Journal of Kerbala University , Vol. 7 No.1 Scientific. 2009

The effect of grading of fine aggregate on some properties of concrete

Dr Riadh S. Al-Rawi
Prof. /College of Engineering /baghdad university /Iraq
Dr. Adil .M. Abdul Latif
Lecturer /College of Engineering /Kerbala university /Iraq
Email: molaadil@yahoo.com
Amar.J. Al-Dulaimy
Civil Eng./Iraq

Abstract:

In concrete construction, sands of good grading used in preparing concrete mixes is considered as one of the important problems in Iraq .The reason is that the quantities of sand conforming to the Iraqi specifications in grading are beginning to decrease .There are, however, large quantities of sand which can not be used in preparing concrete mixes because they are not conforming to the Iraqi specifications. During this research, many trials have been made to increase the range of grading of fine aggregate . 576 concrete cubes were cast using different concrete mixes designed according to the (ACI 211.1 1991) . Two types of cement are used with variable water cement ratios and different grading of fine aggregate . Most of these grading were out of Iraqi specifications. Slump test was made for all concrete mixes and compressive strength was made for all concrete cubes at ages of (7,28,56 and 90)days. The results obtained show the possibility of using different grading of fine aggregate with fineness modulus ranges from (1.4 to 3.7) which is much wider than the range of fineness modulus in (ACI 211.1 1991) ,noticing that these different grading of fine aggregate did not adversely affect the slump or compressive strength.

الخلاصه:

تعد مشكلة الحصول على ركام جيد التدرج من المشاكل المهمه في صناعة الخرسانه في العراق. ويعود السبب في ذلك الى ان الركام المطابق للمواصفه العراقيه بدأ بالتناقص. لذلك فان كميات كبيره من الركام المتوفر حاليا لاتستخدم بسبب عدم مطابقتها للمواصفات العراقيه. في هذا البحث اجريت عدة محاولات لزيادة مدى تدرج الركام الناعم المستخدم. ولقد تم صب 576 نموذج خرساني باستخدام العديد من الخلطات الخرسانيه المصممه بموجب المدونه الامريكيه المرقمه 211.1 لسنة 1991. لقد تم استخدام تدرجات مختلفه للركام مع نوعين من السمنت ونسب ماء الى سمنت متغيره. ولقد كانت معظم تدرجات الركام المستخدمه خارج حدود المواصفه العراقيه .وقد تم اجراء فحص الهطول لجميع الخلطات وكذلك مقاومة الانضغاط في اعمار 7و28و56و90 يوم. لقد اثبتت النتاج امكانية استخدام تدرجات مختلفه من الركام تتراوح من معامل نعومه مقداره 1.4 الى 3.7 وهو مدى اوسع من المدى المعطى بموجب المدونه الامريكيه 211.1 لسنة 1991 دون التأثير بشكل سلبي على الهطول او مقاومة الانضغاط.

.Introduction:

In Iraq, the properties of fine aggregate are different for different locations. Fine aggregates obtained from rivers have a grading problem. River sand, found along the bank of Tigris and Euphrates contains fine and rounded particles[1], In the middle and south of Iraq river sand contains high percentages of very fine aggregate with an amount of silt and clay[2]. There are many quarry of sand or of all-in aggregates in Iraq. Few of them are suitable to be used for concrete .The rest are rarely used in concrete, since their properties do not conform to grading requirements, and/or have high sulfate content. Fine and coarse sand with acceptable sulfate contents are available in Iraq in large reserves but are not used due to their non-compliance with requirements of the current specifications for the grading. So it was decided to study the workability and strength of concrete in which such sand are used.

