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Full Length Research Paper

Utilization of the Industrial By-products to produce Geopolymer Concrete

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Abstract
Using by-product materials in concrete has a significant attention in present time. This paper has been performed to study the performance of tow by-product materials; silica fume and dealuminated kaolin as cementitious materials in concrete. The paper study the mechanical properties of concrete containing different percentage of 5 %, 10%, 15%, and 20% dealuminated kaolin or silica fume as cement replacement materials. Fresh concrete tested for slump, while hardened concrete specimens are tested for compressive strength, tensile strength, and elastic modulus at the age of 7 and 28 days. The results show that the mechanical properties of concrete with percentages of silica fume or dealuminated kaolin are enhanced. Also, it is found that 15% silica fume and 5% delauminated kaolin appears to be the optimal percentage of cement replacement.

***Keywords**: Dealuminated kaolin, Geopolymer, Strength, silica fume, by-product*

Introduction

Geopolymer concrete is a concrete based on binders produced by a chemical reaction of alkaline liquids with the silicon and the aluminium in source materials or by-product materials such as kaolin, silica fume, clay, slag and rice husk ash, the chemical reaction that takes place case is a polymerization process [1]. Geopolymer paste produced by a polymeric reaction binds the coarse and fine aggregates in geopolymer concrete. Geopolymer concrete can be used to produce pre-cast concrete, structural elements, concrete pavements, and concrete used to resist heat and aggressive environments [2, 3]. This paper focuses on study properties of concrete produced using silica fume and delaminated kaolin as cement replacement; Silica fume is a by-product produced from manufacture of silicon and its alloys. Silica fume can react with free lime to produce C–S–H, but also modifies the microstructure of the cement paste due to its fine particle size[4].Dealuminated kaolin is a by-product material formed during production of alum and considers an environmental Pollutant. Silica fume and dealuminated kaolin used here individually as cement replacement with percentages of 5%, 10%, 15%, and 20%.

Table1: Chemical composition of ordinary Portland cement, silica fume, and dealuminated kaolin.

Components	**Percentage by weight %**		
	OPC	SF	DK
SiO_2	21.36	95.00	83.00
Al_2O_3	5.57	1.50	5.00
Fe_2O_3	3.35	1.50	0.50
CaO	62.50	0.80	0.08
Na_2O	0.24	2.00	3.40

Research Objectives

The main objective is to produce applicable concrete mixes using by-product materials as a replacement for cement, in order to reducing solid environmental pollutants.

Experimental Study

Materials

Detailed information about the available materials and their characteristics are given in this section.

- Coarse aggregate: crushed dolomite of maximum size of 12.5 mm was used herein as coarse aggregate. Sieve analysis and Physical properties of dolomite, are shown in Fig. 1 and Table 2 respectively.

- Fine aggregate: Natural sand with fineness modulus of 3.48 was used. Sieve analysis and Physical properties are shown in Fig.1 and Table 3 respectively.

