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Design of High Compressive Strength Concrete Mix without Additives

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ABSTRACT
In this paper, the crashed Basalt and uncrushed granite is used in concrete mixes as coarse aggregate. The selected materials, with high specification using special production techniques, the properties ,the mix design procedure and mix proportion of the high strength concrete (HSC) were discussed. Different proportions of Ordinary Portland cement (410,430 and 450) kg/m^3 with different crashed Basalt and uncrushed Granite coarse aggregate amount (1120 and 1050) kg/m^{3}and fine aggregate with fine modulus of 3.65 were used. Eight concrete mixes were prepared: two as control mix for crashed Basalt and uncrushed Granite, three with crashed Basalt and three with uncrushed Granite coarse aggregate with mix amount(410:680:1120,430:610:1050 and 450:550:1050) kg/m3,(cement: fine aggregate: coarse aggregate)respectively. The study showed that the use of granite coarse aggregate in concrete mixes has a clear effect in mix proportion. The compressive strength of concrete was measured at ages of 7, 28 and 56 days and it was found that the granite (Mix3) of (450:550:1050) kg/m^3 with w/c of 0.46 give the highest of strength in 28 and 56 days among the abovementioned mixes its 56 and 64 N/mm^2 respectively. The paper shows that good results of compressive strength and workability of concrete were obtained when using granite coarse aggregate.
Keywords: Concrete, Basalt coarse aggregate, uncrushed Granite coarse aggregate, Compressive strength.

I. INTRODUCTION

Concrete is one of the most common materials and widely used in construction work it plays an important role in infrastructure and private buildings construction. Understanding the basic behaviours of concrete is essential for civil engineering students to become civil engineering profession Concrete is a manmade building material that looks like stone. The word “concrete” is derived from the Latin concretus, meaning “to grow together.” Concrete is a composite material composed of coarse granular material (the aggregate or filler) embedded in a hard matrix of material (the cement or binder) that fills the space among the aggregate particles and glues them together. Alternatively, we can say that concrete is a composite material that consists essentially of a binding medium in which are embedded particles or fragments of aggregates. The simplest definition of concrete can be written as: Concrete: filler + binder .Depending on what kind of binder is used, concrete can be named in different waysals. As a structural material, the compressive strength at an age of 28 days is the main design index for concrete [1, 2, 3, and 4]. There are several reasons for choosing compressive strength as the representative index. First, concrete is used in a structure mainly to resist the compression force. Second, the measurement of compressive strength is relatively easier. Finally, it is thought that other properties of concrete can be related to its compressive strength through the microstructure. Pursuing high compressive strength has been an important direction of concrete development. A high compressive strength could be achieved by reducing the w/c ratio. However, to keep a concrete workable, there is a minimum requirement on the amount of water; hence, the w/c ratio reduction is limited, unless other measures are provided to improve concrete’s workability [5,6and 7]. For this reason, progress in achieving high compressive strength High strength concrete is a type of high performance concrete. The primary difference between high strength concrete and normal-strength concrete relates to the compressive strength that refers to the maximum resistance of a concrete sample to be applied pressure although there is no precise point of separation between high strength concrete and normal strength of concrete. The American concrete institute ACI [1] defines high strength concrete as concrete with a compressive strength greater than 41MPa (6000psi). high strength concrete is a superior product with increased modulus of elasticity, lower creep and drying, Shrinkage, excellent freeze thaw resistance, low permeability and increased chemical resistance high strength concrete is specified where reduced weight is important or where architectural considerations call for small support element by carrying load more efficiently than normal strength concrete High strength concrete HSC also reduces the total amount of materials placed and lower the overall cost of the structure, Although a 97 MPa (14000psi) concrete costs approximately three time as much as a 20 MPa (3000 Psi) concrete, its compressive strength is nearly five times greater, thus it is economical[8,9]. In this research work the locally available constituents material of concrete were selected for the purpose to obtained high strength concrete HSC.

