|
| M50 (Control mix) | 0.33 | 100 % OPC | 00 % | 35 | - |
| M50UFFA50MK0 | 0.30 | 50% OPC+50% UFFA | 00 % | 40 | +14.28 |
| M50UFFA45MK5 | 0.28 | 50% OPC+45% UFFA | 05 % | 32 | 9.37 |
| M50UFFA40MK10 | 0.28 | 50% OPC+40% UFFA | 10 % | 30 | 16.67 |
| M50UFFA45MK15 | 0.28 | 40% OPC+45% UFFA | 15 % | 28 | 25.00 |
| M50UFFA40MK20 | 0.28 | 40% OPC+40% UFFA | 20 % | 26 | 34.61 |

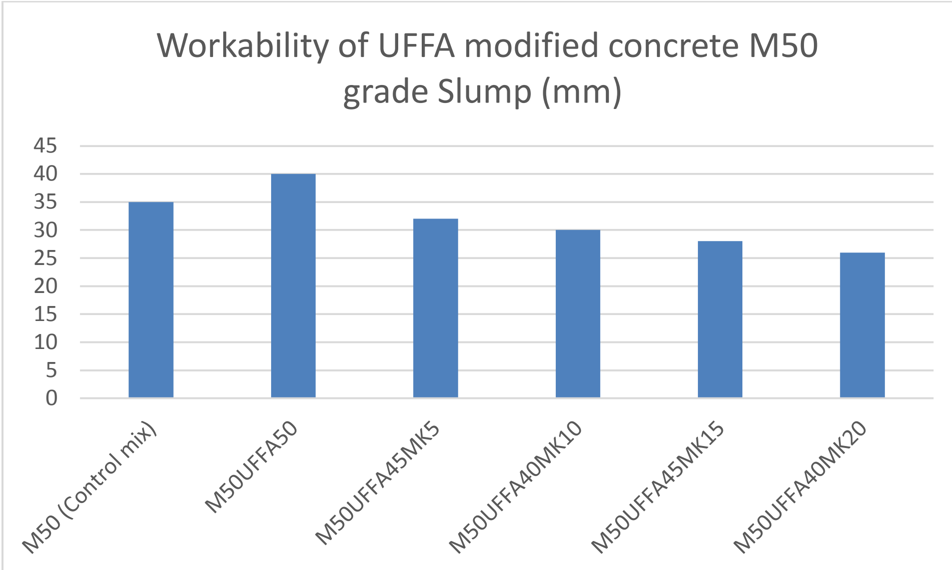


Fig. 6.2 Workability of UFFA modified concrete M50 grade

It is clear from the above fig that workability of concrete for M50 grade is also found to be reduced. It was found that increase in Metaoline content results in reduction in slump. Maximum decrease in slump was 34.61% for concrete blended with 40%UFFAand 20%MK. Workability of 50% UFFA concrete is found to be 14.28 % more as compare to OPC concrete.

**Table 6.3 Workability of UFFA modified concrete M60**

| Mix | W/C Ratio | Cement + UFFA (%) | Meta-kaolin (%) | Slump value (mm) | Decrease in slump value (%) as compared to OPC concrete |
|---|---|---|---|---|---|
| M60 (Control mix) | 0.28 | 100 % OPC | 00 % | 30 | - |
| M60UFFA50MK0 | 0.26 | 50% OPC+50% UFFA | 00 % | 35 | +16.67 |
| M60UFFA45MK5 | 0.24 | 50% OPC+45% UFFA | 05 % | 28 | 7.14 |
| M60UFFA40MK10 | 0.24 | 50% OPC+40% UFFA | 10 % | 26 | 15.38 |
| M60UFFA45MK15 | 0.24 | 40% OPC+45% UFFA | 15 % | 24 | 25.00 |
| M60UFFA40MK20 | 0.24 | 40% OPC+40% UFFA | 20 % | 22 | 36.36 |