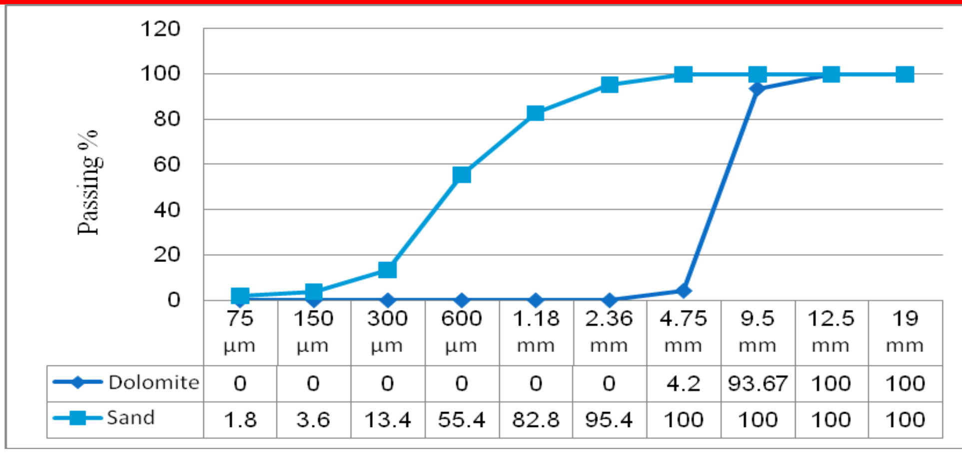

Fig 1. Grading of Coarse and Fine Aggregate

Table 2. Physical Properties of crushed dolomite

Physical Property	Value
Specific Gravity of oven dry	2.57
Dry rodded weight (kg / m^3)	1403
Nominal max.Size (mm)	12.5
Absorption by weight %	1.34

Table 3. Physical Properties of sand

Physical Property	Value
Specific Gravity of oven dry	2.65
Dry rodded weight (kg / m^3)	1664
Fineness modulus	3.48
Absorption by weight %	3

- Cement: Ordinary Portland cement (OPC) CEMI-42.5N that meets the ASTM C150 requirements was used [5].The chemical composition of ordinary Portland cement shown in Table1.
- Silica fume (SF): is a by-product of manufacture of ferrosilicon alloys in The Egyptian Chemical Industries - Kima, Aswan – Egypt. The chemical composition of silica ume shown in Table1.
- Dealuminated kaolin (DK): is a reactive aluminosilicate formed as a by-product during manufacture of alum in The Egyptian Aluminum Sulphate Company. The chemical composition of dealuminated kaolin shown in Table1.
- Chemical admixture**:** 1% Sikament-163M high range water reducer (HRWR) complies with ASTM C494 type F was used [6].
- Water**:** Potable tap water complies with ASTM C 94 has been used in mixing and curing concrete.

Concrete Mix Design

The mix proportions were calculated based on the absolute volume method according to Procedures outlined in ACI (211.1-91) for mixture proportioning [7]. Employing the sequence outlined in that standard practice, the quantities of ingredients per cubic meter of concrete given in Table 4.

Mixing, casting and curing

Mixing was carried out in a 60 kg revolving electric mixer of pan drum type. Then concrete was cast into steel moulds immediately after mixing. Vibrating table has been used in consolidating concrete. Specimens were removed from moulds after 24 hours and cured in clean water for 28 days.

Test Specimens and Instrumentations

Cube specimens of 15 cm side length were used for both of unit weight and compressive Strength tests. Cylindrical specimens of 15x30 cm were used in both of splitting tensile strength and modulus of elasticity tests.

Results and Discussion

Slump

Figure 2 shows the slump values of concrete mixes. It can be seen that slump of concrete mixes containing silica fume as a cement replacement with any percentage less than slump of control mixes by 61% or 22.7% at least.While,replacement of cement by dealuminated kaolin with percentages of 5%, 10%, 15%, and 20% results in lower slump than control mix ranging between 15.5%

and 27.5% . Also, the results shows that slump of concrete mixes with silica fume are the lower than slump of both concrete mixes containing dealuminated kaolin and control mix. This decrease in slump with increase of silica fume or dealuminated kaolin percentage is due to the surface area of silica fume and dealuminated kaolin (14000 cm^2/gm and 4200 cm^2/gm respectively) are more than that of OPC (3310 cm^2/gm) at the same time, mixing water weights are the same

Table 4.Concrete Mix Proportions (kg / 1 m^3 Concrete)

Mix designation	Coarse agg.	Fine agg.	Cement	SF	DK	Water	HRWR
Control mix (CM)	912	514	420	0	0	168	4.2
SF-5	912	514	399	21	0	168	4.2
SF-10	912	514	378	42	0	168	4.2
SF-15	912	514	357	63	0	168	4.2
SF-20	912	514	336	84	0	168	4.2
DK-5	912	514	399	0	21	168	4.2
DK-10	912	514	378	0	42	168	4.2
DK-15	912	514	357	0	63	168	4.2
DK-20	912	514	336	0	84	168	4.2

