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Effect of Sudanese Aggregate on Production of High Strength Concrete

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Abstract: *This paper presents the results of an experimental investigation carried out to evaluate the performance of high strength concretes, containing supplementary cementitious materials. The main aim of the investigation program is first to check ability to prepare high strength concrete of grade M80 MPa with locally available aggregates namely, Marble and Granit and then to study the effects of high strength concretes to drying shrinkage. The concrete specimens were tested at different age level, 7-days and 28-days for mechanical properties of concrete, cube compressive strength, and length change due to drying shrinkage .Also fresh concrete properties and slump tests has been performed. The second part presents the results of an experimental investigation carried out to evaluate the shrinkage of high strength concrete. Twelve specimens were tested for28-days for mechanical properties of concrete, cube compressive strength, and twelve specimens were tested for 28, 56-days for concrete length change. High strength concrete is made by partial replacement of cement by silica fume and silica fume with fly ash. This paper presents one of experimental laboratory investigations being carried out for production and characterization of high strength concrete for heightening of an existing concrete dam in the south of Sudan. Brief description of the main features of the dam and concrete works are presented. Hundreds of specimens were performed and tested using local Sudanese aggregates with addition of supplementary cementitious materials (Silica Fume and Fly Ash) and Super plasticizers. Thirty three trial mix designs of grade (80 MPa) of high strength concretes had been successfully produced and their mechanical properties were measured and documented. The results have offered an important insight for locally available aggregates in Sudan to Contribute in high strength concrete. It is concluded that local aggregates, Marble and Granit, in combination with supplementary cementitious materials can be utilized in producing high strength concrete in Sudan. The relationship between high strength concrete and drying shrinkage is a weak direct relationship.*

Keywords– *Compressive strength, drying shrinkage, Fly ash, High strength concrete, Silica fume.*

I. Introduction

It is only natural that hydraulic cement concrete would be viewed as a single material, but in reality, concrete is much better understood when viewed as a composite material comprised of two fundamentally different materials—filler (i.e. aggregate) and binder (i.e. paste). Material properties, principally those mechanical in nature are fundamentally derived from the relative similarities (or differences) in the properties of the aggregate and paste. For this reason, the laws governing the selection of materials and proportions of concrete are by no means static. The most influential factor affecting the strength and largely influencing the durability of concrete is the water-binder (water-cement) ratio. (1)

Hydraulic cement concrete is a two-component composite material fundamentally consisting of aggregates and paste. The principles applicable to proportioning structural concrete are primarily driven by the relative mechanical properties of paste and aggregate. (1)

Aggregates overwhelmingly occupy the largest volume of any constituent in concrete and profoundly influence concrete performance in both the fresh and hardened states. Selection of appropriate aggregates is important for all structural concretes, regardless of strength. Among the most important parameters affecting the performance of concrete are the packing density and corresponding particle size distribution (gradation) of the combined aggregates used. (1)

The optimum gradation of fine aggregate for high-strength concrete is determined more by its effect on water demand than on particle packing. High-strength concretes typically contain high volumes of cementitious (i.e. powder) sized material. As a result, fine sands that would be considered acceptable for use in conventional concretes may be less suited for high strength concrete due to the sticky consistency may result. (1)

Given the critical role that the interfacial transition zone plays in high-strength concrete, the mechanical properties of coarse aggregate will have a more pronounced effect than they would in conventional-strength concrete. Important parameters of coarse aggregate are shape, texture, grading, cleanliness, and nominal maximum size. (1)

The paper presents the results of an experimental investigation carried out to evaluate the ability to use two different local Sudanese aggregate, marble from south Sudan and granite from north of Sudan with supplementary cementitious materials in producing high strength concrete M80 MPa [2, 3, 4], and in the second part of the experimental investigation to evaluate the shrinkage of High Strength Concrete. Shrinkage is the strain measured on a load-free concrete Specimen. Shrinkage is the decrease of concrete volume with time. This decrease is due to change in moisture content of the concrete and physio-chemical changes, which occur without stress attributable to actions external to the concrete.