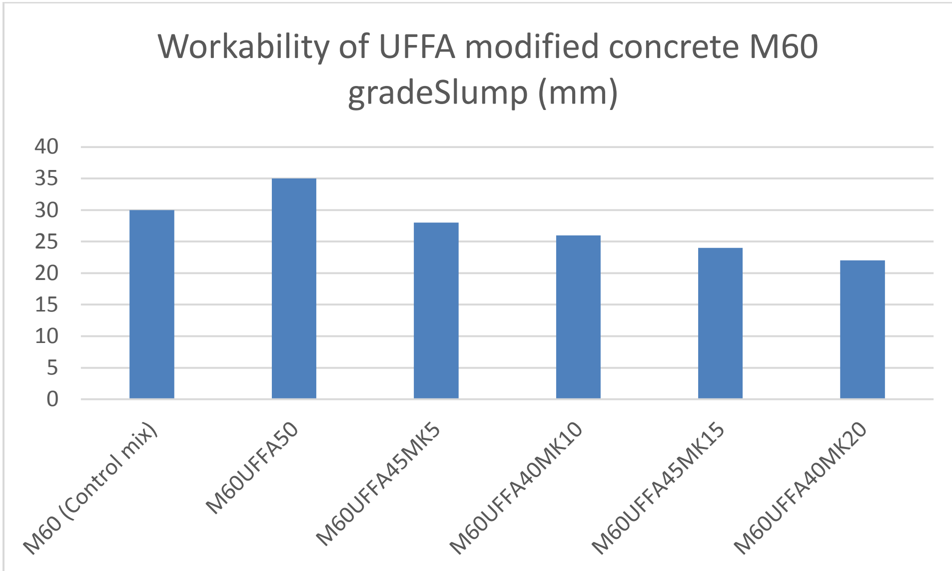


Fig. 6.3 Workability of UFFA modified concrete M60 grade

Above fig shows that workability of concrete for M60 grade is also found to be reduced. AS percentage of metakoline increases workability decreases. Maximum reduction 36.36% in slump is found at 40%UFFAand 20%MK. Workability of 50% UFFA concrete is found to be 16.67% more as compare to OPC concrete.

**Table 6.4 Density of UFFA modified concrete M40**

| Mix | W/C Ratio | Cement + UFFA (%) | Meta-kaolin (%) | Average weight of cubes in gram | Density of cubes kg/m$^3$ |
|---|---|---|---|---|---|
| M40 (Control mix) | 0.38 | 100 % OPC | 00 % | 8630 | 2557.03 |
| M40UFFA50MK0 | 0.32 | 50% OPC+50% UFFA | 00 % | 8580 | 2542.22 |
| M40UFFA45MK5 | 0.30 | 50% OPC+45% UFFA | 05 % | 8560 | 2536.29 |
| M40UFFA40MK10 | 0.30 | 50% OPC+40% UFFA | 10 % | 8540 | 2530.37 |
| M40UFFA45MK15 | 0.30 | 40% OPC+45% UFFA | 15 % | 8520 | 2524.44 |
| M40UFFA40MK20 | 0.30 | 40% OPC+40% UFFA | 20 % | 8450 | 2503.37 |

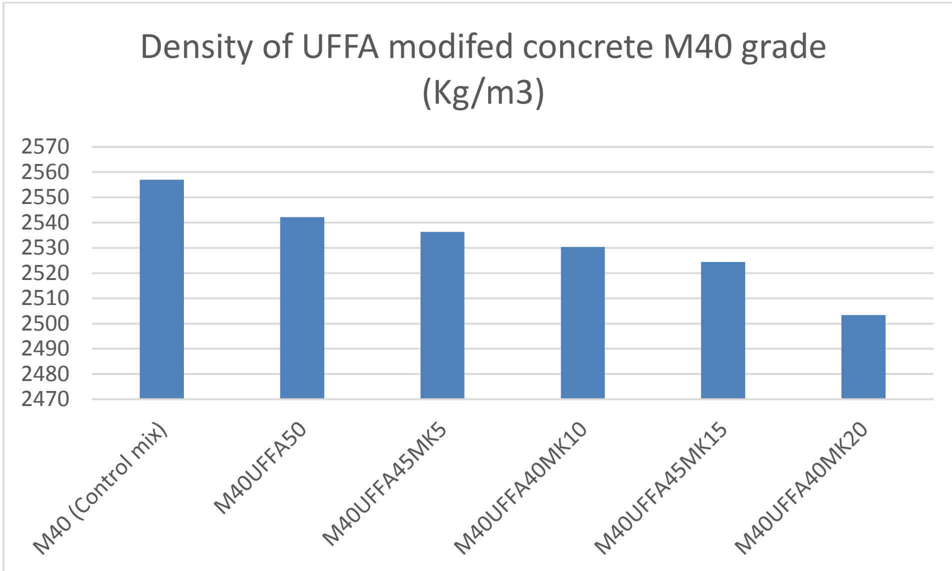


Fig. 6.4 Density of UFFA modified concrete M40 grade

It is clear that the density of UFFA and MK concrete decreases as compared to OPC concrete. Variation in density of various concrete mix are shown in fig. 6.4. Maximum density 2557.03 kg/m$^3$is found at 100% OPC concrete while lowest density 2503.37 kg/m$^3$ is found at 40%UFFA and 20%MK.