II. CASE STUDY

This paper deals with HSC, special requirements, additional special materials and the benefits of its use in the structural members of buildings. Basic ingredients of HSC are generally the same as normal strength concrete ''NSC'' (i.e. cement, fine aggregate, coarse aggregate, water). Higher material quality may be needed in HSC. In this paper concrete mixes were designed, prepared and tested in the laboratory. At first tests were carried out on the components of concrete mix (cement, coarse aggregate, fine aggregate and water) then several concrete mixes were prepared using crashed Basalt and uncrushed Granite as coarse aggregate with different mixes proportion. This was done in order to achieve high compressive strength concrete without additives. The results of laboratory experiments were analyzed and discussed to investigate the effect of both crashed basalt and uncrushed granite on compressive strength of hardened concrete.

III. CONSTITUENTS of CONCRETE

***Cement*:** An ordinary Sudanese Portland Cement PC 42.5 manufactured by mass was used conforming to EN 197-1 cement. Conforming to British Standard No .12 of 1996 with specific gravity 3.15.Initial and final setting times of the cement were 110min and 323min respectively.

***Fine Aggregate*:** The fine aggregate used in the experimental program was natural river sand. The specific gravity and water absorption of the sand are 2.59 and 0.91espectively.

***Coarse Aggregate*:** Crushed Basalt stones of size 20mm from Jabal Toryia and uncrushed granite stones from Satat – Gadarif State were used as course aggregate. The properties of coarse aggregate and fine aggregate are presented in table 1.

Table 1 Properties of Aggregate

Properties	Coarse Aggregate		Fine Aggregate
	Basalt	Granite	
Specific gravity	2.855	2.54	2.59
Apparent	2.88	2.69	2.65
Absorption	0.6	1.8	0.91
Bulk density (kg/m3)	1769	1650	1692

Water: water from Khartoum city water distribution system was used in the concrete mix at temperature of 4°C has been cool using ice after conducting chemical analysis of water.

IV. MIX DESIGN METHODS

ACI curing method was used to design concrete mixes. Concrete specimens with different mix proportions of two types of coarse aggregate (crashed basalt and uncrushed granite) were prepared.

The aggregate dry density used was 1769 kg/m^3, and the maximum aggregate size use in all mixes was 20mm.using standard cubes moulds (100*100*100) mm, 9 cubes represented each mix proportion, were casted and tested at ages 7, 28 &56 days.

Components of mix materials

Concrete Mixes Design: the proportions of mixes and amounts of material for all mixture as illustrated table2:

Table 2 Shows the amount and mix proportions

MIXES NO	Mix proportion	Cement(Kg/m^3)	Fine Aggregate(Kg/m^3)	Course Aggregate(Kg/m^3)	W/C Ratio
Basalt Mix1	1:1.66:2.73	410	680	1120	0.5
Basalt Mix 2	1:1.42:2.44	430	610	1050	0.43
Basalt Mix3	1:1.22:2.33	450	550	1050	0.46
Granite Mix1	1:1.66:2.73	410	680	1120	0.5
Granite Mix2	1:1.42:2.44	430	610	1050	0.43
GraniteMix3	1:1.22:2.33	450	550	1050	0.46

V. RESULTS of EXPERIMENTS of FRESH and HARDENED CONCRETE

The results of fresh and hardened concrete tests for different mix proportions using crashed Basalt and uncrushed Granite as coarse aggregate represented in Table 3 to11 and depicted graphically in Figures 1 to 7.

