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Developing a rational method to participation cementitious mortars containing Meta-Kaolin for application in additive manufacturing

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3D PRINTING OF CONCRETE

Developing a rational method to proportion cementitious mortars containing Meta-Kaolin for application in additive manufacturing

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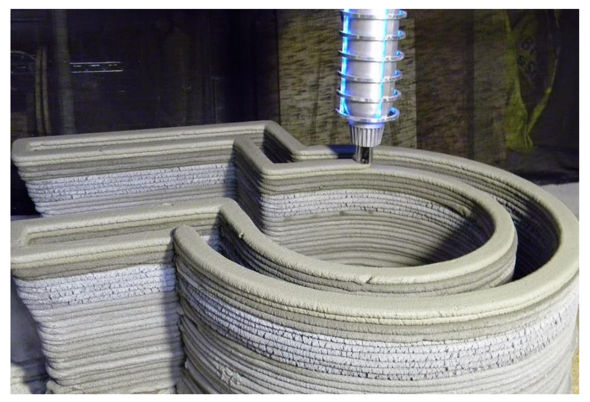
INTRODUCTION

Large-scale, cement-based additive manufacturing processes, often referred to as 3D concrete printing (3DCP), have been under development for the last 10years and more than 30 groups world-wide are currently engaged in research. 3DCP disposes of the need for conventional moulds by precisely placing, or solidifying, specific volumes of material in sequential layers by a computer controlled positioning process.



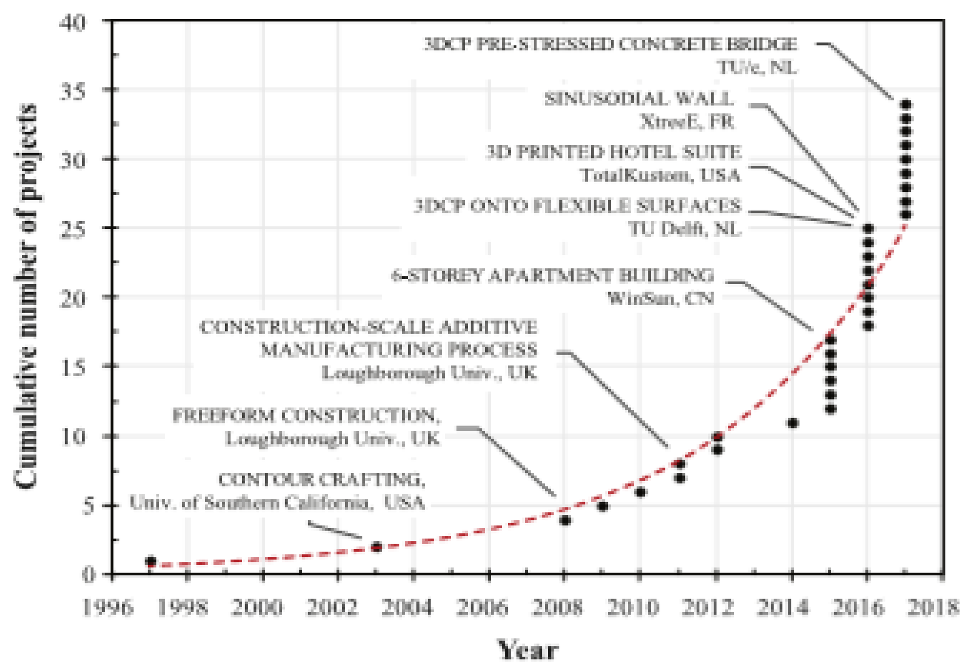
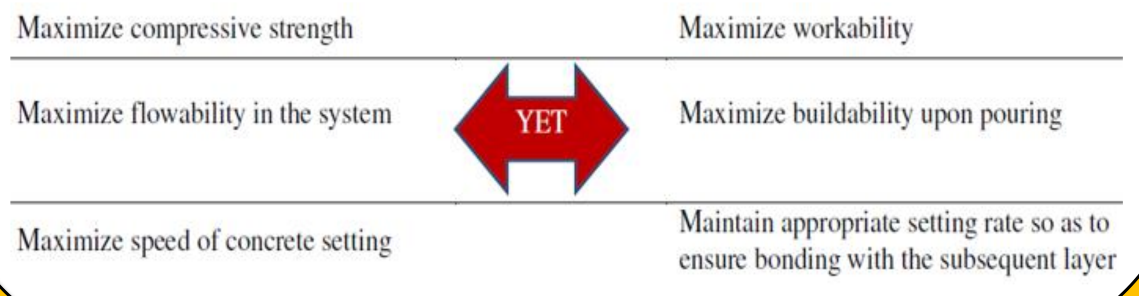


