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A THESIS REPORT ON

Effect of Activated Carbon, CMC and Fly Ash on Different Grade of Concrete

BY

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076/MSMSE/001

SUBMITTED TO THE DEPARTMENT OF APPLIED SCIENCE AND CHEMICAL ENGINEERING IN PARTIAL FULFILLMENT OF THE REQUIREMENT FOR

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CERTIFICATE OF THESIS APPROVAL

This is to certify that they have read, and recommended to the Institute of Engineering for acceptance, a thesis report titled "**Effect of Activated Carbon, CMC and Fly Ash on Different Grade of Concrete"** submitted by **Mr. Adarsha Chauhan (076-MSMSE-001)** in the partial fulfillment of the requirements for the degree of **Masters of Science in Material Science and Engineering**.

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ABSTRACT

Cement is the extensively used material in the world after water. Adding new functional materials to like Activated Carbon (AC), Carboxymethylcellulose (CMC) sodium salt, fly ash (FA), PCE (Poly Carboxylic Ether) based plasticizer can improve the quality and add novel characteristics. Also, reducing the usage of cement.

This study focused on the investigation of compressive strength and modulus of elasticity after introduction of CMC, AC, FA on different grade of concrete. 41 batches of concrete were prepared and tested for M 30 and M 25 grade concrete. The AC being a highly hydrophobic material, agglomeration occurs. CMC sodium salt aqueous solution is chosen surfactant to form the gel structure to disperse the AC. Standard mix design of 132 concrete cubes were carried out varying CMC, AC, FA and its effects were analyzed.

Keywords: Concrete, Mix Design, Carboxymethylcellulose sodium salt, Activated Carbon, Fly Ash

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ABBREBRIATION AND SYMBOLS

AC	: Activated Carbon
CMC	: Carboxy methyl cellulose
w/c	: water cement ratio
FA	: Fly Ash
CA	: CA
VOC	: Volatile Organic Compound
MPa	: Mega Pascle
M 30	: Mix Design concrete for 30 MPa Strength
M 25	: Mix Design concrete for 25 MPa Strength
FM	: Fineness Modulus
IST	: Initial Setting Time
FST	: Final Setting Time
XRD	: X-Ray Diffraction
FTIR	: Fourier Transform Infrared
SEM	: Scanning Electron Microscope
OPC	: Ordinary Portland Cement
IS	: Indian Standard
ACI	: American Concrete Institute
wt.	: weight
max.	: maximum
min.	: minimum
avg.	: average

CHAPTER 1: INTRODUCTION

1.1 Background

During the manufacture of 1 ton cement is estimated at 0.85 -1.1 ton CO2 is produced(Deja et al., 2010; Fayomi et al., 2019). CO_2 is predominant greenhouse gas contributing to the human caused climate change (IPCC 2013). The carbon intensity of global cement production needs to be reduced. Forty of the world's leading cement and concrete manufacturers today join forces to accelerate the shift to greener concrete by pledging to cut CO_2 emissions by a further 25% by 2030, marking a decisive step in the race to 'Net Zero' concrete by 2050(CAT, 2022; United Nations, 2022).

Global Cement and Concrete Association(GCCA, 2021) has set seven-point action plan to net zero future. Some of them are: savings in clinker production and binders, investment in technology and innovation, add novel chemistry alternative to Portland cement clinker, increase natural uptake of CO_2 in concrete and efficiency in concrete production.

CO_2 are entrapped by carbonation in concrete but is not significant compared to quantities released during concrete production. So to entrap large CO_2, AC is has many upside among adsorbents like zeolites, carbon molecular sieves, silicas and metal oxides(Dantas et al., 2011; Plaza et al., 2012; Shafeeyan et al., 2011).

AC is integrated in cement paste to minimize air pollution and VOCs(Krou et al., 2015). In cement mortars, fine aggregate was replaced by AC to improve its physical and mechanical strengths(Justo-Reinoso et al., 2018). Also, concrete can become conducting due to the continuous percolating network of conductive AC and modulus of elasticity was also increased(Pellenq, 2019).

AC are difficult to dissolve or disperse in water(Adeleke et al., 2019). CMC disperses AC, making little hydrophilic(Qiu et al., 2007). CMC in OPC has improved the Compressive Strength, water resistance, porosity reduction and acid resistance. Despite this, setting time of cement has increased(Farooque et al., 1970; Mishra et al., 2003).

The XRD and SEM observation indicate that organic polymer CMC influences the hydration of OPC and micro structure(Farooque et al., 2010).

FA decrease the waste materials and their associated environmental impacts through reusing capability. Also reduces the OPC consumption amount and its associated CO_2 releases from cement manufacturing(González-Kunz et al., 2017). Replacement level of FA with cement of 15- 25% for high strength concrete is seen fruitful(Malhotra et al., 2000).

It has been found that by use of FA, min. cement content is reduced which helps in consuming FA and saving cement(Mishra et al., 2015).

Conductive fillers are frequently used in cement-based composites for greater electrical conductivity and electrical resistance. Self-heating cement-based composites are created by including conductive fillers like carbon fibers, steel fibers, graphite, and nickel particles. In a cold environment, infrastructures such as urban highways, bridges, and airport runways are prone to freezing or being buried with snow, jeopardizing their safety and the daily lives of users. Self-heating cement-based composites are being proposed as a means of heating infrastructure and melting snow and ice(D. Wang et al., 2020).

Concrete is a porous material and its pore network is connected closely. AC is an inert filler which reduces the presence of pores enhancing the performance of concrete and increases workability. It can entrap harmful gases and it can act as conducting material on addition of porous conducting material.

On the contrary, AC is hydrophobic so it does not disperse in water evenly. For even distribution of AC in the concrete mix CMC is used which is good surfactant.

Use of FA in concrete to reduce the percentage of cement content and to use industrial waste FA to make green environment for sustainable life. Also, increase in workability is observed.

Use of PCE based plasticizer on cement improves consistency and has higher hydration heat and IST.

Such functional concrete is to be developed with AC, CMC and FA.

1.2 Problem statement

Forecast of 24,000 premature death per year by 2030 in Nepal will be responsible due to poor quality of air(Fiore et al., 2012). Making sustainable functional concrete by mixing AC, CMC and FA at once could be way out to solution to less carbon emission. As we know AC cannot be directly mixed with water as it is a hydrophobic material with high density. Therefore, it must be mixed with one of the chemical surfactants such as alginate or ethylcellulose, or carboxymethyl cellulose to distribute it evenly in the concrete. Carboxymethyl Cellulose is chosen. CMC aqueous solution with AC mix in concrete mix performance of concrete is assessed and interaction of CMC, AC, PCE plasticizer and FA is never studied to my knowledge. So now, the major question is how does the novel mix affect the mechanical property of concrete.

1.3 Research Questions

Some of the research questions encountered at the very beginning of the thesis are:

i. What is the process for making the AC, CMC water suspension?

ii. How does the addition of AC and CMC effect the mechanical property of concrete?

iii. How does the addition of AC, CMC, FA and plasticizer affect the mechanical properties of concrete?

1.4 Objectives

The main objective of thesis is to investigate the effect of the AC, CMC, FA on M 30 and M 25 grade concrete.

The other general objectives are:

i. To evaluate the performance of concrete varying CMC, AC and FA content.
ii. To compare the effect of additives on different grade of concrete.

1.5 Limitation

i. It only considers 28th day compressive strength.

ii. It only considers for M 30 and M 25 grade of concrete.

For M 30 grade concrete:

i. Interaction between CMC-AC-FA is studied for 3 FA ratio for 2 CMC-AC ratio.

ii. No interaction between only AC addition to concrete is not studied.

For M 25 grade concrete:

i. No interaction between CMC-AC-FA is studied.

CHAPTER 2: LITERATURE REVIEW

Comprehensive analysis of literature related to a similar study was conducted to identify, locate, analyze and organize the document related to research problem. This involved a review of various books, proceedings, presentation, patent, articles, journals, online sources, and relevant documents to gain an understanding of how the similar situation was analyzed and solutions were suggested. Literature review was done with usage of AC, CMC, FA and plasticizers are separately enlisted below. Also different prospect benefits of using it are mentioned.

2.1. AC on concrete

On addition of AC on concrete showed 20-25% NO_2 adsorption and with creation of smaller amount Nitrate ions in concrete(Horgnies et al., 2014).

(Tommaso & Bordonzotti, 2016) used AC in concrete in optimal dose to high performance concrete of 65 MPa showed no effect on its performance in both hardened and fresh state. Also, reduction of NO_x group and showed excellent fire resisting property. Use of 1 % AC will lower the carbon footprint of concrete. The study has showed compressive strength as below:

Table 1 Compressive Strength for different mix by Tommaso

Mixture	Percentage of AC	Compressive Strength (7 days)	Compressive Strength (28 days)
0	0	50	65.3
Mix 1	0.48	52.3	71.8
Mix 2	1.06	51.3	65.8
Mix 3	1.43	53	61.8

(Zhang et al., 2017)experimentally showed the addition of AC to concrete is an effective method of decreasing the rate of radon exhalation. Different types of AC, such as those derived from nut shell, coconut shell, coal, and wood, have varying rates of decreasing radon exhalation, with nut shell and coconut shell-based AC showing the highest reduction rates of 44.3% and 47.1%, respectively, while coal and wood-based AC have lower reduction rates of 29.0% and 19.2%, respectively. Although AC with a larger specific area tends to have a more significant impact on reducing radon exhalation rates, it is important to note that the specific area of the AC is only one of several factors that contribute to the reduction effect, and it is not the sole determining factor. The study has showed compressive strength as below:

Table 2 Compressive Strength for different mix by Zhang

Mixture	Percentage of AC	Compressive Strength (28 days)	Compressive Strength (28 days)
0	0	45.8	45.8
Mix 1	1	49.7	45.6
Mix 2	3	48.1	43.7
Mix 3	5	49	50.3
Mix 4	10	49.4	45.7
Mix 5	12	46.7	46.2
		Cocunut Shell Based AC	Coal Based AC

2.2. CMC on concrete

The impact of the sodium salt of CMC on the characteristics of OPC has been analyzed. The study examined the changes in properties such as setting time, heat of hydration, compressive strength, and fracture toughness. Study concluded the mix Cement/CMC mix of 1% has been found to have improved strength and fracture toughness as compared with OPC. The material has shown better corrosion resistance in HCl, H_2SO_4 and sea-water. At different ages of 7, 28, and 91 days, the cement mixed CMC achieved its highest compressive strength when the additive content was 0.25%, 0.50%, and 0.50%, respectively. Specifically, the max. compressive strength observed for these mixtures was 32.53 MPa at 7 days, 45.87 MPa at 28 days, and 64.37 MPa at 91 days. The compressive strength of the cement-only control group was measured at 7, 28, and 91 days and recorded as 31.3, 43.7, and 53.5 MPa, respectively(Mishra et al., 2003). Delay in setting time and decrease in heat of hydration was observed when increasing CMC content in mix as table below:

Table 3 Setting time for different mix by Mishra

Percentage of CMC	Initial Setting Time (min)	Final Setting Time (min)
0	130	230
0.05	169	328
0.1	195	345
0.25	235	370
0.5	325	495
1	415	555
2	510	630
3	605	705
4	706	783

CMC has both hydrophobic and hydrophilic sides that improves dispersion. 0.4%, 0.8%, 1.2% and 1.6% CMC was used for dispersion of carbon fiber. Upto 0.8% showed shows good dispersion and research concluded that increase of pH increases dispersion(Akbar et al., 2014). The inclusion of CMC and silica fume increased Carbon Nano Fiber dispersion(H. Wang et al., 2017).

Carboxylmethyl Cellulose Sulfate (CMC-S) has a high potential for usage as a cement and concrete additive as a water reducer, set retarder, and water reducer and set retarder (Huang et al., 2014).

2.3. Fly Ash on concrete

Review study by (Ahmaruzzaman, 2010) on FA summarized below:

i. One potential use of FA is as an inexpensive adsorbent in construction to eliminate pollutants like organic compounds, flue gas, and metals.

ii. FA has demonstrated positive outcomes in removing pollutants such as NO_x, SO_x, organic compounds, mercury, and dyes from air and water.

iii. The adsorption capacity of FA can be enhanced through chemical and physical activation processes.

iv. Researchers worldwide have undertaken significant studies to find ways to utilize FA and minimize its environmental impact.

v. FA is a by-product of coal combustion and known to cause environmental pollution.

vi. FA can also be utilized as a light wt. aggregate, mine backfill, road sub-base, and for zeolite synthesis.

vii. Continuous research and development in this field can aid in finding more efficient and sustainable ways to utilize FA while minimizing its environmental impact.

viii. Nevertheless, environmental concerns must be considered while utilizing FA to avoid causing further damage to the ecosystem.

ix. FA holds immense potential for use in the construction industry due to its properties as an effective adsorbent and light wt. aggregate.

In (Naik, 1987)study, the impact of high FA content, specifically FA, on concrete's setting and hardening was investigated. The results revealed that as the proportion of FA replacement increased, the setting time also increased, ranging from a few minutes to several hours. The effect was most prominent in high-replacement concretes with a greater amount of FA replacement.

The delay in setting time was attributed to the pozzolanic nature of FA, which reacts slowly with calcium hydroxide produced during cement hydration, resulting in additional calcium silicate hydrate (C-S-H) gel formation. As the amount of FA increased, the available calcium hydroxide for reaction decreased, resulting in a longer setting time.

2.4. Plasticizer on concrete

Plasticizer in concrete improve the strength of hardened concrete without increasing the amount of cement by reducing admixtures are used to reduce the mixing water, compared to concrete without admixtures, while maintaining the same slump. Concrete containing a water-reducing admixture is more workable and can improve the pumpability of the concrete, remains more cohesive and is less prone to segregation during placement. High strength concrete has lower w/c ratio and high content of fines to fill intergranular space to achieve denser packing instead of water(Etsuo, 2003; Plank et al., 2009).

2.5. Prospects benefits

The study by (Mahoutian et al., 2015) investigated the air void characteristics of AC-FA concrete and found that AC decreased the air void content surface area. Also, the study concluded that ink-prepared specimens provided more accurate and reliable air void characteristics compared to epoxy impregnated specimens in any future image analysis for studying air void character.

FA is a supplementary cementing material that has been successfully used in concrete to enhance its mechanical properties and durability. Other materials such as slag, silica fume, construction and demolition wastes, rice husk ash, biomass ash, wood waste, blast furnace slag, steel slag, ceramic wastes, glass powder, marble powder, and other mineral powders have also been used as partial replacements for cement in concrete mixtures to improve their mechanical properties and sustainability(Aprianti S, 2017).

If Carbon black is dispersing in system, it is beneficial to uplift strength and durability of concrete due to its fineness. CMC as dispersing agent was used in research(Sama, 2020).

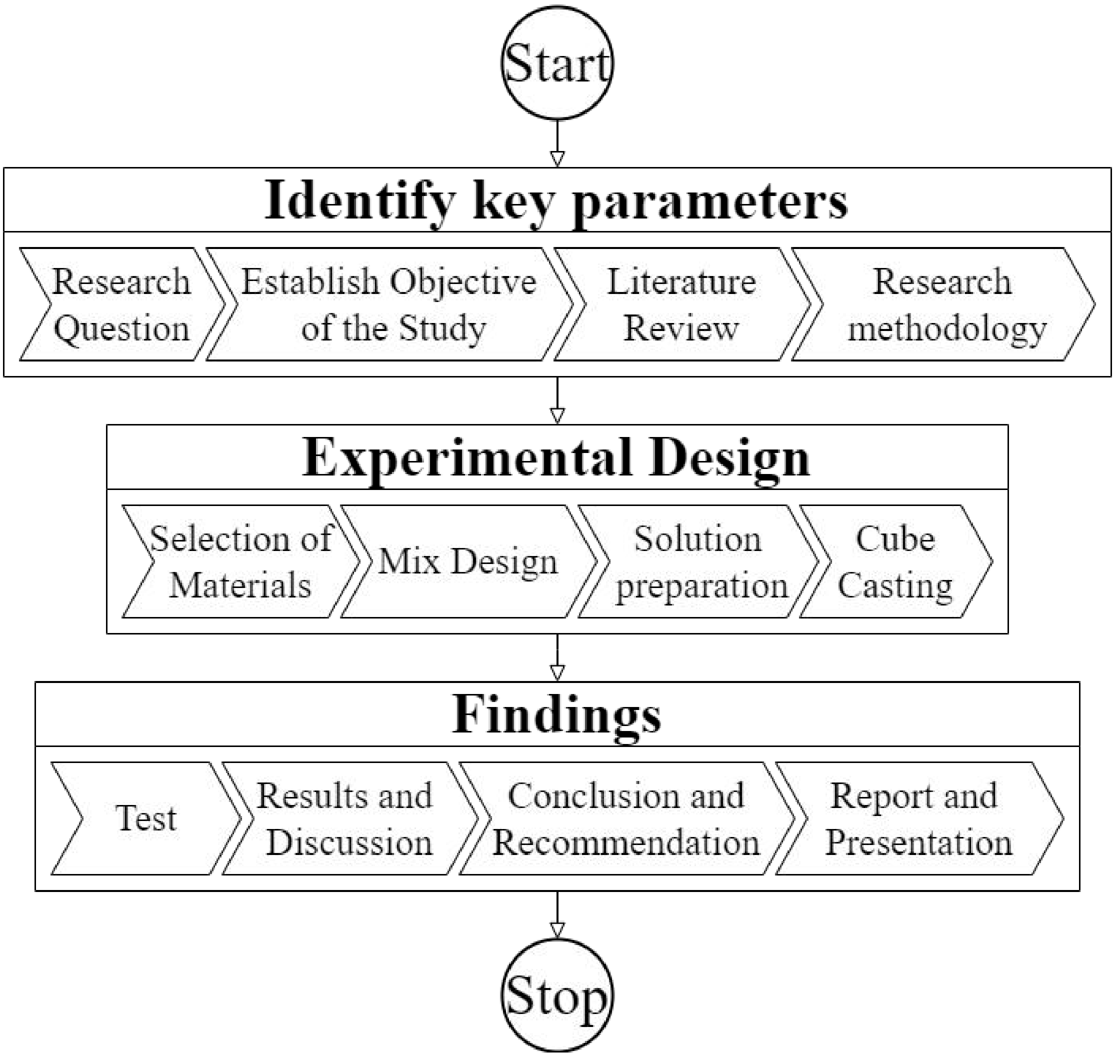
It was found that modified AC has higher CO_2 sequestration capacity. 1 kg of such modified AC concrete contain 5 gm of AC and can hold 12 mg CO_2 adsorbed, while 22 gm carbon would be stored as calcite. Whereas, for traditional concrete 13 gm is stored as calcite(Hamad, 2019).

CHAPTER 3: MATERIALS AND METHODOLOGY

3.1 Research Design

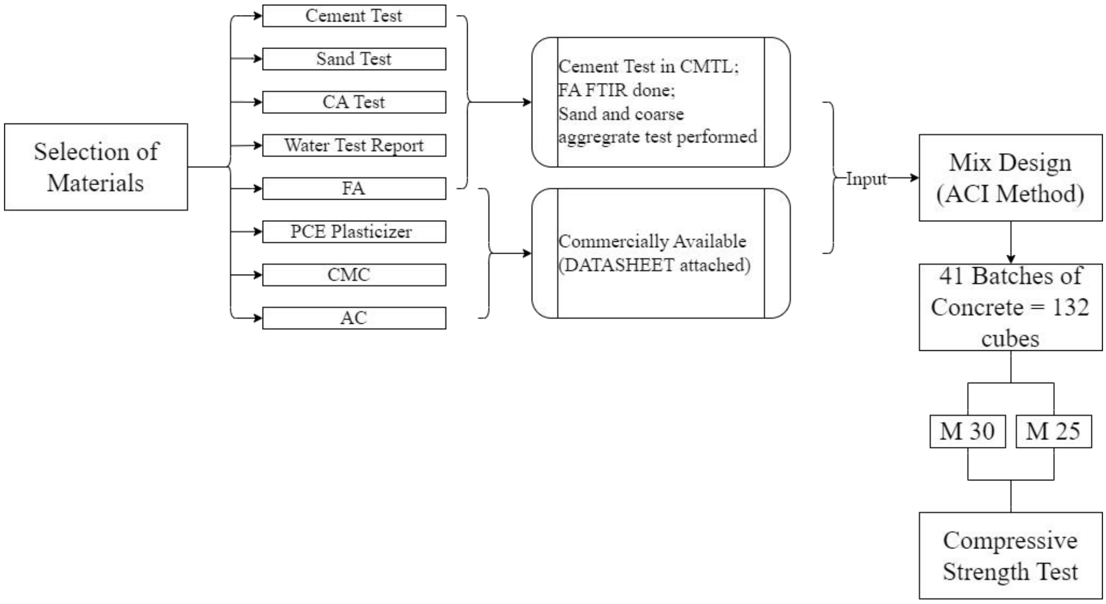
The research design of the thesis comprises of identifying key parameters, experimental design and interpreting the test results. Below flowchart shows the basic idea and work flow of this experimental thesis design.

Figure 1 Flowchart showing research design



Suitable material selections in concrete is includes specimen arrangements, preparations, experimental procedures, measurement techniques. Different types of test were done to select the materials used in research. Following test were conducted and calculation are presented in ANNEX. Whereas, mix design is placed in later in this section. Total of 132 cubes sample were casted and compressive strength test was carried out.

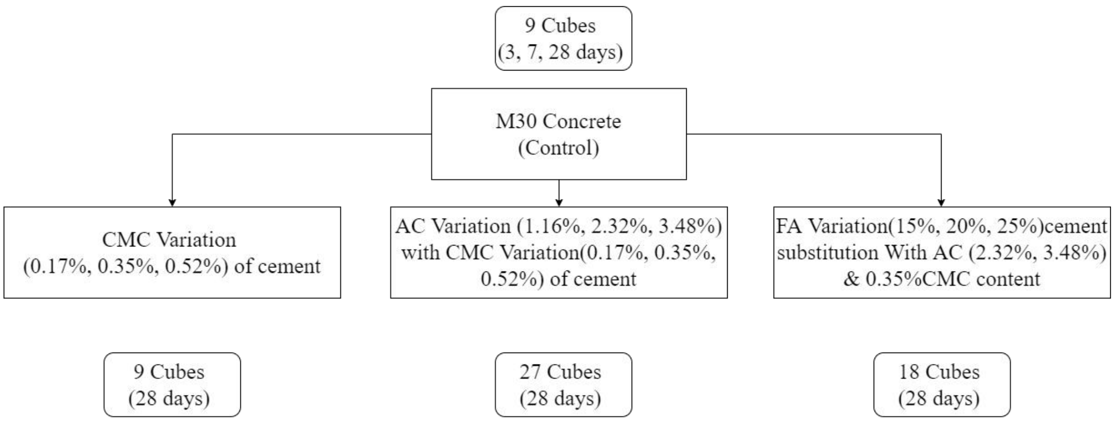
Figure 2 Test performed



Certain target strength of concrete was set to M 30 and M 25 grade from mix design by ACI method using water reducing admixture for M 30 grade only. PCE based plasticizer was used. In M 30 and M 25 grade concrete, different addition were performed.

The procedure for preparation of concrete, concrete with CMC content, concrete with AC and CMC, and a varying amount of carbon is shown in the flow chart below:

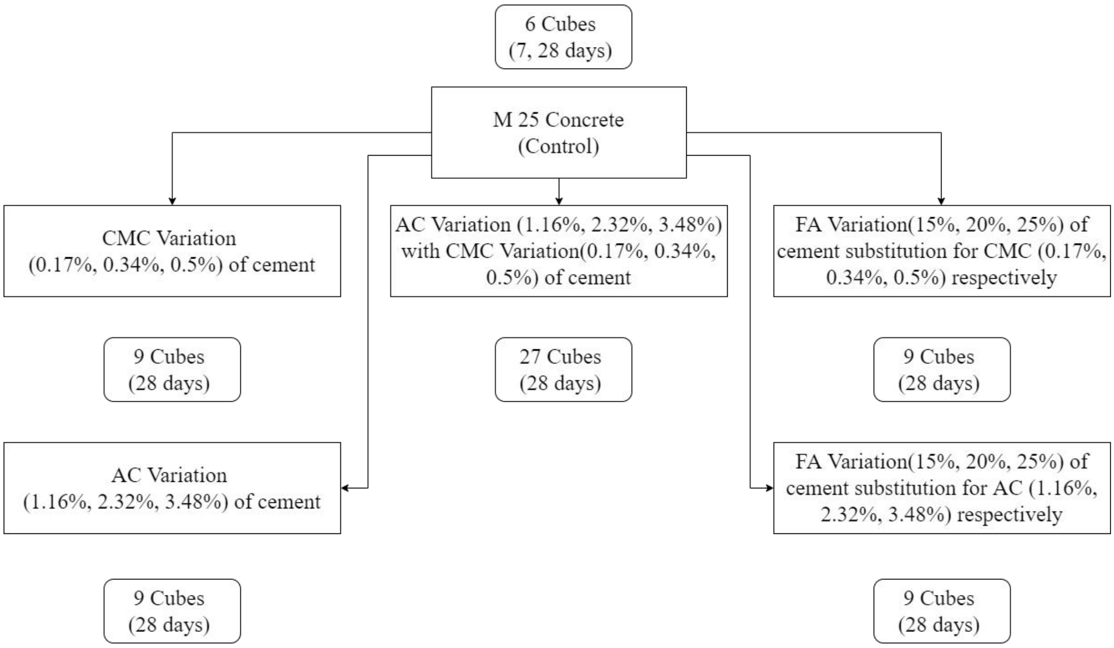
Figure 3 Different Variation of AC, CMC, FA on M30 grade concrete



All 63 concrete cubes were tested to compressive strength by compressive testing machine and for different content variation strain gauge was used for calculation of modulus of elasticity.