**Table 6.5 Density of UFFA modified concrete M50**

| Mix | W/C Ratio | Cement + UFFA (%) | Meta-kaolin (%) | Average weight of cubes in gram | Density of cubes kg/m$^3$ |
|---|---|---|---|---|---|
| M50 (Control mix) | 0.33 | 100 % OPC | 00 % | 8732 | 2587.25 |
| M50UFFA50MK0 | 0.30 | 50% OPC+50% UFFA | 00 % | 8612 | 2551.70 |
| M50UFFA45MK5 | 0.28 | 50% OPC+45% UFFA | 05 % | 8590 | 2545.18 |
| M50UFFA40MK10 | 0.28 | 50% OPC+40% UFFA | 10 % | 8560 | 2536.29 |
| M50UFFA45MK15 | 0.28 | 40% OPC+45% UFFA | 15 % | 8530 | 2527.40 |
| M50UFFA40MK20 | 0.28 | 40% OPC+40% UFFA | 20 % | 8540 | 2503.37 |

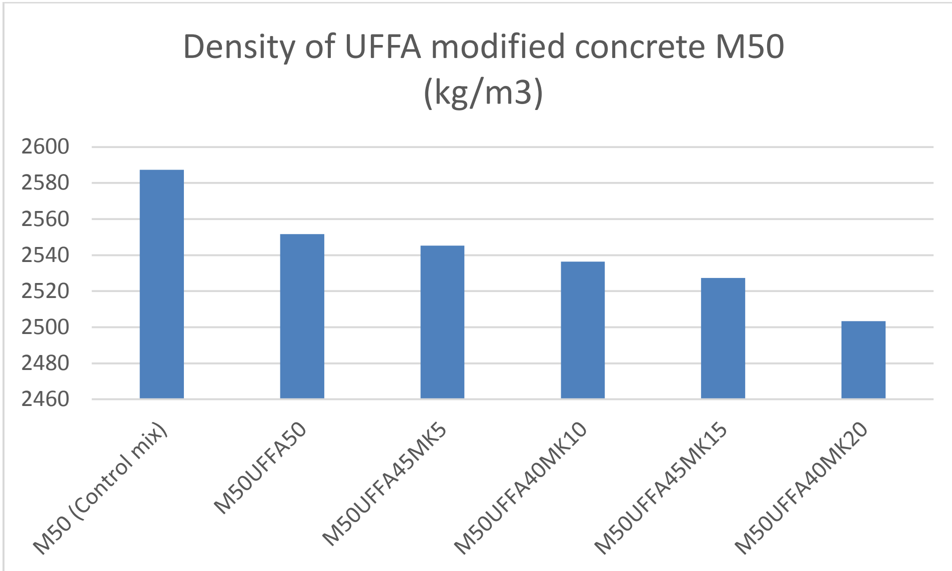


Fig. 6.5 Density of UFFA modified concrete M50 grade

It is clear that the density of UFFA and MK concrete decreases as compared to OPC concrete. Variation in density of various concrete mix are shown in fig. 6.5. Maximum density 2587.25 kg/m$^3$is found at 100% OPC concrete while lowest density 2503.37 kg/m$^3$ is found at 40%UFFA and 20%MK.