Figure 1: The rise in large-scale additive manufacturing for construction applications since the concept inception in 1997.

OBJECTIVES

- **The focus of the present study is to examine the behavior of cementitious mixtures prepared with portland cement in combination with meta-kaolin and other admixtures such as super plasticizer (SP), viscosity modifying agent (VMA) and additives such as polypropylene (PP) fibers.**
- **In this parametric study, the influence of meta-kaolin addition at various dosage levels on the rheological and mechanical behavior of mortars was investigated Rheological properties of mortars (i.e. yield stress and plastic viscosity) were determined using ICAR PLUS rheometer to correlate the fundamental rheological properties with the performance measures such as extrudability, buildability, thixotropic open time and shape retention.**
- **Setting time of various mortar mixes were also determined using ASTM C403 method. The compressive strength and flexural strength of the material was evaluated.**



MATERIALS & METHODS

MIX DESIGN

After several experiments on different mix compositions, three optimum mixes as shown in the table 1 were chosen to examine the fresh and hardened properties of the mix.

Mix type	w/c ratio	c/s ratio	SP (%)	VMA (%)	Fibres (%)
Control	0.35	1.22	0.3	0.2	0.05
Meta 2.5%	0.32	1.22	0.3	0.2	0.05
Meta 5%	0.33	1.22	0.3	0.2	0.05
Meta 7.5%	0.34	1.22	0.3	0.2	0.05
Meta 10%	0.35	1.22	0.3	0.2	0.05