M 25 grade concrete was also casted whose mix design is without water reducing agent to see interaction of CMC, AC, FA on concrete. Total of 69 concrete cubes were casted and compressive strength of 28 days was calculated.

Figure 4 Different Variation of AC, CMC, FA on M30 grade concrete



3.2 Selection of Material

Following are the materials used:

3.2.1 Ordinary Portland Cement

OPC is a type of cement that is frequently used in construction. It is created by grinding clinker into a fine powder, and clinker is primarily made up of calcium silicates. This cement is widely used due to its affordability, flexibility, and capacity to resist damage. OPC cement is a extensively used material in various construction projects such as the construction of buildings, bridges, and roads due to its beneficial properties. OPC cement is composed of several chemical compounds, including(Taylor, 1997):

Table 4 Composition of OPC Cement

S.N.	Chemical Compound	Chemical Formula	Content	Function

1	Tricalcium silicate	Ca_3SiO_5	50-70%	Provides strength and durability to concrete by responding with water to form calcium silicate hydrate (C-S-H) gel.
2	Dicalcium silicate	Ca_2SiO_4	10-30%	Contributes to the strength of cement over a longer period of time than tricalcium silicate.
3	Tricalcium aluminate	$Ca_3Al_2O_6$	5-15%	Imparts early strength to concrete by reacting with water to form calcium aluminate hydrate (C-A-H) gel which is responsible for the IST time of cement.
4	Tetracalcium aluminoferrite	$Ca_4Al_2Fe_2O_{10}$	<10%	Contributes to the color of cement and also contribute to the early strength development.
5	Gypsum	$CaSO_4.2H_2O$	<5%	Regulates the setting time of cement and prevents flash setting.
6	(MgO, Fe_2O_3, alkalies, etc.)	-	<5%	Contribute to the properties of cement such as workability, setting time, and strength.

OPC cement of 53 Grade was used in our research.

Several stages are involved in the production of OPC cement, including raw material extraction, crushing, grinding, and mixing. The main raw ingredients in OPC cement production are limestone, clay, and gypsum(PCA, 2023).

It is stated by the Indian Standards Institution (ISI) that the grade of OPC cement is determined by the compressive strength of the cement after 28 days of curing and that an increase in the proportion of clinker in the cement results in higher compressive strength(ISI, 2013). Likewise, the American Concrete Institute (ACI) observes that an increase in clinker content leads to an increase in both compressive strength and heat of hydration of OPC cement(ACI, 2014).

OPC cement of 53 grade was used manufactured by Shivam Cement was tested according to IS 4031-1988 and compressive strength for 3, 7 and 28 days and used. Also, Normal Consistency, IST and FST were calculated in CMTL Pulchowk Campus and report is placed below in ANNEX.

3.2.2 Activated Carbon

Activated carbon is a versatile and highly porous material utilized in several applications, including purification of water and air, gas separation, and energy storage. It results from carbonization of organic materials and activation by subjecting the carbonized matter to a mixture of gases or an oxidizing agent, such as carbon dioxide and steam. The activation process yields a porous network structure that boosts the carbon's surface area, thereby facilitating efficient adsorption of impurities. AC is manufactured by carbonizing organic materials, such as coal, coconut shells, and wood, followed by activation through exposure to an oxidizing agent or a mixture of gases, like steam and carbon dioxide. This leads to the creation of a network of pores and increases the carbon's surface area, allowing it to effectively adsorb impurities. AC has wide range of application in different field(Marsh, H., & Reinoso, 2006).

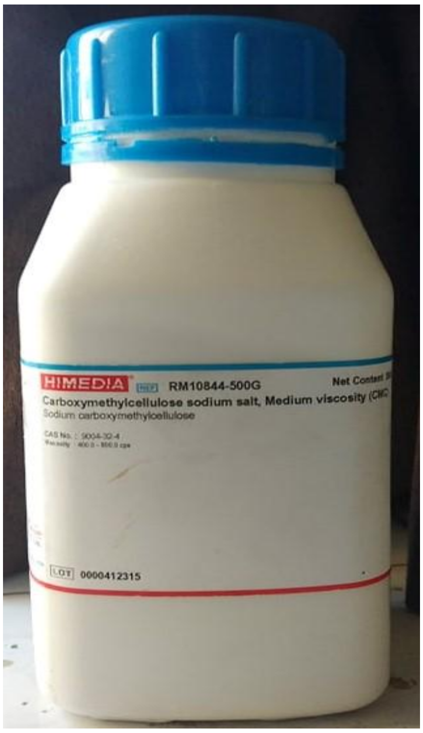
Commercially available AC in Kathmandu from Eureka Suppliers, Tripureshowr, Kathmandu was used in this research with company proclaimed specification is attached in ANNEX.

3.2.3 Carboxymethyl Cellulose Sodium Salt

Carboxymethylcellulose (CMC) or cellulose gum is a cellulose derivative that contains carboxymethyl groups (-CH2-COOH) that are attached to some of the hydroxyl groups of the glucopyranose monomers that comprise the cellulose backbone. It is frequently used as the sodium salt, sodium CMC. It was sold under the brand name Tylose, which is a registered trademark of SE Tylose.

The alkali-catalyzed reaction of cellulose with chloroacetic acid produces CMC. The cellulose is liquid and chemically reactive due to the polar (organic acid) carboxyl groups.

Image 1 CMC used



CMC's functional properties are determined by the number of hydroxyl groups participated in the substitution reaction and as well as the chain length of the cellulose backbone structure and the degree of clustering of the carboxymethyl substituents (Hollabaugh, 1945).

Commercially available CMC in Kathmandu from Himedia supplied by Eureka Suppliers, Tripureshowr, Kathmandu was used in this research with company proclaimed specification is attached in ANNEX.

3.2.4 Fly Ash

Commercially available processed FA for concrete application by DIRK India Pvt. Ltd. in Kathmandu supplied by Acme Suppliers, Pulchowk, Lalitpur was used in this research with company proclaimed specification is attached in ANNEX.

FA FTIR report is presented in ANNEX.

3.2.5 Fine Aggregate and CA

Fine Aggregate from Sankhu and CA from Kavrepalanchowk whose avg. FM was found 2.78 and dry rodded bulk density as 1575.61 kg/m^3.

i. Sampling of fine aggregate and CA was done according to ASTM D75

ii. FM of sand was found according to ASTM C128 and ASTM C33

iii. Dry rodded bulk density of CA was found according to ASTM C29

Calculation are presented in ANNEX.

3.2.6 Poly Carboxylic Ether (PCE) Based Superplasticizer

Commercially available PCE based water reducing agent known as flowgel from Acme Suppliers, Pulchowk, Lalitpur was used in this research with company proclaimed specification is attached in ANNEX. Flowgel is 4th generation high performance super-plasticizers based on a modified polycarbolxylic ether. It confirms to IS:9103-1999 and ASTM C-494-1981(Type- G).

3.2.7 Water

It is necessary to use the min. amount of mixing water to achieve workability in concrete while maintaining its strength. There is guideline emphasizes the significance of controlling water content in the mixture(IS10262, 2009).

Likewise, ACI emphasizes that the water content of the mix plays a crucial role in determining the final properties, including strength and durability, of the concrete(ACI 211, 2002).

Tap water was used from the Heavy lab. Water test report from Water Lab is placed in ANNEX.

3.3 Tools and Test Performed

The equipment, tools and test performed during this thesis is enlisted under:

3.3.1. Compressive Testing Machine

The Compressive Testing Machine (CTM) is a mechanical device used to determine the compressive strength of construction materials, such as concrete. It applies pressure on a sample until it fails, enabling the calculation of the max. load it can handle before collapsing. Typically, the CTM is equipped with a load cell, loading platen, and control panel to monitor the load and deformation during testing. This device is crucial in construction quality control to ensure that materials used in construction meet the required strength standards for safety and longevity. The CTM is typically powered by hydraulic or electric sources.

Image 2 Compressive Testing Machine

3.3.2. Strain Gauge

A strain gauge is a device that can detect the deformation or change in length of a material under an applied force, thus allowing for the precise calculation of the resulting strain. By measuring the strain and the applied force, the modulus of elasticity of the material can be determined, which is a crucial factor in analyzing its structural behavior and durability.

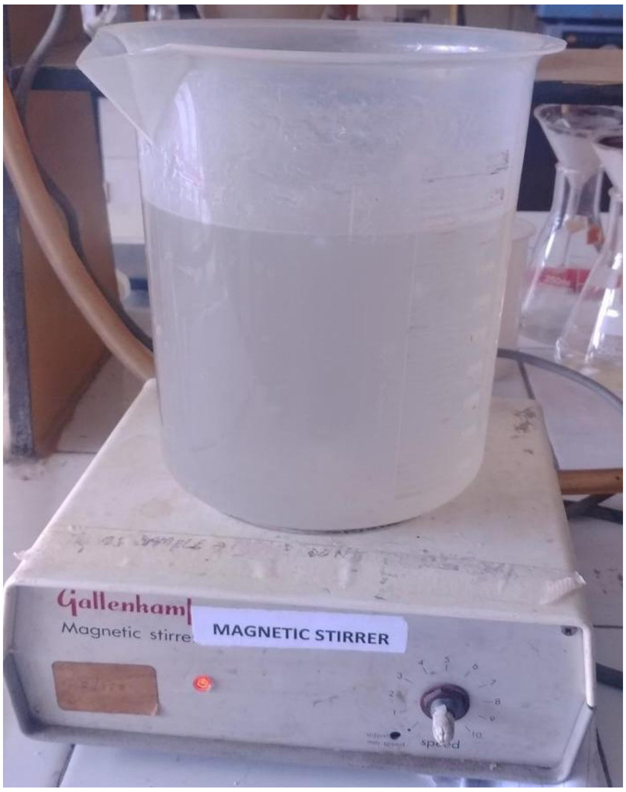
Strain gauges are particularly useful for measuring small changes in deformation due to their high sensitivity and accuracy. They can be employed to measure strain in a wide range of materials, including concrete, which enables the calculation of its modulus of elasticity.

Image 3 Strain Gauge

3.3.3. Magnetic Stirrer

A magnetic stirrer is an instrument that is utilized in laboratories for producing a magnetic field that causes a stir bar or flea to rotate quickly when it is immersed in a liquid. The liquid is stirred by the rotation of the stir bar, ensuring homogeneity of the sample. The magnetic stirrer is composed of a motorized base that generates a rotating magnetic field and a container or flask that is capable of withstanding heat, which contains the liquid to be stirred. The stir bar is placed in the container or flask and is held in place by the magnetic field. The degree of mixing can be controlled by adjusting the speed of rotation, and temperature can also be controlled by some magnetic stirrers, making them suitable for various laboratory applications, including chemical reactions, titrations, and biological assays.

Image 4 Magnetic Stirrer with CMC solution



3.3.4. Cube Mould

These moulds are typically made of steel or cast iron and have tight-fitting lids to prevent any leaks during the casting process. Once the concrete is poured into the mould, it is left to set and cure for a specific period of time before being tested for its compressive strength.

Image 5 150 mm cube molds

3.3.5. Vibrating Table

A flat vibrating device is employed in the concrete industry to consolidate the material and eliminate any entrapped air bubbles. Usually made of steel or concrete, the equipment shakes at a high frequency to facilitate uniform distribution and removal of air pockets. This is critical in concrete casting processes where air bubbles may compromise the integrity and robustness of the material. Poor consolidation can result in weak sections of concrete, leading to cracks or other imperfections.

Image 6 Vibrating Table

3.4 Preparation of Solution

The amount of cement is found from mix design required for the preparation of the concrete was first calculated. Then from percentage of CMC and AC addition is concrete quantity of CMC and AC is worked out for different 41 batches of concrete.

3.5 Mix Design

Mix design was performed for M 30 and M 25 grade concrete by ACI Method.

3.4.1. M 30 mix design

i. Slump Determination

From table 22,

Adopt Placing Condition for Concreting of lightly reinforced sections with vibration Degree of workability: Medium

Values of workability: 25mm-75mm slump for 20mm max. nominal aggregate

ii. max. Size of CA

Adopt max. size of CA as 20mm

iii. Water Cement Ratio determination

For 30MPa= 305.81kgf/cm^2 From table 31, Interpolating;We get w/c ratio by wt. as 0.541

iv. Approximate mixing water for the desired workability and max. size of CA

From table 32,

For slump: 3cm to 5cm

max. Size of aggregate 20mm

For non air entrained concrete Adopt approximate mixing water 185 kg/m^3

v. Cement Content Determination and check

Cement Content = Water content / w/c ratio = 185/0.541 = 341.98 kg/m^3

Check based on exposure condition, from table 5 max. Size of CA 20mm

Type of Concrete Reinforced concrete

Exposure Severe

max. free w/c ratio 0.45

min. Cement Content 320 kg/m^3

Adopt w/c ratio 0.45

Cement Content to be used 185/0.45 **= 411 kg/m3**

Use of high range water reducing admixture ASTM C-494-1981(Type G)

(0.2%-1.5%of cement wt.(w/w)) decreases the water content 12% to 30 %. So, reducing water content by 20 % i.e.

Use mixing water 185×0.8= 148 kg/m^3

Actual w/c ratio 0.36

Use high range water reducing admixture 0.7% of cement content i.e 2.88 kg/m3

vi. Determination of amount of CA

FM of Sand 2.78 (Sankhu Sample)

max. Size of CA 20mm

Volume of dry rodded CA per unit volume of concrete by table 33. Interpolating we get, for 20mm CA and 2.78 FM,

Volume of dry rodded CA per unit volume of concrete 0.622

Dry rodded bulk density of the aggregate 1575.61 kg/m^3 (Sankhu Sample)
Dry wt. of CA 0.622×1575.61=980.03 kg/m^3

vii. Determination of amount of fine aggregate

Nominal max. size of CA 20mm

For non air entrained concrete

First estimate of wt. of fresh concrete 2345 kg/m^3

wt. of fine aggregate wt. of fresh concrete- wt. of all other ingredients= 2345-411-148-980-2.88 =803.12 kg/m^3

viii. Water content adjustment

Water content in Fine Aggregate 9%

Water content in CA 0.00%

Total free surface moisture in Fine Aggregate =9%×803.12 =72.28 kg/m^3

wt. of **Fine Aggregate** in field condition =803.12+72.28 **=875.40 kg/m^3**

CA absorbs 4% water =4%×980.03=39.20 kg/m^3

wt. of **CA** in field condition =980.03-39.20 **=940.83kg/m^3**

Water in Fine Aggregate that acts as mixing water =72.28-39.20 =33.08kg/m^3

Actual **Water** to be used as mixing water =148-33.08 =**114.92kg/m^3**

3.4.2. M 25 mix design

i. Slump Determination

From table 22, Adopt Placing Condition for Concreting of lightly reinforced sections with vibration Degree of workability: Medium

Values of workability: 25mm-75mm slump for 20mm max. nominal aggregate

ii. max. Size of CA

Adopt max. size of CA as 20mm

iii. Water Cement Ratio determination

For 25 MPa= 254.85 kgf/cm^2

From table 31, Interpolating; We get w/c ratio by wt. as 0.61

iv. Approximate mixing water for the desired workability and max. size of CA

From table 32, For slump: 3cm to 5cm

max. Size of aggregate 20mm

For non air entrained concrete Adopt approximate mixing water 185 kg/m^3

v. Cement Content Determination and check

Cement Content Water content / w/c ratio 185/0.61=303.28 kg/m^3

Check based on exposure condition, from table 5 max. Size of CA 20mm

Type of Concrete Reinforced concrete

Exposure Severe

max. free w/c ratio 0.5

min. Cement Content 300 kg/m^3

Adopt w/c ratio 0.5

Cement Content to be used 185/0.5 **= 370 kg/m3**

vi. Determination of amount of CA

FM of Sand 2.78 (Sankhu Sample)

max. Size of CA 20mm

Volume of dry rodded CA per unit volume of concrete by table 33. Interpolating we get, for 20mm CA and 2.78 FM,

Volume of dry rodded CA per unit volume of concrete 0.622

Dry rodded bulk density of the aggregate 1575.61 kg/m^3 (Sankhu Sample)
Dry wt. of CA 0.622×1575.61=980.03 kg/m^3

vii. Determination of amount of fine aggregate

Nominal max. size of CA 20mm

For non air entrained concrete, First estimate of wt. of fresh concrete 2345 kg/m^3

wt. of fine aggregate wt. of fresh concrete- wt. of all other ingredients= 2345-370-185-980.03 =809.97 kg/m^3

viii. Water content adjustment

Water content in Fine Aggregate 6.55%

Water content in CA 0.00%

Total free surface moisture in Fine Aggregate =6.55%%×809.97 =53.05 kg/m^3

wt. of **Fine Aggregate** in field condition =809.97+53.05 **=863.02 kg/m^3**

CA absorbs 4% water =4%×980.03=39.20 kg/m^3

wt. of **CA** in field condition =980.03-39.20 **=940.83kg/m^3**

Water in Fine Aggregate that acts as mixing water =53.05-39.20 =13.85 kg/m^3

Actual Water to be used as mixing water =185-13.85 =**167.29 kg/m^3**

Volume calculation

The volume of each ingredient of concrete was calculated by taking the volume of concrete 1 m^3 for M 30 and M 25 grade. Summary of mix design is presented in below figures and volume calculation are presented in ANNEX.

Figure 5 Mix Design Composition for 1 m^3 M 30

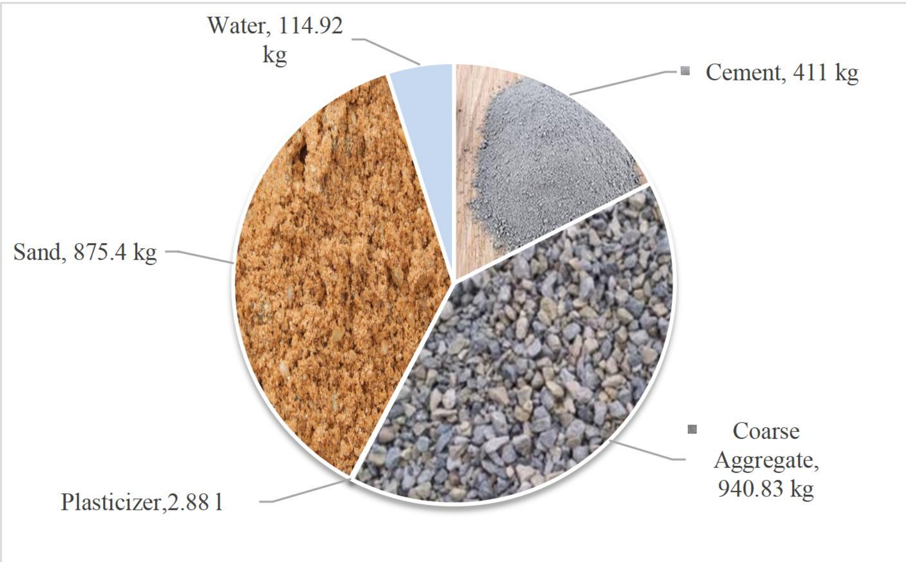
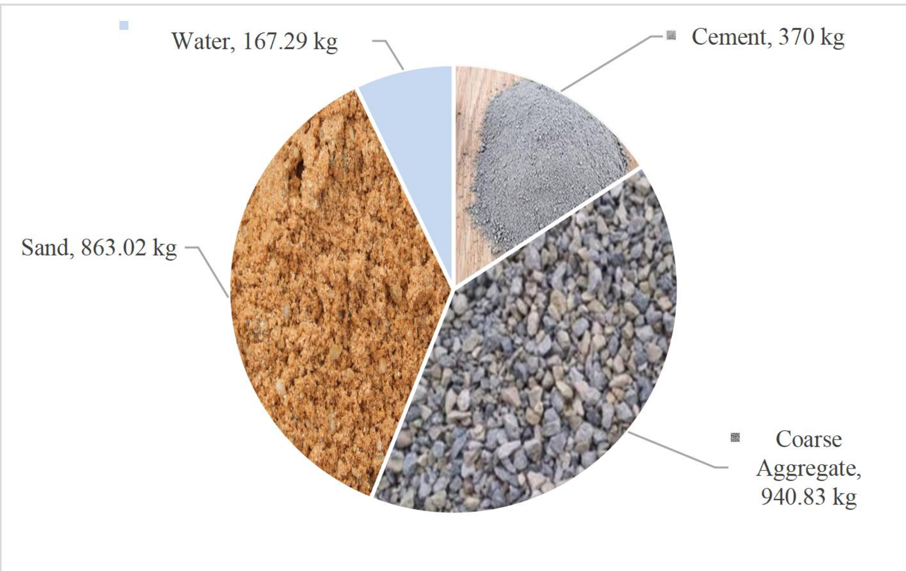


Figure 6 Mix Design Composition for 1 m^3 M 25



Preparation of concrete cubes

The number of molds accounted for the experiment, added to a total of twenty-seven. Special attention was given while casting the cube. The mold was greased up so that the cube could easily be removed from the mold after a day.

Casting, Drying and Curing of Cubes

The cubes were casted in cube mould of 150mm × 150mm × 150mm size. After the preparation of concrete cubes, the cubes were set for the next 24 hrs except for mix containing CMC which was set for 48 hrs. The specimen was demolded after set and cured with tap water for 28 days. After letting them dry for a given time.

Testing of concrete cubes

After end of curing period, concrete cubes were saturated surface dried and compressive strength test was carried on accordance to ASTM C192 as:

i. Three test specimens of standard size (150mm × 150mm × 150mm) using the same mix design and curing conditions.

ii. Place test specimens on the CTM with the smooth surfaces facing each other and centered under the loading platen.

iii. Applying a load gradually at a constant rate of 35 MPa/min until the specimen fails suddenly and without significant deformation or cracking. The max. load applied just before the specimen fails was recorded.

iv. Calculation the compressive strength of each specimen using the formula: Compressive strength = max. load / Cross-sectional area of the cube.

v. ACI method specifies the use of a min. of three specimens, and the avg. compressive strength of the three specimens should be used to represent the compressive strength of the concrete in the structure.

vi. Report the compressive strength of each specimen. Convert the units to MPa as per your requirement. and the avg. strength of the three specimens along with relevant information such as the date of testing, wt. of cube, curing conditions, mix design, and any deviations from the standard testing procedure.

CHAPTER 4: RESULTS AND DISCUSSION

4.1 Compressive Strength for M 30 grade

The summary of results for M 30 grade is presented in below table. Its interpretation and discussion is explained in this section.

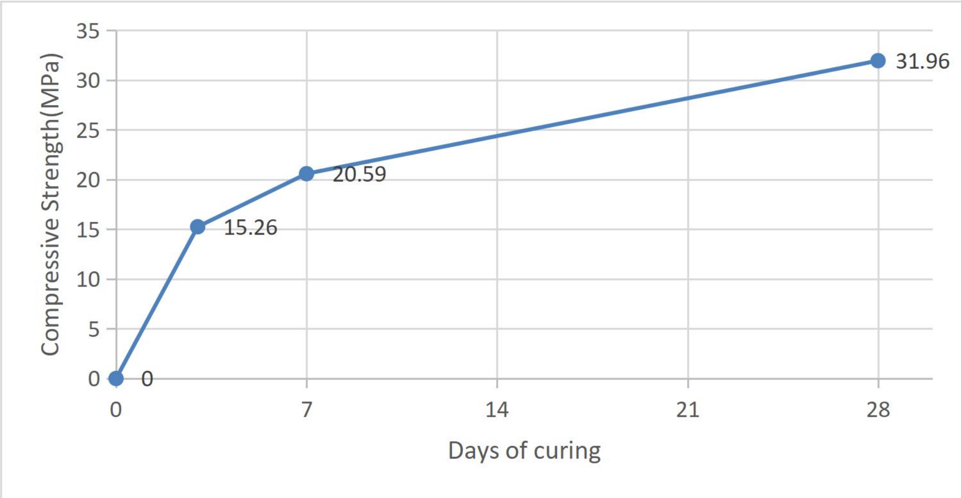
Table 5 Compressive Strength and avg. Modulus of Elasticity for M 30 concrete

S.N.	Description	CMC kg/m^3	AC kg/m^3	FA kg/m^3	Avg. Compressive Strength(MPa)	Avg. Modulus of Elasticity (GPa)
1	Control				31.96	
2	Concrete with CMC					
	CMC 1	0.69	-	-	26.50	
	CMC 2	1.38	-	-	24.03	
	CMC 3	2.07	-	-	23.20	
3	Concrete with CMC-AC					
	1AC-1	0.69	4.60	-	20.00	23156
	1AC-2	1.38	4.60	-	18.96	20755
	1AC-3	2.07	4.60	-	17.19	20605
	2AC-1	0.69	9.19	-	19.11	21441
	2AC-2	1.38	9.19	-	20.74	22820
	2AC-3	2.07	9.19	-	19.70	21324
	3AC-1	0.69	13.79	-	19.41	21900
	3AC-2	1.38	13.79	-	18.52	22527
	3AC-3	2.07	13.79	-	17.19	20045
4	Concrete with CMC-AC-FA					
	FA-1	1.38	9.19	61.65	16.74	19603
	FA-2	1.38	9.19	82.2	16.22	20848
	FA-3	1.38	9.19	102.75	15.63	19334
	FA-4	1.38	13.79	61.65	18.30	20346
	FA-5	1.38	13.79	82.2	18.59	19818
	FA-6	1.38	13.79	102.75	15.85	20551

The control contains mix design for M 30. Concrete with CMC include the same composition as control with additional CMC, concrete with CMC-AC include same composition as control with additional CMC and AC content, and concrete with CMC-AC-FA include same composition as control with addition of CMC, AC content and replacement of cement content with FA.

