FIELD ADJUSTMENT FOR CONCRETE MIXES IN ACCORDANCE WITH MOISTURE CONDITIONS OF AGGREGATES +

تعديل اوزان مكونات الخلطات الخرسانية في مواقع العمل نسبة الى حالة الركام من حيث محتوى الرطوبة

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Abstract:

American Concrete Institute (ACI) mix design method, was used to calculate the quantities of the constituents (cement, water, sand, and gravel) of a specific Non-air-entrained concrete of a specified workability and compressive strength. These quantities are calculated on the basis that the aggregates were in the saturated-surface dry (S.S.D.) condition. Aggregates in the S.S.D. condition can be prepared and controlled in the laboratory, but in the field, it is difficult and impossible to gain it. Therefore, nine probabilities of moisture conditions of the aggregates will be arise in the site works (at the mixer), and, in order to overcome this problems, field adjustment with relation to moisture condition of aggregates must be done when the concrete compounds were put in the mixer. Experimental work shows that, the 7 and 28 days compressive strengths are (27.10) and (38.74) MPa respectively using the mix proportions of the reference mix designed by the ACI method and the S.S.D. aggregates. Good results (an average value of 35.80 MPa) are obtained using the nine probable cases of moisture condition other than the S.S.D. All the adjusted mix proportions can be used practically and successfully, and their values are acceptable comparing with the 28-day characteristic strength (34.00) MPa of the reference mix obtained using the ACI method. Finally, empirical expressions are derived to calculate the adjusted quantities of concrete constituents for the nine probable cases of moisture conditions.

Keywords: Field Adjustment, Moisture Conditions, Absorption Capacity, Surface Moisture.

المستخلص:

تم اتباع طريقة معهد الخرسانة الامريكي (ACI) لتصميم الخلطات الخرسانية في حساب كميات المكونات (السمنت ، الماء ، الرمل ، والحصى) الداخلة في انتاج خلطة خرسانية (غير مهواة) ذات خواص نوعية من قابلية التشغيل ومقاومة الانضغاط. ان هذه المكونات تم حسابها على اساس ان الركام المستخدم (الرمل والحصى) يكون في حالة المشبع-الجاف السطح (S.S.D.) ، وان هذا النوع من الركام بالامكان تهيأته واستعماله والسيطرة عليه مختبريا ، الا انه في موقع العمل والصب يكون من الصعب بل من المستحيل الحصول على هذا النوع من الركام. لذلك ، ظهرت تسعة احتمالات لتواجد الركام في مواقع العمل نسبة الى محتواه للرطوبة ، ولاجل علاج هذه المشكلة الموقعية يجب

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اجراء التعديلات اللازمة على اوزان المواد الداخلة في الخرسانة نسبة الى وضع الركام من حيث الرطوبة السطحية وقابلية الامتصاص ، ويطلق على هذه العملية تعديل الوجبات (Field Adjustment). النتائج العملية بينت بان مقاومة الخرسانة بعمر (7 و 28) يوم كانت (27.10) و (38.74) نيوتن/ملم٢ على التوالي وتم الحصول عليها باستخدام نسب المزج للخلطة المرجعية باتباع طريقة (ACI) لتصميم الخلطات الخرسانية والركام في حالة ال (S.S.D.). تم الحصول على نتائج جيدة (معدل مقاومة الانضغاط 35.80 نيوتن/ملم٢) باستعمال الاحتمالات التسعة لحالة الركام من حيث محتواه للرطوبة ما عدا حالة الركام المشبع وجاف السطح. لذلك ، فبالامكان استخدام كافة نسب المزج المعدلة بشكل عملي وناجح ، ونتائج هذه الحالات التسعة مقبولة مقارنة مع مقاومة الانضغاط المرجعية والتي قيمتها 34.00 نيوتن/ملم2 والمستحصلة باتباع طريقة (ACI) لتصميم الخلطات الخرسانية. اخيرا ، فقد تم اشتقاق علاقات رياضية تستعمل لحساب كميات المواد المعدلة للاحتمالات التسعة الخاصة بحالة الركام وفقا لمحتواه للرطوبة.
الكلمات المفتاحية: تعديل الوجبات ، حالات الرطوبة ، قابلية الامتصاص ، الرطوبة السطحية.