Table 3 Results of slump and Compressive Strength Tests of the Basalt Mix1

Age	Area(mm^2)	Slump(mm)	Failure load(kN)	Compressive strength(N/mm^2)	Average Compressive strength(N/mm^2)
7days	10000	100	485	48.5	48.0
			460	46.0	
			490	49.0	
28days			570	57.0	55.0
			530	53.0	
			550	55.0	
56days			630	63.0	58.0
			580	58.0	
			530	53.0	

Table 4 Results of Slump and Compressive Strength Tests of the Basalt Mix2

Age	Area(mm^2)	Slump(mm)	Failure load(kN)	Compressive strength(N/mm^2)	Average Compressive strength(N/mm^2)
7days	10000	80	390	39.0	43.0
			450	45.0	
			460	46.0	
28days			490	49.0	52.0
			580	58.0	
			490	49.0	
56days			550	55.0	60.5
			630	63.0	
			640	64.0	

Table 5 Results of Slump and Compressive Strength Tests of the Basalt Mix3

Age	Area(mm^2)	Slump(mm)	Failure load(kN)	Compressive strength(N/mm^2)	Average Compressive strength(N/mm^2)
7days	10000	70	400	40.0	41.5
			460	46.0	
			380	38.5	
28days			520	52.0	52.0
			520	52.0	
			510	51.0	
56days			570	57.0	57.0
			570	57.0	
			480	48.0	

Table 6 Results of Slump and Compressive Strength Tests of the Granite Mix1

Age	Area(mm^2)	Slump(mm)	Failure load(kN)	Compressive strength(N/mm^2)	Average Compressive strength(N/mm^2)
7days	10000	80	325	32.5	40.0
			400	40.0	
			395	39.5	
28days			495	49.5	50.5
			510	51.0	
			505	50.5	
56days			575	57.5	56.0
			545	54.5	
			555	55.5	

Table 7 Results of Slump and Compressive Strength Tests of the Granite Mix2

Age	Area(mm^2)	Slump(mm)	Failure load(kN)	Compressive strength(N/mm^2)	Average Compressive strength(N/mm^2)
7days	10000	80	480	48.0	51.0
			500	50.0	
			550	55.0	
28days			600	60.0	53.0
			530	53.0	
			460	46.0	
56days			600	60.0	60.5
			620	62.0	
			590	59.0	

Table 8 Results of Slump and Compressive Strength Tests of the Granite Mix3

Age	Area(mm^2)	Slump(mm)	Failure load(kN)	Compressive strength(N/mm^2)	Average Compressive strength(N/mm^2)
7days	10000	90	570	57.0	54.0
			530	53.0	
			520	52.0	
28days			580	58.0	56.0
			550	55.0	
			550	55.0	
56days			650	65.0	64.0
			515	51.5	
			625	62.5	

Table (9) Average for Results of compressive strength and slump tests (Basalt mixes)

Basalt mixes	Slump	Average Compressive strength N/mm^2		
		7days	28days	56days
Control mix(Basalt)	0	28.5	33.0	39.0
Basalt mix1	100	48.0	55.0	58.0
Basalt mix2	80	43.0	52.0	60.5
Basalt mix3	70	41.5	52.0	57.0

Table (10) Average for results of compressive strength and slump tests (Granite mixes)

Basalt mixes	Slump	Average Compressive strength N/mm^2		
		7days	28days	56days
Control mix(Granite)	50	40.5	49.0	54.0
Granite mix1	80	40.0	50.5	56.0
Granite mix2	80	51.0	53.0	60.0
Granite mix3	90	54.0	56.0	64.0

Table (11) Results of mix3 in Granite and Basalt aggregate compared with control mix

Type of aggregate	Slump	Average Compressive strength N/mm^2		
		7days	28days	56days
Control mix(Basalt)	0	28.5	33.0	39.0
Control mix(Granite)	50	40.5	49.0	54.0
Basalt mix3	70	43.0	52.0	57.0
Granite mix3	90	54.0	56.0	64.0

