Effect of Alccofine and M-Sand on the modulus of elasticity of sustainable concrete

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Abstract. In this study to examine the effect of Alccofine (AF) on modulus of elasticity of concrete with M-Sand as fine aggregate, mixes of M25 and M40 grades of concrete were prepared using different proportions of Alccofine (0%, 5%, 10%, 15%, 20% and 25%) as a replacement of cement. Compressive strength (CMS), stress-strain relationship and modulus of elasticity (E) were measured after twenty eight days of curing. It was observed that the addition of Alccofine resulted in the strengthening of the concrete, its stiffness and elastic response. The stress–strain curves gave steeper ascending curves and stress carrying capacity than the control mixes, which meant better deformation resistance. The Modulus of elasticity showed a rise with the increment of Alccofine content up to 20% after that, there was a slight decrease. Among the investigated mixes, the optimum performance was achieved at 20% Alccofine replacement. Furthermore, a strong positive correlation was observed between CMS and modulus of elasticity, confirming that increased concrete strength was accompanied by enhanced stiffness. The findings demonstrate the effectiveness of Alccofine in improving the elastic properties of M-sand concrete and highlight its potential as a supplementary cementitious material (SCMs) to produce sustainable concrete.

Keywords: Alccofine, M-Sand, modulus of elasticity, stress–strain behaviour, compressive strength

1 Introduction

The need for environmentally-friendly construction materials has been rising, which has led to the utilization of SCMs and alternatives to fine aggregates for concrete production. The ultrafine slag-based material Alccofine has been effectively utilized to improve the particle packing density and microstructural characteristics of cementitious composites through its filler and pozzolanic effects [1]. Likewise, due to river sand scarcity and environmental issues in river sand mining, manufactured sand (M-Sand) has also become a choice of finding a replacement for natural river sand [2,3,4].The incorporation of sustainable materials has been shown to enhance the overall performance and service life of concrete structures [3-6].The modulus of elasticity is one of the engineering properties of concrete

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that defines the stiffness, deformation characteristics and serviceability of concrete structures. The correct evaluation of the elastic modulus is crucial when predicting the deflection, crack development, and serviceability performance of reinforced concrete structures [7]. By its filler effect and pozzolanic activity, Alccofine can change the microstructure of concrete, which can lead to a denser cement matrix and better interfacial transition zone [8]. Hence, it is required to study the impact of Alccofine on the Modulus of Elasticity, which plays vital role in assessing the behaviour of structures.

Recent studies have demonstrated that the incorporation of alternative materials can improve the performance, sustainability, and economic viability of concrete construction [9,13]. A study [1] demonstrated that 30% Alccofine in concrete showed superior CMS, Young’s modulus, modulus of rupture and durability properties than the control concrete. Sakthivel [9] studied the impact of fly ash and GGBS on the CMS and elasticity modulus of concrete. The study indicated that the early-age strength declined with the replacement of fly ash, significant enhancement in strength was noted after 90 days for up to 30% replacement. Kanthe [11] showed that the addition of fly ash as well as rice husk ash enhanced the CMS, modulus of elasticity and durability characteristics of concrete with optimum value at 20% replacement of cement. Jamenraja [12] demonstrated that the modulus of elasticity and CMS were raised by around 14.35% and 15.15% respectively when compared with the CC by the use of AF and Nano Silica.

Despite many studies have examined Alccofine's effects mechanical as well as durability properties of concrete, there was limited research on its effect on the modulus of elasticity in concrete made with M-Sand. This study focuses on impact of Alccofine on Elastic modulus of M-Sand concrete. The CMS and modulus of elasticity were measured, compared to assess influence of Alccofine on concrete stiffness.