Introduction:

1. **Proportioning of concrete mixes[1,2,3]:**

Proportioning a concrete mix means determining the relative amounts of materials to be used in batches of concrete for a particular purpose. The process sometimes called "design" of mix. It involves consideration of available materials and their costs, requirements of placing and finishing the concrete, and properties of the hardened concrete such as durability, strength, and volume constancy. The proportioning of the ingredients of concrete mixtures is a highly important phase of concrete technology, in that it provides the means of meeting the fundamental requirements of quality and economy. The procedure of proportioning a concrete mix consists of the following steps: checking the maximum size of aggregate, to take the structural limitations into consideration; estimation and checking the water/cement ratio; determination of the free mixing water; determination and checking the cement content; determination of the coarse aggregate content; determination of the fine aggregate content; and these quantities are calculated on the basis that aggregates (sand and gravel) were put in the mixer in the saturated-surface dry (S.S.D.) condition, but practically it is difficult to gain the aggregates in this ideal condition in the site work, therefore, it is essential to make the required adjustment (field adjustment) for the quantities of materials depending on the condition of the aggregates in the field according to their surface moisture and absorption capacity.

2. Moisture and absorption[4,5,6]:

As regards moisture content and absorption capacity, the various states in which an aggregate may exist are:

2.1. Oven-dry (Bone-dry): all moisture, external and internal, driven off, usually by heating at 100-1100C. Prolonged drying the aggregate in an oven will reduce the moisture of the aggregate until no moisture whatever is left, absorption capacity is such as : (absorption capacity = 100).

2.2. Air-dry: no surface moisture on the particles, some internal moisture, but particles not saturated. When aggregate is allowed to stand free in dry air, some of the water contained in the pores will evaporate and the aggregate will be less than saturated, absorption capacity is such as: (100 > absorption capacity > 0).

2.3. Saturated-Surface Dry (S.S.D.): when all the pores in the aggregate are full filled with water, no free or surface moisture on the particles, absorption capacity is such as: (absorption capacity = 0).
2. 4. Wet (Damp): when all the pores in the aggregate are full filled with water (saturated) and with free or surface moisture on the particles, absorption capacity is such as: (absorption capacity = 0).

2.5. Wet with absorption capacity: free or surface moisture on the particles but the particles are not saturated (i.e. particles have absorption capacity > 0). This case appear when a sudden flood of water come to the aggregate for some time, or a high rainfall water fall on the aggregate, in this case, some of the pores will be free from moisture and other are saturated, with free or surface moisture on the particles. The net water taken into calculation is equal to: (surface moisture – absorption capacity).
Normally, it is assumed that at the time of setting of concrete the aggregate is in a saturated-surface dry condition. If the aggregate is batched in a dry condition it is assumed that sufficient water will be absorbed from the mix to bring the aggregate to a saturated condition, and this absorbed water is not included in the net or effective mixing water. The various moisture conditions are represented diagrammatically in Figure (1).

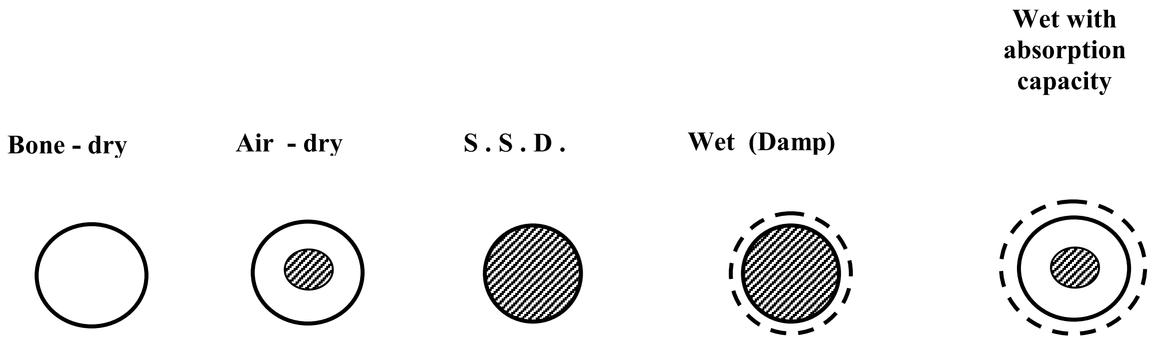


Fig. (1): Diagrammatic representation of moisture in aggregate[1].