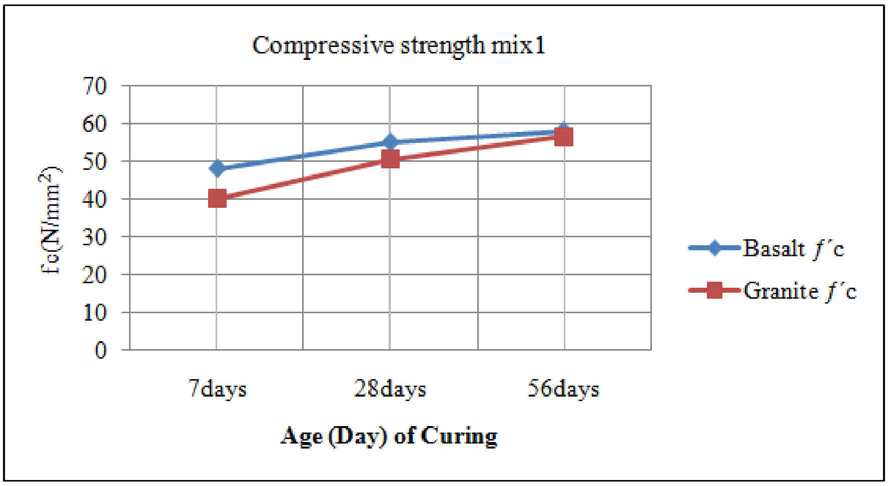

Fig (1) Comparison between strength developments of MIX1 for Basalt &Granite Aggregate

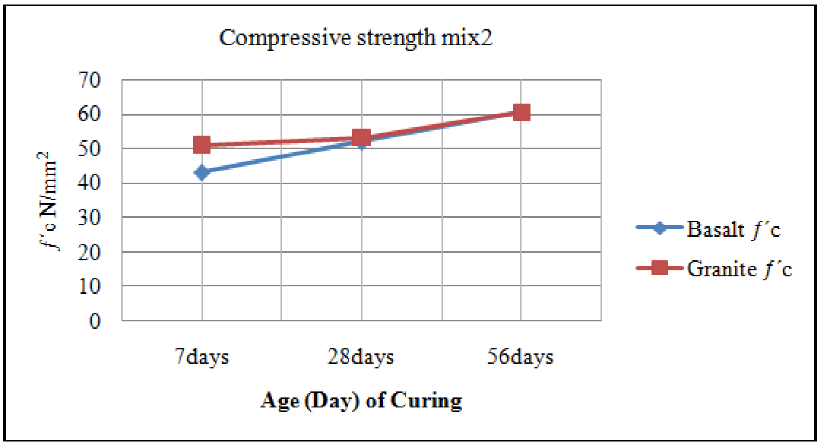

Fig (2) Comparison between strength developments of MIX2for Basalt &Granite Aggregate

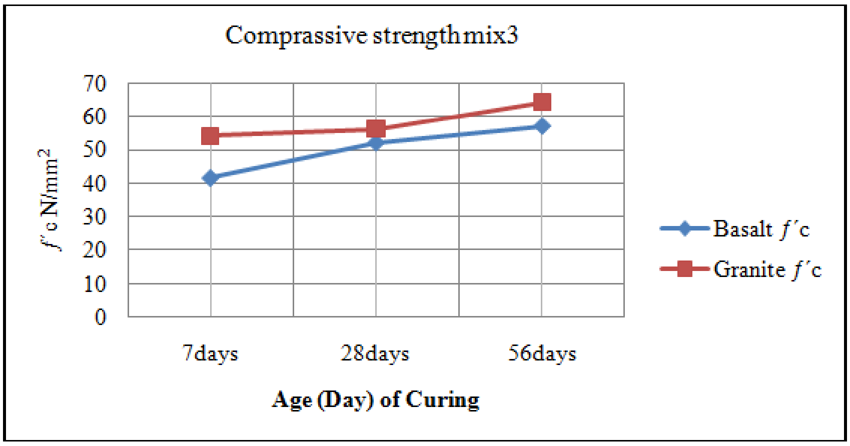

Fig (3) Comparison between strength developments of MIX3for Basalt &Granite Aggregate