Table 1: Optimum mixes tested for fresh and hardened properties

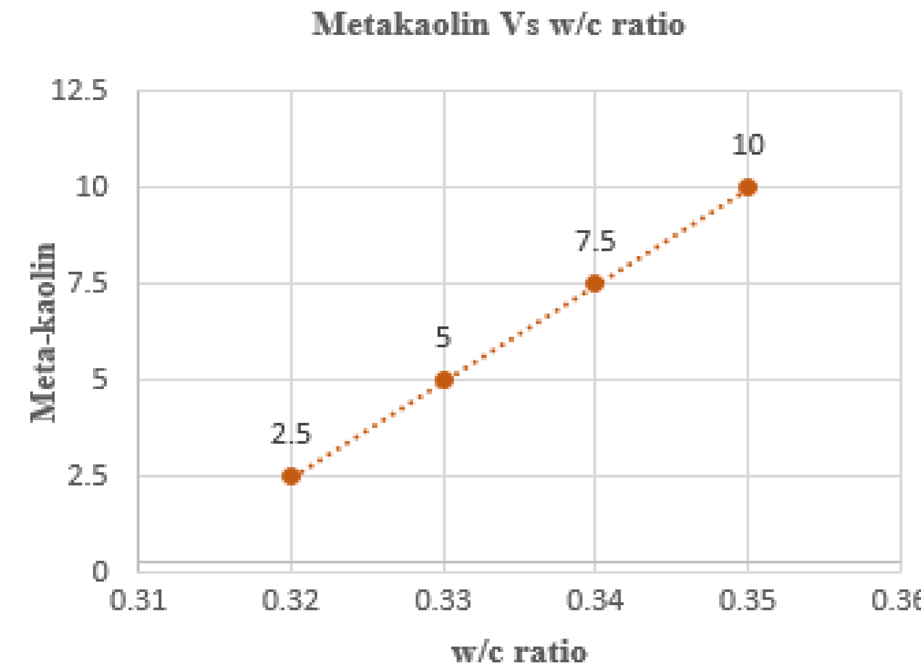


Figure 2: Varying w/c ratio by increasing the Meta-kaolin dosage

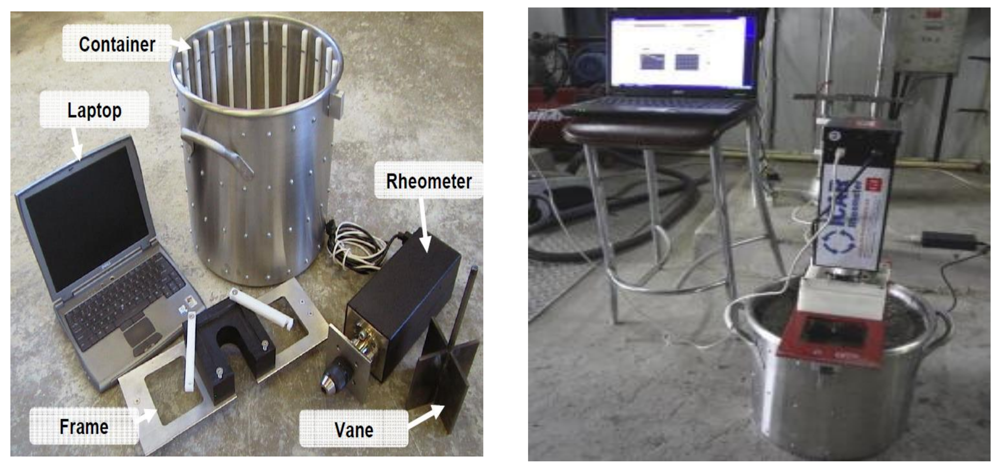
FLOW TABLE TEST

ASTM C1437: Standard Test Method for Flow of Hydraulic Cement Mortar

PENETRATION RESISTANCE TEST

ASTM C403:Standard Test Method for Time of Setting of Concrete Mixtures by Penetration Resistance

ICAR PLUS RHEOMETER



It to used characterize the static yield stress, the dynamic yield stress and plastic viscosity of the concrete