2 Materials & mix proportions

Ordinary Portland Cement (OPC) 53 grade, conforming to IS 12269:2013, was the primary binder (specific gravity 3.15). Alccofine 1203, an ultrafine slag-based material (specific gravity 2.90), used to partially replace cement. The fine aggregate (specific gravity 2.70, fineness modulus 2.91) used was manufactured sand (M-sand) of Zone II. The coarse aggregate used (specific gravity 2.80, fineness modulus 6.86) was crushed granite of maximum size of 20 mm. Polycarboxylate ether (PCE) based superplasticizer was used. Mixing and curing was done with potable water. Concrete grade M25 & M40 have been prepared following IS 10262:2019. The proportions used in the mix are given in Table 1.

Table.1 Mix proportions for AF mixes in (kg/Cu.m) [4]

Mix	Cement	M-Sand	Aggregate (20 mm)	Aggregate (12 mm)	SP	Water
M25	335.00	740.75	798.40	532.27	-----	144.05
M40	380.00	703.24	791.56	527.71	3.80	144.44

3 Experimental program

To investigate the effect of Alccofine on the modulus of elasticity of M-Sand concrete, twelve concrete mixes were prepared, six mixes for M25 and 6 mixes for M40 grade. The grades comprising 0-25% interval with 5% increment of Alccofine replacement level were taken for each grade with M-Sand as sand replacement. The M25 and also M40 grade control mix has been given with binder as cement and M-Sand as fine aggregate,specified as M25-AF0, M40-AF0, respectively. Other mixes included increasing amounts of Alccofine up to 25%. Cubes (100 mm) and cylinder (150 mm × 300 mm) specimens were cast and demolded after 24 hours and water cured. Subsequent to 28 days,CMS was tested on cubes and modulus of elasticity on cylinders following IS 516:2015 standards. Three samples were analyzed for each mix and the average results were reported. Deformation and stiffness was evaluated by stress–strain data obtained from modulus tests. Correlation has been verified between the CMS and MOE. This study was undertaken to determine the levels of Alccofine that can be used and the impact that such a replacement has on strength and elasticity.

4 Results and discussion

4.1 Effect of Alccofine on compressive strength (CMS)

CMS of M25-AF as well as M40-AF concrete mixes augmented with the incorporation of Alccofine. This shows Alccofine improves the mechanical performance of M-Sand concrete.The CMS of M25-AF mixes rose from 34.02 MPa in the control mix to 40.44 MPa at 20% AF. The strength increment was 18.87%. Likewise, the M40-AF mixes strength improved from 50.92 MPa to 61.65 MPa with 20% Alccofine content, which is an increase of approximately 21.08%. The declining in strength was observed beyond 20%. The variation in compressive strength with AF content was illustrated in Fig.1.The enhancement in strength at AF20 may be due to the refinement of pores because of filler effect of ultra-fine particles and also the formation of additional C-S-H gel due to pozzolanic reaction [14].

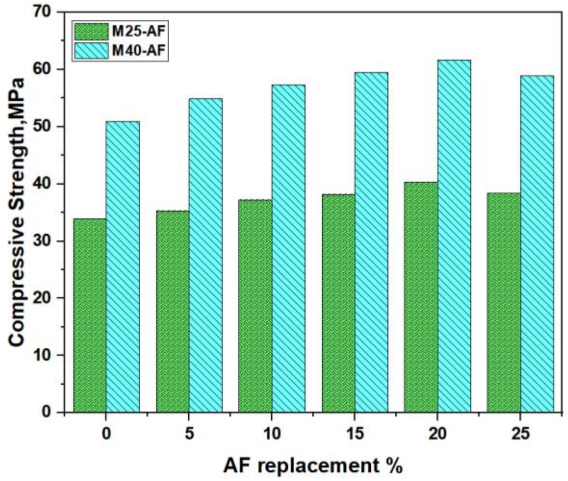

Fig.1. CMS of AF mixes

4.2 Effect of Alccofine on modulus of elasticity

The stress vs strain curves of both M25-AF and M40-AF mixes from Fig.2 and Fig.3 demonstrated that Alccofine enhanced the stiffness of concrete. All mixes showed a classic non-linear response, with the stress rising steeply at low strains and then decreasing in stiffness as the peak stress was approached.

