IOSR Journal of Mechanical and Civil Engineering (IOSR-JMCE)
e-ISSN: 2278-1684,p-ISSN: 2320-334X, Volume 12, Issue 2 Ver. I (Mar - Apr. 2015), PP 52-59
www.iosrjournals.org

Production of High Strength Concrete in Sudan

Ali Ahmed. A. Ahmed [1], Salih Elhadi. M. Ahmed [2]
[1]*(Senior Concrete Engineer at SMEC International Pty .Ltd-Sudan, Sudan)*
[2]*(Professor of structural engineering / Sudan university for science and technology, Sudan)*

Abstract: *The aim of this paper to evaluate the performance of high strength concretes containing supplementary cementitious materials. Now a day concrete had demanding requirements both in terms technical performance and economy. The main aim of the investigation program is first to prepare the Strength of concrete of grade M80 with locally available ingredients by using two different methods to produce high strength concrete, method one is statistical approach which was described in ACI211.4, and method two is statistical approach by using statistical software program, namely, JMP statistical software program. In these models, each response (resultant concrete property) such as strength, slump, is expressed as an algebraic function of factors. The concrete specimens were tested at different age levels, 7-days and 28-days for mechanical properties, namely, cube compressive strength, fresh properties, in terms of slump test.This paper presents a part of an ongoing 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. Various percentages of silica fume and fly ash were added at different water/cementitious materials (w/cm) ratios. Thirty three trial mix designs of grade (80 MPa) high strength concrete had been successfully produced and their mechanical properties were measured and documented. The results has offered an important insight for optimizing the fresh and hardened characteristics of high strength concrete and permitted to develop guidelines for optimum mix design methods for high strength concrete from locally available aggregates in Sudan. It is concluded that local concrete materials, in combination with supplementary cementitious materials can be utilized in producing high strength concrete in Sudan.*
Keywords: *Compressive strength, Fly ash, High strength concrete, Silica fume, Statistical model.*

I. Introduction

High Strength Concrete is a relatively recent development in concrete technology made possibly by the introduction of efficient water-reducing admixtures and high strength cementitious materials. This paper will discuss the materials technology underlying the development of high strength concrete, examining the selection of optimum constituent materials and considering the concrete mix design. The properties of both fresh and hardened high strength concrete will be discussed; finally, the production of high strength concrete, illustrated by trial mixes and two approaches will be examined. It is intended that this will lead to an understanding of the potential benefits and limitations of high strength concrete, together with the experience required to produce and use the material in a practical and effective manner.(1)

This paper presents a part of an ongoing experimental laboratory investigation 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.

When considering high strength concrete one must first define what is meant by 'high strength' the perception of what level of compressive strength constitutes. 'High strength' has been continually revised upwards over the past 20 years or so, and may be continued to rise in the near future. A simple definition for 'High strength' would be 'concrete with a compressive strength greater than that covered by current codes and standards'. In the UK this would include concrete with a characteristic compressive strength of 60 MPa or more. (1) In USA concrete with a characteristic compressive strength of 55 MPa or more is considered to be a high strength concrete, but this is not a fixed level and may change with a time.

High-strength concrete mix proportioning is a more critical process than the design of normal strength concrete mixtures. Usually, specially selected pozzolanic and chemical admixtures are employed, and the attainment of a low water-cementitious ratio is considered essential. Many trial batches are often required to generate the data that enables the researcher to identify optimum mix proportions. [(2)]

There is no "scientific" method for proportioning. This means that there is no chart that can be used to derive the mixture ingredients to meet a specified level of performance. There are simply too many variables for such a chart to be developed. Here are some general rules for proportioning: [(3)]

Prescriptive specifications, means specify concrete mixture proportions to be used for all similar projects. This procedure may cause differences in performance from project to project because the performance of silica-fume concrete very much depends upon the interaction of the specific materials used. In this case one should follow the prescriptive proportions and test to verify that acceptable hardened concrete properties are achieved.