RESULTS

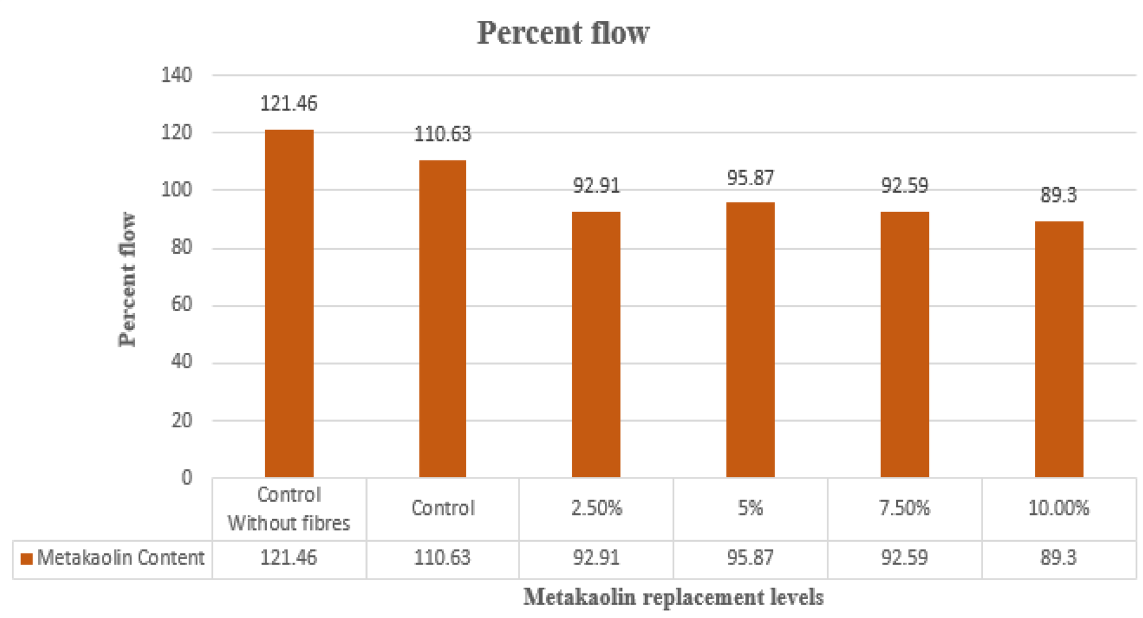


Figure 3: Percent flow of each mix was determined (Flow table test)
It is understood from the figure that mixes containing Meta-Kaolin have less percent flow which is required for a 3D Printable mix

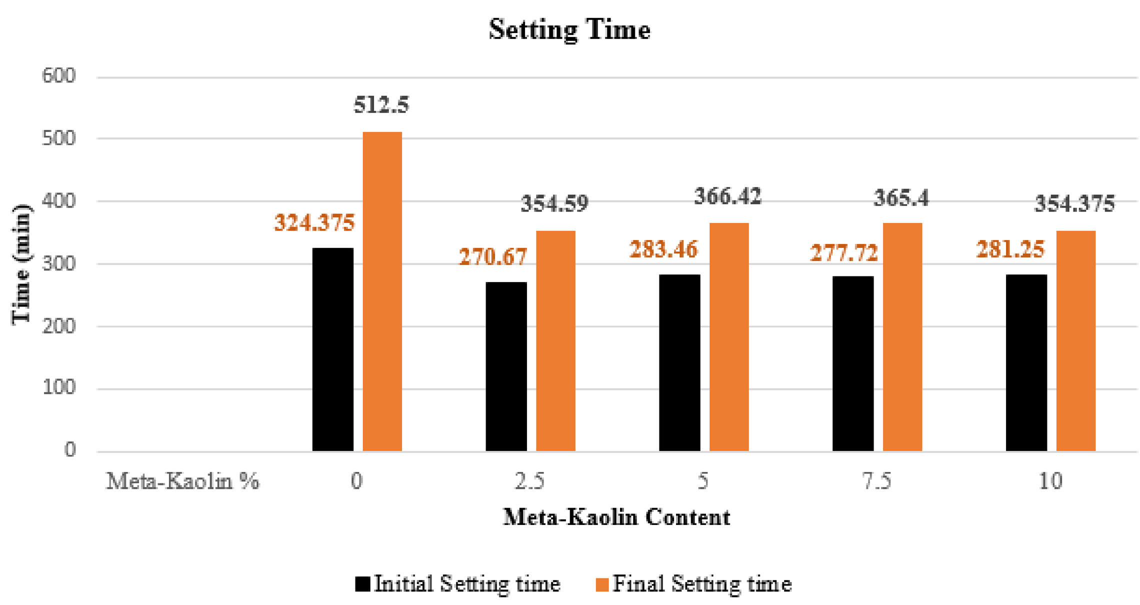


Figure 4: Setting time of Meta-Kaolin mixes were determined by Penetration resistance test. Meta-Kaolin mixes showed faster setting properties than control mix