In a concrete mix, if the aggregate are not fully saturated, some of the mixing water is absorbed; on the other hand, free moisture on the surfaces of the aggregate particles becomes a part of the mixing water. Hence in computations of the net or effective ratio of water to cement, and in calculations relating to proportions of mixes by weight, the saturated-surface dry condition is used as the basis On the job, the fine aggregate usually carry some free moisture. Freshly washed coarse aggregates contain free water, but since they dry quickly, they are ordinarily partially dry when used. The total internal moisture content of an aggregate in the saturated-surface dry condition may be termed the "absorption capacity", although it is sometimes referred to simply as the "absorption". The amount of water required to bring an aggregate from the air-dry condition to the saturated-surface dry condition is herein termed the "effective absorption". The absorption capacity is a measure of the porosity of an aggregate; it is also used as a correction factor in the determinations of free moisture by the oven-drying method. The free moisture is commonly determined by drying or by displacement methods, although other methods have been employed. In the laboratory, oven-drying is most commonly employed.

2. Porosity and absorption of aggregate[1,7,8]:

The presence of internal pores in the aggregate particles was related with the specific gravity of aggregate, and indeed the characteristics of these pores are very important in the study of its properties. The porosity of aggregate, its permeability, and absorption, influence such properties of aggregate as the bond between it and the cement paste, the resistance of concrete to freezing and thawing, as well as its chemical stability and resistance to abrasion. It is known that, the apparent specific gravity of aggregate is also depends on its porosity. The pores in aggregate vary in size over a wide range, the largest being large enough to be seen under a microscope or even with the naked eye, but even the smallest aggregate pores are generally larger than the gel pores in the cement paste. On the other hand, pores affect the durability of aggregate subjected to alternating freezing and thawing. However, water can enter the pores, the amount and rate of penetration depending on their size. The order of porosity of some common rocks is given in Table (1).

Table (1): Porosity of some common rocks

Rock group	Porosity (%)
Gritstone	0.0 – 48.0
Quartz	1.9 – 15.1
Limestone	0.0 – 37.6
Granite	0.4 – 3.8

And since aggregate represents some three-quarters of the volume of concrete it is clear that the porosity of aggregate materially contributes to the overall porosity of concrete. Although there is no clear-cut relation between the strength of concrete and the water absorption of aggregate used, the pores at the surface of the particle affect the bond between the aggregate and the cement paste, and may thus exert some influence on the strength of concrete.

Aim of the research:

This research is done in many directions:
(a) Designing a Non-air-entrained concrete mix using the American Concrete Institute (ACI) mix design method having a specified workability and compressive strength using the available tested cement and aggregates.
(b) Making the required field adjustment for the quantities of the concrete constituents with regard to moisture conditions (surface moisture and absorption capacity) of the aggregates used.
(c) Using the adjusted mix proportions in preparing different concrete mixes in order to test workability and compressive strengths at 7 and 28 days.
(d) Finally, this research includes also deriving and preparing many simple formulas used in the adjustment calculations for any mix proportions and different moisture conditions of the available aggregates (sand, gravel, or both) in sites.

Experimental investigation:

1. Materials:
1.1. Cement: Iraqi ordinary Portland cement (Type I)/Badoosh Factory is used, its physical properties are shown in Table (2)[9].

1.2. Aggregates:
1.2.1. Coarse aggregates: sieve analysis is done in accordance with BS : 882 : 1992, results are shown in Table (3). Coarse aggregate is prepared by separating the sample in many sizes using the standard sieves used, then remix these individual sizes using the calculated satisfying percentages retained on each sieve to prepare the tested specimen used in concrete.

1.2.2. Fine aggregates: sieve analysis is done in accordance with BS : 882 : 1992, results are shown in Table (4). Fine aggregate is prepared by separating the sample in many sizes using the standard sieves used and then remix these individual sizes using the calculated satisfying percentages retained on each sieve to prepare the tested specimen used in concrete. Main properties of coarse and fine aggregates were shown in Table (5).
1.2.3. Notes: no admixtures are used; tap water is used; concrete is mixed mechanically; normal curing is applied.