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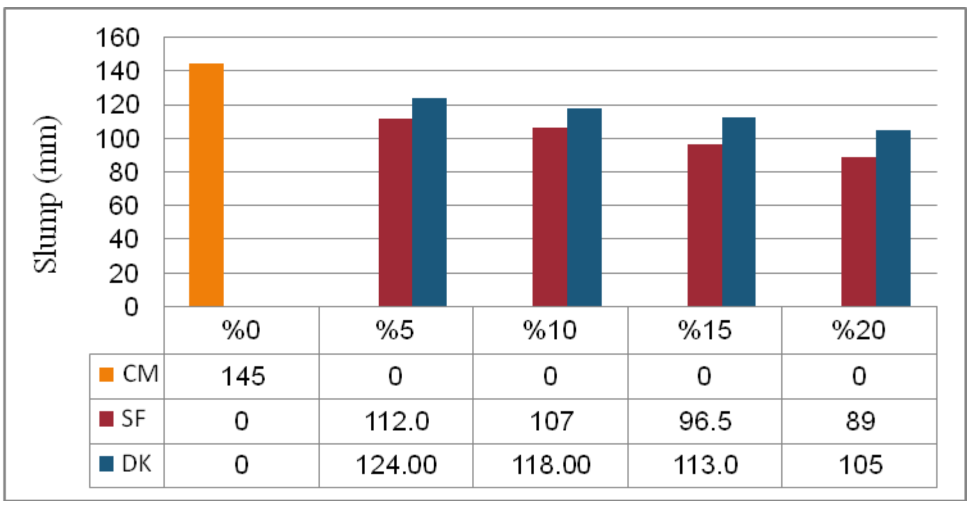

Fig 2. Slump Values of Concrete Mixes

Compressive Strength

Figures 3and 4 show the test results of concrete compressive strength after 7 and 28 day. It was found that use of 5 %, 10%, and 15% silica fume or dealuminated kaolin results in increase in compressive strength than that of control mix, while 20% SF increasing compressive strength of concrete than control mix but mix contains 20%DK is less than compressive strength of control mix either after 7 days or 28 day. Also, the results indicate that the concrete mix containing 5 % DK gave higher compressive strength than that of the other concrete mixes. Compressive strength of concrete mix contains 15% SF exceeds 450kg/cm^2, this means that this percentage of replacement is suitable to produce high strength concrete mixer. Finally, cement replacement with 15% SF or 5% DK give concrete mixes with higher compressive strength after 28 days than that of concrete mix with cement only.

Figures 5 and 6 represent the relative compressive strength for concrete mixes containing silica fume and dealuminated kaolin with respect to compressive strength of control mix. Compressive strength at age of 7 days for concrete mixes containing 15% SF and 5% DK are higher than strength of control mix by 34.7% and 40.6% respectively. While, compressive strength of the same mixes are higher than that of CM by 52% and 37.5% respectively. Also Fig.5 and Fig.6 indicate that compressive strength of mixes containing 5% SF and 20% DK lower than strength of control mix by 6% and 21% for compressive strength after 7and 28 days respectively.