2-Literature review:-

It is well-known that the properties of concrete , such as strength, workability, modulus of elasticity and durability, depend to a very substantial degree on the amount and properties of aggregate. The grading of aggregate is a major factor influencing the workability of the concrete mix. The main factors which govern the desired aggregate grading are : the surface area of the aggregate, the relative volume occupied by the aggregate, the workability of the concrete mix and the tendency to segregation[3].Many researchers, however, reported that a sand of unorthodox grading can produce a workable and strong concrete provided that it is blended with suitable coarse aggregate in a proper proportion [4,5,6,7]. Two main characteristics of aggregate affect the water content of a given mix, the first is the total surface area and the second is the particle interlock. Both are function of grading that may change the consistency of concrete if the mixing water is held constant[8]. It is reported, however, that the effect of grading is much less in rich mixes than in lean one. In case of rich mixes it is possible to produce mixes with wide limits of grading and have the same workability[9]. Although the approved range of fineness modulus of sand is (2.4 to 3.2)[10], Al-Qassab has successfully widen this range from 1.5 to 3.0 using local Iraqi aggregates[11]. This supported the work of Iambert[8] who has successfully used fine aggregate of fineness modulus of 1.9 producing high quality concrete . Abrams[12]concluded that the grading of aggregate having the same fineness modulus will require the same quantity of water to produce mix of the same plasticity and give concrete of the same strength. Many other researchers [13,14] supported by experimental results, Abrams work. Bloem and Walker [15] dispelled traditional beliefs that the concrete strength is independent of gradation of coarse aggregate .They showed that the concrete strength is higher for smaller size of graded aggregate than for large ones when fixing the cement content and slump. Mclntosh[16]results, confirmed that, using given materials with a fixed aggregate/cement ratio but adjusting the fine aggregate content, approximately the same workability and strength are obtained with gap and continuous grading. Al-Qassab[11] concluded that for workable concrete different fineness modulus of sand will not affect the compressive strength as long as the type of coarse aggregate, W/C ratio and slump are the same. Al-Salihi[5] concluded that concrete containing river sand with low sulfate content gains strength similar to concrete containing comparable natural sand. Newman[17] reported that in order to obtain the same compressive strength of concrete containing very fine sand or coarse sands using constant W/C ratio, the coarse/fine aggregate ratio should be increased when using very fine sands or decreased when using coarse sands to obtain a constant total surface area for the types of sand.

3-Expremental work:

a) Materials:

Two different ordinary Portland cements were used .Table (1) shows the chemical and physical properties of these cement which conform the Iraqi specifications. Natural sand from Karbala was used which was out of Iraqi specifications. Table (2) shows the grading and physical properties of the sand. Ten deferent fineness modulii (1.4,1.6,1.8,2.3,2.6,2.8,2.9,3,3.2 and 3.7) with eleven grading were obtained from this sand by sieving and remixing . Coarse aggregate from Samra was used. Table (3) shows the grading and physical properties of the coarse aggregate which conform the Iraqi specifications.

b) Mix proportioning:

The ACI method (ACI 211.1 1991) of mix design was used because of its simplicity and applicability and because it covers a wide range of maximum aggregate size . Slump value of (75-100) mm were used because it is the slump recommended for usual concrete works in which consolidation is done by mechanical vibration . Maximum aggregate size of 20 mm was chosen because it is a common size used in practice. W/C ratio of 0.4,0.5 and 0.6 were used.

(Table 1)
Chemical and physical properties of the cements used

property	Cement 1	Cement 2	Iraqi specification limits
CaO %	61.17	62.2	
SiO_2 %	22.39	21.8	
Al_2O_3 %	6.08	5.1	
MgO %	2.8	3.4	Max 5%
Fe_2O_3 %	3.08	3.3	
SO_3 %	1.6	2.3	Max 2.8%
L.O.I %	2.31	1	Max 4%
I.R %	0.38	0.7	Max 1.5
L.S.F	0.83	0.85	(0.66-1.02)
Fineness m^2/Kg	250	270	Not less than 230
Soundness %	0.35	0.24	Max 0.8%

(Table 2)
Chemical and physical properties of the original sand(from which the used sands were obtained)

property	Result	Iraqi specification limits
Grading zone	Out of zones	
Fineness modulus	3.06	
Apparent specific gravity	2.53	
Absorption %	1%	
Sulfate content %	0.25%	Max 0.5% for substructure Max 0.75% for superstructure
Moisture content %	0.25%	
Percentage passing sieve size 75 micron	1.5%	Max 5%