Table (2): Physical properties of the cement[10,11,12,13,14,15]

Properties	Used cement	Typical value
Blain Fineness, cm2/gm.	2350	2250 , min.
Relative density	3.15	3.15
Setting time (Vicat method): Initial time, minutes. Final time, hours.	 135 6.0	 60 , min. 10 , max.
Compressive strength (average): 3-day age, kg/cm2. 7-day age, kg/cm2.	 284.8 378.5	 150 , min. 230 , max.
Soundness, Autoclave test, %.	0.6	0.8 , max.

Table (3): Sieve analysis of coarse aggregates[16]

Sieve size (mm.)	Weight of coarse aggregate retained on each sieve (gm.)	Percentage retained on each sieve (%)	Cumulative percentage retained on each sieve (%)	Percentage passing of each sieve (%)	BS : 882 : 1992 (Medium)
40	0	0	0	100	100
20	0	0	0	100	100 – 90
14	1650	33	33	67	80 – 40
10	750	15	48	52	60 – 30
5.0	2450	49	97	3	10 – 0
Pan	150	3	100	–	–
Total	5000				
FM			5.78		

Maximum aggregate size (M.A.S):

In order to calculate the maximum aggregate size of the coarse aggregate, the sieve laid over the sieve with % Cumulative retained ≥ 15 % gives the maximum aggregate size, therefore, ¾ in. (20 mm.) Sieve gives the Maximum aggregate size, i.e., M.A.S. = 20 mm.
Minimum Cement Content (Cmin.): it is obtained applying the formulae[1]:

$$C_{min} = \frac{550}{5\sqrt{d}} = \frac{550}{5\sqrt{20}} = 302.1 \text{ kg/m3}$$

where: d = maximum size of coarse aggregate

Table (4): Sieve analysis of fine aggregates[16]

Sieve size (mm.)	Weight of fine aggregate retained on each sieve (gm.)	Percentage retained on each sieve (%)	Cumulative percentage retained on each sieve (%)	Percentage passing of each sieve (%)	BS : 882 : 1992 (Medium)
4.75	0	0	0	100	100
2.36	0	0	0	100	100 – 65
1.18	170	17	17	83	100 – 45
0.60	170	17	34	66	80 – 35
0.30	280	28	62	38	48 – 5
0.15	330	33	95	5	15 – 0
Pan	50	5	100	-	-
Total	1000				
FM			2.08		

Table (5): Main properties of coarse and fine aggregates[17,18,19,20]

Property	Coarse aggregate	Fine aggregate
Bulk sp. Gravity	2.68	2.59
S.S.D. sp. Gravity	2.70	2.67
App. sp. Gravity	2.74	2.89
Absorption capacity (%)	0.81	4.60
Surface moisture (%)	2.3	7.5
Rodded unit weight (kg/m3)	1766	1778
Voids content (%)	34.59	33.41
Angularity No.	1.59	0.41
Angularity index	1.24	1.06
Fineness modulus	5.78	2.08

2.Concrete mix design[1,5]:

This part of the research includes calculating the quantities of materials using the American Concrete Institute (ACI) method of concrete mix design to produce a Non-air-entrained concrete (reference mix) of 28-day compressive strength of 5000 psi (34.0 MPa) with plastic consistency (medium workability, slump = 80 – 130 mm.), satisfying the properties of materials (cement, coarse and fine aggregates) which are tabulated in Tables (2, 3, 4, and 5). Applying the ACI mix design method, the following results are obtained:
M.A.S. = 20 mm.,
Water content = 200 kg/m3,
Water/Cement ratio = 0.480,
Weight of cement = 200/0.48 = 416.7 kg/m3,
Weight of gravel = 0.7 x 1766 x 1.0 = 1236 kg/m3,
Weight of fresh concrete = 2355 kg/m3, and
Weight of sand = 2355 – (200 + 416.7 + 1236) = 502 kg/m3.
Thus, the weights of materials per cubic meter of concrete are:

Constituents	Water	Cement	Sand	Gravel
Weights (kg/m3)	200	416.7	502	1236
Percentages	0.480	1.000	1.205	2.966

And, the mix proportions are (1 : 1.205 : 2.966 , w/c = 0.480).
The above quantities are calculated on the basis that both aggregates (sand and gravel) are in the saturated-surface dry (S.S.D.) condition.