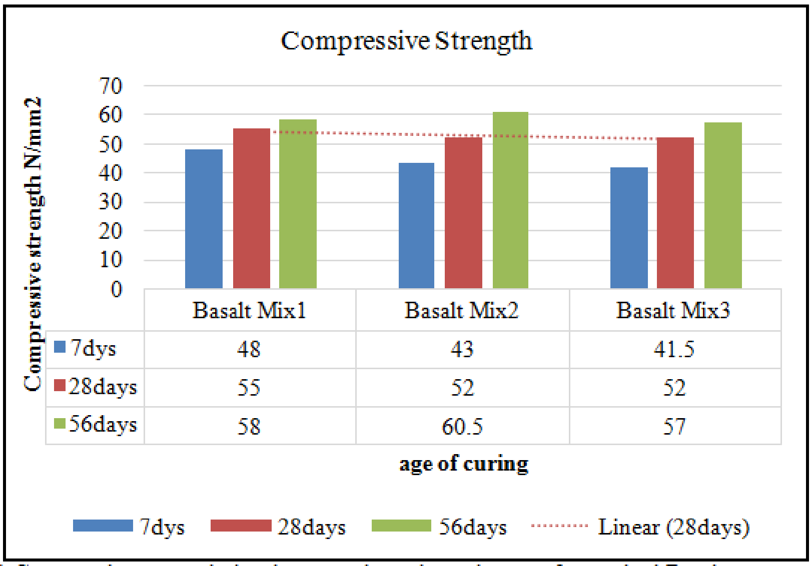

Fig (4) Compressive strength development throughout the ages for crashed Basalt aggregate mixes

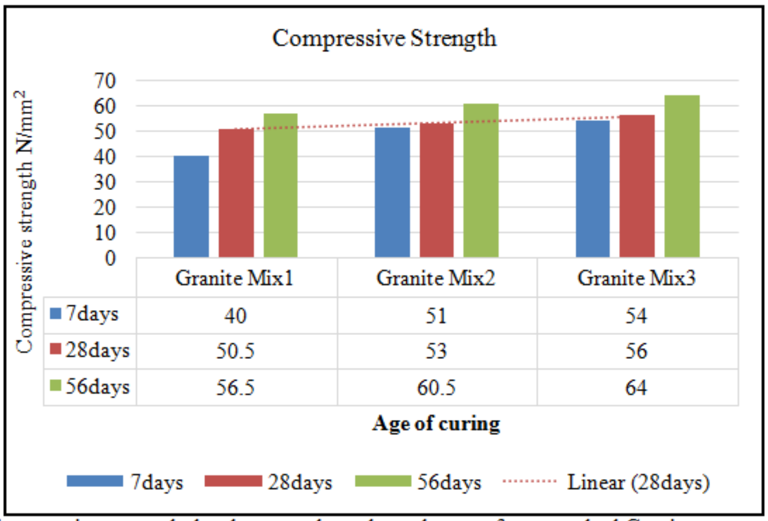

Fig (5) Compressive strength development throughout the ages for uncrushed Granite aggregate mixes

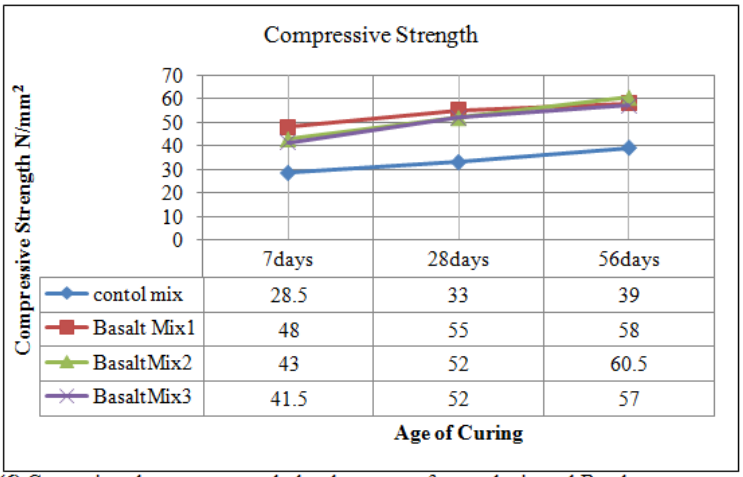

Fig (6) Comparison between strength developments of control mix and Basalt aggregate mixes