This paper is a part of an ongoing experimental laboratory investigations being carried out for production and characterization of high strength concrete for heightening of Roseires Dam, which, located on Blue Nile River in Sudan, was constructed in 1960s for power generation and irrigation purposes. It has been decided to heighten this composite concrete buttress and earth fill dam by 10m to increase its storage capacity.

The raising works of Roseires concrete dam comprise the addition of mass concrete, reinforced concrete, and post-tensioning requirements into both crest and the downstream portions of the dam. The concrete dam section is divided into 11 typical structures along its 1km length. The total numbers were 69 buttresses. Because each structure has its specific geometry and function different design methodologies are needed for each.

Drying shrinkage is shrinkage occurring in a specimen that is allowed to dry. Drying shrinkage occurs after the concrete has already attained its final set and a good portion of the chemical hydration process in the cement gel has been accomplished. Drying shrinkage of high strength concrete, although perhaps potentially larger due to higher paste volumes, do not, in fact appear to be appreciably large than normal strength concrete. This is probably due to the increase in stiffness of stronger mixes.

Laboratory studies indicate that adding a HRWRA to a cement paste increases the drying shrinkage of the paste. Some laboratory data confirm that HRWRAs can increase concrete drying shrinkage at a given water-cement ratio and cement content (given paste content), but this effect has not been definitively established. Therefore, the drying shrinkage of flowing concrete should be similar to, or slightly greater than, that of the same concrete mixture without any HRWRA. If there is a simultaneous reduction in cement content and **w/cm** when the HRWRA is added, drying shrinkage can be reduced. [5]

Figure (1) Roseires Dam Concrete Section upstream view

II. Materials Used

2.1 Cement

In this research, a locally produced ordinary Portland cement type I, conforming to ASTM C150 (OPC 42.5N) [6]which is extensively used in Sudan, was used in the trial batches production. The specific gravity of cement used was 3.15, initial and final setting times were 2.2 and 3.6, other physical and mechanical properties for cement are shown in Table (1).

Table (1) Physical and Mechanical Properties of Cement

Test according to BSEN196		Result
Normal Consistency		27.4%
Setting Time	Initial Setting Time	2.2 hour
	Final Setting Time	3.6 hour
Loss on ignition		1.95%
Compressive Strength	2 days	32.1 MPa
	28 days	60.7 MPa

2.2 Aggregates

The coarse and fine aggregates used in this study were crushed marble processed from the local quarries around Damazin City, the quarry for Roseires Dam Heightening Project. The maximum aggregate size was 20 mm, The specific gravity and absorption of the coarse aggregates, determined in according with ASTM C127 [(7)] were 2.84 and 0.25respectively, whereas those of fine aggregates, determined in accordance with ASTM C128 [(8)]were 2.839 and 0.45 respectively. All the sand samples were tested for their absorption percentage in saturated surface dry (SSD) condition. Organic impurities in sand were tested in accordance with ASTM C-40. The water-cement ratio of all trial mixes were based on saturated surface dry condition (SSD) of the aggregates, different type of aggregates from another quarry was used. To compare with marble, granite aggregates from Merwei Dam (another recently constructed concrete dam in the north of Sudan) location were used.

Figure (2) Different types of Aggregates production process

2.3 Chemical Admixtures (Superplasticizer)

The superplasticizer used in this study has the trade name of "PCA-(I)" from Jiangsu Bote new Materials Company-China. PCA-(I) is a polycarboxylate polymer-basedcomposite admixture. It is a liquid which has the performance of high range water reduction, excellent slump retention and strengthening. The specific gravity of the superplasticizer was 1.085 and the PH was 8.11 with nil chloride content percentage by weight. It is specially adapted for the production of high durability concrete, self-compacting concrete, high compressive strength concrete, and high workability concrete. PCA-(I) superplasticizer is formulated to comply with the ASTM specifications for concrete admixture: ASTM494, Type G [(9)].