(Table 3)
Chemical and physical properties of the coarse aggregate used

property	Result	Iraqi specification limits
Grading zone	Within the limits	
Fineness modulus		
Apparent specific gravity	2.63	
Absorption %	0.6%	
Sulfate content %	0.08%	Max 0.1%
Moisture content %	0.15%	
Percentage passing sieve size 75 micron	0.3%	Max 3%

c) Test program:
Cube specimens (100x100x100)mm were used to study the influence of grading of sand on the compressive strength of concrete. The specimens were tested at the ages of (7,28,56 and 90) days. The specimens were prepared according to (BS 1881:part 108:1983) and tested according to (BS 1881:part 4:1983).Slump test, chosen as an appropriate test to determine the workability, was conducted for all mixes according (ASTM C143-91)

4- Result and discussion:

(Table 4) and (Table 5) show the mixes proportions and the results of slump tests for cement1 and cement2 respectively. It is clear that the same water content (187 Kg/m^3) produces the same slump for different fineness modulus of sand with 20 mm maximum size of coarse aggregate. It can be concluded that for the range of fineness modulus of sand adopted in this work, the net mixing water requirement was not affected by the fineness modulus of sand when the surface area and maximum

size of coarse aggregate are kept constant for the two cements used. For sand of fineness modulus of (1.4 and 1.6) the experiments were repeated with less coarse aggregate (10%) and then the quantity of sand recalculated . This is because that using very fine aggregate leads to an increase in volume of coarse aggregate and decrease the volume of fine aggregate. As a result, the mix was found to be undersanded. The increase in volume of coarse aggregate may lead to difficulties with concrete cast by pumping. The compressive strength of concrete for the ages (7,28,56 &90) for all mixes are shown in (Table 6). From this Table, the following observations can be seen:

1. The compressive strength of concrete made with 20 mm maximum size of coarse aggregate was not affected when using sand with different fineness modulus of sand for all ages and for different W/C ratio used.
2. Result for mixes with fineness modulus of sand (1.4 and 1.6) were found to be undersanded, therefore the experiments were repeated with less coarse aggregate (10%) and then the quantity of sand recalculated to make other mixes (12),(13), (25),(26),(38) and(39). The compressive strength results obtained from original mixes were slightly higher than that of adjusted mixes.
3. The variation in the grading of the sands (one conforming to Iraqi specifications and other one not conforming to this specifications) but have the same fineness modulus (mix 6 and 7) ,(mix 19 and 20) and (mix 33 and 34), did not cause clear change in compressive strength of concrete.
4. Cement 2 gave compressive strength at early age (7 days) higher than that of Cement 1 because of the higher content of C_3S and C_3A in Cement 2, but this difference was not affected by using sand of different fineness modulus.
5. Different fineness modulus of sand has no effect on the strength development rate of concrete.

(Table 4)

Concrete mixes proportions and the results of slump tests for cement 1

Mix No.	F.M	W\C	Net water Kg/m^3	Cement Kg/m^3	Sand Kg/m^3	Gravel Kg/m^3	Slump mm
1	1.4	0.4	187	467.5	443	1235	85
2	1.6	0.4	187	467.5	474	1202.5	80
3	1.8	0.4	187	467.5	505	1170	80
4	2.3	0.4	187	467.5	583	1089	95
5	2.6	0.4	187	467.5	630	1040	80
6	2.8	0.4	187	467.5	662	1007.5	90
7	(2.8)•	0.4	187	467.5	662	1007.5	85
8	2.9	0.4	187	467.5	677.5	991	75
9	3.0	0.4	187	467.5	692	975	85
10	3.2	0.4	187	467.5	724	942.5	95
11	3.7	0.4	187	467.5	802	862	85
12	(1.4)	0.4	187	467.5	561	1112	95
13	(1.6)	0.4	187	467.5	590	1082	90
14	1.4	0.5	187	374	518	1235	95
15	1.6	0.5	187	374	549	1202.5	90
16	1.8	0.5	187	374	580	1170	85
17	2.3	0.5	187	374	658	1089	105
18	2.6	0.5	187	374	705	1040	85
19	2.8	0.5	187	374	737	1007.5	95
20	(2.8)•	0.5	187	374	737	1007.5	95
21	2.9	0.5	187	374	725.5	991	90
22	3.0	0.5	187	374	768	975	95
23	3.2	0.5	187	374	799	942.5	115
24	3.7	0.5	187	374	877	862	100
25	(1.4)	0.5	187	374	636	1112	100