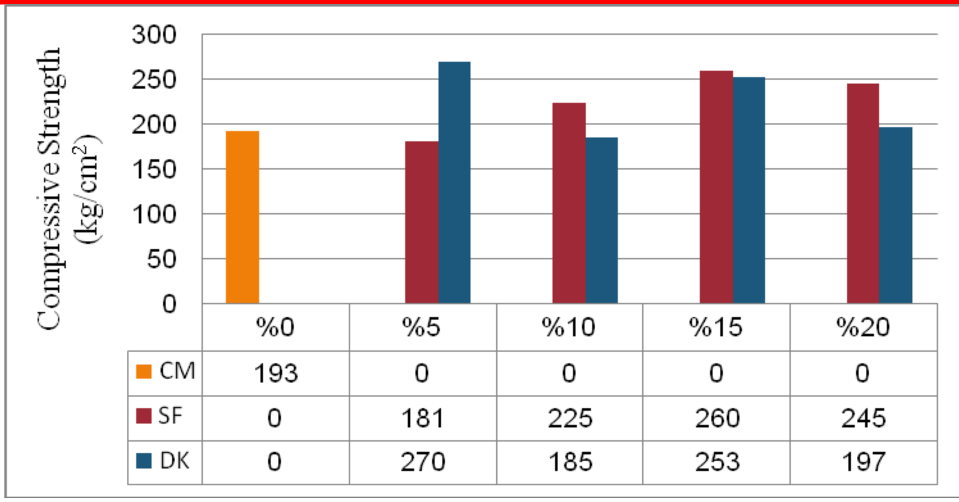

Fig 3. Compressive Strength after 7 days

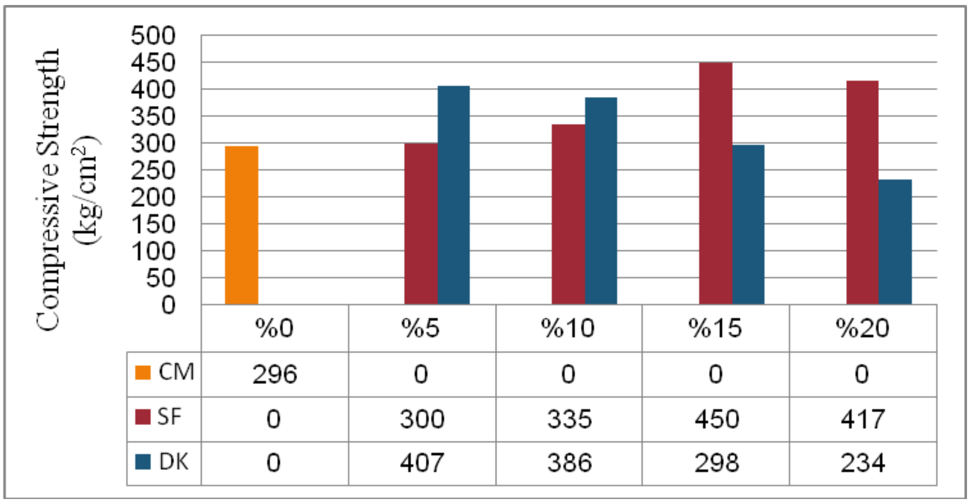

Fig 4. Compressive Strength after 28 days

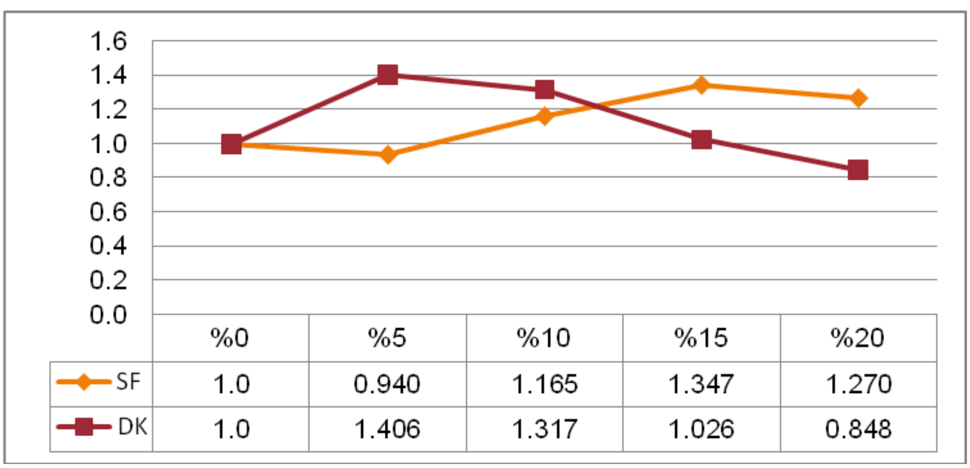

Fig 5. Relative Compressive Strength to Control Mix -7 days

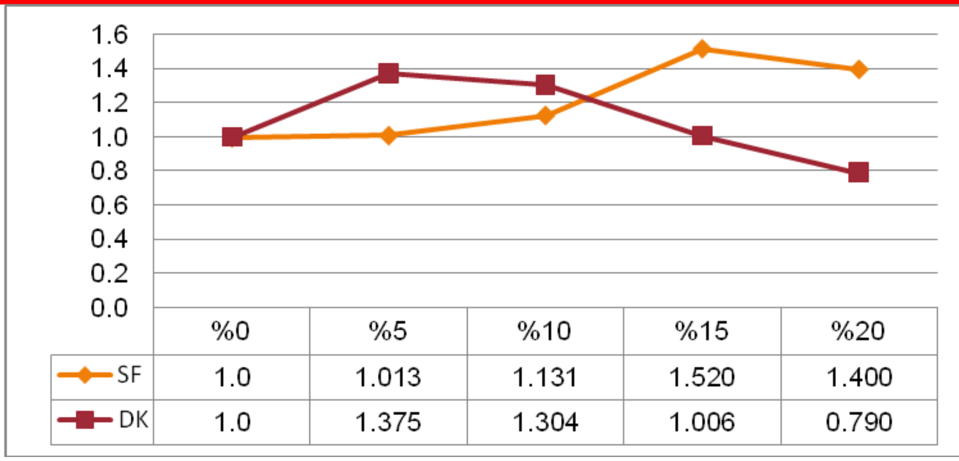

Fig 6. Relative Compressive Strength to Control Mix -28 days

Tensile Strength

Figures 6 and 7 show the results of splitting tensile strength test for concrete mixes after 7and 28 days. It can be seen that use of 5 %,10%,and 15% DK results in increase in tensile strength up to 39,36.5,and 27.42 kg/cm^2 after 7days ,while reach to 45.7, 43.3 ,and 38.6 kg/cm^2 after 28days. Furthermore, concrete containing 20% DK gives lower tensile strength than concrete of 0%, 5%, 10%, and 15% Dk.

Figure 8 represent the relative tensile strength for concrete mixes containing dealuminated kaolin with respect to tensile strength of control mix. Figure 8 show that tensile strength of concrete mix (M1) higher than strength of control mix by 44.4% and 26.9% for strength after 7 and 28 days respectively. Also Fig.8 indicates that tensile strength of mixes containing 10% and 15% DK higher than strength of control mix by 35.1%, and 1.15% for compressive strength after 7 days, while the tensile strength after 28 days of mixes containing 10% and 15% DK higher than that of control mix by 20.2%, and 7.2% respectively.