**Table 6.6 Density of UFFA modified concrete M60**

| Mix | W/C Ratio | Cement + UFFA (%) | Meta-kaolin (%) | Average weight of cubes in gram | Density of cubes kg/m$^3$ |
|---|---|---|---|---|---|
| M60 (Control mix) | 0.28 | 100 % OPC | 00 % | 8735 | 2588.14 |
| M60UFFA50MK0 | 0.26 | 50% OPC+50% UFFA | 00 % | 8710 | 2580.74 |
| M60UFFA45MK5 | 0.24 | 50% OPC+45% UFFA | 05 % | 8680 | 2571.85 |
| M60UFFA40MK10 | 0.24 | 50% OPC+40% UFFA | 10 % | 8650 | 2562.96 |
| M60UFFA45MK15 | 0.24 | 40% OPC+45% UFFA | 15 % | 8615 | 2552.59 |
| M60UFFA40MK20 | 0.24 | 40% OPC+40% UFFA | 20 % | 8590 | 2545.18 |

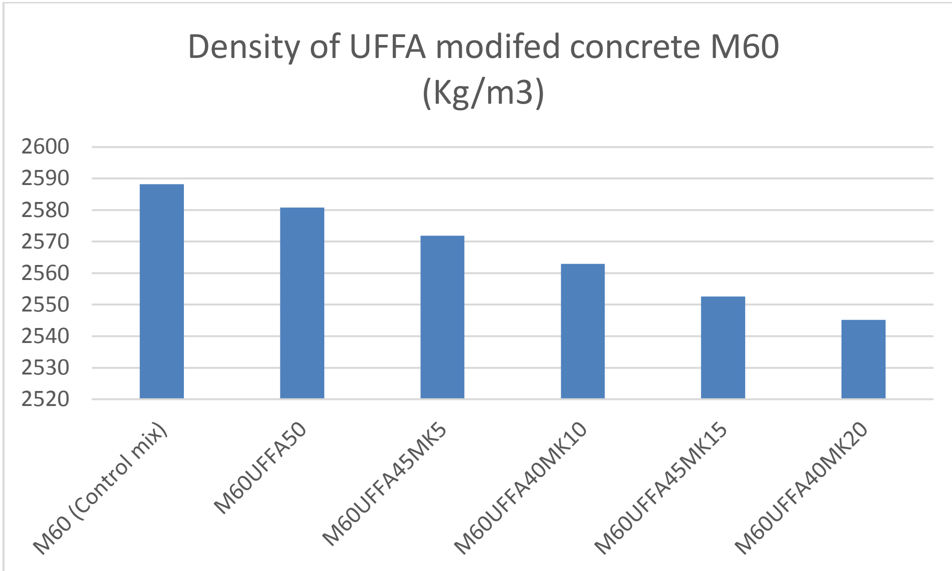


Fig. 6.6 Density of UFFA modified concrete M60 grade

It is clear that the density of UFFA and MK concrete decreases as compared to OPC concrete. Variation in density of various concrete mix are shown in fig. 6.6. Maximum density 2588.14 kg/m$^3$is found at 100% OPC concrete while lowest density 2545.18 kg/m$^3$ is found at 40%UFFA and 20%MK.

**Table 6.7 Water absorption test of UFFA modified concrete M40**

| Mix | W/C Ratio | Cement + UFFA (%) | Meta-kaolin (%) | Dry weight of cubes in (gram) | Wet weight of cubes in (gram) | Water absorbtion (%) |
|---|---|---|---|---|---|---|
| M40 (Control mix) | 0.38 | 100 % OPC | 00 % | 8630 | 8728 | 1.35 |
| M40UFFA50MK0 | 0.32 | 50% OPC+50% UFFA | 00 % | 8580 | 8734 | 1.76 |
| M40UFFA45MK5 | 0.30 | 50% OPC+45% UFFA | 05 % | 8560 | 8745 | 2.16 |
| M40UFFA40MK10 | 0.30 | 50% OPC+40% UFFA | 10 % | 8540 | 8720 | 2.10 |
| M40UFFA45MK15 | 0.30 | 40% OPC+45% UFFA | 15 % | 8520 | 8787 | 3.13 |
| M40UFFA40MK20 | 0.30 | 40% OPC+40% UFFA | 20 % | 8450 | 8765 | 3.72 |