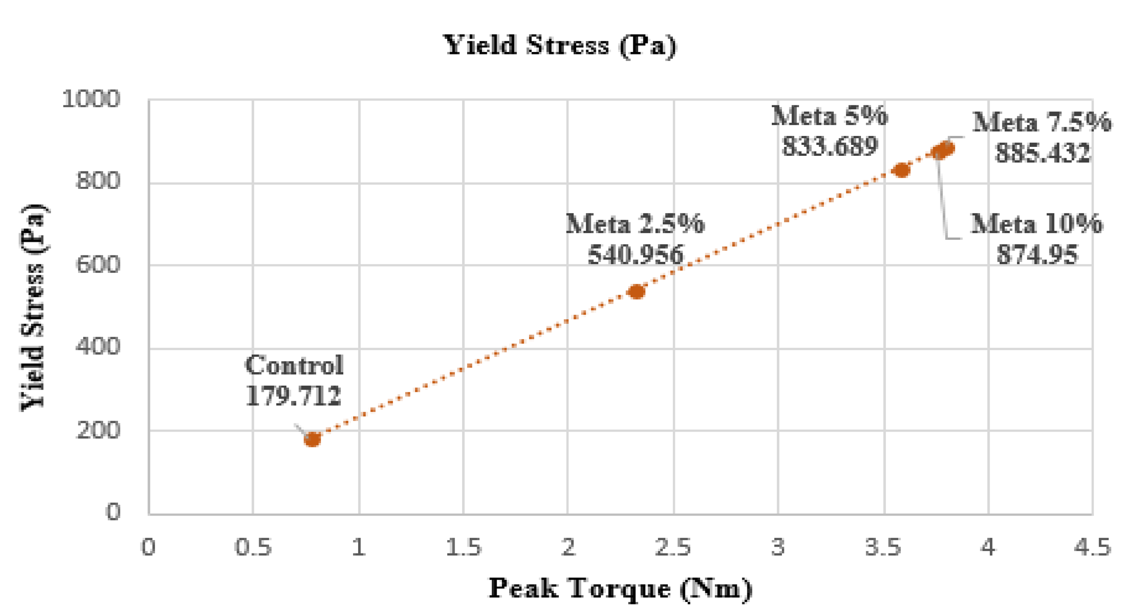


Figure 5: Yield stress increased with increase in Meta-Kaolin dosage (Determined by Icar plus Rheometer)