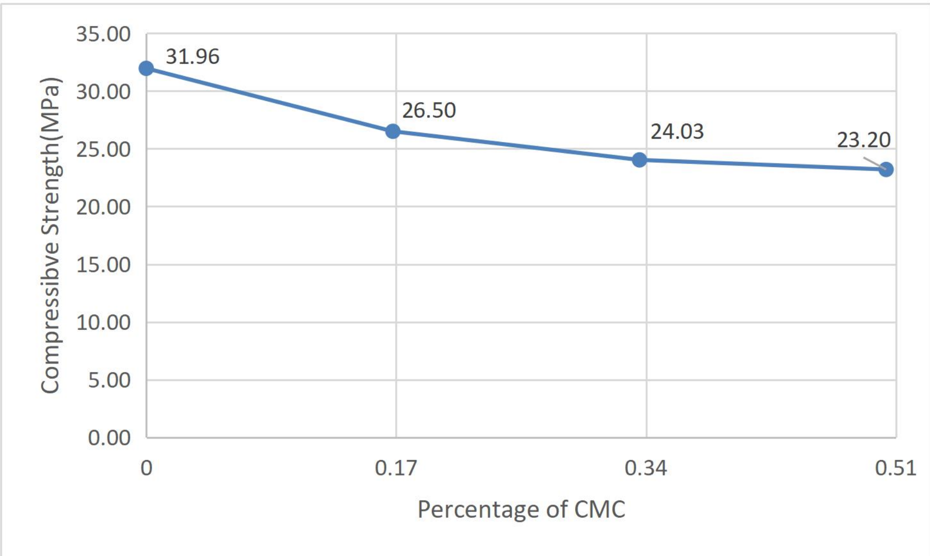
Compressive strength of control concrete was found to be 15.26 MPa, 20.59 MPa and 31.96 MPa for 3 days, 7 days and 28 days respectively.

Figure 7 Plot of compressive Strength of M 30 control vs days of curing



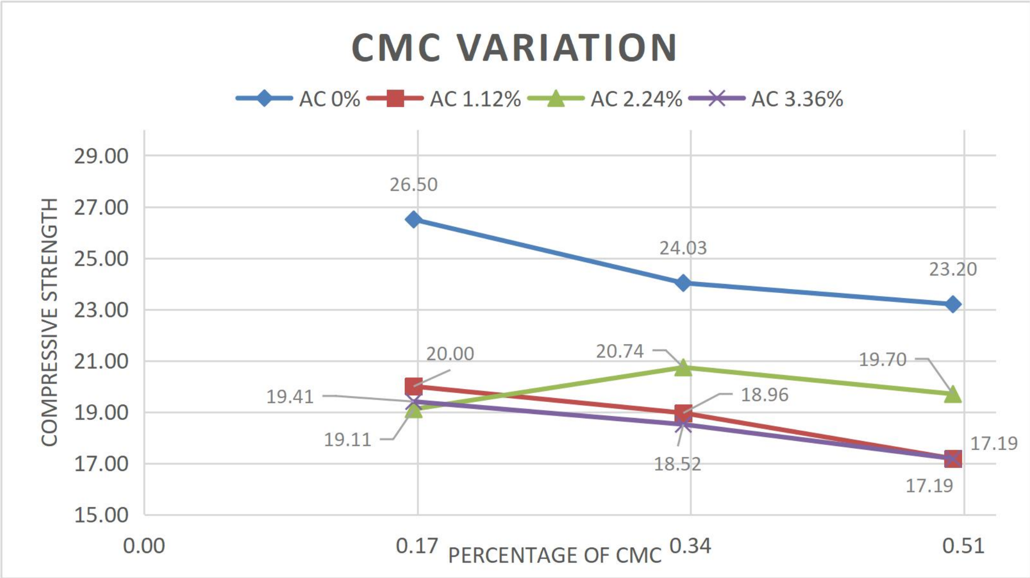
The 28-day compressive strength of CMC addition of 0.17%, 0.34%, 0.5% of cement mass on concrete was 24.87 MPa, 21.87 MPa, 21.27 MPa respectively.

Figure 8 Compressive strength plot for CMC concrete



The 28 day compressive strength of AC addition of 1.12%, 2.24%, 3.36% of cement mass on concrete for different ratio of CMC is plotted in below figure.

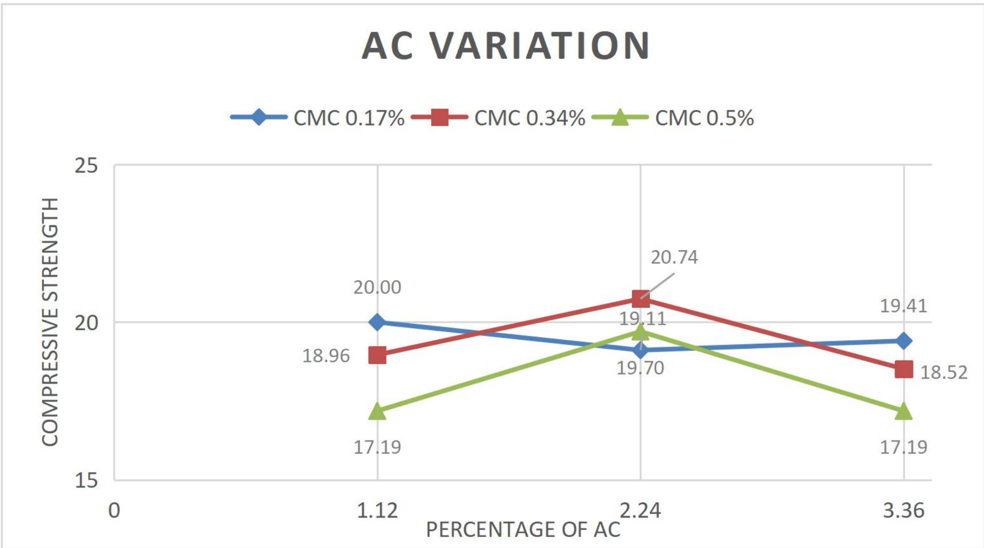
Figure 9 Compressive Strength plot for CMC-AC concrete CMC variation



On increasing the CMC content, compressive strength shows declination for every AC content except for AC 2.24% whose strength goes on increasing till 0.34% addition of CMC and slight drop in strength is seen.

The 28 day compressive strength of CMC addition of 0.17%, 0.34%, 0.5% of cement mass on concrete for different ratio of AC is plotted in below figure.

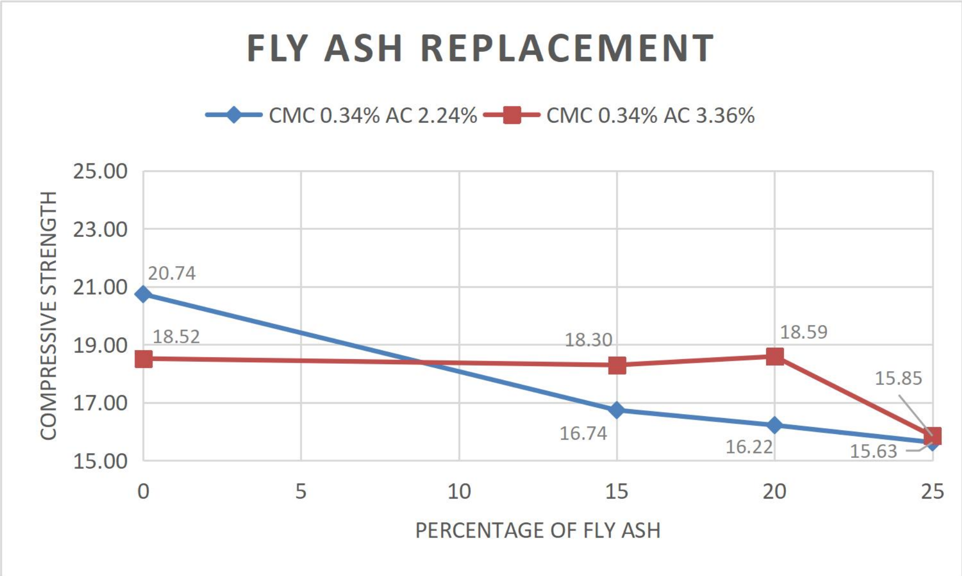
Figure 10 Compressive Strength plot for CMC-AC concrete AC variation



On increasing the AC content, compressive strength shows increment for 0.17% CMC content. Also, for other two CMC ratio compressive strength shows increment till 2.24% addition of AC and slight drop in strength is seen.

The 28 day compressive strength of CMC addition of 0.34% & AC addition of 2.24%, 3.36% of cement mass on concrete for different ratio of replacement of FA is plotted in below figure.

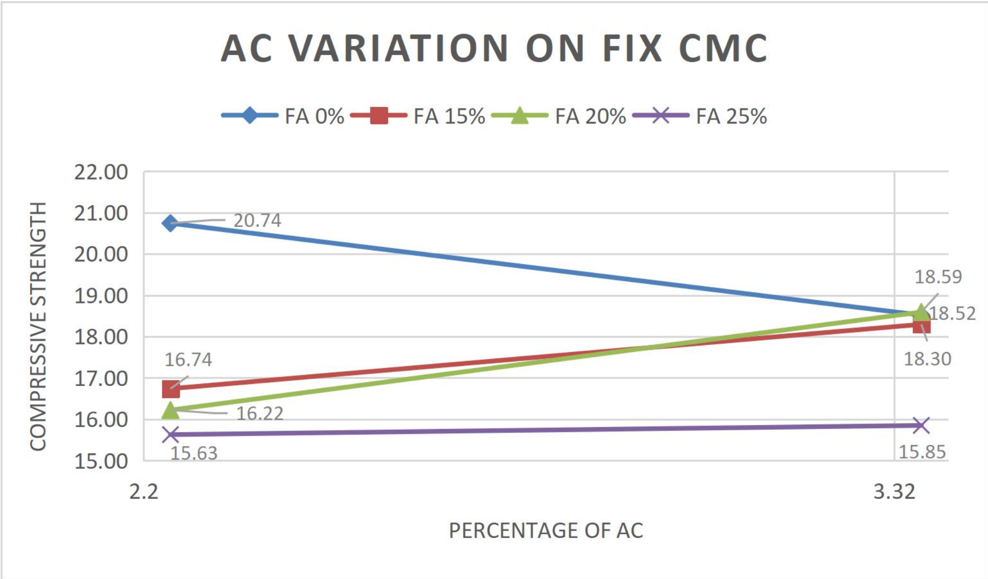
Figure 11 Compressive Strength plot for CMC-AC-FA concrete FA variation



For fix 0.34% CMC ratio, on increasing the FA replacement content, compressive strength shows decreasing trend for 2.24% AC & 0.34% CMC. Whereas, for 3.36% AC & 0.34% CMC compressive strength goes on increasing till 20% increment and decreased at 25% replacement.

The 28 day compressive strength of CMC addition of 0.34% & AC addition of 2.24%, 3.36% of cement mass on concrete for different ratio of replacement of FA is plotted in below figure.

Figure 12 Compressive Strength plot for CMC-AC-FA concrete AC variation



For fix 0.34% CMC ratio, on increasing the AC content, compressive strength shows decreasing trend for 0% FA. Whereas, for 15%, 20%, 25% replacement compressive strength goes on increasing. Among all this replacement 15% FA replacement seems to be good replacement. Also 20% FA replacement has similar compressive strength.

Compressive strength calculation are shown in ANNEX.

4.2 Modulus of Elasticity for M 30 grade

Strain gauge was used to find deflection in different load and from which strain is calculated and corresponding stress was plotted. From that, linear part in the diagram is noted in separate chart and linear line is drawn to find out modulus of elasticity.

For different addition to concrete, Stress Vs Strain plot for M 30 grade is only drawn and averaged to find out modulus of elasticity placed at Table and figure are placed in ANNEX.

From that Stress Vs Strain plot linear part is considered and st line is plotted and equation of straight line $y = m \times x + c$ is found out where m is slope of the equation known as modulus of elasticity and c is intercept length. This plot are placed in ANNEX. Also R^2 value is found out which refers to strength of the relationship between linear model and the dependent variable on a convenient 0 – 100% scale.

4.3 Compressive Strength for M 25 grade

The summary of results and discussion for M 25 grade is presented in below section.

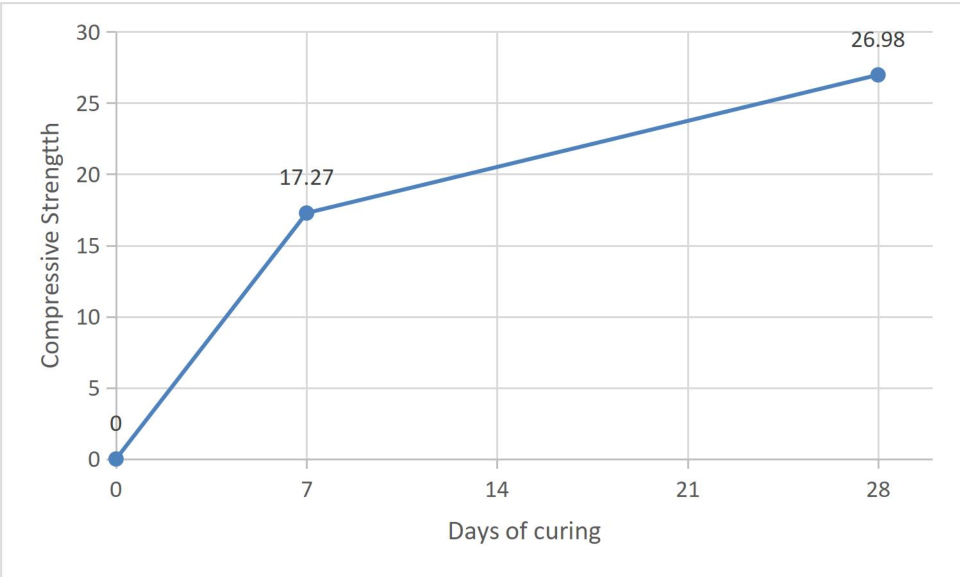
Table 6 avg. compressive strength for M 25 concrete

S.N.	Description	FA replacement %	CMC kg/m3	AC kg/m3	FA kg/m3	Avg. Compressive Strength(MPa)
1	Control					26.98
2	Concrete with CMC					
	CC 1	-	0.62	-	-	23.85
	CC 2	-	1.24	-	-	23.26
	CC 3	-	1.86	-	-	21.33
3	Concrete with AC					
	C1	-	-	4.14	-	20.00
	C2	-	-	8.28	-	26.67
	C3	-	-	12.41	-	21.19
3	Concrete with CMC-AC					
	C1C1	-	0.62	4.14	-	20.00
	C2C1	-	1.24	4.14	-	19.85
	C3C1	-	1.86	4.14	-	20.59
	C1C2	-	0.62	8.28	-	24.59
	C2C2	-	1.24	8.28	-	17.93
	C3C2	-	1.86	8.28	-	18.37
	C1C3	-	0.62	12.41	-	21.63
	C2C3	-	1.24	12.41	-	20.30
	C3C3	-	1.86	12.41	-	17.93
4	Concrete with AC-FA					
	CF1	15	-	4.14	55.5	25.93
	CF2	20	-	8.28	74	25.63
	CF3	25	-	12.41	92.5	26.96
5	Concrete with CMC-FA					
	CCF1	15	0.62	-	55.5	23.41
	CCF2	20	1.24	-	74	20.59
	CCF3	25	1.86	-	92.5	18.07

The control concrete contains mix design for M 25 including cement, fine aggregate, CA and water. Concrete with CMC include the same composition as control with addition of CMC. Concrete with AC contain same composition as control including addition of AC to concrete. Concrete with CMC-AC include same composition as control with additional CMC and AC content. Concrete with AC-FA contain same composition as control with additional AC and replacement to cement with FA content to mix. Concrete with CMC-FA contain same composition as control with additional CMC and replacement to cement with FA content to mix. The detail variation table is placed on ANNEX.

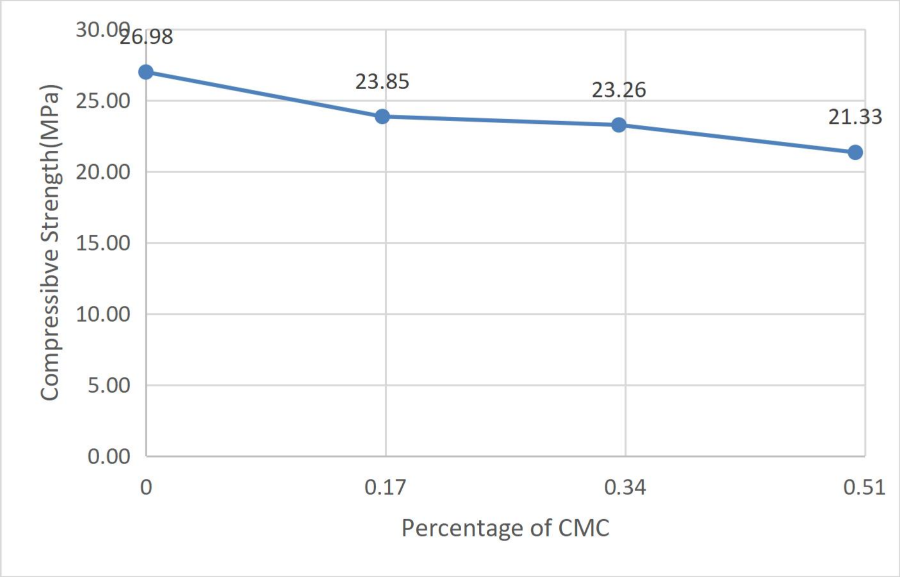
Compressive strength of control concrete was found to be 17.27 MPa and 26.98 MPa for 7 days and 28 days respectively.

Figure 13 Plot of compressive Strength of M 25 control vs days of curing



The 28-day compressive strength of CMC addition of 0.17%, 0.34%, 0.5% of cement mass on concrete was 23.85 MPa, 23.26 MPa, 21.33 MPa respectively.

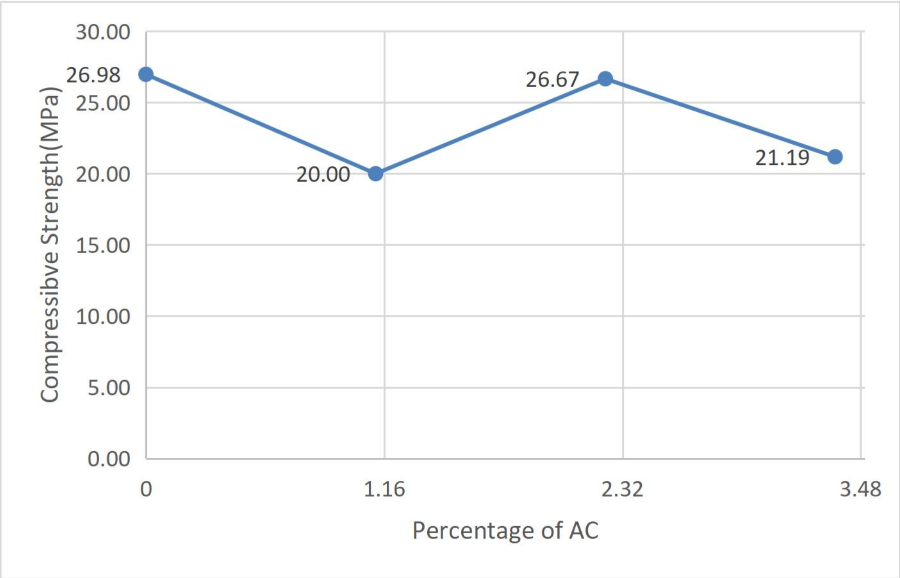
Figure 14 Compressive strength plot for CMC concrete



On increasing 0.17% of cement CMC content on concrete, decrease in compressive strength is seen.

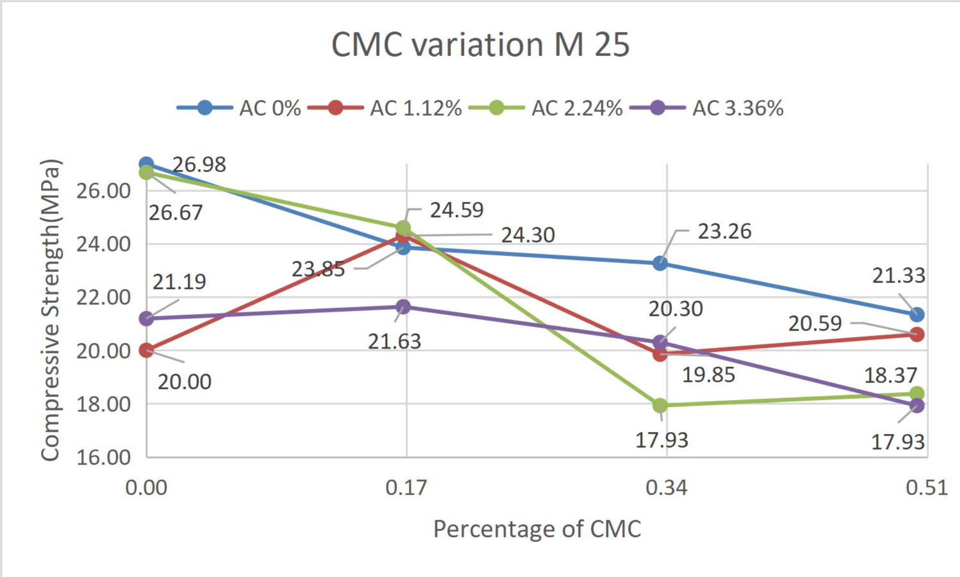
The 28-day compressive strength of AC addition of 1.12%, 2.24%, 3.36% of cement mass on concrete was 20 MPa, 26.67 MPa, 21.19 MPa respectively.

Figure 15 Compressive strength plot for AC concrete



The 28 day compressive strength of AC addition of 1.12%, 2.24%, 3.36% of cement mass on CMC-AC concrete for different ratio of CMC is plotted in below figure.

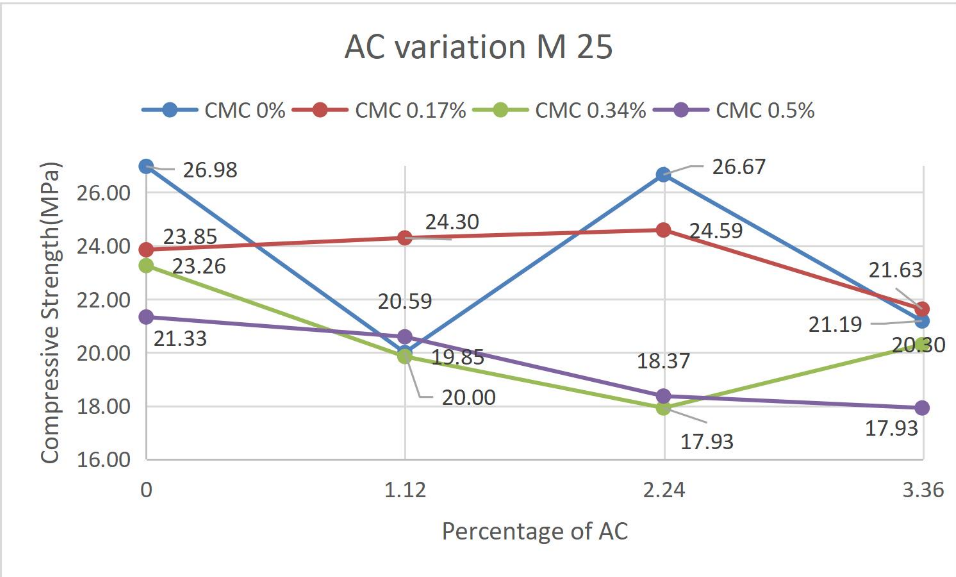
Figure 16 Compressive Strength plot for CMC-AC concrete CMC variation



On increasing the CMC content, compressive strength shows declination for every AC content. Except for AC 1.12% and AC 3.36% whose strength increases till 0.17% addition of CMC and eventually declination is seen.

The 28 day compressive strength of CMC addition of 0.17%, 0.34%, 0.5% of cement mass on CMC-AC concrete for different ratio of AC is plotted in below figure.

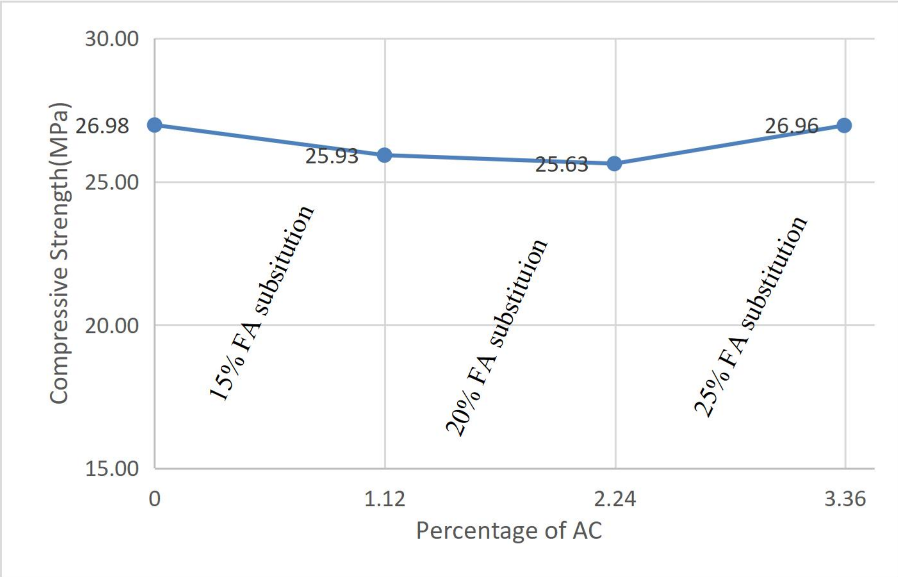
Figure 17 Compressive Strength plot for CMC-AC concrete AC variation



On increasing the AC content, compressive strength shows increment for CMC 0.17% till 2.24% AC addition. For other CMC ratio decrease is seen compressive strength in the case of CMC-AC concrete.