If the specification is performance based, one should remember that local materials will determine the final mixture performance. It should not be assumed that a mixture that was developed and used elsewhere will provide the same results when local materials are used. Mixtures used elsewhere are excellent starting points, but the influence of project materials on the results obtained must be determined. For a performance specification, time should not be wasted in developing a mixture if the project materials have not yet been identified. [(3)]

Tests should be done at both the laboratory and production scale during mixture development. The process is too complex to predict what the outcome will be without appropriate testing. A plenty of time should be allowed for the necessary testing. [(3)]

Finally, following the procedure described in the ACI 211.4. This procedure has evolved over many years and is the best recommendation currently available. [(4)]

Another approach is to use JMP statistical software program, response surface designs were used for modeling a curved quadratic surface to continuous factors, these factors and its ranges by kg/m^3 are present in table (1), to modeling and predicting compressive strength and workability for high strength concrete depending on the test results. [(5)]

Both methods need many of trial mixes design , cubes and slump test results for mix optimization.

Hence the purpose of this paper was to study the potentiality and possibility of use Sudanese aggregate with supplementary cementitious materials silica fume and fly ash in high strength concrete mixes, and to study the effect of concrete ingredients on compressive strength, workability and cost of high strength concrete. It is also aimed to make a statistical modeling to predict compressive strength and workability of high strength concrete.

Component	**ID**	**Minimum**	**Maximum**
Water-cement ratio w/cm	x_1	0.19	0.3
Silica fume Type KD-12	x_2	50	126
Fly Ash Type F	x_3	0	83
Super Plasticizer type PCA(1)	x_4	7.77	13.44
Fine aggregate	x_5	268	704
Coarse aggregate	x_6	991	1235

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.

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:

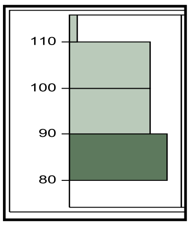
Lime saturated-water curing method was used in this study. Concrete casting was performed according to BS EN 12390-1:2000. [13] Molds were covered to prevent loss of water from evaporation. Specimens were kept for 24 hours in molds at a temperature of about 23 C in casting room, and then cured for the 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]

IV. Optimization Of Mixes

Two approaches was used, the statistical approach which has been described in ACI 211.4 and another one is the JMP statistical program to make a modeling for predicting Compressive Strength and Slump for high strength concrete.

V. Results

Table (6) presents the optimum mix proportions for grade 80 (MPa), Table (8) presents the optimum mix proportions for grade 90 (MPa) and Table (10) presents the optimum mix proportions for grade 100 (MPa) which were used in the dam construction project. From the tables it is clear that there are three different grades of high strength concrete (80, 90, 100MPa) successfully produced using local Sudanese aggregates and silica fume and silica fume with fly ash. w/cm ratios ranges between 0.19~0.3. Silica fume and fly ash replacements in the range of 6.7 to 15% and zero to 15% of cementunise materials respectively. Cement content is range between 390 and 560 Kg/m3 for the three grades. Trial batches were carried out, test specimens are fabricated and tested, and results are analyzed using standard statistical methods. Method one is the statistical approach which described in ACI211.4 and method two is the statistical approach by using statistical software program, called, JMP statistical software program. These methods include fitting empirical models to the data for each performance criterion. In these models, each response ,resultant concrete property, such as strength, slump, is expressed as an algebraic function of factors ,individual component proportions, such as w/cm, coarse aggregate, fine aggregate, chemical admixture dosage, and supplementary cementitious materials content has been fed in.

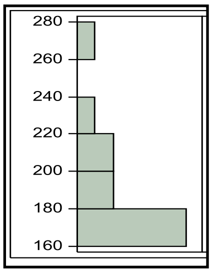


100.0%	maximum	110.6
75.0%	quartile	102.6
50.0%	median	95.3
25.0%	quartile	86.65
0.0%	minimum	80

Figure (2) Categories of Ave 28days Compressive Strength (MPa) for (above 80 MPa, above 90 MPa and above 100 MPa)