26	(1.6)	0.5	187	374	665	1082	100
27	1.4	0.6	187	312	567.5	1235	95
28	1.6	0.6	187	312	599	1202.5	100
29	1.8	0.6	187	312	630	1170	95
30	2.3	0.6	187	312	708	1089	100
31	2.6	0.6	187	312	755	1040	90
32	2.8	0.6	187	312	786.5	1007.5	110
33	(2.8)•	0.6	187	312	786.5	1007.5	100
34	2.9	0.6	187	312	902	991	105
35	3.0	0.6	187	312	818	975	95
36	3.2	0.6	187	312	849	942.5	110
37	3.7	0.6	187	312	926	862	95
38	(1.4)	0.6	187	312	685	1112	105
39	(1.6)	0.6	187	312	715	1082	105

• Sand non conforming Iraqi specification

(Table 5)

Concrete mixes proportions and the results of slump tests for cement 2

Mix No.	F.M	W\C	Net water Kg/m^3	Cement Kg/m^3	Sand Kg/m^3	Gravel Kg/m^3	Slump mm
40	1.4	0.4	187	467.5	443	1235	80
41	3.0	0.4	187	467.5	692	975	75
42	3.7	0.4	187	467.5	802	862	80
43	1.4	0.5	187	374	518	1235	85
44	3.0	0.5	187	374	768	975	80
45	3.7	0.5	187	374	877	862	85
46	1.4	0.6	187	312	567.5	1235	90
47	3.0	0.6	187	312	818	975	85
48	3.7	0.6	187	312	926	862	85

(Table 6)

Compressive strength of concrete for the ages (7,28,56 &90)

Mix No.	W\C	7-day Compressive strength MPa	28-day Compressive strength MPa	56-day Compressive strength MPa	90-day Compressive strength MPa
1	0.4	26	41	45.5	48.5
2	0.4	25.5	39	45	47
3	0.4	24	38	44.5	46.5
4	0.4	24	37	43	45.5
5	0.4	22.5	35	42	44.5
6	0.4	24.5	38	42	43.5
7	0.4	25	36	40	42.5
8	0.4	23.5	36	43	45.5
9	0.4	24	38	42.5	44.5
10	0.4	21.5	35	41.5	44
11	0.4	22.5	36	42	45
12	0.4	24	38	43.5	45
13	0.4	23.5	37	42	44
14	0.5	22.5	29	35	37
15	0.5	21.5	28	34	35.5

16	0.5	21	27	33	34
17	0.5	20.5	25	32	34.5
18	0.5	19	24.5	32	34
19	0.5	21	25.5	31.5	34
20	0.5	22	25	29	33.5
21	0.5	21	26	33.5	35
22	0.5	20.5	26	32.5	35
23	0.5	19.5	23.5	31	34.5
24	0.5	20	25	32	34
25	0.5	21	27	32.5	35
26	0.5	21	25	33	35
27	0.6	15	21.5	29	32
28	0.6	14	19.5	29	30
29	0.6	13	19	28	29.5
30	0.6	13.5	17.5	27	28.5
31	0.6	13	17	26.5	29
32	0.6	12.5	17.5	26	28.5
33	0.6	12	16.5	24.5	29
34	0.6	13	18.5	28.5	30.5
35	0.6	13.5	18	27	28.5
36	0.6	13.5	17	26.5	29
37	0.6	14	18.5	27	29
38	0.6	13.5	20	26	29
39	0.6	13	18	25	28
40	0.4	33	46	49	50.5
41	0.4	30.5	44	47	48
42	0.4	29	43	45	48
43	0.5	30	37	38	40
44	0.5	28	32	35	38
45	0.5	27	33	36	39
46	0.6	24	29	31	34
47	0.6	20.5	25	30	32
48	0.6	21	24.5	29	32

6- Conclusions:

a) An attempt was made in this work to extend the range of the fineness modulus to cover finer sand down to fineness modulus of 1.4 and coarser sand up to fineness modulus 3.7 using maximum size of aggregate 20mm. It could be concluded that normally proportioned concrete with good workability and compressive strength was produced by using the above extended range.