The 28 day compressive strength of AC-FA concrete for different substitution and addition of AC is presented below.

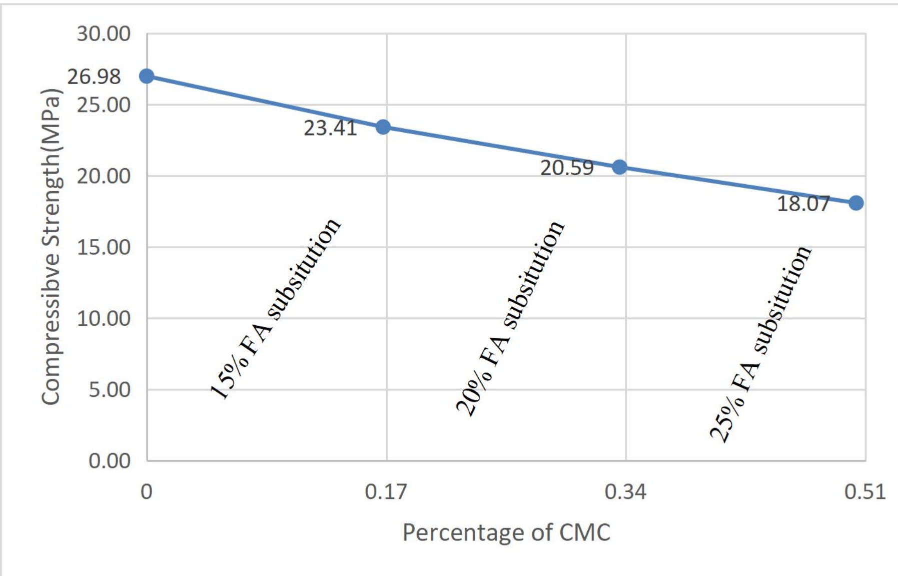
Figure 18 Compressive Strength plot for AC-FA concrete



AC-FA concrete shows no declination in compressive strength below 25 MPa upto 3.36% addition of AC.

The 28 day compressive strength of CMC-FA concrete for different substitution and addition of AC is presented below.

Figure 19 Compressive Strength plot for CMC-FA concrete

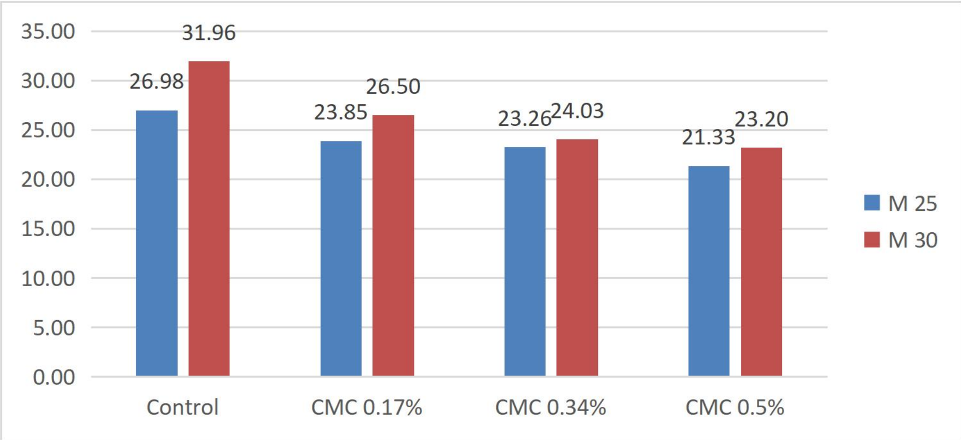


CMC-FA concrete shows declination in compressive strength below 25 MPa upto 0.5% addition of CMC. Compressive strength calculation are shown in ANNEX.

4.4 Comparison between M 30 and M 25 grade of concrete

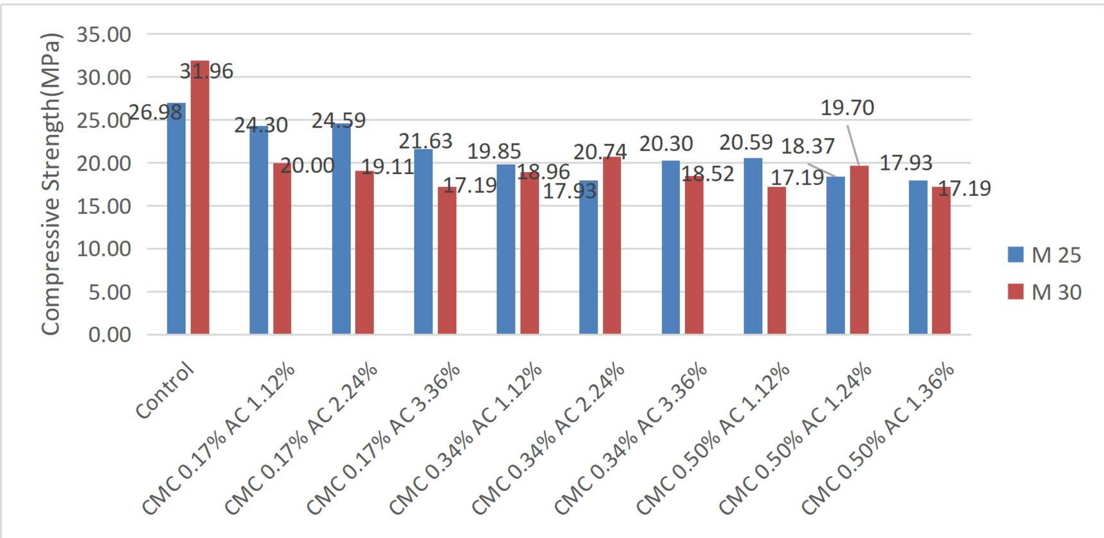
In CMC concrete, For M 30 grade concrete on increasing CMC content shows 12%, 20% and 23% decrease in compressive strength, whereas, M 25 shows 5%, 7% and 15% reduction as respective below shown addition.

Figure 20 Comparison chart for CMC concrete



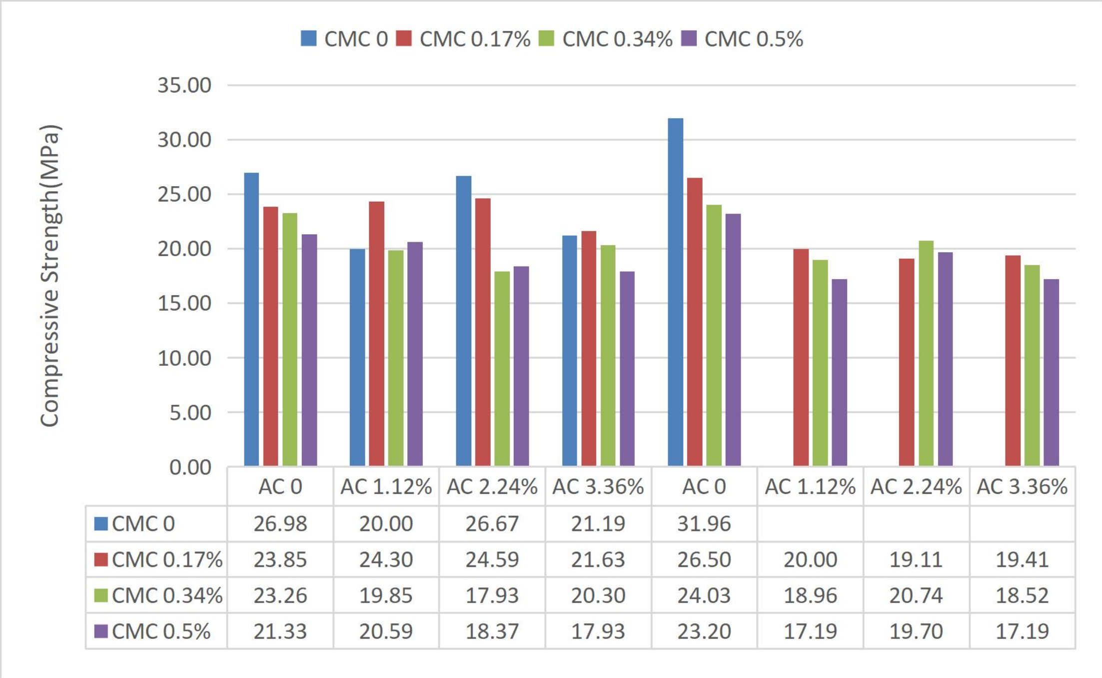
In CMC-AC concrete, comparison between every M 30 and M 25 is shown in below bar diagram. Maximum reduction in strength is seen up to 29% for M 25 and up to 43% for M 30 grade concrete. Among 9 CMC-AC concrete, 7 CMC-AC concrete for M 30 mix has less strength than of M 25 concrete.

Figure 21 Comparison chart for CMC-AC concrete



Summary table showing different CMC percentage for different mix of concrete. Right four joined bar chart is for M 30 concrete and other four for M 25.

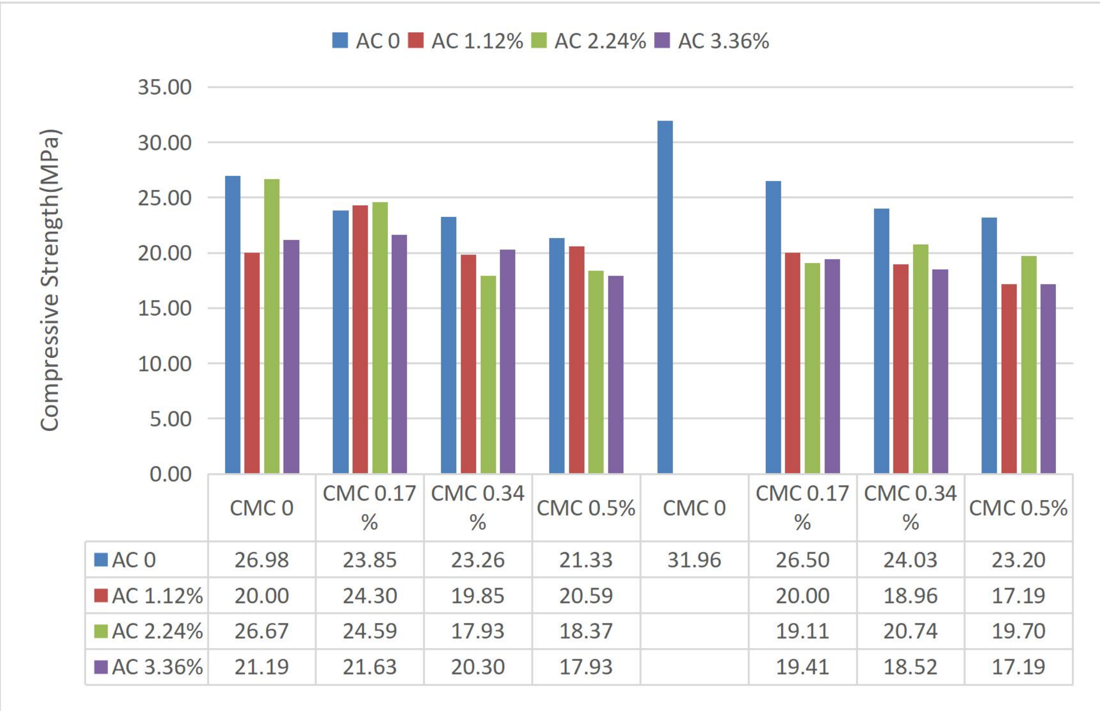
Figure 22 Comparison chart AC



	AC 0	AC 1.12%	AC 2.24%	AC 3.36%	AC 0	AC 1.12%	AC 2.24%	AC 3.36%
CMC 0	26.98	20.00	26.67	21.19	31.96			
CMC 0.17%	23.85	24.30	24.59	21.63	26.50	20.00	19.11	19.41
CMC 0.34%	23.26	19.85	17.93	20.30	24.03	18.96	20.74	18.52
CMC 0.5%	21.33	20.59	18.37	17.93	23.20	17.19	19.70	17.19

Summary table showing different AC percentage for different mix of concrete.

Figure 23 Comparison chart CMC



	CMC 0	CMC 0.17 %	CMC 0.34 %	CMC 0.5%	CMC 0	CMC 0.17 %	CMC 0.34 %	CMC 0.5%
AC 0	26.98	23.85	23.26	21.33	31.96	26.50	24.03	23.20
AC 1.12%	20.00	24.30	19.85	20.59		20.00	18.96	17.19
AC 2.24%	26.67	24.59	17.93	18.37		19.11	20.74	19.70
AC 3.36%	21.19	21.63	20.30	17.93		19.41	18.52	17.19

CHAPTER 5: CONCLUSION AND RECOMENDATIONS

5.1 Conclusion

Novel addition of AC, CMC, FA and plasticizer in attempt of creating sustainable concrete was done in this work. ACI method of mix design was adopted to cast M 30 and M 25 grade concrete. 19 batches of concrete were casted for M 30 grade of concrete and 22 batches of concrete were casted for M 25 grade concrete. Sand, aggregate, cement, water was tested in lab. Laboratory grade AC, CMC was used. Commercially, available FA and plasticizer was used. FTIR of fly ash has been done. Compressive Strength test and modulus of elasticity was found out for M 30 grade concrete. Compressive strength test of M 25 grade of concrete was calculated.

For M 30 grade concrete:

i. For CMC concrete, Increase in CMC content up to 0.5% addition in concrete shows decrease in 28-day compressive strength.

ii. For CMC-AC concrete, increasing the CMC content, compressive strength shows declination for every AC content except for AC 2.24% whose strength goes on slight increase till 0.34% addition of CMC and very slight drop in strength is seen.

iii. Drop of strength is distinctly seen for CMC-AC concrete.

iv. On increasing the AC content, compressive strength shows increment for 0.17% CMC content. Also, for other two CMC ratio compressive strength shows increment till 2.24% addition of AC and slight drop in strength is seen. This shows that AC is increasing strength in concrete.

v. For CMC-AC-FA concrete, compressive strength reduced 50 % upto 15.63 MPa.

For M 25 grade concrete,

i. For CMC concrete, increase in CMC content up to 0.5% addition in concrete shows decrease in 28-day compressive strength.

ii. For AC concrete, compressive strength was found to be declining for AC 1.12% whereas for AC 2.24% satisfactory result seen and again for AC 3.36% descent is seen.

iii. For CMC-AC concrete, On increasing the AC content, compressive strength shows increment for CMC 0.17% till 2.24% AC addition. For other CMC ratio decrease in compressive strength is seen.

iv. For AC-FA concrete, compressive strength do not decrease for any (FA 15% to FA 25%) and (AC 1.12% to 3.36%). So, we can conclude that on introduction of AC and FA on concrete has no negative impact on compressive strength.

v. For CMC-FA concrete, compressive strength of such concrete is inversely proportional to addition of CMC.

5.2 Recommendation

In the present work, laboratory grade AC and CMC were used. Modified AC and CMC could be used. Only 28-day compressive strength is calculated, for further research 7 days, 56 days & 90 days would be useful. Also, fresh concrete property, flexural strength, electrical resistivity would make great value.

Also, some useful recommendation for further study to make AC-CMC solution and mix design step is suggested below:

i. While mixing aqueous solution beaker was used. Instead, wide spread bucket could be used.

ii. Mixing CMC in surrounding temperature takes 6-10 hours in magnetic stirrer. while warm water will make it faster.

iii. At first mix CMC to little amount of water. And, place 1 liter warm water in wide spread bucket in magnetic stirrer for 30-45 min and solution is ready.

iv. Only after even aqueous solution AC should be added or agglomeration is seen.

v. Dry mix of aggregate is thoroughly mix for 5 min. After even texture, cement is added for 3-5 min. Then novel-character solution is placed. After even mix, plasticizer is placed and again mixed for 5 min and concrete is placed.

BIBLIOGRAPHY

ACI. (2014). Building Code Requirements for Structural Concrete (ACI 318-14). In *American Concrete Institute*.

ACI 211. (2002). *Standard Practice for Selecting Proportions for Normal, Heavyweight, and Mass Concrete (ACI 211.1-91)*.

Adeleke, O. A., Ismail, N., Fadilat, A., Apandi, N., Latiff, A. A. A., Saphira, M. R., Daud, Z., Ab Aziz, N. A., Al-Gheethi, A., Kumar, V., & Ahsan, A. (2019). Principles and Mechanism of Adsorption for the Effective Treatment of Palm Oil Mill Effluent for Water Reuse. In *Nanotechnology in Water and Wastewater Treatment: Theory and Applications* (pp. 1–33). Elsevier Inc. https://doi.org/10.1016/B978-0-12-813902-8.00001-0

Ahmaruzzaman, M. (2010). A review on the utilization of fly ash. *Progress in Energy and Combustion Science*, *36*(3), 327–363. https://doi.org/10.1016/j.pecs.2009.11.003

Akbar, A. Y., Lestari, Y., Ramadhan, G., Candra, S. A., & Sugiarti, E. (2014). The influence of carboxy methyl cellulose (CMC) and solution pH on carbon fiber dispersion in white cement matrix. *Applied Mechanics and Materials*, *493*, 661–665. https://doi.org/10.4028/www.scientific.net/AMM.493.661

Aprianti S, E. (2017). A huge number of artificial waste material can be supplementary cementitious material (SCM) for concrete production – a review part II. *Journal of Cleaner Production*, *142*, 4178–4194. https://doi.org/10.1016/j.jclepro.2015.12.115

CAT. (2022). Global reaction to energy crisis risks zero carbon transition. In *Climateactiontracker.Org* (Issue June). https://climateactiontracker.org/documents/1055/CAT_2022-06-08_Briefing_EnergyCrisisReaction.pdf

Dantas, T. L. P., Luna, F. M. T., Silva, I. J., de Azevedo, D. C. S., Grande, C. A., Rodrigues, A. E., & Moreira, R. F. P. M. (2011). Carbon dioxide-nitrogen separation through adsorption on activated carbon in a fixed bed. *Chemical Engineering Journal*, *169*(1–3), 11–19. https://doi.org/10.1016/j.cej.2010.08.026

Deja, J., Uliasz-Bochenczyk, A., & Mokrzycki, E. (2010). CO2 emissions from Polish cement industry. *International Journal of Greenhouse Gas Control*, *4*(4), 583–588.

https://doi.org/10.1016/j.ijggc.2010.02.002

Etsuo, S. (2003). *Molecular Structure and Dispersion-Adsorption Mechanisms*.

Farooque, K., Yeasmin, Z., Halim, M., Mahmood, A., & Mollah, M. (1970). Effect of Carboxymethyl Cellulose on the Properties of Ordinary Portland Cement. *Bangladesh Journal of Scientific and Industrial Research*, *45*(1), 1–8. https://doi.org/10.3329/bjsir.v45i1.5171

Farooque, K., Yeasmin, Z., Halim, M., Mahmood, A., & Mollah, M. (2010). Effect of Carboxymethyl Cellulose on the Properties of Ordinary Portland Cement. *Bangladesh Journal of Scientific and Industrial Research*, *45*(1), 1–8. https://doi.org/10.3329/bjsir.v45i1.5171

Fauzi, A., Nuruddin, M. F., Malkawi, A. B., & Abdullah, M. M. A. B. (2016). Study of Fly Ash Characterization as a Cementitious Material. *Procedia Engineering*, *148*, 487–493. https://doi.org/10.1016/j.proeng.2016.06.535

Fayomi, G. U., Mini, S. E., Fayomi, O. S. I., & Ayoola, A. A. (2019). Perspectives on environmental CO2 emission and energy factor in Cement Industry. *IOP Conference Series: Earth and Environmental Science*, *331*(1). https://doi.org/10.1088/1755-1315/331/1/012035

Fiore, A. M., Naik, V., Spracklen, D. V., Steiner, A., Unger, N., Prather, M., Bergmann, D., Cameron-Smith, P. J., Cionni, I., Collins, W. J., Dalsøren, S., Eyring, V., Folberth, G. A., Ginoux, P., Horowitz, L. W., Josse, B., Lamarque, J. F., Mac Kenzie, I. A., Nagashima, T., … Zeng, G. (2012). Global air quality and climate. *Chemical Society Reviews*, *41*(19), 6663–6683. https://doi.org/10.1039/c2cs35095e

García Lodeiro, I., Macphee, D. E., Palomo, A., & Fernández-Jiménez, A. (2009). Effect of alkalis on fresh C-S-H gels. FTIR analysis. *Cement and Concrete Research*, *39*(3), 147–153. https://doi.org/10.1016/j.cemconres.2009.01.003

GCCA. (2021). Concrete Future - The GCCA 2050 Cement and Concrete Industry Roadmap for Net Zero Concrete. In *Global Cement and Concrete Association*. https://gccassociation.org/concretefuture/wp-content/uploads/2021/10/GCCA-Concrete-Future-Roadmap.pdf

González-Kunz, R. N., Pineda, P., Bras, A., & Morillas, L. (2017). Plant biomass ashes in cement-based building materials. Feasibility as ecoefficient structural mortars and grouts. *Sustainable Cities and Society*, *31*, 151–172. https://doi.org/10.1016/j.scs.2017.03.001

Hamad, H. (2019). *Modification and performance of carbon fo carbon dioxide sequestration*. *April*.

Hollabaugh, C. B. (1945). CARBOXYMETHYLCELLULOSE Uses and Applications. In *Industrial & Engineering Chemistry* (pp. 943–947). https://doi.org/10.1021/ie50430a015

Horgnies, M., Serre, F., Dubois-brugger, I., & Gartner, E. (2014). NOx De - pollution Using Activated Charcoal Concrete - From Laboratory Experiments to Tests with Prototype Garages. *Cement and Concrete Research*, *42*(10), 1348–1355.

Huang, F. Y., Wu, X. J., Ying, W. F., Yu, Y. P., & Chi, H. X. (2014). Effect of carboxylmethyl cellulose sulfate (CMC-S) on the hydration process of cement paste. *Advanced Materials Research*, *838–841*, 123–126. https://doi.org/10.4028/www.scientific.net/AMR.838-841.123

IS10262, (2009).

ISI. (2013). IS 12269:2013. *Bureau of Indian Standards, New Delhi*.

Justo-Reinoso, I., Srubar, W. V., Caicedo-Ramirez, A., & Hernandez, M. T. (2018). Fine aggregate substitution by granular activated carbon can improve physical and mechanical properties of cement mortars. *Construction and Building Materials*, *164*, 750–759. https://doi.org/10.1016/j.conbuildmat.2017.12.181

Krou, N. J., Batonneau-Gener, I., Belin, T., Mignard, S., Javierre, I., Dubois-Brugger, I., & Horgnies, M. (2015). Reactivity of volatile organic compounds with hydrated cement paste containing activated carbon. *Building and Environment*, *87*, 102–107. https://doi.org/10.1016/j.buildenv.2015.01.025

Mahoutian, M., Lubell, A. S., & Bindiganavile, V. S. (2015). Effect of powdered activated carbon on the air void characteristics of concrete containing fly ash. *Construction and Building Materials*, *80*, 84–91. https://doi.org/10.1016/j.conbuildmat.2015.01.019

Malhotra, M. V., Zhang, M. H., Read, P. H., & Ryell, J. (2000). Long-term mechanical properties and durability characteristics of high-strength/high-performance concrete incorporating supplementary cementing materials under outdoor exposure conditions. *ACI*

Structural Journal, *97*(5), 518–525. https://doi.org/10.14359/9284

Marsh, H., & Reinoso, F. R. (2006). *Activated Carbon*. Elsevier.

Mishra, S., Kenna-o, D., Sonam, L., Pamtheid, P., & Taram, R. (2015). *Effects of Fly Ash and Super Plasticiser on Cement Content in M30 Grade Concrete*. *1*, 2411–2416. https://doi.org/10.15680/IJIRSET.2015.0404121

Mishra, Singh, V. K., Narang, K. K., & Singh, N. K. (2003). Effect of carboxymethyl-cellulose on the properties of cement. *Materials Science and Engineering A*, *357*(1–2), 13–19. https://doi.org/10.1016/S0921-5093(02)00832-8

Naik, T. (1987). *Setting and hardening of high fly ash content concrete. Paper presented at Washington, the American Coal Ash Association's 8th International Coal Ash Utilization Symposium. USA*.

PCA. (2023). *Portland Cement Association*. https://www.cement.org/

Pellenq, R. J. M. (2019). United States Patent Application Publication (10) Pub . No . : US 20190218144A1 Patent Application Publication. In *Physical Chemistry Chemical Physics*.

Plank, J., Schroefl, C., Gruber, M., Lesti, M., & Sieber, R. (2009). Effectiveness of polycarboxylate superplasticizers in ultra-high strength concrete: The importance of PCE compatibility with silica fume. *Journal of Advanced Concrete Technology*, *7*(1), 5–12. https://doi.org/10.3151/jact.7.5

Plaza, M. G., González, A. S., Pevida, C., Pis, J. J., & Rubiera, F. (2012). Valorisation of spent coffee grounds as CO2 adsorbents for postcombustion capture applications. *Applied Energy*, *99*, 272–279. https://doi.org/10.1016/j.apenergy.2012.05.028

Puligilla, S., & Mondal, P. (2015). Co-existence of aluminosilicate and calcium silicate gel characterized through selective dissolution and FTIR spectral subtraction. *Cement and Concrete Research*, *70*, 39–49. https://doi.org/10.1016/j.cemconres.2015.01.006

Qiu, J., Xu, L., Peng, J., Zhai, M., Zhao, L., Li, J., & Wei, G. (2007). Effect of activated carbon on the properties of carboxymethylcellulose/activated carbon hybrid hydrogels synthesized by γ-radiation technique. *Carbohydrate Polymers*, *70*(2), 236–242. https://doi.org/10.1016/j.carbpol.2007.04.001

Sama, T. (2020). *Effect of Nano Cellulose and Nano Carbon Black on Cement Paste*.