Table (5) 28days Concrete Compressive strength above 80MPa and Cost estimation

Test No	Casting Date	Test Date	Ave Compressive Strength (Mpa) for 28days	Slump mm	Aggregate Types	W/Cm Ratio	Cement (kg/m^3)	Silica Fumetype KD-12 (kg/m3)	Fly Ash (kg/m3)	Super Plasticizer type PCA(1) (kg/m3)	Water (kg/m3)	Fine Aggregate (kg/m3)	Coarse Aggregate (kg/m3)	Cost of m3 $
1	30-Oct-09	27-Nov-09	81.2	190	Marble	0.28	500	56	0	8.88	155	689	1023	166.4
2	31-Oct-09	28-Nov-09	80	182	Marble	0.27	416	56	83	7.77	150	704	1003	165.3
3	6-Nov-09	4-Dec-09	80.9	190	Marble	0.24	545	55	0	9.6	145	648	1042	174.4
5	14-Nov-09	12-Dec-09	87.6	195	Marble	0.23	587	65	0	10.432	147	601	1045	192.2
8	7-Dec-09	4-Jan-10	86.3	207	Marble	0.2	647	126	67	13.44	168	399	1050	275.1
10	13-Jan-10	10-Feb-10	80.3	220	Granite	0.27	550	50	0	9.6	162	586	1022	170
11	14-Jan-10	11-Feb-10	83.7	230	Granite	0.25	550	50	50	9.6	163	586	1022	179.5
13	15-Jan-10	12-Feb-10	87	170	Granite	0.23	600	50	50	11.2	161	499	1013	189.5
14	20-Jan-10	17-Feb-10	84.2	180	Granite	0.3	495	55	0	9.6	165	615	1027	164.5
15	26-Jan-10	23-Feb-10	83.5	200	Granite	0.23	595	70	35	11.9	161	498	1011	205.2
18	29-Jan-10	26-Feb-10	88.2	200	Granite	0.21	655	77	39	13.09	162	346	1095	224.4
19	8-Feb-10	8-Mar-10	88.5	143	Granite	0.21	630	70	0	11.2	147	357	1195	204.9



100.0%	maximum	275.1
75.0%	quartile	205.125
50.0%	median	184.5
25.0%	quartile	167.3
0.0%	minimum	164.5

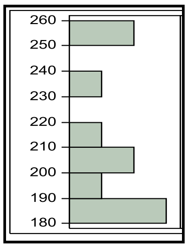
Figure (3) Distributions Cost of m^3 $for compressive strength above 80 MPa

Table (6) the optimum mix proportions for grade 80 MPa.

No	Test No	Casting Date	Test Date	Ave Compressive Strength (Mpa) for 28days	Slump mm	Aggregate Types	W/Cm Ratio	Cement (kg/m^3)	Silica Fumetype KD-12 (kg/m3)	Fly Ash (kg/m3)	Super Plasticizer type PCA(1) (kg/m3)	Water (kg/m3)	Fine Aggregate (kg/m3)	Coarse Aggregate (kg/m3)	Cost of m3 $
1	14	20-Jan-10	17-Feb-10	84.2	180	Granite	0.3	495	55	0	9.6	165	615	1027	164.5
2	2	31-Oct-09	28-Nov-09	80	182	Marble	0.27	416	56	83	7.77	150	704	1003	165.3
3	1	30-Oct-09	27-Nov-09	81.2	190	Marble	0.28	500	56	0	8.88	155	689	1023	166.4

Table (7) 28days Concrete Compressive strength above 90MPa and Cost estimation

Test No	Casting Date	Test Date	Ave Compressive Strength (Mpa) for 28days	Slump mm	Aggregate Types	W/Cm Ratio	Cement (kg/m^3)	Silica Fumetype KD-12 (kg/m3)	Fly Ash (kg/m3)	Super Plasticizer type PCA(1) (kg/m3)	Water (kg/m3)	Fine Aggregate (kg/m3)	Coarse Aggregate (kg/m3)	Cost of m3 $
4	11-Nov-09	9-Dec-09	91.1	205	Marble	0.2	587	115	77	10.75	154	443	1057	253.5
6	5-Dec-09	2-Jan-10	96.4	188	Marble	0.22	708	62	0	12.32	169	385	1191	213.2
7	6-Dec-09	3-Jan-10	97.7	216	Marble	0.21	670	62	0	12.32	162	268	1231	205.4
9	7-Dec-09	4-Jan-10	91.7	215	Marble	0.2	672	118	0	12.64	158	440	1025	259.1
12	15-Jan-10	12-Feb-10	91.5	165	Granite	0.22	650	50	50	12	165	466	991	199.3
16	28-Jan-10	25-Feb-10	96.9	220	Granite	0.22	660	90	0	12.75	165	467	992	230.2
20	11-Feb-10	11-Mar-10	95.3	155	Granite	0.23	572	78	0	10.4	150	469	1149	201.4
25	21-Feb-10	21-Mar-10	96.9	159	Granite	0.21	528	72	0	9.6	126	500	1225	187.4
29	1-Mar-10	29-Mar-10	94.5	205	Granite	0.24	528	72	0	9.6	144	587	1091	187.2
30	21-Mar-10	18-Apr-10	97.9	185	Granite	0.23	528	72	0	9.6	138	593	1101	187.3