b) The net mixing water requirement was not affected by the different fineness modulii of sand adopted in this when the concrete mix is designed keeping the surface area and maximum size of coarse aggregate constant for both types of ordinary Portland cement used (cement1 and cement2) and for different W/C ratios.

c) The different fineness modulii of sand adopted in the present work are in the range (1.4 to 3.7). They were found to have slightly effect on the slump of concrete mixes designed in the present work in which the slump values were very close and within the design range of (7.5-12.5) cm.

d) Low values of fineness modulii (i.e., 1.4 &1.6 that was adopted in the present work have the property that the volume of coarse aggregate is considerably larger than the volume of fine aggregate in the mix. Such mixes are said to be undersanded. As stated in the ACI standards, this can be corrected by reducing the coarse aggregate quantity by 10% of the total aggregate and

recalculating the quantity of fine aggregate in order to make a more workable mix. Such mixes were found to have slight effect on the slump for different W/C ratios and a slight effect on the compressive strength for the different ages (7,28,56 & 90) days.

e) It was found that using two different gradings of sand both having the same fineness modulus of (2.8), but one of them is conforming to (I.Q.S. 45/1984) and the other is not, have no clear difference in slump values and compressive strength values at different ages (7,28,56,90) days.

f) Using sands of different fineness modulii in the range (1.4 to 3.7) had slightly affects on the compressive strength of concrete for the ages (7,28,56 &90) days for different W/C ratios.

g) Using different fineness modulii have slightly effect on the strength development rate of concrete.

References:

1- Rouf, Z.A, Sand of Iraq, The engineer, Iraq Engineering Association,Sep.1965,Baghdad, Iraq.

2- Salah, S.A, Effect of Fine Sand on Properties of Concrete, M.Sc Thesis , Baghdad University, College of Engineering ,1978, Iraq.

3- Sanaswamy, K.T, Kamsundra, A, and Khandekar A.A, Concrete Technology,1978,India,pp.4-5

4- Al-Salihi, R.A., Proposed Revision of Iraqi Specifications for Concrete Ingredients to Cope with Post War Era, M.Sc Thesis , Baghdad University, College of Engineering ,1994, Iraq.

5- Powers, T.C., The Properties of Fresh Concrete, Willy , New York, London, Sydney, 1968,p16.

6- Geynor,R.D., The Effect of Fine Aggregate on Concrete Mixing Water Requirement, Presented at 47^{th} annual convention of the National sand and Gravel Association, San Francisco, February 14,1936

7- Popovics,S., Reef Shell-Beach Sand Concrete, Living with Marginal Aggregate, ASTM Special Technical Publication 597,Philadelphia,1976,pp97-113

8- ACI 221R -1989, Guide for Use Normal Aggregate in Concrete ,American Concrete Institute, 1990, Michigan, USA.

9- Imbert, D.C, Influence of the Grading of Aggregate on Concrete Mix Proportions, Highway Research Record No.441, Highway Research Board, Washington D.C,1973,pp44-55.

10- ACI 211R -91, Standard Practice for Selecting Proportions for Normal, Heavyweight and Mass Concrete ,American Concrete Institute, 1994, Michigan, USA.

11- Al-Qassab,F.F., Concrete Mix Design Related to Local Condition, M.Sc Thesis , Baghdad University, College of Engineering ,1986, Iraq.

12- Abrams,D.A., Design of Concrete Mixture, Chicago, Lewis Institute,1918

13- Popovics,S., The Use of Fineness Modulus For Grading Evaluation of Aggregate for Concrete, Magazine of Concrete Research Vol.18, No.56,September,1966,pp131-140.

14- Hummel,A. Die Auswertung von Sicbenanlysen und der Abrams Sche Feinheitsmodul ,Zement Vol.19,No.15,1930,pp355-364.

15- Walker,S., and Bloam,D.L., Effects of Aggregate Size on Properties of Concrete, ACI Journal , Proceeding Vol.60,October,1963,pp.1429-1454.

16- Mclntosh, J.D., The Selection of Natural Aggregate for Various Types of Concrete Work, R.C. R.,4, No.5,London,1957,pp.282-305.

17- Newman,A.J., and Teychenne, D.C., A Classification of Natural Sand and Its Use in Concrete Mix Desigen,pp.137