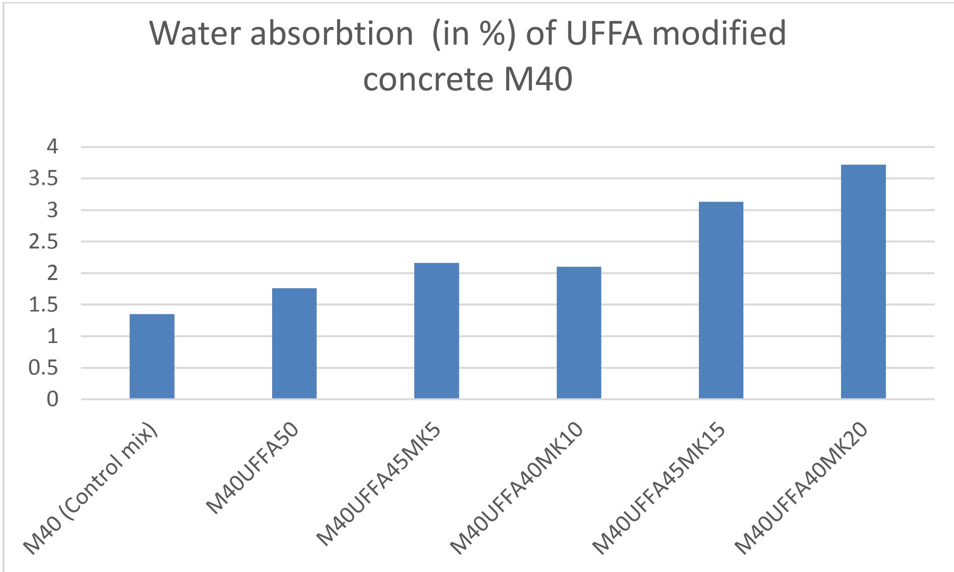


Fig. 6.7 Water absorption of UFFA modified concrete M40 grade

It is clear that the water absorbtion of UFFA and MK concrete decreases as compared to OPC concrete. Fig. 6.7 shows water absorption of various concrete mixes. Maximum water absorption 3.72 % is found at 40%UFFA and 20%MK.

**Table 6.8 Water absorption of UFFA modified concrete M50**

| Mix | W/C Ratio | Cement + UFFA (%) | Meta-kaolin (%) | Dry weight of cubes in (gram) | Wet weight of cubes in (gram) | Water Absorbtion (%) |
|---|---|---|---|---|---|---|
| M50 (Control mix) | 0.33 | 100 % OPC | 00 % | 8732 | 8850 | 1.35 |
| M50UFFA50MK0 | 0.30 | 50% OPC+50% UFFA | 00 % | 8612 | 8760 | 1.71 |
| M50UFFA45MK5 | 0.28 | 50% OPC+45% UFFA | 05 % | 8590 | 8762 | 2.00 |
| M50UFFA40MK10 | 0.28 | 50% OPC+40% UFFA | 10 % | 8560 | 8745 | 2.16 |
| M50UFFA45MK15 | 0.28 | 40% OPC+45% UFFA | 15 % | 8530 | 8720 | 2.22 |
| M50UFFA40MK20 | 0.28 | 40% OPC+40% UFFA | 20 % | 8540 | 8760 | 2.57 |

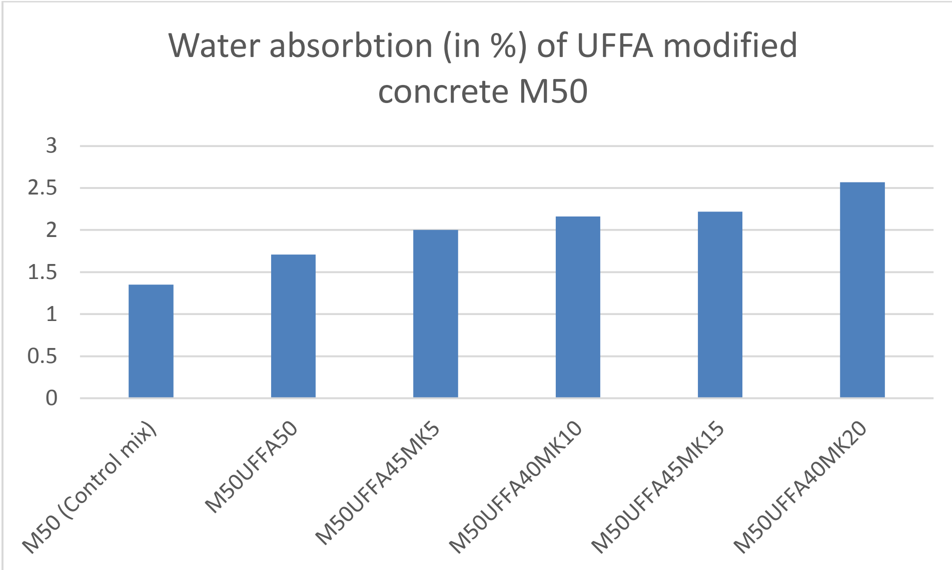


Fig. 6.8 Water absorption of UFFA modified concrete M50 grade

It is clear that the water absorption of UFFA and MK concrete decreases as compared to OPC concrete. Fig. 6.8 shows water absorption of various concrete mixes. Maximum water absorption 2.57% is found at 40%UFFA and 20%MK.