2.4 Silica Fume

The Silica fume(SF) used in this study was in accordance with the most international standards such the European BS EN 13263 Silica fume for concrete, Part 1:2005 Definitions, requirements and conformity criteria Part 2:2005 Conformity evaluation, and the American ASTM C1240-97b, Standard specification for silica fume for use as a mineral admixture in hydraulic- cement concrete, mortar and grout.[(10)]

Table (2) Physical Properties of KD-12 Silica Fume

Test items	Specified limits according to ASTM C12405, BS EN13263	Test Results
Absolute density (kg/m^3)	≥2200	2249
Loss on ignition (%)	≤3.5	1.88
Coarse particle	≤1.5	1.1
SiO_2 (%)	≥86	92
Carbon content (%)	≤2.5	2.3
Moisture (%)	≤1	0.85
Specific area (m^2/g)	≥15	20

2.5 Fly ash

Fly ash used in this study was manufacture by Zouxian power plant-China. The properties of fly ash are presented in Tables 3,4. ASTM C618; the requirement for Class F and Class C fly ashes, and the raw or calcined natural pozzolans, Class N, for use in concrete. Fly ash properties may vary considerably in different areas and from different sources within the same area. The preferred fly ashes for use in high strength concrete have a loss on ignition not greater than 3 percent, have a high fineness, and come from a source with a uniformity meeting ASTM C 618 requirements [11].

Table(3) Chemical Properties of Fly Ash

Test items	Specified limits according to BS 3892	Test Results
SO_3 (%)	Max.2.0%	1.68%
Chloride (%)	Max.0.1%	0.03%
Calcium Oxide (%)	Max.10%	8.4%

Table(4) Physical Properties of Fly Ash

Test items	Specified limits according to BS 3892	Test Results
Loss on ignition (%)	Max.7.0%	1.39%
Moisture Content	Max.0.5%	0.29%
Fineness	Max.12%	8.24%
Particle Density	Min.2000kg/m^3	2039kg/m^3
Water Requirement	Max.95% (30%Fly Ash+70%Cement)	92%
Soundness	Max.10mm	9.02mm
Strength Factor	Min.0.8	0.83

III. Experimental Programme

4.1 Slump Test:

After mixing, a portion of the fresh concrete was placed aside for plastic properties determination. Slump of fresh concrete was measured according to ASTM C143. Precautions were taken to keep the slump between 150-200 mm to obtain pumpable concrete for dam construction. [12]

4.2 Compressive Strength test:

Lime saturated-water curing method was used in this study. Concrete casting was performed according to BS EN 12390-1:2000. [13] Molds were covered to prevent loss of water from evaporation. Specimens were kept for 24 hours in molds at a temperature of about 23 C in casting room, and then cured for the specified time at approximately 23 C ± 2 C. [14]The specimens were tested in dry state for compressive strengths tests, in accordance with BS EN 12390-3:2002. [15]

4.3 Drying Shrinkage:

Shrinkage of concrete was measured with the help of 'Shrinkage Apparatus' as shown in Figure 3.

Concrete beams specimens of 75mm × 75mm in cross section and 280mm length were cast with various concrete mixes. Pins were embedded at both ends of the specimens to hold them in the shrinkage apparatus. Specimens were cured in water for 7 days before testing for shrinkage. Initial readings of the specimens were taken with the help of dial gauge attached to the apparatus. Then the specimens were air dried for 28 and 56 days. Again the final reading of each specimen was taken after the specified period of air-drying. The change in length of each specimen was calculated from the difference of final and initial dial gauge readings. Then the shrinkage strain was calculated. Determination of length change of hardened concrete-drying shrinkage tests in accordance with ASTM C-157 M. [16]