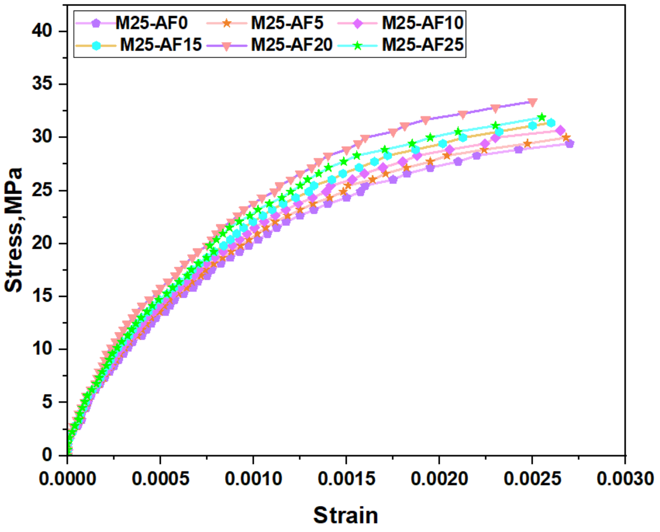

Fig.2. Curves of Stress vs Strain for M25-AF mixes

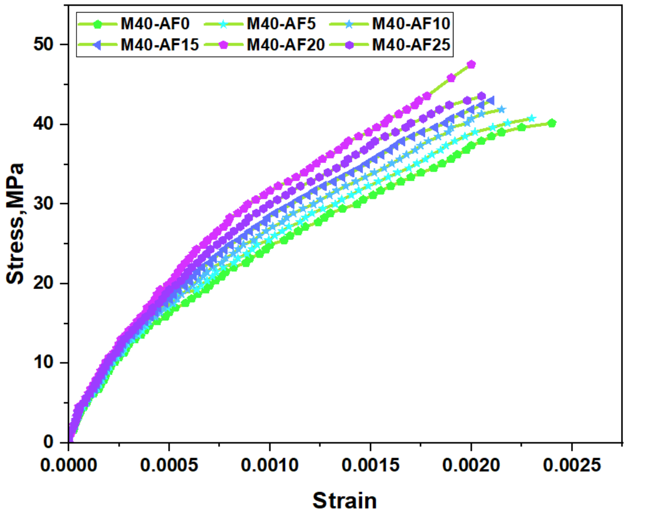

Fig 3. Curves of Stress vs Strain for M40-AF mixes

The AF-modified concretes exhibited higher stress values than the control mixes at the same strain levels, which suggests that the AF-modified concretes have higher load-carrying capacity and resistance to deformation. This improvement was more pronounced with increasing AF content up to 20% with M25-AF20 and M40-AF20 having the highest peak stresses and steepest ascending branches. This behaviour indicates that the matrix was being densified and the aggregate–paste bonding was improved, thus delaying the initiation and propagation of cracks. The results showed that at beyond 20% AF, only minor improvements were seen, which suggests that 20% AF offers the most favourable stress–strain response.

The modulus of elasticity of both M25-AF and M40-AF mixes showed a gradual rise with the increase of AF replacement as depicted in Fig.4, suggesting an increase in stiffness and resistance to deformation.M25-AF mixes exhibited percentage increases of approximately 2.99%, 4.83%, 5.87%, 8.62% and 3.43% at 5%, 10%, 15%,20% and 25% AF replacement, respectively when compared to control mix. Likewise, the M40-AF mixes demonstrated significant enhancements at the corresponding replacement levels of approximately 6.41%, 12.73%, 17.92%, 23.66% and 14.90%. The positive effect of AF is more pronounced in the M40 concrete, indicating that the higher strength concrete exhibitied more benefit than M25 grade concrete mixes. The enhanced modulus of elasticity of both grades results from the better particle compactness, lower porosity along with denser interfacial transition zone that contributes to the stiffness of the concrete matrix [15]. The results show that both M25-AF as well as M40-AF mixes with 20% AF replacement exhibited enhanced elastic properties.