100.0%	maximum	259.1
75.0%	quartile	236.025
50.0%	median	203.4
25.0%	quartile	187.375
0.0%	minimum	187.2

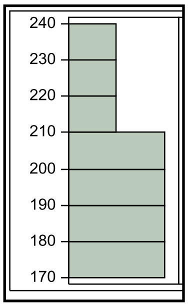
Figure (4) Distributions Cost of m^3 $ for compressive strength above 90 MPa

Table (8) the optimum mix proportions for grade 90 MPa.

No	Test No	Casting Date	Test Date	Ave Compressive Strength (Mpa) for 28days	Slump mm	Aggregate Types	W/Cm Ratio	Cement (kg/m^3)	Silica Fumetype KD-12 (kg/m3)	Fly Ash (kg/m3)	Super Plasticizer type PCA(1) (kg/m3)	Water (kg/m3)	Fine Aggregate (kg/m3)	Coarse Aggregate (kg/m3)	Cost of m3 $
1	29	1-Mar-10	29-Mar-10	94.5	205	Granite	0.24	528	72	0	9.6	144	587	1091	187.2
2	30	21-Mar-10	18-Apr-10	97.9	185	Granite	0.23	528	72	0	9.6	138	593	1101	187.3
3	25	21-Feb-10	21-Mar-10	96.9	159	Granite	0.21	528	72	0	9.6	126	500	1225	187.4

Table (9) 28days Concrete Compressive strength above 100MPa and Cost estimation

Test No	Casting Date	Test Date	Ave Compressive Strength (Mpa) for 28days	Slump mm	Aggregate Types	W/Cm Ratio	Cement (kg/m^3)	Silica Fumetype KD-12 (kg/m3)	Fly Ash (kg/m3)	Super Plasticizer type PCA(1) (kg/m3)	Water (kg/m3)	Fine Aggregate (kg/m3)	Coarse Aggregate (kg/m3)	Cost of m3 $
17	29-Jan-10	26-Feb-10	105.2	170	Granite	0.19	655	77	39	9.6	146	296	1184	222
21	15-Feb-10	15-Mar-10	100.6	162	Granite	0.2	660	90	0	12	150	382	1145	230.1
22	17-Feb-10	17-Mar-10	104.7	161	Granite	0.23	528	72	0	9.6	138	491	1202	187.2
23	19-Feb-10	19-Mar-10	109.2	121	Granite	0.2	500	75	50	10	125	457	1235	194.5
24	19-Feb-10	19-Mar-10	100.4	134	Granite	0.2	572	78	0	9.6	130	451	1218	201.1
26	24-Feb-10	24-Mar-10	106.1	116	Granite	0.19	616	84	0	11.2	133	436	1180	216
27	25-Feb-10	25-Mar-10	104.3	215	Granite	0.22	540	78	32	10.4	143	521	1106	201.5
28	28-Feb-10	28-Mar-10	110.6	77	Granite	0.2	480	72	48	9.6	117	503	1233	187.5
31	31-Mar-10	28-Apr-10	103.6	115	Marble	0.23	484	66	0	8.8	124	551	1225	173.1
32	14-Apr-10	12-May-10	102.4	125	Marble	0.22	585	65	0	10.4	140	641	1190	193
33	25-Apr-10	23-May-10	102.8	145	Marble	0.22	575	50	0	10	138	662	1177	176.6