Shafeeyan, M. S., Daud, W. M. A. W., Houshmand, A., & Arami-Niya, A. (2011). Ammonia modification of activated carbon to enhance carbon dioxide adsorption: Effect of pre-oxidation. *Applied Surface Science*, *257*(9), 3936–3942. https://doi.org/10.1016/j.apsusc.2010.11.127

Taylor, H. F. W. (1997). Cement chemistry. *Cement Chemistry*. https://doi.org/10.1680/cc.25929

Tommaso, M. Di, & Bordonzotti, I. (2016). *NO x Adsorption, Fire Resistance and CO 2 Sequestration of High Performance, High Durability Concrete Containing Activated Carbon *Istituto Meccanica dei Materiali SA (IMM SA) † Gamatec SA Second International Conference on concrete Sustainability, Madrid*. *x*. www.imm.ch

United Nations. (2022). *Emissions Gap Emissions Gap Report 2022*. https://www.unenvironment.org/interactive/emissions-gap-report/2019/

Wang, D., Zhang, W., & Han, B. (2020). New generation of cement-based composites for civil engineering. In *New Materials in Civil Engineering* (pp. 777–795). Elsevier. https://doi.org/10.1016/B978-0-12-818961-0.00025-9

Wang, H., Gao, X., & Wang, R. (2017). The influence of rheological parameters of cement paste on the dispersion of carbon nanofibers and self-sensing performance. *Construction and Building Materials*, *134*, 673–683. https://doi.org/10.1016/j.conbuildmat.2016.12.176

Zhang, Y., Wang, Y., Yang, C., Li, G., & Yan, H. (2017). Study on the reduction of radon exhalation rates of concrete with different activated carbon. *Key Engineering Materials*, *726 KEM*(2), 558–563. https://doi.org/10.4028/www.scientific.net/KEM.726.558

ANNEX

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ANNEX-A: Choice of Materials

I. OPC Cement Test Report

Image 7 OPC test report

TRIBHUVAN UNIVERSITY
INSTITUTE OF ENGINEERING
PULCHOWK CAMPUS
DEPARTMENT OF CIVIL ENGINEERING
CENTRAL MATERIAL TESTING LABORATORY
TEST STATEMENT

CEMENT TEST

Project :	NA	Report No:	7911CMTL032
Client :	Adarsha Chauhan/Gaurav Raj Neupane (Material Science and Engineering)	Date :	10/2/2079
Contractor :	NA	Standard:	IS 4031-1988
Contract No:	NA		
Brand/Type:	Shivam OPC (53 Grade)		
Sand:	Standard Sand		
Water:	Tap Water		

Physical Properties:

Room Temperature	=	NA °C	Prefered : (27 ± 2 °C)
Relative Humidity	=	NA	Prefered : (65 ± 5 %)
Normal Consistency	=	30.5 %	
Initial Setting Time	=	91 Min.	IS (30 Minutes)
Final Setting Time	=	216 Min.	IS (600 Minuets)

Compressive Strength

		3 Days Result			7 Days Result			28 Days Result		
Sample No.		1	2	3	1	2	3	1	2	3
Date of Casting		9/4/2079								
Date of Testing		9/7/2079			9/11/2079			10/2/2079		
Age	Days	3			7			28		
Sample Size	mm	70.0 x 70.0 x 70.0			70.0 x 70.0 x 70.0			70.0 x 70.0 x 70.0		
Area of Sample	mm^2	4900	4900	4900	4900	4900	4900	4900	4900	4900
Vol. of Sample	cm^3	343	343	343	343	343	343	343	343	343
Load	kN	181.59	157.17	176.28	221.00	202.52	213.41	274.52	276.75	284.17
Comp. Strength	N/mm^2	37.058	32.076	35.976	45.102	41.331	43.552	56.025	56.479	57.995
Avg. Comp. Strength	N/mm^2	**35.04**			**43.33**			**56.83**		
Weight	gm	845	839	848	854	835	846	845	854	847
Density	T/m^3	2.46	2.45	2.47	2.49	2.43	2.47	2.46	2.49	2.47

Note: Material supplied by Adarsha Chauhan/Gaurav Raj Neupane (Material Science and Engineering)

Tested By	Checked By	Approved By
(Jr. Er. Lilambar Kr. Sah)	(Mr. Rajendra Raj Panta)	(Str. Er. Arun Paudel)

Ananda Niketan, Pulchowk, Lalitpur, Nepal, Tel. 5548835, Email: cmtl@ioe.edu.np, www.pcampus.edu.np/

II. Sand/CA Test

i. Determination of FM of aggregate was done according to ASTM C128 and ASTM C33 Sampling of fine aggregate and CA was done according to ASTM D75

ii. Determination of dry rodded bulk density of CA was done according to ASTM C29 Seive analysis of CA was done according to ASTM C136-01

iii. Specific Gravity of CA was done according to ASTM C 127-88 Specific Gravity of FA was done according to ASTM C 128-97

iv. Water Content of FA and CA was done according to ASTM D2216 − 19

avg. FM of Sand = 2.78

Dry rodded bulk density was found to be 1575.61 kg/m^3.

CA water content = 0%; Sand water content= 8%

Mean bulk specific gravity (SSD) was found to be 1636

i. FM of Sand

Sankhu Sample A wt. of sample 600gm

Seive Size	**wt. of seive(gm)**	**wt. of seive and sand(gm)**	**wt. of sand retained (gm)**	**Percentage wt. retained (%)**	**Cumulative percentage wt. retained (%)**
4.75mm	420	502.5	82.5	13.8	13.8
2.36mm	323	345	24.5	4.1	17.8
1.18mm	308.5	416.5	108	18.0	35.8
600µm	344.5	440.5	96	16.0	51.8
300µm	325.5	455	129.5	21.6	73.4

150µm	298.5	402	103.5	17.3	90.7
Pan	400.5	456.5	56	9.3	
			600		283.3
				FM	**2.83**

Sankhu Sample B wt. of sample 600gm

Seive Size	**wt. of seive(gm)**	**wt. of seive and sand(gm)**	**wt. of sand retained (gm)**	**Percentage wt. retained (%)**	**Cumulative percentage wt. retained (%)**
4.75mm	420	495	75	12.5	12.5
2.36mm	323	344	21	3.5	16.0
1.18mm	308.5	409.5	101	16.8	32.8
600µm	344.5	442	97.5	16.3	49.1
300µm	325.5	460.5	135	22.5	71.6
150µm	298.5	411	112.5	18.8	90.3
Pan	400.5	458.5	58	9.7	
			600		272.3
				FM	**2.72**

Sankhu Sample C

wt. of sample 600gm

Seive Size	wt. of seive(gm)	wt. of seive and sand(gm)	wt. of sand retained (gm)	Percentage wt. retained (%)	Cumulative percentage wt. retained (%)
4.75mm	420	501	81	13.5	13.5
2.36mm	323	347	24	4.0	17.5
1.18mm	308.5	410	101.5	16.9	34.4
600µm	344.5	440.5	96	16.0	50.4
300µm	325.5	458	132.5	22.1	72.5
150µm	298.5	410.5	112	18.7	91.2
Pan	400.5	453.5	53	8.8	
			600		279.5
				FM	**2.80**

Avg. FM= 2.78

ii. Dry rodded bulk density

wt. of container 967 g

wt. of water and container 2830 g

Temperature of water 25^0C

Temperature of water(^{0}C)	**Density of water(kg/m^3)**
21.1	997.97
26.7	996.59

25	?

Interpolating for 25^0C we get density of water **997.01** **kg/m^3**

wt. of water 1863 g

Volume of water 0.0019 m^3

Sample	wt. of aggregate and container(kg)	wt. of container(kg)	Volume of water(m^3)	Dry rodded Bulk Density(kg/m^3)
A	3.904	0.967	0.0019	1545.79
B	3.984	0.967	0.0019	1587.89
C	3.994	0.967	0.0019	1593.16
			Mean	1575.61

Dry rodded bulk density = **1575.61 kg/m^3**

iii. CA sieve analysis

Sample A Sankhu

Sieve Size	wt. of sieve(g)	wt. of sieve and CA(g)	wt. of CA retained (g)	% wt. retained	Percentage Passing (%)
19 mm	907.5	1017.5	110	4.4	95.6
12.5 mm	772	2560.5	1788.5	71.54	24.06

9.5 mm	809	1172.5	363.5	14.54	9.52
4.75 mm	812	1023	211	8.44	1.08
Pan	887.5	914.5	27	1.08	0
			2500		

Sample B Sankhu

Sieve Size	wt. of sieve(g)	wt. of sieve and CA(g)	wt. of CA retained (g)	% wt. retained	Percentage Passing (%)
19 mm	907.5	1040.5	133	5.32	94.68
12.5 mm	772	2635	1863	74.52	20.16
9.5 mm	809	1112	303	12.12	8.04
4.75 mm	812	996	184	7.36	0.68
Pan	887.5	904.5	17	0.68	0
			2500		

iv. Water content of CA and sand

For M 30 mix

Determination of water content

S.N.	Description	wt. of container (w1)	Wet sample + container wt. (w2)	Dry sample+ container wt. (w3)	water Content	wt. of water / wt of dry sample
1	CA A	700	11200			
2	CA B-1010	853	1103	1102.5	0.002	0.3%
3	CA C-1051	838.5	1088.5	1087.5	0.004	
4	CA D-1004	837.5	1087.5	1087	0.002	
5	FiA 1051	10.51	30.51	29.16	0.072	8%
6	FiA 1004	10.08	30.08	28.54	0.083	
7	FiA 1010	9.18	29.18	27.66	0.082	
8	Fi F	874	3874			

For M 25 mix, Determination of moisture content ASTM D2216

S.N.	Description	wt. of container(w1)	Wet sample+ container wt. (w2)	Dry sample+ container wt. (w3)	Moisture Content	wt. of water / wt of dry sample
1	CA-1(Main)	240	710	710	0.00	0

2	CA-2(Black)	335	885	885	0.00	
3	CA-3(Bronge)	480	925	925	0.00	
4	FiA-1(3)	9.452	37.399	35.661	6.63	
5	FiA-2(10)	9.511	35.242	33.717	6.30	
6	FiA-3(1002)	11.516	41.293	39.415	6.73	6.55

v. Specific Gravity of CA

Mass of container A and field condition of CA	11200
Mass of container A and oven dry CA	10487.5
Mass of oven dry CA	9787.5

Dividing above sample into three equal parts i.e. 3262g for CA-A

The divided sample is immersed in water for 24 hours and weighed.

Sample	Mass of SSD CA in air(g)	Mass of Saturated CA in water(g)	Bulk Specific Gravity (SSD)
Container P	3272	3270	1636
Container Q	3272	3270	1636
Container R	3272	3270	1636

Mean bulk specific gravity(SSD) was found to be 1636

III. AC Specification

Table 8 AC Specification

Headings	Index
CAS	7440-44-0
Molecular Formula	C
Molecular wt. (g/mol)	12.01
MDL Number	MFCD00133992
InChI Key	OKTJSMMVPCPJKN-UHFFFAOYSA-N
Synonym	acticarbone
PubChem CID	5462310
ChEBI	CHEBI:27594
IUPAC Name	carbon
SMILES	[C]
Formula wt.	12.01
Chloride	0.2% Max
Packaging	Composite Container
Sulfate	0.2% Max
Loss on Drying	10% Max (at 120°C)
Heavy Metals	0.005% Max (as Pb)
Density	1.8g/mL
Residue after Ignition	5% Max
Melting Point	3652°C
Quantity	500g
Appearance	Black fine powder
pH	2.0-3.5

IV. CMC Specification

Table 9 CMC Specification

Headings	**Index**
Appearance	White to yellow to light tan powder
Solubility	10 mg soluble in 1 mL of water
pH (1% in water at 25 deg Celsius)	6.50- 8.00
FTIR	Matches with the standard pattern
Loss on drying (at 110°C, 2 hrs.)	<= 15.00%
Viscosity (2% in water at 25°C)	400 - 800 cps
WGK	1
Storage Temperature(°C)	Store below 30°C
Product Name	Carboxymethylcellulose sodium salt, Medium viscosity (CMC)
Synonym	Sodium carboxymethylcellulose
Shelf Life	4 years

V. FA Specification and FTIR

Commercially available class F fly ash from Dirk India Pvt. Ltd. supplied by Acme Engineering Associates, Pulchowk, Lalitpur has below proclaimed specification.

Image 8 FA Specification

Dirk India Pvt. Limited

Regd Office:10, India House, Geetanjali Colony, Indiranagar, Nasik - 422009
Phone:(0253) 2322816, 2322815, Fax:(0253) 2326678
www.pozzocrete.co.in www.dirkgroup.com

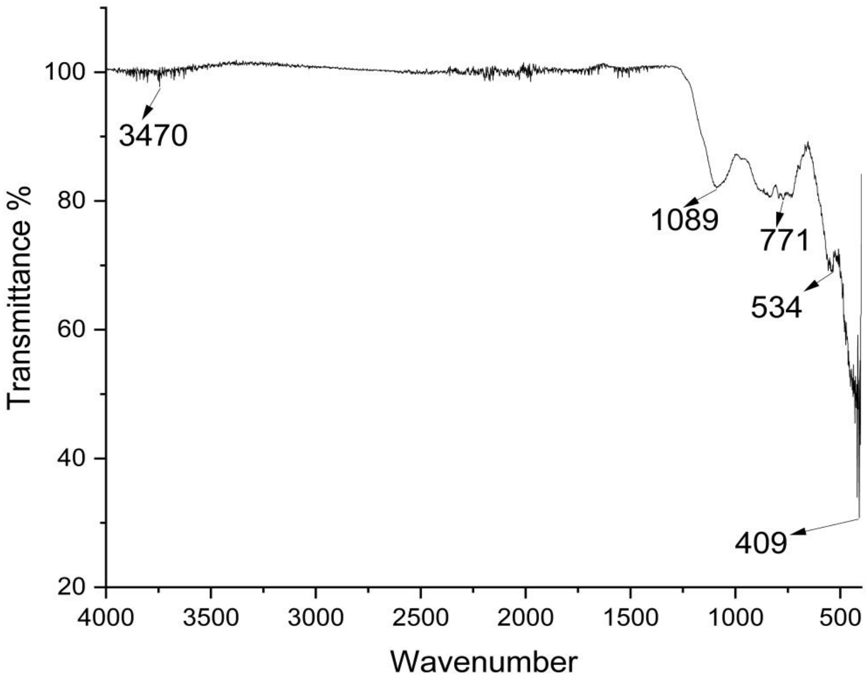
Document No.:	F/QC/007 -A
Rev	0

Pozzocrete 60

SPECIMEN TEST CERTIFICATE

Test No.	Test	Unit	EN 450-Specification 'S Category'	Pozzocrete 60 Typical Test Results
1	Fineness - Specific Surface by Blaine's Permeability Method(Min.)	m^2/kg	320	340
2	ROS # 350(45 MIC) Max.	%	34	17.20
3	Lime Reactivity(Minimum)	N/mm^2	4.5	5.48
4	Moisture Content(Max.)	%	2	0.27
5	Autoclave Expansion(Max.)	%	0.8	0.029
6	Compressive Strength At 28 days -	N/mm^2	80% of strength of plain cement mortar cubes (min.)	
	Pozzocrete + Cement Mortar			32.11 96.14%
	Plain Cement Mortar			33.40
7	Chemical Analysis			
	Test %	IS- Specification		
	Loss on Ignition (Max.)	%	5	1.60
	$SiO_2 + Al_2O_3 + Fe_2O_3$	%	70 min. by mass	92.49
	SiO_2	%	35 min. by mass	57.30
	MgO	%	5 max. by mass	2.13
	SO_3	%	3.00 max. by mass	1.06
	Na_2O	%	1.5 max. by mass	0.73
	Total Chlorides	%	0.05 max. by mass	0.029

Image 9 FA FTIR test



In FTIR analysis, there are typically six band ranges. The band area and indicator details for fly ash are presented in the table below(García Lodeiro et al., 2009; Puligilla & Mondal, 2015):

Table 10 Indication for different peaks in band range

Band Range(cm^{-1})	Indication	Peak Number
4000-3500	Loss of $Ca(OH)_2$	0
3500-1600	Stretching (-OH), bending (H-O-H)	0
1600-1000	Gains Si-O-Si bands typical of quartz	1
1000-800	Loss of gel $CaCO_3$	0
800-500	Symmetric stretching of Si-O-Si and Al-O-Si	2
<500	Bending vibrations of Si-O-Si and O-Si-O bonds	1
Total Band Points		4

This fly ash has a total of four band points. More peak number suggests increased production of (C-S-H) & (C-A-H) and structural bond(Si-O-Al) & (-Si-O-Si-) in the band range 800-500 cm^{-1}(Fauzi et al., 2016).

VI. Plasticizer Specification

Image 10 PCE Specification

A&A

Additives & Allied Industries

ADMIXTURES
TECHNICAL DATASHEET

PROPERTIES

Main Ingredient	: Polycarboxylic ether
Appearance	: Light Brown liquid
PH	: 7 ± 1
Specific Gravity	: 1.10 ± 0.02
Sett ing & Hardening	: Even at high dosage it dose not have retarding effect on the setting time.
Chloride Content	: Nil. as per BS - 5075 (Part-I)
Compatibility	: Can be used with all types of OPC, Pozzolana Cement including Sulphate Resisting Cement.
Consistency	: FLOWGEL is formulated from carefully selected raw material and manufactured under controlled conditions to give a consistent product.
Handling	: FLOWGEL is formulated from chemicals which present no fire or health hazards.
Toxicity	: Non-toxic
Shelf Life	: If stored in unopened containers at normal ambient temp., a shelf-life of approx. 12 months could be expected.

METHOD OF USE

FLOWGEL is supplied ready for use. For maximum dispersion throughout the mix, measured quantity of FLOWGEL should be directly added into the mixer at the same time as the mixing water. On no account should it be added to the dry cement. To achieve the best results, the mixer along with material should be rotated for at least 2-3 minutes.

RATE OF ADDITION

The optimum dosage should be determined by site trials with the particular concrete mix. As a guide the rate of addition is generally in the range of 0.2-1.5% on cement wt.(w/w)

PACKING

FLOWGEL is available in 15, 20, 40, 100 & 200 Kgs. Carbuoys.

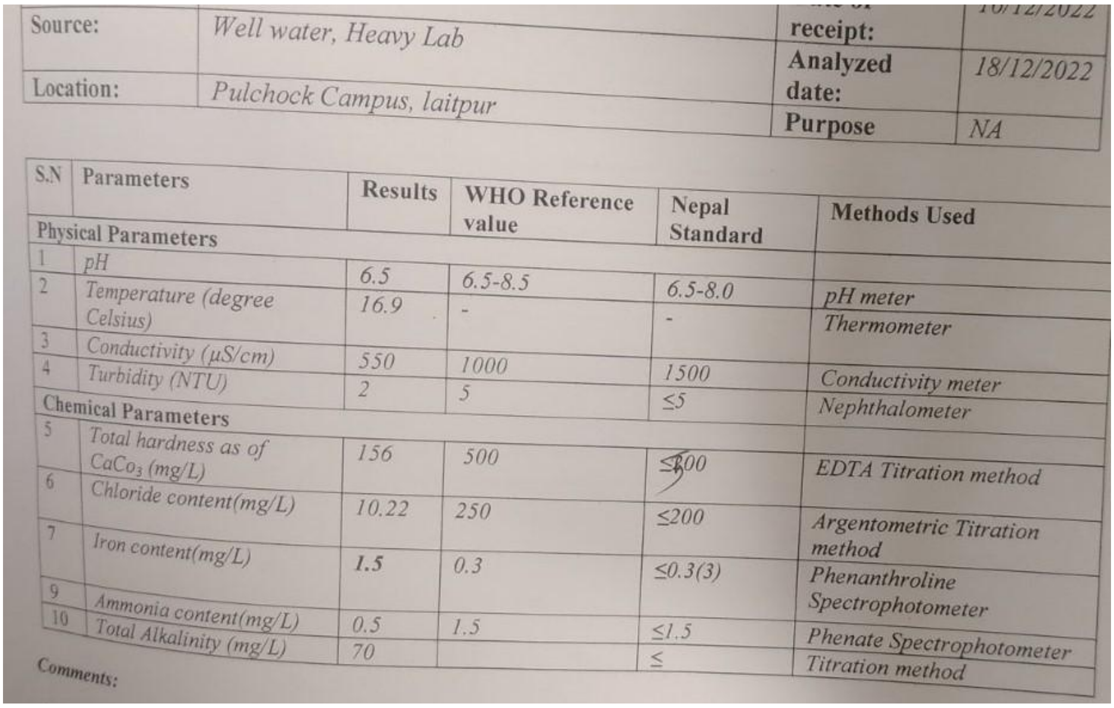
A&A

Additives & Allied Industries
Kathmandu, Nepal.

VII. Water Test

Water quality test report is presented from Water Lab, Department of Civil Engineering, Pulchowk Campus.

Image 11 Water Test Report



Source:	*Well water, Heavy Lab*	[illegible] receipt:	[illegible]
		Analyzed date:	*18/12/2022*
Location:	*Pulchock Campus, laitpur*	Purpose	*NA*

S.N	Parameters	Results	WHO Reference value	Nepal Standard	Methods Used
Physical Parameters					
1	*pH*	*6.5*	*6.5-8.5*	*6.5-8.0*	*pH meter*
2	*Temperature (degree Celsius)*	*16.9*	-	-	*Thermometer*
3	*Conductivity (μS/cm)*	*550*	*1000*	*1500*	*Conductivity meter*
4	*Turbidity (NTU)*	*2*	*5*	*≤5*	*Nephthalometer*
Chemical Parameters					
5	*Total hardness as of $CaCo_3$ (mg/L)*	*156*	*500*	*≤500*	*EDTA Titration method*
6	*Chloride content(mg/L)*	*10.22*	*250*	*≤200*	*Argentometric Titration method*
7	*Iron content(mg/L)*	***1.5***	*0.3*	*≤0.3(3)*	*Phenanthroline Spectrophotometer*
9	*Ammonia content(mg/L)*	*0.5*	*1.5*	*≤1.5*	*Phenate Spectrophotometer*
10	*Total Alkalinity (mg/L)*	*70*		*≤*	*Titration method*

Comments:

ANNEX-B: MIX DESIGN

I. Table Volume Calculation for casting of M 30 concrete

Description	No. of cubes	Wet volume of cube (m3)	Dry volume of cube (m3)	Quantity of Cement (kg)	Quantity of plasticizer(ml)	Quantity of Sand(Kg)	Quantity of coarse aggregate(kg)	Quantity of water(kg)	Quantity of CMC (in gm)	Quantity of AC(gm)	Fly Ash(Kg)
Control	9	0.03	0.045	18.48	221.72	39.35	42.30	5.17			
with CMC	3	0.01	0.015	6.17	73.98	13.13	14.11	1.72	10.34		
	3	0.01	0.015	6.17	73.98	13.13	14.11	1.72	20.69		
	3	0.01	0.015	6.17	73.98	13.13	14.11	1.72	31.03		
CMC-AC	3	0.01	0.015	6.17	73.98	13.13	14.11	1.72	10.34	68.95	
	3	0.01	0.015	6.17	73.98	13.13	14.11	1.72	20.69	68.95	
	3	0.01	0.015	6.17	73.98	13.13	14.11	1.72	31.03	68.95	
	3	0.01	0.015	6.17	73.98	13.13	14.11	1.72	10.34	137.90	
	3	0.01	0.015	6.17	73.98	13.13	14.11	1.72	20.69	137.90	
	3	0.01	0.015	6.17	73.98	13.13	14.11	1.72	31.03	137.90	
	3	0.01	0.015	6.17	73.98	13.13	14.11	1.72	10.34	206.86	
	3	0.01	0.015	6.17	73.98	13.13	14.11	1.72	20.69	206.86	
	3	0.01	0.015	6.17	73.98	13.13	14.11	1.72	31.03	206.86	
CMC-AC-FA	3	0.01	0.015	6.17	73.98	13.13	14.11	1.72	20.69	137.90	0.92
	3	0.01	0.015	6.17	73.98	13.13	14.11	1.72	20.69	137.90	1.23
	3	0.01	0.015	6.17	73.98	13.13	14.11	1.72	20.69	137.90	1.54
	3	0.01	0.015	6.17	73.98	13.13	14.11	1.72	20.69	137.90	0.92
	3	0.01	0.015	6.17	73.98	13.13	14.11	1.72	20.69	137.90	1.23
	3	0.01	0.015	6.17	73.98	13.13	14.11	1.72	20.69	137.90	1.54
	63	0.21 m^3	0.31 m^3	129.45 kg	1553.36 ml	275.71 kg	296.32 kg	36.19 kg	372.34 gm	2068.56 gm	7.40 kg

II. Table Volume Calculation for casting of M 25 concrete

Description	No. of cubes	Wet Volume of concrete in (m3)	Dry volume of concrete in (m3)	Quantity of Cement (kg)	Concentration of CMC (%)	Concentration of AC(%)	Concentration of Fly Ash(%)	Quantity of Sand(Kg)	Quantity of CA(kg)	Quantity of water(kg)	Quantity of CMC (in gm)
Control	6	0.02	0.030	11.09				25.86	28.20	5.13	
with CMC	3	0.01	0.015	5.54	0.17			12.93	14.10	2.56	9.30
	3	0.01	0.015	5.54	0.34			12.93	14.10	2.56	18.60
	3	0.01	0.015	5.54	0.50			12.93	14.10	2.56	27.91
AC only	3	0.01	0.015	5.54		1.12		12.93	14.10	2.56	
	3	0.01	0.015	5.54		2.24		12.93	14.10	2.56	
	3	0.01	0.015	5.54		3.36		12.93	14.10	2.56	
CMC+ AC	3	0.01	0.015	5.54	0.17	1.12		12.93	14.10	2.56	9.30
	3	0.01	0.015	5.54	0.17	2.24		12.93	14.10	2.56	9.30
	3	0.01	0.015	5.54	0.17	3.36		12.93	14.10	2.56	9.30
CMC+ AC	3	0.01	0.015	5.54	0.34	1.12		12.93	14.10	2.56	18.60
	3	0.01	0.015	5.54	0.34	2.24		12.93	14.10	2.56	18.60
	3	0.01	0.015	5.54	0.34	3.36		12.93	14.10	2.56	18.60
CMC+ AC	3	0.01	0.015	5.54	0.50	1.12		12.93	14.10	2.56	27.91
	3	0.01	0.015	5.54	0.50	2.24		12.93	14.10	2.56	27.91
	3	0.01	0.015	5.54	0.50	3.36		12.93	14.10	2.56	27.91
CMC+FA	3	0.01	0.015	5.54	0.17		15	12.93	14.10	2.56	9.30
	3	0.01	0.015	5.54	0.34		20	12.93	14.10	2.56	18.60
	3	0.01	0.015	5.54	0.50		25	12.93	14.10	2.56	27.91
AC+FA	3	0.01	0.015	5.54		1.12	15	12.93	14.10	2.56	
	3	0.01	0.015	5.54		2.24	20	12.93	14.10	2.56	
	3	0.01	0.015	5.54		3.36	25	12.93	14.10	2.56	
	69	0.23	0.34	127.52 kg				297.44 kg	324.26 kg	58.99 kg	279.05 gm

III. Mix Design Reference

TABLE 22 SUGGESTED RANGES OF VALUES OF WORKABILITY OF CONCRETE FOR DIFFERENT PLACING CONDITIONS

(*Clause* 3.1.2.2)

PLACING CONDITIONS	DEGREE OF WORKABILITY	VALUES OF WORKABILITY
(1)	(2)	(3)
Concreting of shallow sections with vibration	Very low	20-10 seconds, Vee-Bee time or 0.75-0.80, compacting factor
Concreting of lightly reinforced sections with vibration	Low	10-5 seconds, Vee-Bee time or 0.80-0.85, compacting factor
Concreting of lightly reinforced sections without vibration, or heavily reinforced sections with vibration	Medium	5-2 seconds, Vee-Bee time or 0.85-0.92, compacting factor or 25-75 mm, slump for 20 mm* aggregate
Concreting of heavily reinforced sections without vibration	High	Above 0.92, compacting factor or 75-125 mm, slump for 20 mm* aggregate

*For smaller aggregate the values will be lower.