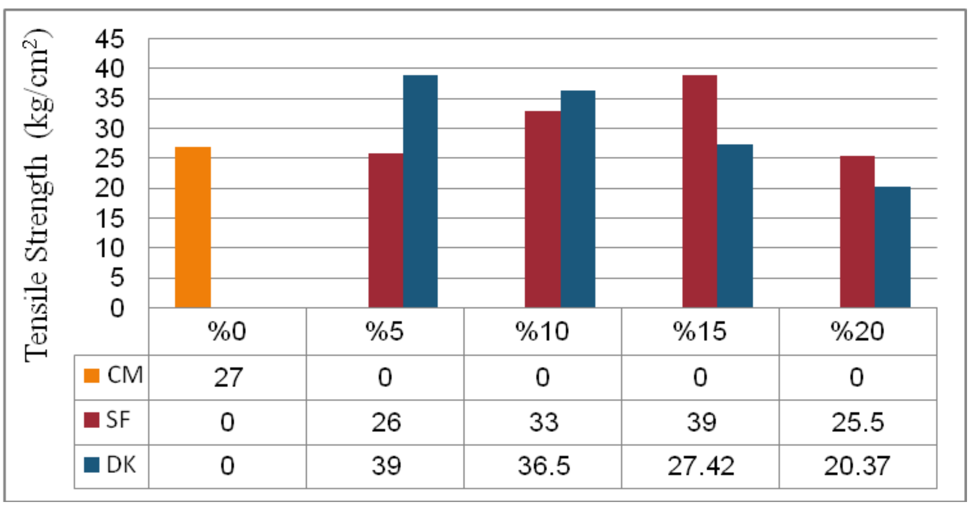

Fig 7. Tensile Strength after 7 days

Modulus of Elasticity

Figure 11 indicates that use of 10 %, 15%, and 20% SF results in increase in elastic modulus up to 6.6%, 23.3% and 18.3% more than elastic modulus of control mix, while elastic modulus of concrete mixes containing 5% and 10% DK results in increase in elastic modulus up to 17.5% and 14.5% less than elastic modulus of control mix. Furthermore, concrete containing 15% SF gave the higher value of elastic modulus than that of the other concrete mixes.