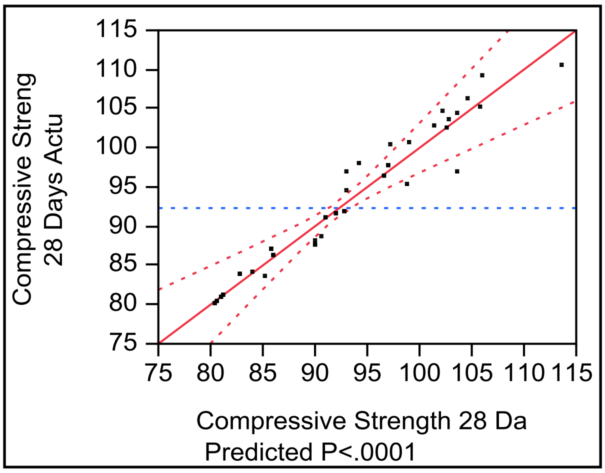


100.0%	maximum	230.1
75.0%	quartile	216
50.0%	median	194.5
25.0%	quartile	187.2
0.0%	minimum	173.1

Figure (5) Distributions Cost of m^3 $ for compressive strength above 100 MPa

Table (10) the optimum mix proportions for grade 100 MPa.

No	Test No	Casting Date	Test Date	Ave Compressive Strength (Mpa) for 28days	Slump mm	Aggregate Types	W/Cm Ratio	Cement (kg/m^3)	Silica Fumetype KD-12 (kg/m3)	Fly Ash (kg/m3)	Super Plasticizer type PCA(1) (kg/m3)	Water (kg/m3)	Fine Aggregate (kg/m3)	Coarse Aggregate (kg/m3)	Cost of m3 $
1	31	31-Mar-10	28-Apr-10	103.6	115	Marble	0.23	484	66	0	8.8	124	551	1225	173.1
2	33	25-Apr-10	23-May-10	102.8	145	Marble	0.22	575	50	0	10	138	662	1177	176.6
3	22	17-Feb-10	17-Mar-10	104.7	161	Granite	0.23	528	72	0	9.6	138	491	1202	187.2



Figure(6) The Actual 28 days Compressive strength (MPa) and the Predicted 28 days Compressive strength (MPa) (as per JMP Modeling)

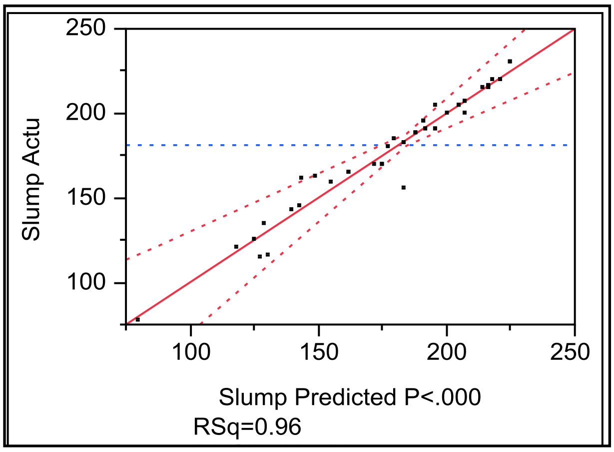


Figure (7) The Actual Slump (mm) and the Predicted Slump (mm) (as per JMP Modeling)

Table (11) The Predicted 28 days compressive strength (MPa) and the Predicted Slump (mm), Compared with actual one(as per JMP Modeling)

Test No	28days Compressive Strength (MPa)	Slump (mm)	The Predicted 28days Compressive Strength (MPa)	The Predicted Slump (mm)
1	102.8	145	100.9347525	140.1424
2	102.4	125	103.9170139	126.9448
3	97.7	216	95.60168308	215.5752
4	96.4	188	97.06626875	186.9326
5	87.6	195	88.59024668	203.735
6	91.1	205	91.99175678	208.4006
7	80.9	190	82.30613001	194.1667
8	81.2	190	81.5225167	183.0659
9	80	182	80.60790439	184.4972
10	86.3	207	85.09439633	208.1903
11	91.7	215	93.42806932	214.788
12	97.9	185	94.82337872	193.9162
13	94.5	205	94.68673894	200.3792
14	104.3	215	96.16855335	185.579
15	110.6	77	113.1813267	107.3607
16	106.1	116	103.9656454	135.809
17	103.6	115	103.5263967	126.7868
18	109.2	121	109.2078038	103.2725
19	96.9	159	102.9670397	135.0619
20	104.7	161	99.16703301	150.4427
21	100.4	134	102.1214425	122.6285
22	100.6	162	94.61164179	145.2861
23	95.3	155	95.9896066	170.7396
24	88.5	143	96.47715012	166.6624
25	105.2	170	102.9417269	165.6175
26	88.2	200	95.17642906	196.492
27	96.9	220	92.87055685	210.2172
28	83.5	200	89.11081385	199.155
29	91.5	165	88.83504028	172.1097
30	87	170	86.86111848	183.6875
31	83.7	230	82.35797703	201.4051
32	80.3	220	81.93894773	202.4333
33	84.2	180	83.08203813	206.7856