SP : 23-1982

TABLE 31 RELATIONSHIP BETWEEN WATER-CEMENT RATIO AND COMPRESSIVE STRENGTH OF CONCRETE

(*Clause* 6.1)

COMPRESSIVE STRENGTH AT 28 DAYS, kgf/cm²	WATER-CEMENT RATIO, BY WEIGHT	
	Non-Air-Entrained Concrete	Air-Entrained Concrete
(1)	(2)	(3)
450	0.38	—
400	0.43	—
350	0.48	0.40
300	0.55	0.46
250	0.62	0.53
200	0.70	0.61
150	0.80	0.71

NOTE — Table 31 is from 'Recommended Practice for Selecting Proportions for Norm-¹ Weight Concrete' Reported by ACI Committee 211 (ACI Manual of Concrete Practice, Part I, 1979). American Concrete Institute, USA.

TABLE 33 VOLUME OF DRY-RODDED COARSE AGGREGATE PER UNIT VOLUME OF CONCRETE

(*Clause* 6.1)

MAXIMUM SIZE OF AGGREGATE mm	FINENESS MODULE OF SAND			
	2.40	2.60	2.80	3.00
(1)	(2)	(3)	(4)	(5)
10	0.50	0.48	0.46	0.44
12.5	0.59	0.57	0.55	0.53
20	0.66	0.64	0.62	0.60
25	0.71	0.69	0.67	0.65
40	0.76	0.74	0.72	0.70
50	0.78	0.76	0.74	0.72
70	0.81	0.79	0.77	0.75
150	0.87	0.85	0.83	0.81

NOTE — Table 33 is from 'Recommended Practice for Selecting Proportions for Normal Weight Concrete' Reported by ACI Committee 211 (ACI Manual of Concrete Practice, Part I, 1979). American Concrete Institute, USA.

Table 5 Minimum Cement Content, Maximum Water-Cement Ratio and Minimum Grade of Concrete for Different Exposures with Normal Weight Aggregates of 20 mm Nominal Maximum Size

(*Clauses* 6.1.2, 8.2.4.1 *and* 9.1.2)

Sl No.	Exposure	Plain Concrete			Reinforced Concrete		
		Minimum Cement Content kg/m³	Maximum Free Water-Cement Ratio	Minimum Grade of Concrete	Minimum Cement Content kg/m³	Maximum Free Water-Cement Ratio	Minimum Grade of Concrete
1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
i)	Mild	220	0.60	–	300	0.55	M 20
iii)	Moderate	240	0.60	M 15	300	0.50	M 25
iii)	Severe	250	0.50	M 20	320	0.45	M 30
iv)	Very severe	260	0.45	M 20	340	0.45	M 35
v)	Extreme	280	0.40	M 25	360	0.40	M 40

NOTES

1 Cement content prescribed in this table is irrespective of the grades of cement and it is inclusive of additions mentioned in **5.2**. The additions such as fly ash or ground granulated blast furnace slag may be taken into account in the concrete composition with respect to the cement content and water-cement ratio if the suitability is established and as long as the maximum amounts taken into account do not exceed the limit of pozzolona and slag specified in IS 1489 (Part 1) and IS 455 respectively.

2 Minimum grade for plain concrete under mild exposure condition is not specified.

TABLE 32 APPROXIMATE MIXING WATER (kg/m³ OF CONCRETE) REQUIREMENTS FOR DIFFERENT SLUMPS AND MAXIMUM SIZES OF AGGREGATES

(*Clause* 6.1)

SLUMP, cm	MAXIMUM SIZES OF AGGREGATES IN mm							
	10	12.5	20	25	40	50	70	150
	Non-Air-Entrained Concrete							
3 to 5	205	200	185	180	160	155	145	125
8 to 10	225	215	200	195	175	170	160	140
15 to 18	240	230	210	205	185	180	170	—
Approximate amount of entrained air in non-air-entrained concrete, percent	3.0	2.5	2.0	1.5	1.0	0.5	0.3	0.2
	Air-Entrained Concrete							
3 to 5	180	175	165	160	145	140	135	120
8 to 10	200	190	180	175	160	155	150	135
15 to 18	215	205	190	185	170	165	160	—
Recommended average total air content, percent	8.0	7.0	6.0	5.0	4.5	4.0	3.5	3.0

NOTE — Table 32 is from 'Recommended Practice for Selecting Proportions for Normal Weight Concrete' Reported by ACI Committee 211 (ACI Manual of Concrete Practice, Part I, 1979). American Concrete Institute, USA.

Table8 estimate of unit weight of fresh concrete

Nominal max. size of CA (mm)	Non air entrained	Air – entrained
9.5	2280	2200
12.5	2310	2230
20	2345	2275
25	2380	2290
37.5	2410	2350
50	2445	2345
75	2490	2405
150	2530	2435

ANNEX-C: COMPRESSIVE STRENGTH

I. Compressive Strength calculation for M 30 concrete

Table Compressive Strength of Control for 3, 7 and 28 days

cubes	Nos	1	2	3	1	2	3	1	2	3
		Control			Control			Control		
dates of casting		Monday,September 12,2022			Monday,September 12,2022			Monday,September 12,2022		
date of testing		Thursday,September 15,2022			Monday,September 19,2022			Tuesday,October 11,2022		
ages	Days	3	3	3	7	7	7	28	28	28
dimension	mm	150	150	150	150	150	150	150	150	150
surface area	sq. mm.	22500	22500	22500	22500	22500	22500	22500	22500	22500
volume	cum	0.003375	0.003375	0.003375	0.003375	0.003375	0.003375	0.003375	0.003375	0.003375
weight	kg	8.175	8.270	8.125	8.440	8.120	8.225	8.225	8.460	8.440
density	kg/m3	2422.22	2450.37	2407.41	2500.74	2405.93	2437.04	2437.04	2506.67	2500.74
breaking load	KN	374	314	342	530	407	453	680	771	706
brealing strength	N/mm2	16.62	13.96	15.20	23.56	18.09	20.13	30.22	34.27	31.38
average breaking strength	N/mm2	15.26			20.59			31.96		

Table Compressive Strength of CMC concrete for 28 days

cubes	Nos	1	2	3	1	2	3	1	2	3
		CMC 1			CMC 2			CMC 3		
dates of casting		Monday,September 12,2022			Monday,September 12,2022			Monday,September 12,2022		
date of testing		Tuesday,October 11,2022			Tuesday,October 11,2022			Tuesday,October 11,2022		
ages	Days	28	28	28	28	28	28	28	28	28
dimension	mm	150	150	150	150	150	150	150	150	150
surface area	sq. mm.	22500	22500	22500	22500	22500	22500	22500	22500	22500

volume	cum	0.003375	0.003375	0.003375	0.003375	0.003375	0.003375	0.003375	0.003375	0.003375
weight	kg	8.340	8.080	7.950	7.880	8.020	8.040	7.970	7.920	7.880
density	kg/m3	2471.11	2394.07	2355.56	2334.81	2376.30	2382.22	2361.48	2346.67	2334.81
breaking load	KN	592	612	585	525	593	504	500	514	552
brealing strength	N/mm2	26.31	27.20	26.00	23.33	26.36	22.40	22.22	22.84	24.53
average breaking strength	N/mm2	26.50			24.03			23.20		

Table Compressive Strength of CMC-AC 1.12% concrete for 28 days

cubes	Nos	1	2	3	1	2	3	1	2	3
		1AC-1			1AC-2			1AC-3		
dates of casting		Thursday,September 15,2022			Thursday,September 15,2022			Thursday,September 15,2022		
date of testing		Wednesday,October 12,2022			Wednesday,October 12,2022			Wednesday,October 12,2022		
ages	Days	28	28	28	28	28	28	28	28	28
dimension	mm	150	150	150	150	150	150	150	150	150
surface area	sq. mm.	22500	22500	22500	22500	22500	22500	22500	22500	22500
volume	cum	0.003375	0.003375	0.003375	0.003375	0.003375	0.003375	0.003375	0.003375	0.003375
weight	kg	7.813	7.930	7.795	8.066	7.978	8.120	7.394	7.411	7.468
density	kg/m3	2314.96	2349.63	2309.63	2389.93	2363.85	2405.93	2190.81	2195.85	2212.74
breaking load	KN	480	460	410	440	430	410	390	400	370
brealing strength	N/mm2	21.33	20.44	18.22	19.56	19.11	18.22	17.33	17.78	16.44
average breaking strength	N/mm2	20.00			18.96			17.19		

Table Compressive Strength of CMC-AC 2.24% concrete for 28 days

cubes	Nos	1	2	3	1	2	3	1	2	3
		2AC-1			2AC-2			2AC-3		
dates of casting		Sunday,September 18,2022			Sunday,September 18,2022			Sunday,September 18,2022		
date of testing		Monday,October 17,2022			Monday,October 17,2022			Monday,October 17,2022		

ages	Days	28	28	28	28	28	28	28	28	28
dimension	mm	150	150	150	150	150	150	150	150	150
surface area	sq. mm.	22500	22500	22500	22500	22500	22500	22500	22500	22500
volume	cum	0.003375	0.003375	0.003375	0.003375	0.003375	0.003375	0.003375	0.003375	0.003375
weight	kg	7.769	8.275	8.163	8.043	8.034	7.829	7.703	7.851	7.694
density	kg/m3	2301.93	2451.85	2418.67	2383.11	2380.44	2319.70	2282.37	2326.22	2279.70
breaking load	KN	450	430	410	460	490	450	430	470	430
brealing strength	N/mm2	20.00	19.11	18.22	20.44	21.78	20.00	19.11	20.89	19.11
average breaking strength	N/mm2	19.11			20.74			19.70		

Table Compressive Strength of CMC-AC 3.36% concrete for 28 days

cubes	Nos	1	2	3	1	2	3	1	2	3
		3AC-1			3AC-2			3AC-3		
dates of casting		Wednesday,September 21,2022			Wednesday,September 21,2022			Wednesday,September 21,2022		
date of testing		Wednesday,October 19,2022			Wednesday,October 19,2022			Wednesday,October 19,2022		
ages	Days	28	28	28	28	28	28	28	28	28
dimension	mm	150	150	150	150	150	150	150	150	150
surface area	sq. mm.	22500	22500	22500	22500	22500	22500	22500	22500	22500
volume	cum	0.003375	0.003375	0.003375	0.003375	0.003375	0.003375	0.003375	0.003375	0.003375
weight	kg	8.033	8.311	8.062	7.847	8.123	7.912	7.563	8.106	7.685
density	kg/m3	2380.15	2462.52	2388.74	2325.04	2406.81	2344.30	2240.89	2401.78	2277.04
breaking load	KN	460	440	410	440	400	410	360	390	410
brealing strength	N/mm2	20.44	19.56	18.22	19.56	17.78	18.22	16.00	17.33	18.22
average breaking strength	N/mm2	19.41			18.52			17.19		

Table 28 day Compressive Strength of CMC=0.34%, AC= 2.24% concrete for different FA

cubes	Nos	1	2	3	1	2	3	1	2	3

		FA-1			FA-2			FA-3		
dates of casting		Friday,September 23,2022			Friday,September 23,2022			Friday,September 23,2022		
date of testing		Thursday,October 20,2022			Thursday,October 20,2022			Thursday,October 20,2022		
ages	Days	28	28	28	28	28	28	28	28	28
dimension	mm	150	150	150	150	150	150	150	150	150
surface area	sq. mm.	22500	22500	22500	22500	22500	22500	22500	22500	22500
volume	cum	0.003375	0.003375	0.003375	0.003375	0.003375	0.003375	0.003375	0.003375	0.003375
weight	kg	7.799	7.874	7.968	7.900	8.088	7.830	7.741	7.964	7.934
density	kg/m3	2310.81	2333.04	2360.89	2340.74	2396.44	2320.00	2293.63	2359.70	2350.81
breaking load	KN	410	370	350	350	400	345	350	340	365
brealing strength	N/mm2	18.22	16.44	15.56	15.56	17.78	15.33	15.56	15.11	16.22
average breaking strength	N/mm2	16.74			16.22			15.63		

Table 28 day Compressive Strength of CMC=0.34%, AC= 3.36% concrete for different FA

cubes	Nos	1	2	3	1	2	3	1	2	3
		FA-4			FA-5			FA-6		
dates of casting		Monday,December 26,2022			Thursday,December 29,2022			Thursday,December 29,2022		
date of testing		Monday,January 23,2023			Thursday,January 26,2023			Thursday,January 26,2023		
ages	Days	28	28	28	28	28	28	28	28	28
dimension	mm	150	150	150	150	150	150	150	150	150
surface area	sq. mm.	22500	22500	22500	22500	22500	22500	22500	22500	22500
volume	cum	0.003375	0.003375	0.003375	0.003375	0.003375	0.003375	0.003375	0.003375	0.003375
weight	kg	7.665	7.890	7.900	7.840	7.555	7.375	7.945	7.866	8.010
density	kg/m3	2271.11	2337.78	2340.74	2322.96	2238.52	2185.19	2354.07	2330.67	2373.33
breaking load	KN	415	400	420	425	380	450	340	380	350
brealing strength	N/mm2	18.44	17.78	18.67	18.89	16.89	20.00	15.11	16.89	15.56
average breaking strength	N/mm2	18.30			18.59			15.85		

II. Compressive Strength calculation for M 25 concrete

Table: Compressive Strength of Control for 7 and 28 days

cubes	Nos	1	2	3	1	2	3
		Control			Control		
dates of casting		Monday,March 20,2023			Monday,March 20,2023		
date of testing		Monday,April 17,2023			Monday,April 17,2023		
ages	Days	7	7	7	28	28	28
dimension	mm	150	150	150	150	150	150
surface area	sq. mm.	22500	22500	22500	22500	22500	22500
volume	cum	0.003375	0.003375	0.003375	0.003375	0.003375	0.003375
weight	kg	7.950	8.105	8.000	8.145	8.065	8.210
density	kg/m3	2355.56	2401.48	2370.37	2413.33	2389.63	2432.59
breaking load	KN	404	371	391	612	625	584
brealing strength	N/mm2	17.96	16.49	17.38	27.20	27.78	25.96
average breaking strength	N/mm2	17.27			26.98		

Table: 28 day Compressive Strength of CMC concrete

cubes	Nos	1	2	3	1	2	3	1	2	3
		CC1			CC2			CC3		
dates of casting		Tuesday,March 21,2023			Tuesday,March 21,2023			Tuesday,March 21,2023		
date of testing		Tuesday,April 18,2023			Tuesday,April 18,2023			Tuesday,April 18,2023		
ages	Days	28	28	28	28	28	28	28	28	28
dimension	mm	150	150	150	150	150	150	150	150	150
surface area	sq. mm.	22500	22500	22500	22500	22500	22500	22500	22500	22500
volume	cum	0.003375	0.003375	0.003375	0.003375	0.003375	0.003375	0.003375	0.003375	0.003375
weight	kg	8.054	8.088	8.117	8.076	7.939	8.105	8.059	7.705	7.779

density	kg/m3	2386.37	2396.44	2405.04	2392.89	2352.30	2401.48	2387.85	2282.96	2304.89
breaking load	KN	510	540	560	510	560	500	460	500	480
brealing strength	N/mm2	22.67	24.00	24.89	22.67	24.89	22.22	20.44	22.22	21.33
average breaking strength	N/mm2	23.85			23.26			21.33		

Table: 28 day Compressive Strength of AC concrete

cubes	Nos	1	2	3	1	2	3	1	2	3
		C1			C2			C3		
dates of casting		Wednesday,March 22,2023			Wednesday,March 22,2023			Wednesday,March 22,2023		
date of testing		Wednesday,April 19,2023			Wednesday,April 19,2023			Wednesday,April 19,2023		
ages	Days	28	28	28	28	28	28	28	28	28
dimension	mm	150	150	150	150	150	150	150	150	150
surface area	sq. mm.	22500	22500	22500	22500	22500	22500	22500	22500	22500
volume	cum	0.003375	0.003375	0.003375	0.003375	0.003375	0.003375	0.003375	0.003375	0.003375
weight	kg	7.865	8.086	7.894	8.231	8.433	8.242	8.083	8.066	7.998
density	kg/m3	2330.37	2395.85	2338.96	2438.81	2498.67	2442.07	2394.96	2389.93	2369.78
breaking load	KN	430	450	470	580	590	630	520	430	480
brealing strength	N/mm2	19.11	20.00	20.89	25.78	26.22	28.00	23.11	19.11	21.33
average breaking strength	N/mm2	20.00			26.67			21.19		

Table: 28 day Compressive Strength of CMC-AC concrete for CMC 0.17%

cubes	Nos	1	2	3	1	2	3	1	2	3
		C1C1			C1C2			C1C3		
dates of casting		Sunday,March 26,2023			Sunday,March 26,2023			Sunday,March 26,2023		
date of testing		Sunday,April 23,2023			Sunday,April 23,2023			Sunday,April 23,2023		
ages	Days	28	28	28	28	28	28	28	28	28
dimension	mm	150	150	150	150	150	150	150	150	150

surface area	sq. mm.	22500	22500	22500	22500	22500	22500	22500	22500	22500
volume	cum	0.003375	0.003375	0.003375	0.003375	0.003375	0.003375	0.003375	0.003375	0.003375
weight	kg	7.838	7.997	7.855	8.096	7.948	7.886	7.532	7.802	8.091
density	kg/m3	2322.37	2369.48	2327.41	2398.81	2354.96	2336.59	2231.70	2311.70	2397.33
breaking load	KN	530	550	560	560	540	560	500	480	480
brealing strength	N/mm2	23.56	24.44	24.89	24.89	24.00	24.89	22.22	21.33	21.33
average breaking strength	N/mm2	24.30			24.59			21.63		

Table: 28 day Compressive Strength of CMC-AC concrete for CMC 0.34%

cubes	Nos	1	2	3	1	2	3	1	2	3
		C2C1			C2C2			C2C3		
dates of casting		Monday,March 27,2023			Monday,March 27,2023			Monday,March 27,2023		
date of testing		Monday,April 24,2023			Monday,April 24,2023			Monday,April 24,2023		
ages	Days	28	28	28	28	28	28	28	28	28
dimension	mm	150	150	150	150	150	150	150	150	150
surface area	sq. mm.	22500	22500	22500	22500	22500	22500	22500	22500	22500
volume	cum	0.003375	0.003375	0.003375	0.003375	0.003375	0.003375	0.003375	0.003375	0.003375
weight	kg	7.600	7.688	7.596	7.421	7.585	7.480	7.861	7.816	7.926
density	kg/m3	2251.85	2277.93	2250.67	2198.81	2247.41	2216.30	2329.19	2315.85	2348.44
breaking load	KN	450	430	460	390	400	420	420	470	480
brealing strength	N/mm2	20.00	19.11	20.44	17.33	17.78	18.67	18.67	20.89	21.33
average breaking strength	N/mm2	19.85			17.93			20.30		

Table: 28 day Compressive Strength of CMC-AC concrete for CMC 0.5%

cubes	Nos	1	2	3	1	2	3	1	2	3
		C3C1			C3C2			C3C3		
dates of casting		Tuesday,March 28,2023			Tuesday,March 28,2023			Tuesday,March 28,2023		

date of testing		Tuesday,April 25,2023			Tuesday,April 25,2023			Tuesday,April 25,2023		
ages	Days	28	28	28	28	28	28	28	28	28
dimension	mm	150	150	150	150	150	150	150	150	150
surface area	sq. mm.	22500	22500	22500	22500	22500	22500	22500	22500	22500
volume	cum	0.003375	0.003375	0.003375	0.003375	0.003375	0.003375	0.003375	0.003375	0.003375
weight	kg	7.486	7.577	7.582	7.345	7.756	7.429	7.475	7.752	7.539
density	kg/m3	2218.07	2245.04	2246.52	2176.30	2298.07	2201.19	2214.81	2296.89	2233.78
breaking load	KN	470	480	440	420	420	400	390	400	420
brealing strength	N/mm2	20.89	21.33	19.56	18.67	18.67	17.78	17.33	17.78	18.67
average breaking strength	N/mm2	20.59			18.37			17.93		

Table: 28 day Compressive Strength of AC-FA concrete

cubes	Nos	1	2	3	1	2	3	1	2	3
		CF1			CF2			CF3		
dates of casting		Thursday,March 23,2023			Thursday,March 23,2023			Thursday,March 23,2023		
date of testing		Thursday,April 20,2023			Thursday,April 20,2023			Thursday,April 20,2023		
ages	Days	28	28	28	28	28	28	28	28	28
dimension	mm	150	150	150	150	150	150	150	150	150
surface area	sq. mm.	22500	22500	22500	22500	22500	22500	22500	22500	22500
volume	cum	0.003375	0.003375	0.003375	0.003375	0.003375	0.003375	0.003375	0.003375	0.003375
weight	kg	8.038	8.068	7.946	8.140	8.110	7.921	8.191	7.920	8.243
density	kg/m3	2381.63	2390.52	2354.37	2411.85	2402.96	2346.96	2426.96	2346.67	2442.37
breaking load	KN	580	580	590	610	550	570	640	580	600
brealing strength	N/mm2	25.78	25.78	26.22	27.11	24.44	25.33	28.44	25.78	26.67
average breaking strength	N/mm2	25.93			25.63			26.96		

Table: 28 day Compressive Strength of CMC-FA concrete

cubes	Nos	1	2	3	1	2	3	1	2	3
		CCF1			CCF2			CCF3		
dates of casting		Friday,March 24,2023			Friday,March 24,2023			Friday,March 24,2023		
date of testing		Friday,April 21,2023			Friday,April 21,2023			Friday,April 21,2023		
ages	Days	28	28	28	28	28	28	28	28	28
dimension	mm	150	150	150	150	150	150	150	150	150
surface area	sq. mm.	22500	22500	22500	22500	22500	22500	22500	22500	22500
volume	cum	0.003375	0.003375	0.003375	0.003375	0.003375	0.003375	0.003375	0.003375	0.003375
weight	kg	7.830	7.610	7.948	7.975	7.970	7.793	7.669	7.411	7.363
density	kg/m3	2320.00	2254.81	2354.96	2362.96	2361.48	2309.04	2272.30	2195.85	2181.63
breaking load	KN	530	500	550	460	450	480	400	400	420
brealing strength	N/mm2	23.56	22.22	24.44	20.44	20.00	21.33	17.78	17.78	18.67
average breaking strength	N/mm2	23.41			20.59			18.07		

ANNEX-D: Modulus of Elasticity

Modulus of elasticity for M 30 grade was calculated for CMC-AC concrete and CMC-AC-FA concrete. And, presented below.