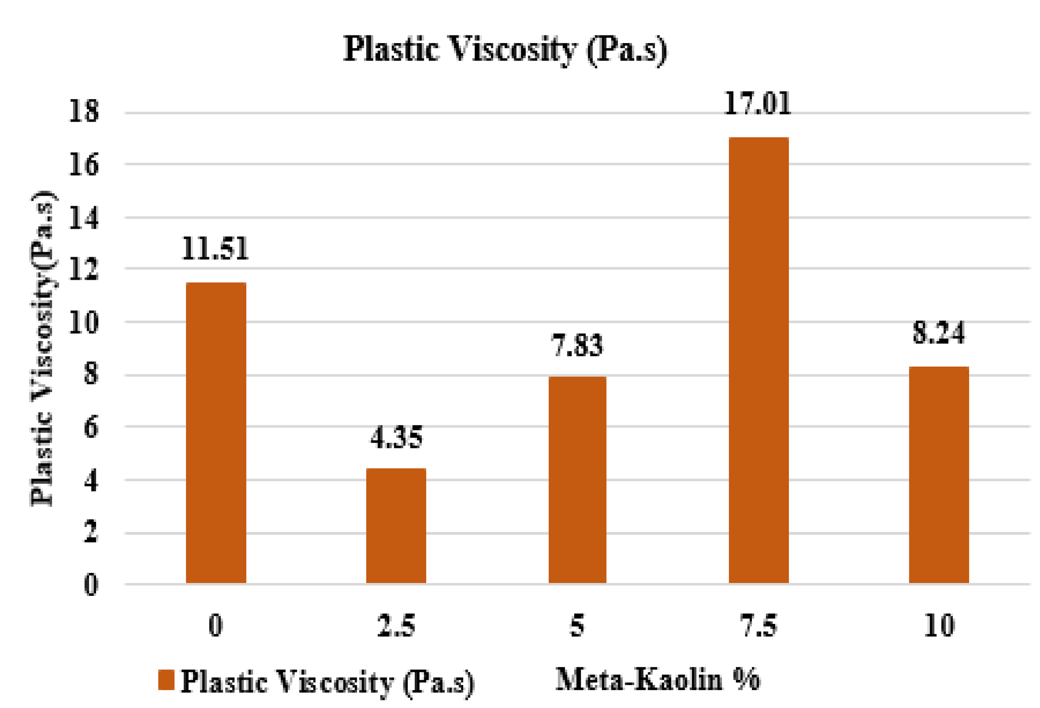


Figure 6: It is determined that plastic viscosity was almost similar for Meta-Kaolin 5% and 10% dosage mixes. Meta-Kaolin 7.5% mix showed a very high plastic viscosity (Determined by Icar plus Rheometer)

RESULTS

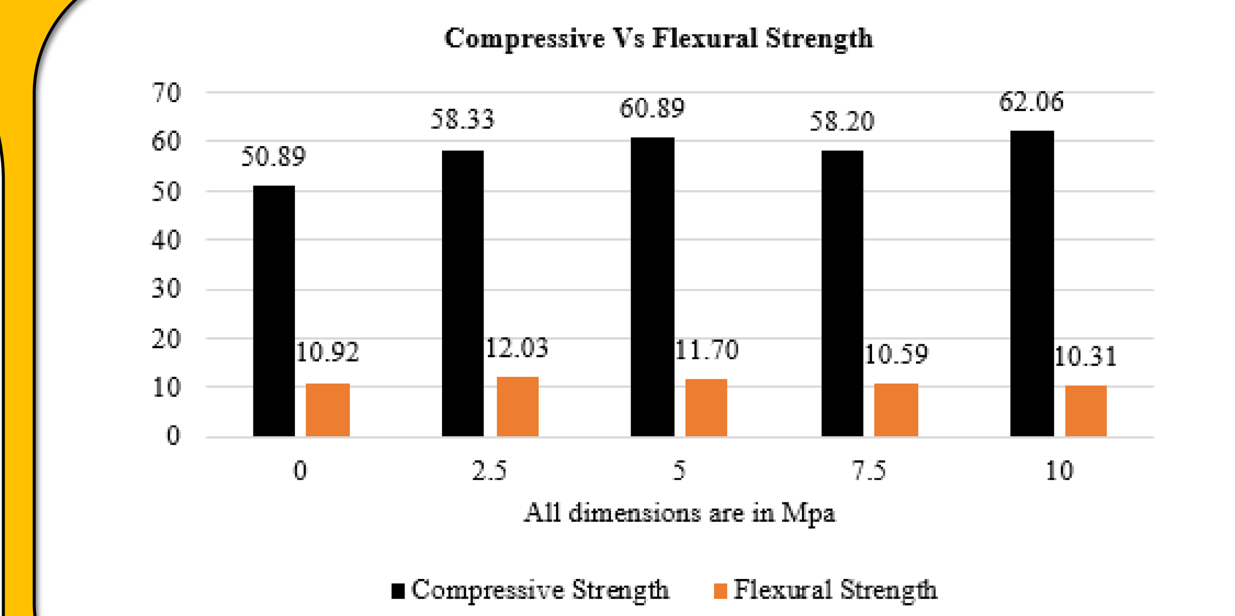


Figure 7: Compressive strength and Flexural Strength

CONCLUSIONS

- **Experimentation on various mixes revealed that Meta-Kaolin mixes had lesser flow and faster setting properties than control mix.**
- **Yield Stress gradually increased with increase in Meta-Kaolin dosage in the mix. Plastic viscosity was high for mix which contained 7.5% Meta-Kaolin with w/c ratio of 0.34.**
- **Correlations showed that when workability reduced, yield stress of the mix increased.**
- **The 7-day compressive strength of mixes with Meta-Kaolin was relatively higher than that of the control mix.**

CASE STUDIES

Lewis Grand Hotel Erects World's First 3D Printed Hotel, Plans to Print Thousands of Homes in the Philippines Next (2016)

3D-Printed Concrete Pedestrian Bridge Completed in China (2018)

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