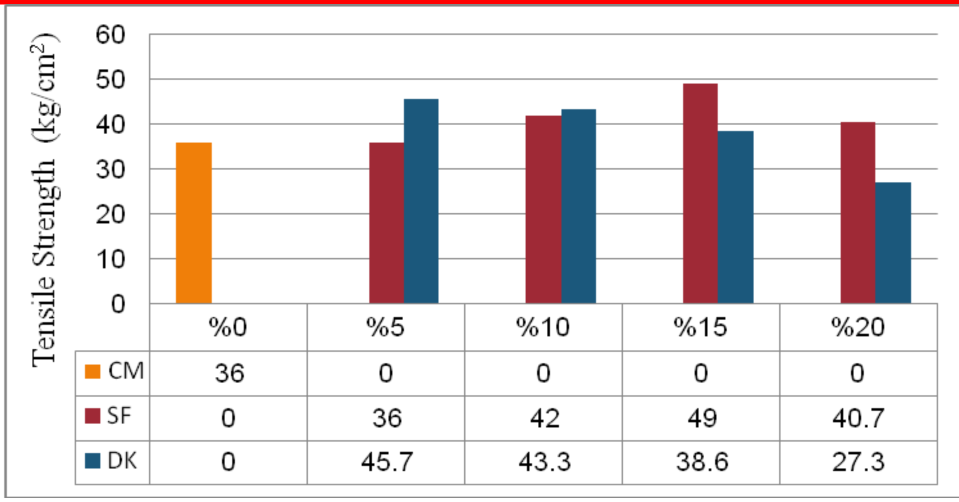

Fig 8. Tensile Strength after 28 days

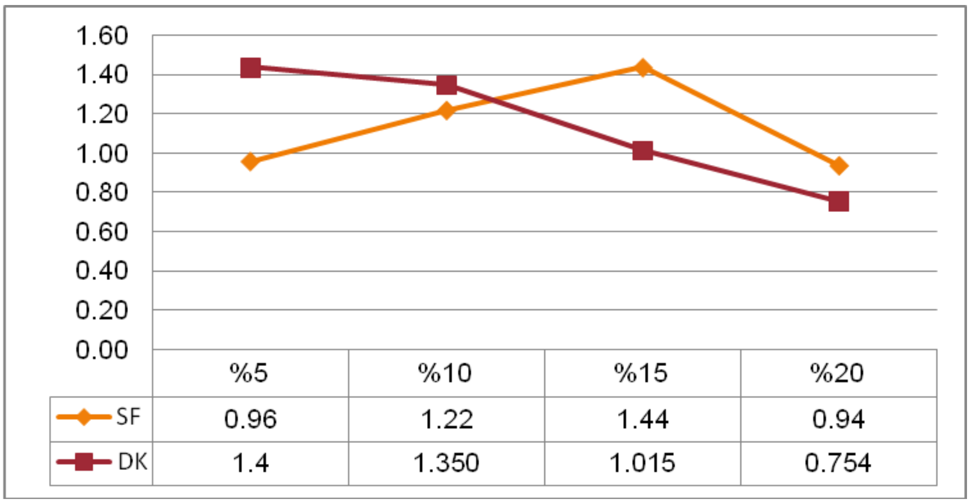

Fig 9. Relative Tensile Strength to Control Mix -7 days

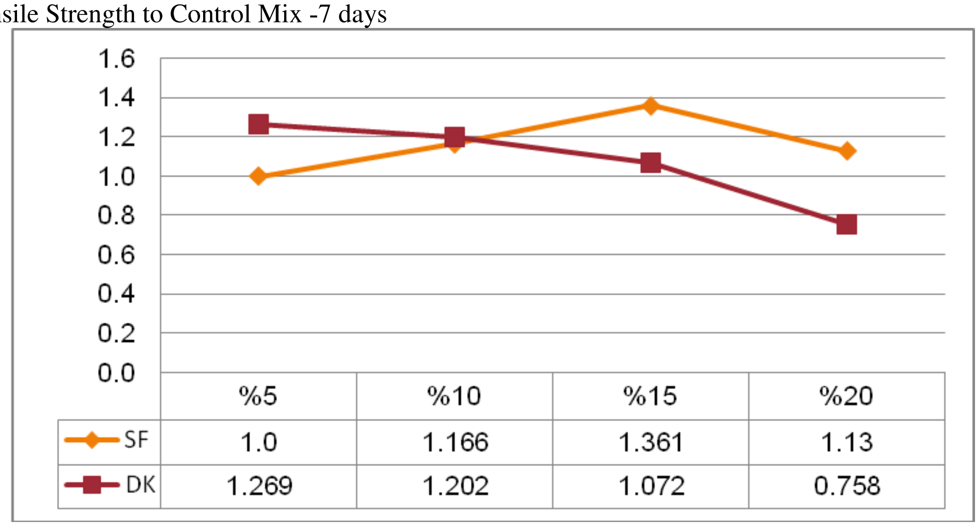

Fig 10. Relative Tensile Strength to Control Mix -28 days

Conclusions

The following conclusions based on the results obtained from the tests considered in this study can be drawn:

- Industrial by-product materials can be used to produce applicable geopolymer concrete with good properties.
- In general, Silica fume and dealuminated kaolin have a positive effect as a cement replacement on the mechanical properties of concrete.

- Concrete mix containing 15 % silica fume has the optimal mechanical properties followed by concrete mixes containing 20% SF, 10% SF, 5% DK, and 10% DK.
- Concrete mixes containing silica fume or dealuminated kaolin have lower slump than that of concrete mix with 0% SF and 0% DK (i.e. control mix).

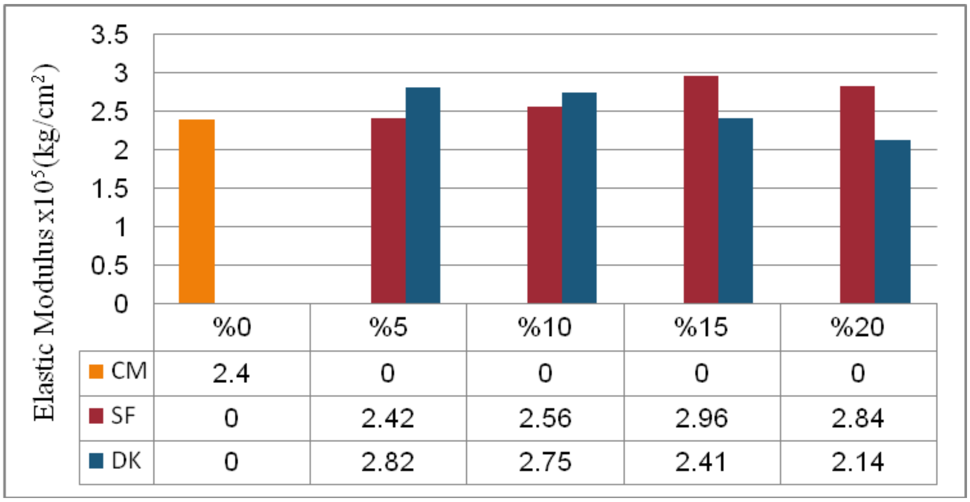

Fig 11. Elastic Modulus of Concrete Mixes

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