Figure(3): Shrinkage measuring apparatus along with calibration rod and specimen

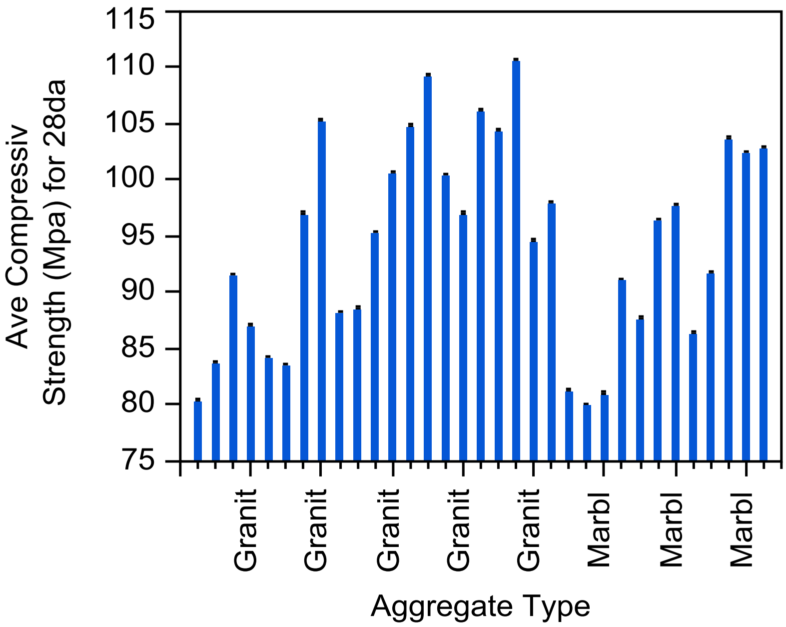
IV. Results

The results of the compressive strength for 7 and 28 days for different mixes, thirty three mixes, twenty- one by marble aggregate and twelve by granite aggregate were present in table(5), and the distribution of compressive strength for 28 days for both type of aggregate were present in figures (4). The results of the shrinkage strains of various concrete mixes with Marble and Granite aggregate are given in Table (6) and Figures (6) and (7) respectively.

Table(5)The results of fresh and hardened concrete properties 7days Compressive Strength(MPa), 28days Compressive Strength(MPa) and Slump(mm).

Test No	Date	Type of Aggregate	Ave 7days Compressive Strength (MPa)	Ave 28days Compressive Strength (MPa)	Slump (mm)
1	30-Oct-09	Marble	75.0	81.2	190.0
2	31-Oct-09	Marble	62.7	80.0	182.0
3	6-Nov-09	Marble	69.8	80.9	190.0
4	11-Nov-09	Marble	79.3	91.1	205.0
5	14-Nov-09	Marble	79.0	87.6	195.0
6	5-Dec-09	Marble	88.1	96.4	188.0
7	6-Dec-09	Marble	77.3	97.7	216.0
8	7-Dec-09	Marble	92.3	86.3	207.0
9	7-Dec-09	Marble	92.2	91.7	215.0
10	13-Jan-10	Granite	65.6	80.3	220.0
11	14-Jan-10	Granite	68.5	83.7	230.0
12	15-Jan-10	Granite	80.4	91.5	165.0
13	15-Jan-10	Granite	85.9	87.0	170.0
14	20-Jan-10	Granite	68.8	84.2	180
15	26-Jan-10	Granite	72.9	83.5	200.0

Test No	Date	Type of Aggregate	Ave 7days Compressive Strength (MPa)	Ave 28days Compressive Strength (MPa)	Slump (mm)
16	28-Jan-10	Granite	86.6	96.9	220.0
17	29-Jan-10	Granite	91.5	105.2	170.0
18	29-Jan-10	Granite	80.2	88.2	200.0
19	8-Feb-10	Granite	81.7	88.5	143.0
20	11-Feb-10	Granite	81.8	95.3	155.0
21	15-Feb-10	Granite	91.9	100.6	162.0
22	17-Feb-10	Granite	98.2	104.7	161.0
23	19-Feb-10	Granite	98.7	109.2	121.0
24	19-Feb-10	Granite	94.7	100.4	134.0
25	21-Feb-10	Granite	88.6	96.9	159.0
26	24-Feb-10	Granite	92.9	106.1	116.0
27	25-Feb-10	Granite	88.4	104.3	215.0
28	28-Feb-10	Granite	101.0	110.6	77.0
29	1-Mar-10	Granite	81.3	94.5	205.0
30	21-Mar-10	Granite	87.1	97.9	185.0
31	31-Mar-10	Marble	90.7	103.6	115.0
32	14-Apr-10	Marble	93.4	102.4	125.0
33	25-Apr-10	Marble	94.1	102.8	145.0