VIII. Deflection- Compressive Load Table

Table: Deflection- Compressive load for AC=1.12%

	1AC-1						1AC-2						1AC-3						
Sample Nos	1		2		3		1		2		3		1		2		3		Stress
weight(kgs)	7.813		7.930		7.795		8.066		7.978		8.120		7.394		7.411		7.468		
	defl	del. l/ l	defl	del. l/ l	defl	del. l/ l	defl	del. l/ l	defl	del. l/ l	defl	del. l/ l	defl	del. l/ l	defl	del. l/ l	defl	del. l/ l	
50	40	0.000267	70	0.000467	40	0.000267	60	0.000400	30	0.000200	30	0.000200	60	0.000400	50	0.000333	40	0.000267	2.22
100	70	0.000467	80	0.000533	70	0.000467	80	0.000533	50	0.000333	50	0.000333	80	0.000533	60	0.000400	65	0.000433	4.44
150	80	0.000533	90	0.000600	90	0.000600	90	0.000600	70	0.000467	70	0.000467	90	0.000600	70	0.000467	105	0.000700	6.67
200	90	0.000600	100	0.000667	105	0.000700	100	0.000667	90	0.000600	80	0.000533	120	0.000800	80	0.000533	120	0.000800	8.89
250	105	0.000700	120	0.000800	120	0.000800	130	0.000867	100	0.000667	100	0.000667	150	0.001000	120	0.000800	140	0.000933	11.11
300	120	0.000800	130	0.000867	145	0.000967	160	0.001067	150	0.001000	120	0.000800	195	0.001300	180	0.001200	160	0.001067	13.33
350	170	0.001133	150	0.001000	160	0.001067	180	0.001200	220	0.001467	190	0.001267	220	0.001467	230	0.001533	190	0.001267	15.56
400	230	0.001533	180	0.001200	180	0.001200	250	0.001667	230	0.001533	250	0.001667	280	0.001867	300	0.002000	240	0.001600	17.78
450	260	0.001733	240	0.001600	250	0.001667	350	0.002333	270	0.001800	260	0.001733							20.00
500	280	0.001867	290	0.001933															22.22
550																			24.44

Table: Deflection- Compressive load for AC=2.24%

	2AC-1						2AC-2						2AC-3						
Sample Nos	1		2		3		1		2		3		1		2		3		Stress
weight(kgs)	7.769		8.275		8.163		8.043		8.034		7.829		7.703		7.851		7.694		
	defl	del. l/ l	defl	del. l/ l	defl	del. l/ l	defl	del. l/ l	defl	del. l/ l	defl	del. l/ l	defl	del. l/ l	defl	del. l/ l	defl	del. l/ l	
50	50	0.000333	30	0.000200	20	0.000133	20	0.000133	40	0.000267	30	0.000200	30	0.000200	60	0.000400	30	0.000200	2.22
100	70	0.000467	40	0.000267	30	0.000200	30	0.000200	60	0.000400	45	0.000300	40	0.000267	70	0.000467	50	0.000333	4.44
150	80	0.000533	50	0.000333	40	0.000267	50	0.000333	70	0.000467	60	0.000400	65	0.000433	90	0.000600	60	0.000400	6.67
200	100	0.000667	80	0.000533	60	0.000400	70	0.000467	80	0.000533	70	0.000467	75	0.000500	100	0.000667	80	0.000533	8.89
250	120	0.000800	120	0.000800	85	0.000567	100	0.000667	90	0.000600	100	0.000667	125	0.000833	120	0.000800	120	0.000800	11.11
300	140	0.000933	145	0.000967	120	0.000800	125	0.000833	110	0.000733	120	0.000800	160	0.001067	140	0.000933	190	0.001267	13.33
350	160	0.001067	170	0.001133	155	0.001033	140	0.000933	130	0.000867	140	0.000933	190	0.001267	170	0.001133	210	0.001400	15.56
400	235	0.001567	290	0.001933	190	0.001267	160	0.001067	150	0.001000	250	0.001667	220	0.001467	200	0.001333	250	0.001667	17.78
450	270	0.001800	360	0.002400	240	0.001600	180	0.001200	190	0.001267	310	0.002067	300	0.002000	220	0.001467	340	0.002267	20.00
500							280	0.001867	300	0.002000					280	0.001867			22.22
550																			24.44

Table: Deflection- Compressive load for AC=3.36%

	3AC-1						3AC-2						3AC-3						
Sample Nos	1		2		3		1		2		3		1		2		3		Stress
weight(kgs)	8.033		8.311		8.062		7.847		8.123		7.912		7.563		8.106		7.685		
	defl	del. l/ l	defl	del. l/ l	defl	del. l/ l	defl	del. l/ l	defl	del. l/ l	defl	del. l/ l	defl	del. l/ l	defl	del. l/ l	defl	del. l/ l	
50	50	0.000333	22	0.000147	90	0.000600	10	0.000067	22	0.000147	35	0.000233	30	0.000200	30	0.000200	45	0.000300	2.22
100	60	0.000400	40	0.000267	110	0.000733	25	0.000167	40	0.000267	50	0.000333	40	0.000267	45	0.000300	60	0.000400	4.44
150	80	0.000533	55	0.000367	120	0.000800	43	0.000287	55	0.000367	60	0.000400	60	0.000400	60	0.000400	70	0.000467	6.67

200	100	0.000667	72	0.000480	125	0.000833	60	0.000400	75	0.000500	70	0.000467	85	0.000567	80	0.000533	90	0.000600	8.89
250	120	0.000800	90	0.000600	130	0.000867	80	0.000533	90	0.000600	90	0.000600	120	0.000800	100	0.000667	130	0.000867	11.11
300	145	0.000967	105	0.000700	132	0.000880	110	0.000733	110	0.000733	140	0.000933	140	0.000933	125	0.000833	170	0.001133	13.33
350	150	0.001000	120	0.000800	150	0.001000	150	0.001000	125	0.000833	180	0.001200	170	0.001133	140	0.000933	240	0.001600	15.56
400	160	0.001067	130	0.000867	155	0.001033	180	0.001200	240	0.001600	200	0.001333	200	0.001333	200	0.001333	250	0.001667	17.78
450	190	0.001267	200	0.001333	170	0.001133	240	0.001600			280	0.001867					290	0.001933	20.00
500	270	0.001800																	22.22
550																			24.44

Table: Deflection- Compressive load for FA(CMC=0.34%, AC=2.24%)

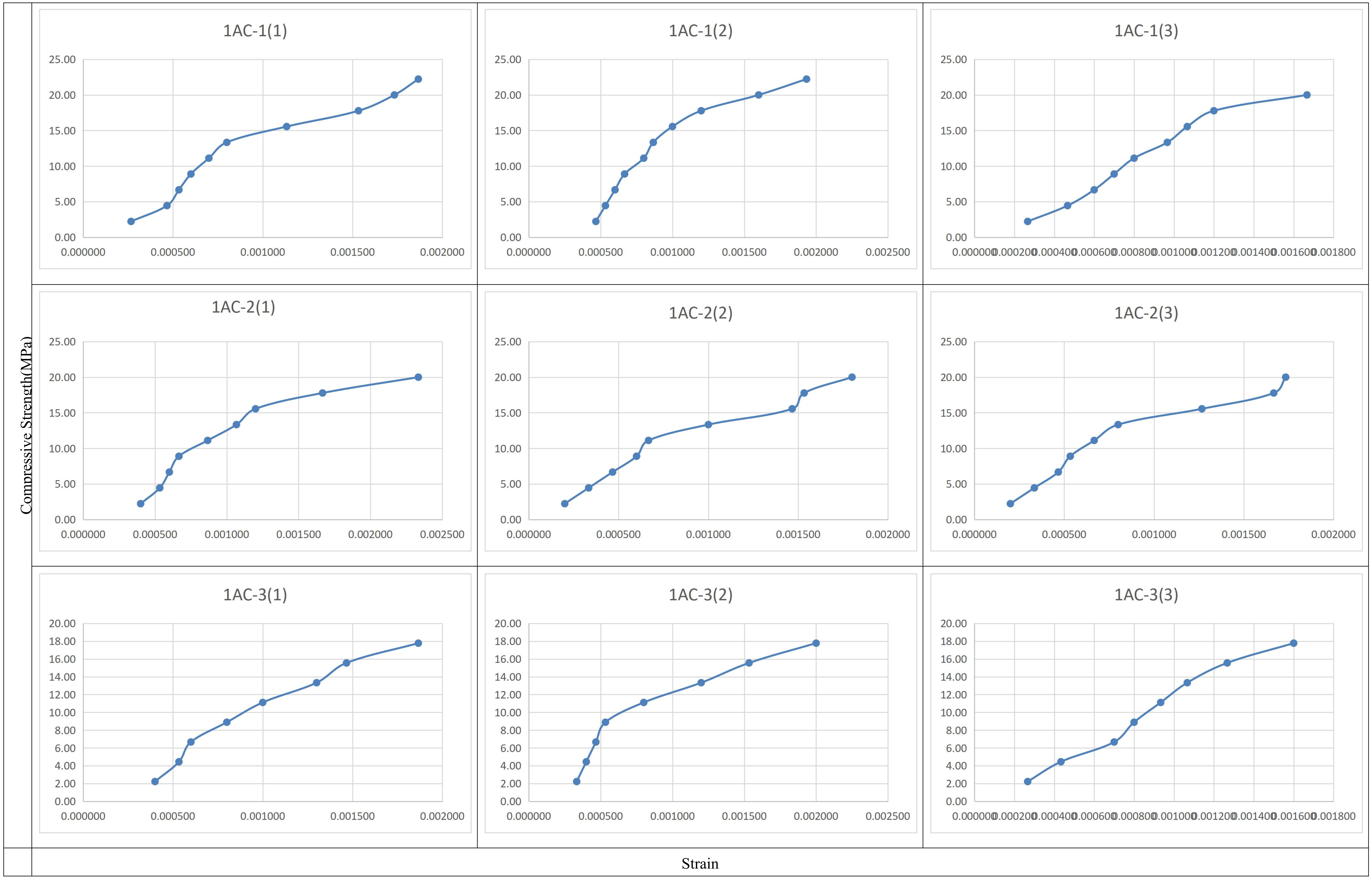
	FA-1						FA-2						FA-3						
Sample Nos	1		2		3		1		2		3		1		2		3		Stress
weight(kgs)	7.799		7.874		7.968		7.900		8.088		7.830		7.741		7.964		7.934		
	defl	del. l/ l	defl	del. l/ l	defl	del. l/ l	defl	del. l/ l	defl	del. l/ l	defl	del. l/ l	defl	del. l/ l	defl	del. l/ l	defl	del. l/ l	
50	10	0.000067	10	0.000067	30	0.000200	30	0.000200	20	0.000133	20	0.000133	35	0.000233	30	0.000200	25	0.000167	2.22
100	20	0.000133	30	0.000200	40	0.000267	50	0.000333	30	0.000200	40	0.000267	40	0.000267	60	0.000400	50	0.000333	4.44
150	40	0.000267	45	0.000300	70	0.000467	70	0.000467	50	0.000333	50	0.000333	60	0.000400	70	0.000467	60	0.000400	6.67
200	50	0.000333	60	0.000400	90	0.000600	90	0.000600	70	0.000467	55	0.000367	80	0.000533	80	0.000533	80	0.000533	8.89
250	70	0.000467	110	0.000733	150	0.001000	140	0.000933	100	0.000667	90	0.000600	90	0.000600	130	0.000867	110	0.000733	11.11
300	100	0.000667	140	0.000933	190	0.001267	180	0.001200	155	0.001033	150	0.001000	120	0.000800	180	0.001200	150	0.001000	13.33
350	120	0.000800	200	0.001333	250	0.001667	200	0.001333	210	0.001400	160	0.001067	180	0.001200	200	0.001333	200	0.001333	15.56
400	150	0.001000	250	0.001667					350	0.002333							220	0.001467	17.78
450	210	0.001400																	20.00
500																			22.22
550																			24.44

Table: Deflection- Compressive load for FA(CMC=0.34%, AC=3.36%)

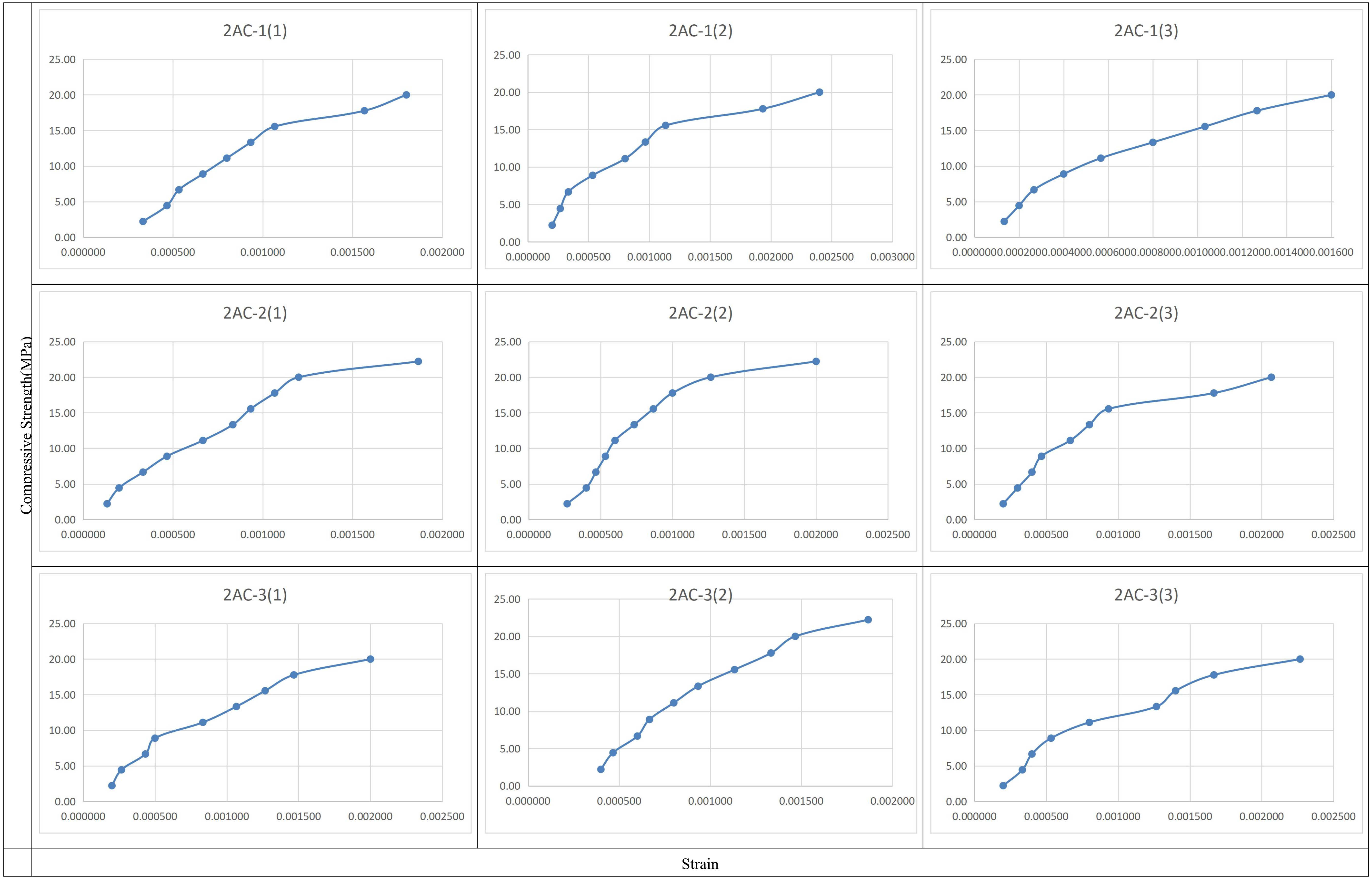
	FA-4						FA-5						FA-6						
Sample Nos	1		2		3		1		2		3		1		2		3		Stress
weight(kgs)	7.330		7.290		7.555		7.665		7.890		7.900		7.700		7.805		7.934		
	defl	del. l/ l	defl	del. l/ l	defl	del. l/ l	defl	del. l/ l	defl	del. l/ l	defl	del. l/ l	defl	del. l/ l	defl	del. l/ l	defl	del. l/ l	
50	20	0.000133	30	0.000200	30	0.000200	20	0.000133	20	0.000133	20	0.000133	30	0.000200	15	0.000100	30	0.000200	2.22
100	30	0.000200	40	0.000267	50	0.000333	30	0.000200	30	0.000200	30	0.000200	40	0.000267	30	0.000200	50	0.000333	4.44
150	50	0.000333	55	0.000367	65	0.000433	40	0.000267	50	0.000333	50	0.000333	65	0.000433	50	0.000333	60	0.000400	6.67
200	70	0.000467	75	0.000500	80	0.000533	70	0.000467	70	0.000467	65	0.000433	70	0.000467	65	0.000433	80	0.000533	8.89
250	100	0.000667	110	0.000733	100	0.000667	120	0.000800	120	0.000800	100	0.000667	90	0.000600	100	0.000667	150	0.001000	11.11
300	120	0.000800	160	0.001067	120	0.000800	180	0.001200	140	0.000933	140	0.000933	110	0.000733	120	0.000800	250	0.001667	13.33
350	140	0.000933	200	0.001333	180	0.001200	200	0.001333	220	0.001467	190	0.001267	200	0.001333	150	0.001000	280	0.001867	15.56
400	155	0.001033	240	0.001600	200	0.001333	230	0.001533	280	0.001867	200	0.001333			330	0.002200			17.78
450	280	0.001867			300	0.002000	260	0.001733			280	0.001867							20.00
500																			22.22
550																			24.44

II. Stress- Strain Plot

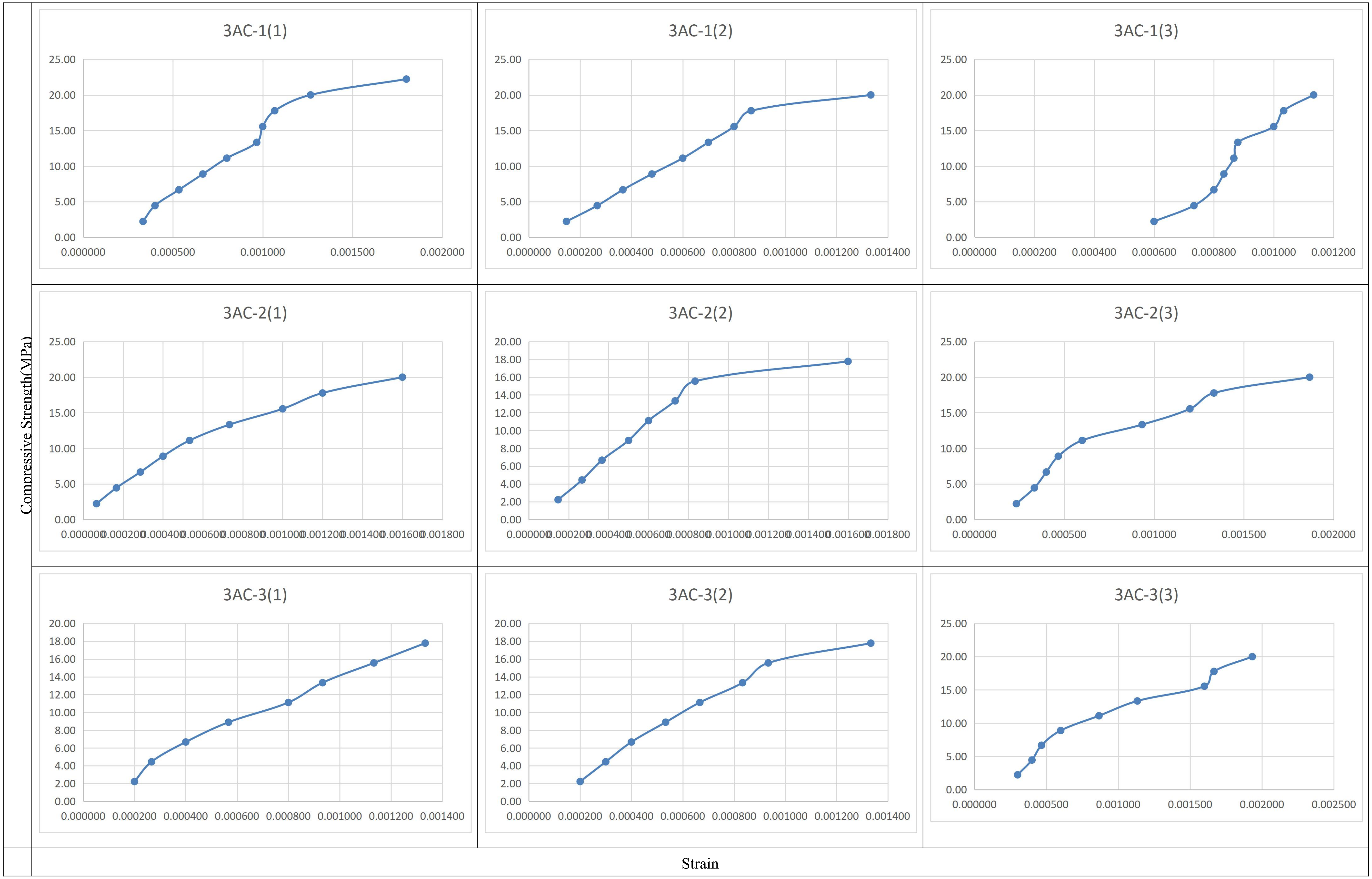
Plot for 1AC



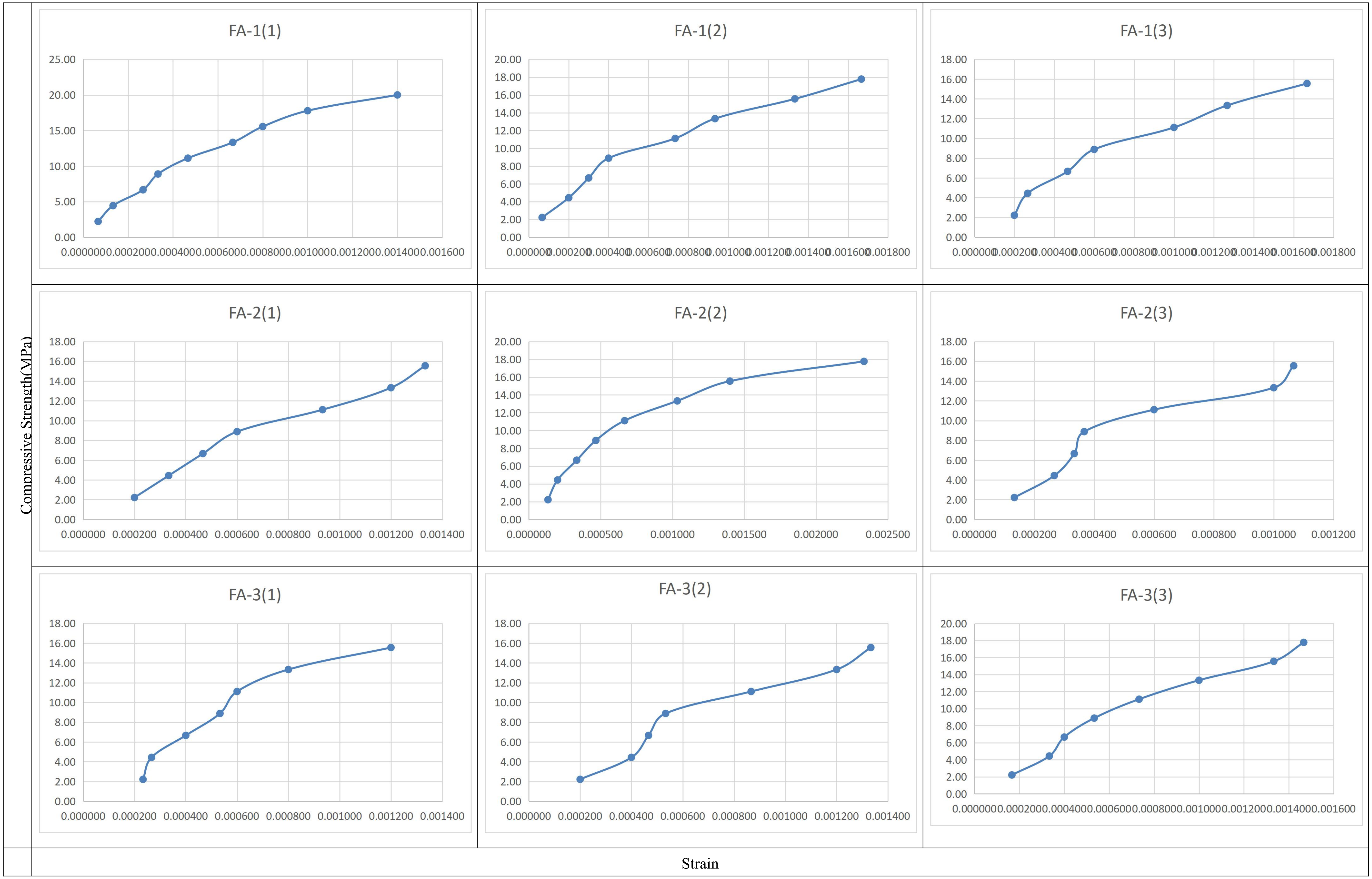
Plot for 2AC


Compressive Strength(MPa)
2AC-1(1)
2AC-1(2)
2AC-1(3)
2AC-2(1)
2AC-2(2)
2AC-2(3)
2AC-3(1)
2AC-3(2)
2AC-3(3)
Strain