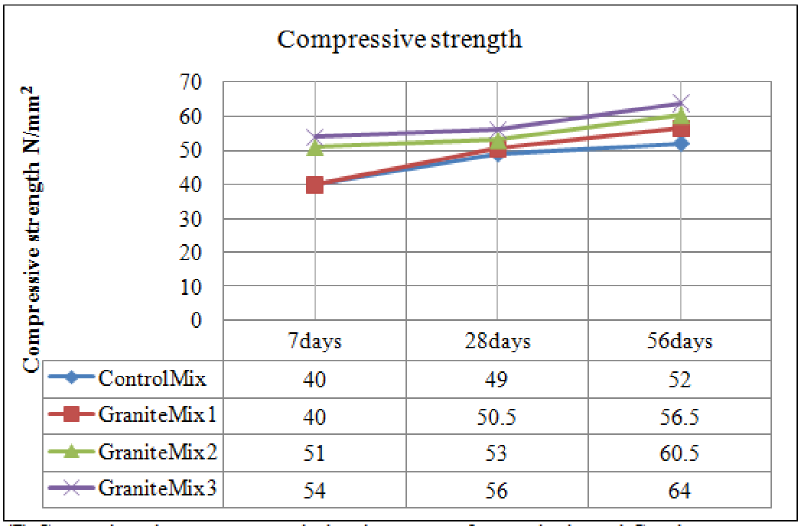

Fig (7) Comparison between strength developments of control mix and Granite aggregate mixes

VI. DISCUCSSION OF THE RESULTS

The results obtained from the different mix proportions using high quality crashed basalt and uncrushed granite coarse aggregate are summarized and discussed as following:

1. Table (3,4,5,10&11) shows that the slump values is decreased with in increased of the cement content for basalt aggregate mixes, and its increased within increased of the cement content for granite aggregate mixes but both of them with in range accordance to ACI mix design (25-100) mm.
2. Figure (1, 2&3) & Table (3, 4, 5, 6, 7&8) shows that the compressive strength is developed in 7, 28&56 days for basalt and granite course aggregate.
3. From Fig (4&6) & Table (2) the compressive strength is decreased with in increased of the cement content in mix1, mix2&mix3 for basalt aggregate mixes.
4. From Fig (5&7) & Table (2) Granite mixes it was found that the compressive strength is increased with in increased of the cement content in different mixes of Granite aggregate .also the Figure shows that in Mix3 Granite aggregate mixes in 56days gives the maximum compressive strength than other mixes.

VII. CONCLUSIONS & RECOMMENDATIONS

In this study the crashed basalt and uncrushed granite coarse aggregate with high quality for basic material, was used to produce high compressive strength concrete in different ages. From the results obtained it can be concluded that:

1. The significant effects of the high quality uncrushed granite coarse aggregate occurred at mix proportion of (450:1050:550:207) kg/m^3, (cement: coarse aggregate: fine aggregate: water), respectively.
2. The production of 1m3 HSC strength of concrete mix proportion (mix3) of material of as follow: cement content 450kg /m^3, fine aggregate 550kg/m^3 ,coarse aggregate 1050kg/m^3 for Granite aggregate in Water temperature 4°C mix temperature 28°C and w/c 0.46 .
3. The compressive strength of concrete with in increased 0f cement content in granite aggregate mixes.
4. The slump values of all mixes, when use high quality crashed basalt and uncrushed granite coarse aggregate with in range accordance to ACI mix design (25-100) mm.

From this study it can be recommended that the uncrushed granite with high material quality, suitable concrete mix proportion and extra quality control procedures can be used to produce high compressive strength concrete.

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