Figure(4) Distributions of 28days Concrete compressive strength (MPa) for two types of aggregate,(using Granite and Marble)

Table (6)The result of concrete compressive strength and drying shrinkage

Date	Water (kg/m3)	w/cm	Ave Slump (mm)	Compressive Strength 28 days(MPa)	Drying Shrinkage % 28 days	Drying Shrinkage % 56 days
20.3.2011	168	0.28	150	88.7	0.012	0.04
10.4.2011	168	0.28	148	100.8	0.01	0.022
18.4.2011	168	0.28	148	114.4	0.0067	0.0253
27.4.2011	169	0.26	150	89	0.0164	0.042
28.4.2011	169	0.26	150	107.1	0.0208	0.0499
1.5.2011	168	0.28	121	109.1	0.016	0.032
6.5.2011	169	0.26	148	93.4	0.01	0.024
7.5.2011	169	0.26	138	101.5	0.018	0.024
12.5.2011	168	0.28	145	105.9	0.0213	0.0347
14.5.2011	169	0.26	150	95.6	0.0107	0.036
16.5.2011	169	0.26	145	100.1	0.0173	0.0267
17.5.2011	169	0.26	85	105.3	0.008	0.0233

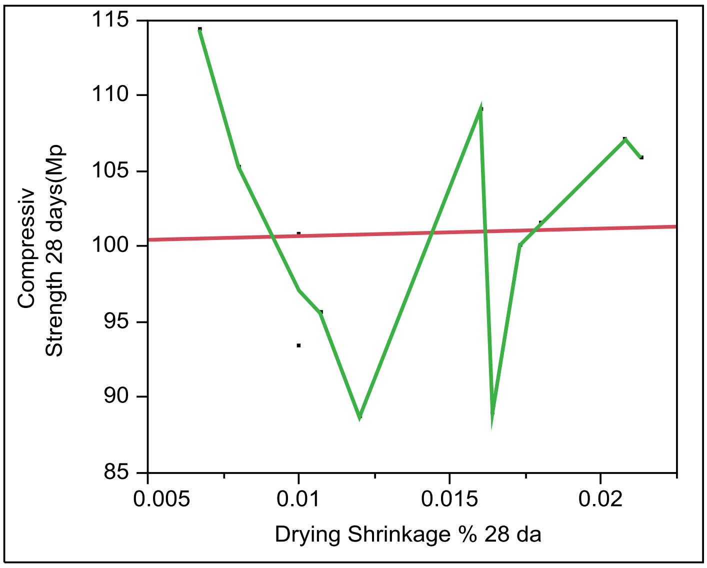


Figure (6) Relationship between 28 days compressive strength (MPa) and28 days drying shrinkage%
28 days Compressive Strength (MPa) = 100.21211 + 49.968173*(28 days Drying Shrinkage %)