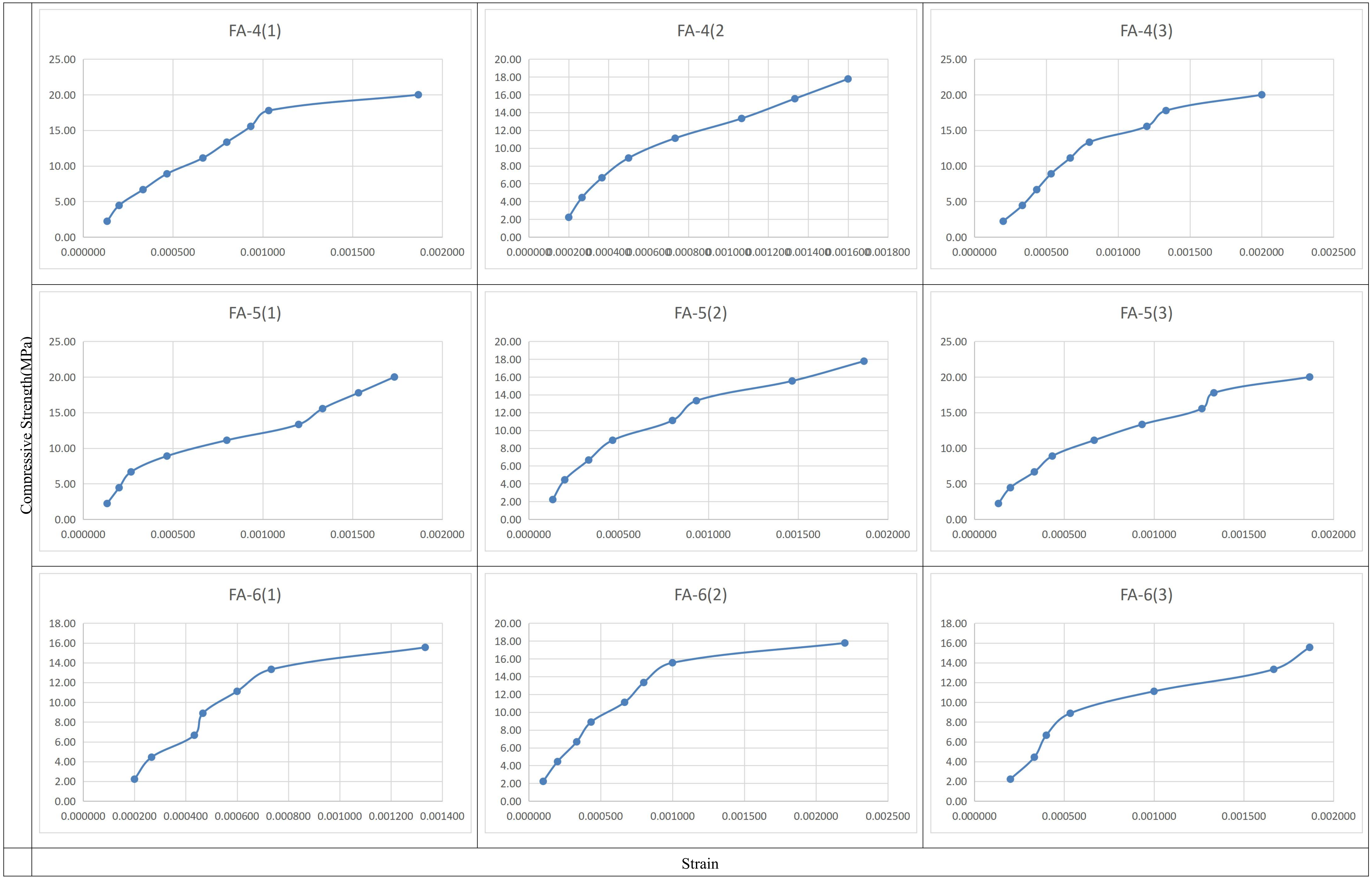
Plot for 3AC


Compressive Strength(MPa)
3AC-1(1)
3AC-1(2)
3AC-1(3)
3AC-2(1)
3AC-2(2)
3AC-2(3)
3AC-3(1)
3AC-3(2)
3AC-3(3)
Strain

Plot for FA and AC=2.24%, CMC=0.34%

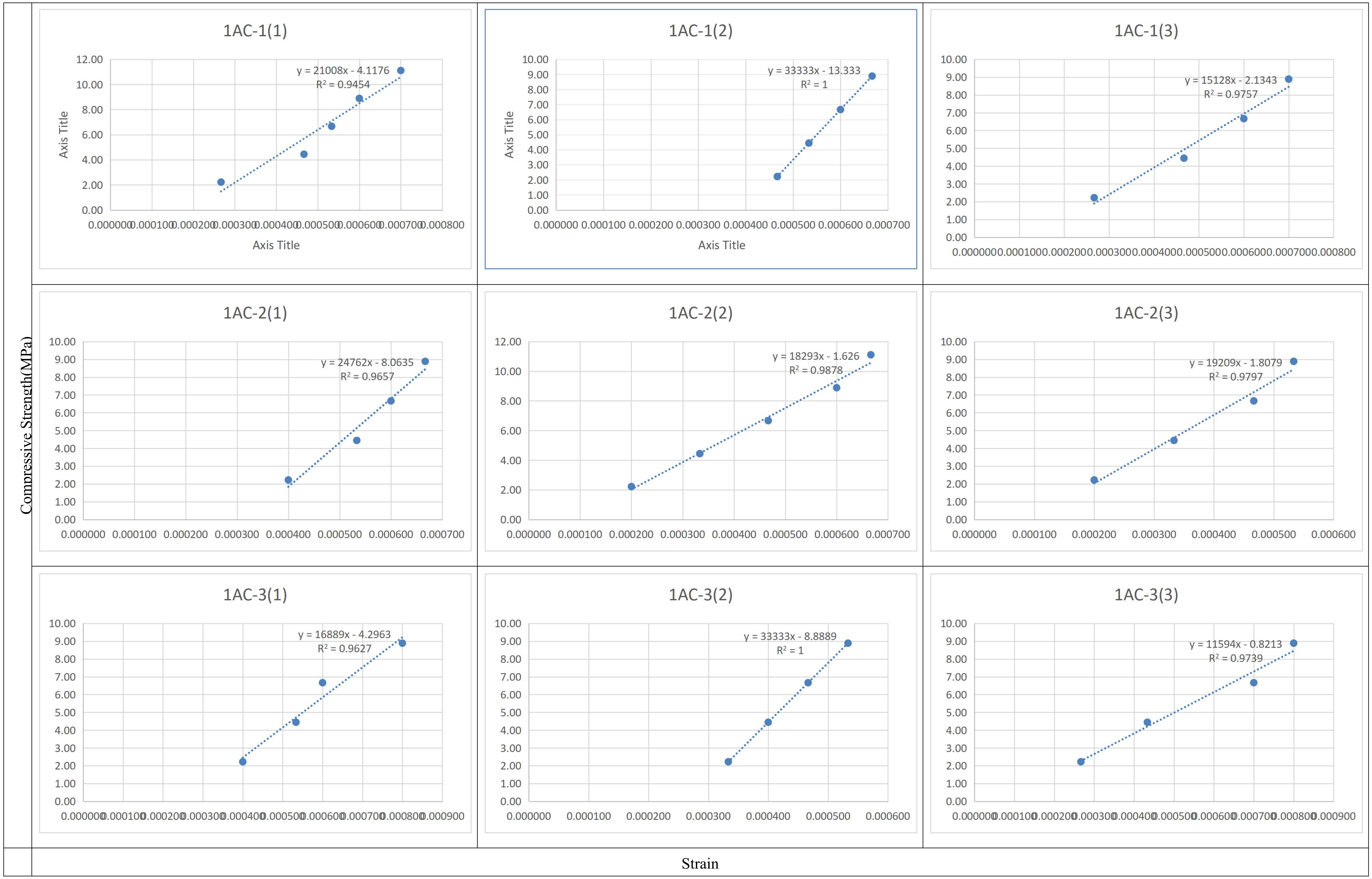


Plot for FA and AC=2.32%, CMC=0.35%

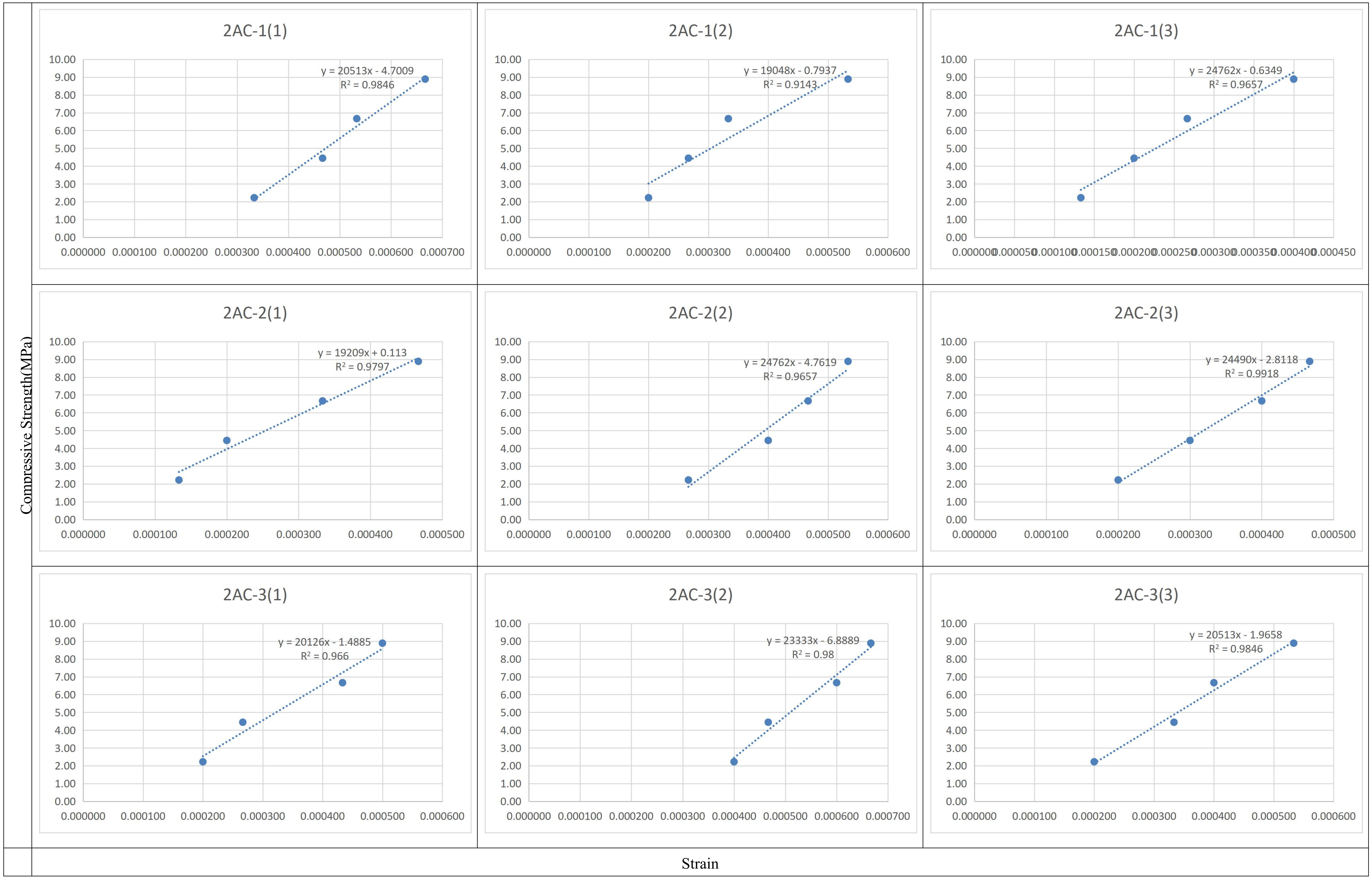


III. Linear Stress- Strain Plot

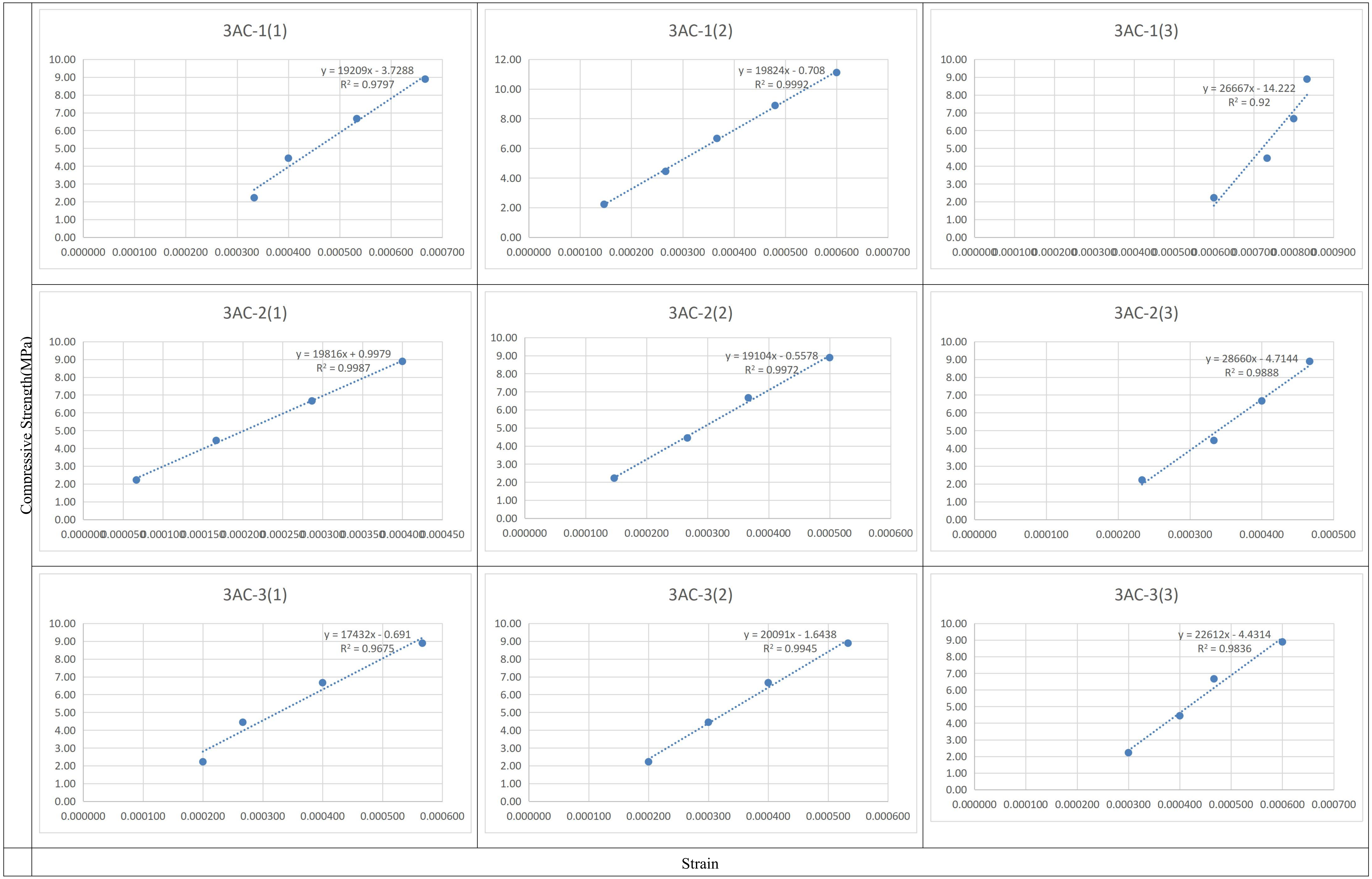
Linear Plot for 1AC



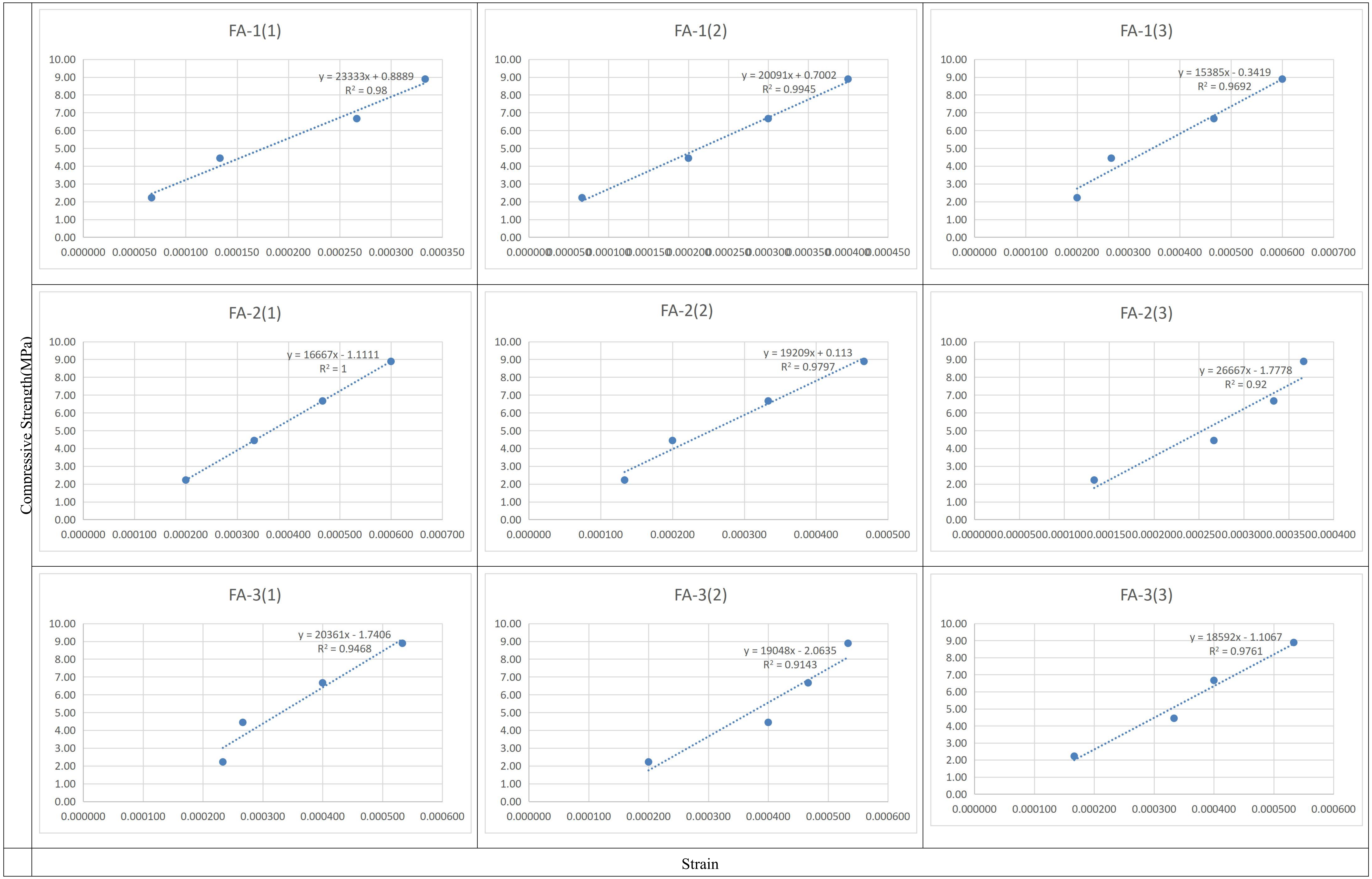
Linear Plot for 2AC



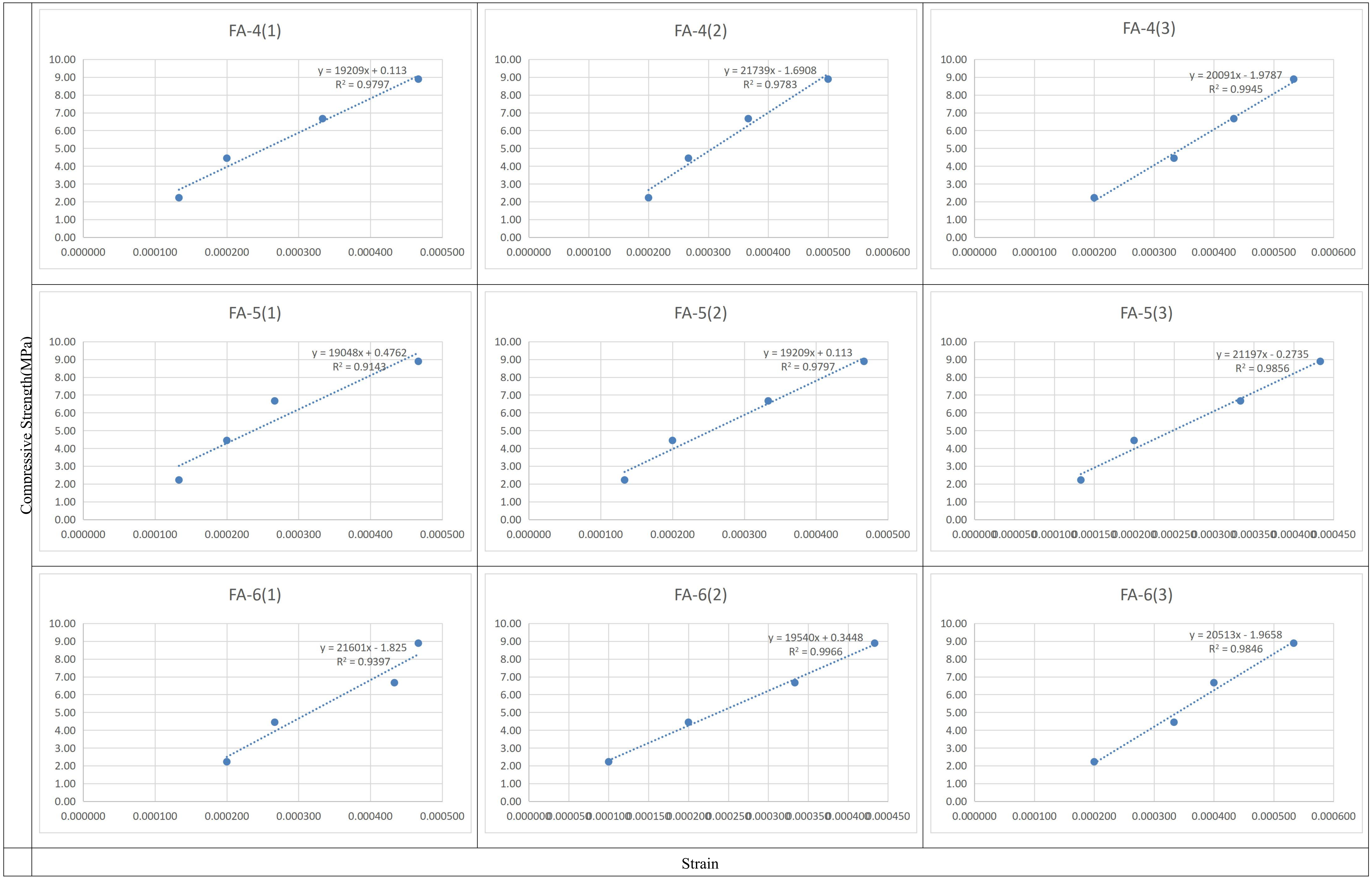
Linear Plot for 3AC



Linear Plot for FA and AC=2.24%, CMC=0.34%


Compressive Strength(MPa)
FA-1(1)
y = 23333x + 0.8889
R² = 0.98
FA-1(2)
y = 20091x + 0.7002
R² = 0.9945
FA-1(3)
y = 15385x - 0.3419
R² = 0.9692
FA-2(1)
y = 16667x - 1.1111
R² = 1
FA-2(2)
y = 19209x + 0.113
R² = 0.9797
FA-2(3)
y = 26667x - 1.7778
R² = 0.92
FA-3(1)
y = 20361x - 1.7406
R² = 0.9468
FA-3(2)
y = 19048x - 2.0635
R² = 0.9143
FA-3(3)
y = 18592x - 1.1067
R² = 0.9761
Strain

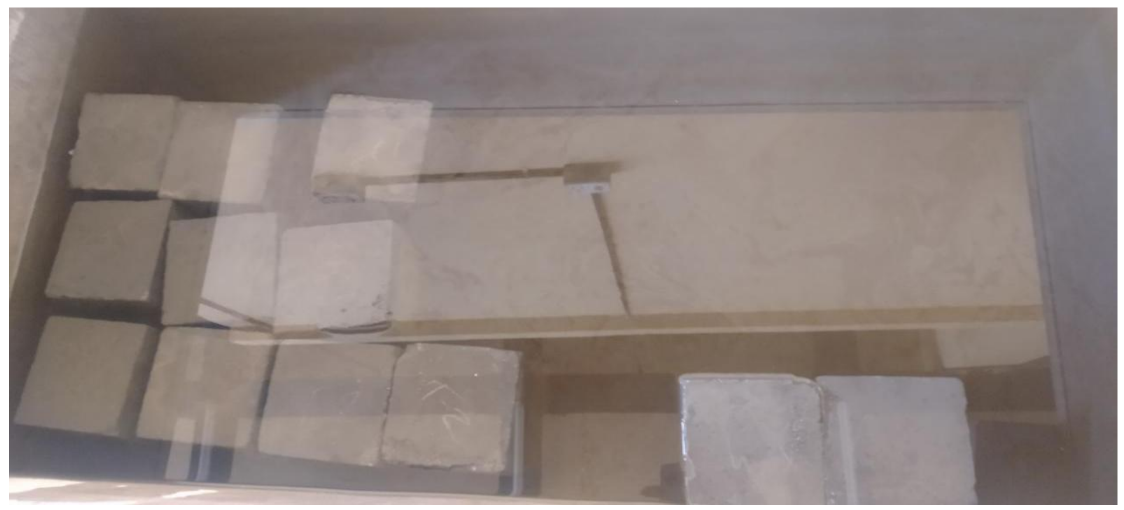
Linear Plot for FA and AC=2.32%, CMC=0.35%



ANNEX-E: Photographs










Mahesh Joshi
to me

Dear Mr.Adarsha Chauhan,
Your abstract has been accepted for ICC-2023. Please register for ICC-2023 to confirm your participation in ICC-2023.

Registration fee should be paid by bank transfer to Nepal Chemical Society in the following account:

Bank Name: Agricultural Development Bank Limited
Account Holder: NEPAL CHEMICAL SOCIETY,
Account Type: Saving,
Account No.: 0209500156408042

Or

Bank Name: Nepal Bank Limited
Account Holder: NEPAL CHEMICAL SOCIETY,
Account Type: current
Account No.: 04500100099092000001