**Table 6.6 Water absorption of UFFA modified concrete M60**

| Mix | W/C Ratio | Cement + UFFA (%) | Meta-kaolin (%) | Dry weight of cubes in (gram) | Weight weight of cubes in (gram) | Water absorption (%) |
|---|---|---|---|---|---|---|
| M60 (Control mix) | 0.30 | 100 % OPC | 00 % | 8735 | 8860 | 1.43 |
| M60UFFA50MK0 | 0.28 | 50% OPC+50% UFFA | 00 % | 8710 | 8854 | 1.65 |
| M60UFFA45MK5 | 0.24 | 50% OPC+45% UFFA | 05 % | 8680 | 8840 | 1.84 |
| M60UFFA40MK10 | 0.24 | 50% OPC+40% UFFA | 10 % | 8650 | 8840 | 2.19 |
| M60UFFA45MK15 | 0.24 | 40% OPC+45% UFFA | 15 % | 8615 | 8810 | 2.26 |
| M60UFFA40MK20 | 0.24 | 40% OPC+40% UFFA | 20 % | 8590 | 8820 | 2.67 |

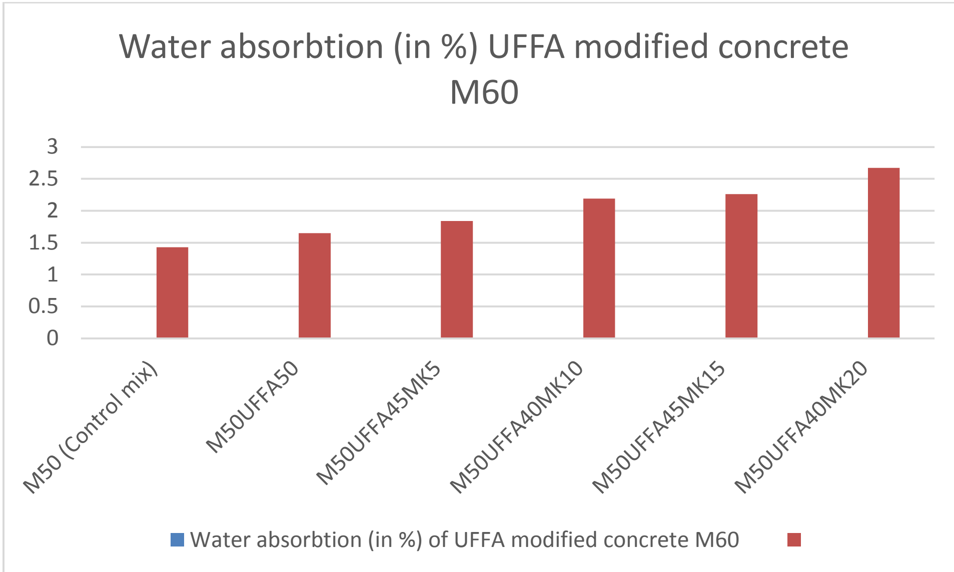


Fig. 6.9 Water absorption of UFFA modified concrete M60 grade

It is clear that the water absorption of UFFA and MK concrete decreases as compared to OPC concrete. Fig. 6.9 shows water absorption of various concrete mixes. Maximum water absorption 2.67% is found at 40%UFFA and 20%MK.

## Conclusion

In this study concrete mixes of various proportions with w/c ratio 0.38 to 0.24 were prepared in the laboratory to determine workability and density. On the basis of results obtained in the laboratory it can be concluded that use of Metakoline reduces the workability of concrete and density of concrete. In comparison to control mix, concrete containing fly ash and Metakoline shows less segregation, a lower rate of waster absorbtion and greater cohesion.

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