R Square	0.00096
Observations	12

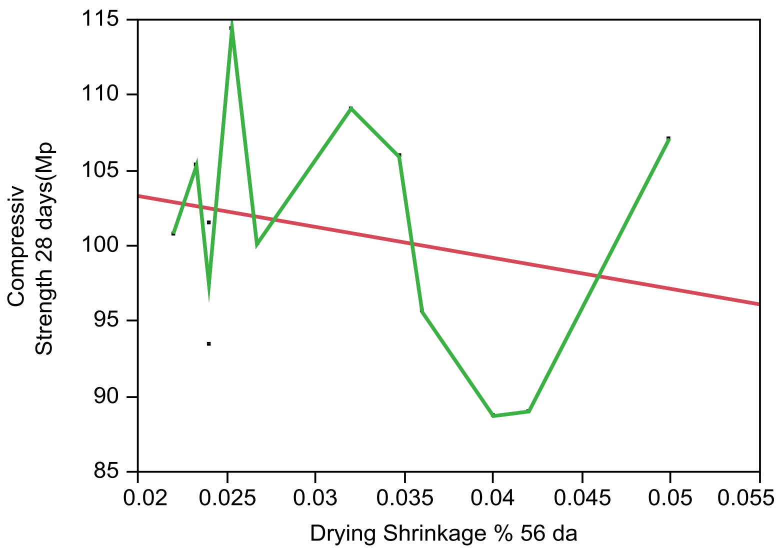


Figure (7) Relationship between28 days compressive strength (MPa) and 56 days drying shrinkage%
28 days Compressive Strength (MPa) = 107.41863 - 205.64233*(56 days Drying Shrinkage %)

R Square	0.052733
Observations	12

V. Conclusions

On the basis of test results the following major conclusions can be drawn:

1. For all mixes design, granite and marble aggregate, the minimum compressive strength for 28 days is 80MPa, the maximum once up to 110 (MPa), these mean we are achieve the desired aim to produce high strength concrete.
2. The design slump range is 50~200mm, the results which were obtained above the minimum limit, minimum slump =77mm, we had 8 tests exceed the maximum limit slightly.
3. From two points above we are satisfy hardened properties and fresh properties for high strength concrete.
4. For both type of aggregate granite from north of Sudan and marble from south of Sudan which we are used in the tests the minimum compressive strength for 28days is 80 MPa and the maximum compressive strength for 28days for granite is 110.6 MPa and maximum once for marble is 103.6 MPa, we can

conclusion that the both type of aggregate can produce high strength concrete.

5. Granite aggregate had a preference in strength than marble aggregate.
6. The drying shrinkage percentage increases with time, drying shrinkage percentage for 56 days it more than 28 days.
7. There are very weak direct relationship between high strength concrete and drying shrinkage percentage.

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References

[1]. Michael A. Caldarone., High strength concrete A practical guide,2009.
[2]. Silica Fume Association, Silica Fume User's Manual, USA, 2005.
[3]. American Concrete Institute, State-of-the-Art Report on High-Strength Concrete, ACI 363. 1997.
[4]. American Concrete Institute, Guide for Selecting Proportions for High-Strength Concrete Using Portland Cement and Other Cementitious Materials , ACI 211.4.2008.
[5]. American Concrete Institute, Guide for the Use of High-Range Water-Reducing Admixtures (Superplasticizers) in Concrete, ACI 212.4R,93.
[6]. American Society for Testing and Materials, ASTM C-150 Standard Specifications for Ordinary Portland Cement, Type I,2003.
[7]. American Society for Testing and Materials, ASTM C-127 Standard test method for Determination of The Specific Gravity and Absorption of the Coarse Aggregates,2000.
[8]. American Society for Testing and Materials, ASTM C-128 Standard test method for Determination of The Specific Gravity and Absorption of the Fine Aggregates,2000.
[9]. American Society for Testing and Materials, ASTM C-494: Standard Specifications for Concrete Super plasticizing Admixtures,2003.
[10]. American Society for Testing and Materials, Standard Specifications for silica fume for use as a mineral admixture in hydraulic-cement concrete, mortar and grout, ASTM C-1240,97.
[11]. American Society for Testing and Materials, ASTM C-618:" Standard Test Method for Physical Properties of Fly Ash,2001.
[12]. American Society for Testing and Materials, Standard Test Method for Slump of Hydraulic-Cement Concrete, ASTM C-143,2003.
[13]. British Standards Institution, Shape, dimensions and other requirements for specimens and moulds, BS EN-12390-1, 2000.
[14]. British Standards Institution, Making and curing specimens for strength tests, BS EN-12390-2, 2000.
[15]. British Standards Institution, Compressive strength of test specimens, BS EN-12390-3, 2002.
[16]. American Society for Testing and Materials, ASTM M Standard test method for Determination of length change of hardened hydraulic-cement mortar and concrete, 1999.