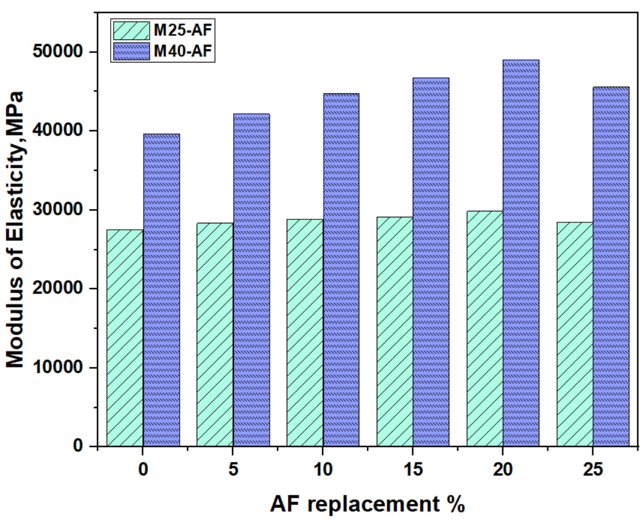

Fig 4. Variation in modulus of elasticity of AF mixes

4.3 Statistical analysis

For AF mixes of both M25 as well as M40 grade, regression analysis was conducted for E and CMS. The findings exhibited coefficient of determination (R^2) of 0.932 (93.2% confidence level) for M25-AF mixes and 0.988 (98.8% confidence level) for M40-AF mixes. The correlation among E and CMS was depicted in Fig.5.

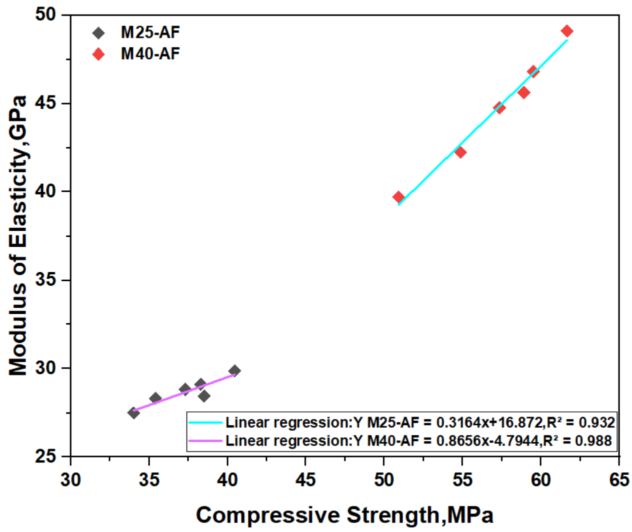

Fig 5. CMS and E correlation

5 Conclusions

The study has assessed the influence of Alccofine along with M-Sand on the elastic modulus of concrete and significant findings are:

1. The incorporation of Alccofine augmented the CMS of both M25 as well as M40 concretes, with the maximum improvement at 20% replacement of Alccofine, indicating that AF20 is the optimum dosage.
2. The stress–strain curves exhibited steeper ascending branches for Alccofine-modified concretes, confirming enhanced elastic behaviour compared to the control mixes.
3. The modulus of elasticity increased with increasing Alccofine content up to 20%, indicating improved stiffness, resistance to deformation and effectiveness in enhancing the elastic properties of both M25 and M40 concretes.
4. A high correlation was observed between the compressive strength (CMS) and modulus of elasticity (E) through statistical analysis,with augmentation of strength,stiffness also enhanced .
5. In conclusion, the findings have demonstrated that 20% Alccofine is the optimum replacement percentage to improve the elastic properties of M-sand concrete and the Alccofine is a potential SCM for sustainable concrete.

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