Table (12) The suggested mixture proportion and it Predicted 28 days compressive strength (MPa) and Slump (mm) (as per JMP Modeling)

Test No	W/Cm Ratio	Silica Fume type KD-12 (kg/m3)	Fly Ash (kg/m3)	Super Plasticizer type PCA(1) (kg/m3)	Fine Aggregate (kg/m3)	Coarse Aggregate (kg/m3)	The Predicted 28days Compressive Strength (MPa)	The Predicted Slump mm
1	0.19	50	20.75	7.77	704	1113	93.8	51.7
2	0.19	50	20.75	9.1875	377	1235	117.0	232.0
3	0.19	50	20.75	9.1875	595	1113	89.9	97.5
4	0.19	50	20.75	10.605	486	1113	97.0	200.0
5	0.19	50	20.75	10.605	595	1052	108.7	106.6

6	0.19	50	41.5	10.605	377	1113	91.5	167.0
7	0.19	50	41.5	12.32	377	1052	93.6	191.9
8	0.19	88	0	7.77	704	1113	86.4	192.8
9	0.19	88	0	9.1875	377	1235	83.3	58.3
10	0.19	88	20.75	9.1875	595	1113	109.5	85.3
11	0.2725	50	0	7.77	704	1052	84.0	129.8
12	0.2725	50	0	7.77	704	991	91.3	56.7
13	0.2725	50	0	9.1875	377	1052	108.5	150.9
14	0.2725	50	0	9.1875	704	1052	81.4	124
15	0.2725	50	0	10.605	595	1052	89.2	171.0
16	0.2725	50	20.75	7.77	704	1113	94.4	191.7
17	0.2725	69	0	9.1875	268	1052	99.9	71.9
18	0.2725	69	0	9.1875	377	1052	94.5	155.6
19	0.3	50	0	7.77	486	991	106.8	142.0
20	0.3	50	0	7.77	704	991	81.5	190.0
21	0.3	50	0	12	595	991	82.5	158.0
22	0.3	50	20.75	7.77	595	1174	89.0	162.8
23	0.3	50	20.75	9.1875	377	1235	102.0	144.8
24	0.3	69	0	9.1875	595	1113	80.2	175.4

VI. Conclusions

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

1. local aggregates with supplementary materials (silica fume and fly ash) and ordinary Portland cement with their optimum proportioning can be successfully used with other chemical admixtures (Super-plasticizer) to produce high strength concrete.
2. The present study shows that the maximum values of compressive strength for different grades were obtained at water-cementitious materials ratios between 0.19 and 0.3.
3. The relationship between compressive strength 28 days (MPa) and cost is direct relationship.
4. Predicted equations were given from JMP statistical program to predict 28 days compressive strength (MPa) and Slump (mm) for high strength concrete where local Sudanese aggregate granite and marble were used.
5. Method No two gave suggestions for a new mixture proportions for high strength concrete in Sudan and it was predict 28 days compressive strength (MPa) and Slump (mm).

Acknowledgements

I would like to thank SMEC International Company for their cooperation during the part of the experimental testing program of this research. Also I would like to thank the Dams Implementation Unit (DIU) of Sudan for allowing the authors to use the information and photographs needed in this research paper.

References

[1]. John Newman and Ban Seng Choo, Advanced Concrete Technology Processes (Elsevier Ltd, First published, 2003).
[2]. American Concrete Institute, State-of-the-Art Report on High-Strength Concrete, ACI 363. 1997.
[3]. Silica Fume Association, Technical Report-Silica Fume User's Manual, USA, 2005.
[4]. American Concrete Institute, Guide for Selecting Proportions for High-Strength Concrete Using Portland Cement and Other Cementitious Materials, ACI 211.4R-08. 2008.
[5]. JMP, A Business Unit of SAS Institute Inc, Design of Experiments Guide, USA, 2012.
[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.