3. Field adjustment[5]:

At this stage of mix design, and as it is mentioned in the introduction article, the quantities of these materials obtained using the (ACI) mix design should be adjusted with relation to moisture conditions (surface moisture and absorption capacity) of the aggregate used In the field, the following nine probable cases of aggregates with regards to moisture conditions are arises, and these cases can be summarized in Table (6).

Table (6): Moisture conditions of aggregates in the field

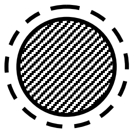
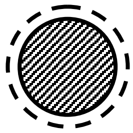
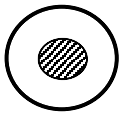
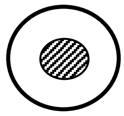
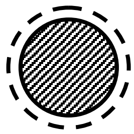
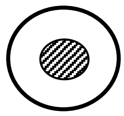
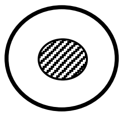
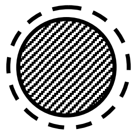
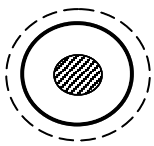
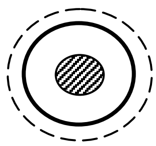
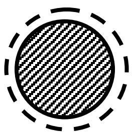
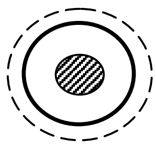
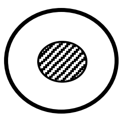
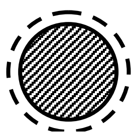
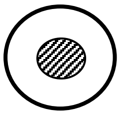
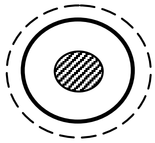
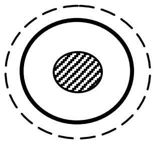
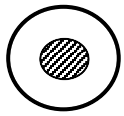
Cases	Sand	Gravel
A	 **Wet (Damp)**	 **Wet (Damp)**
B	 **Air - dry**	 **Air - dry**
C	 **Wet (Damp)**	 **Air - dry**
D	 **Air - dry**	 **Wet (Damp)**
E	 **Wet with absorption capacity**	 **Wet with absorption capacity**
F	 **Wet (Damp)**	 **Wet with absorption capacity**
G	 **Wet with absorption capacity**	 **Wet (Damp)**

Table (6): Continue

Cases	Sand	Gravel
H	 Air - dry	 Wet with absorption capacity
I	 Wet with absorption capacity	 Air - dry

<u>Results and discussion</u>:

From the results shown in Tables (4.1 to 4.9), the following factors are discussed:

1-Effect of moisture condition of aggregates on mix proportions:

In order to perform the field adjustment, mathematical calculations are done depending upon the moisture conditions of the aggregates (surface moisture and absorption capacity), for each case. Different adjusted mix proportions are obtained with respect to moisture conditions of aggregate, as follows:

Weight of surface moisture on sand = 0.075 x 502 = 37.65 kg.

Weight of surface moisture on gravel = 0.023 x 1236 = 28.43 kg.

Weight of absorbed water by sand = 0.046 x 502 = 23.09 kg.

Weight of absorbed water by gravel = 0.008 x 1236 = 10.01 kg.

Table (4.1): Adjusted materials and mix proportions for case (A)

Case	Constituents	Adjusted quantities of:			
		Water	Cement	Sand	Gravel
A	Weights (kg/m3)	133.92	416.7	539.65	1264.43
	Percentages	0.321	1.000	1.295	3.034
	Original mix proportions are (1 : 1.205 : 2.966 , w/c = 0.480)				
	Adjusted mix proportions are (1 : 1.295 : 3.034 , w/c = 0.321)				

Table (4.2): Adjusted materials and mix proportions for case (B)

Case	Constituents	Adjusted quantities of:			
		Water	Cement	Sand	Gravel
B	Weights (kg/m3)	233.1	485.63	502	1236
	Percentages	0.480	1.000	1.034	2.545
	Original mix proportions are (1 : 1.205 : 2.966 , w/c = 0.480)				
	Adjusted mix proportions are (1 : 1.034 : 2.545 , w/c = 0.480)				

Table (4.3): Adjusted materials and mix proportions for case (C)

Case	Constituents	Adjusted quantities of:			
		Water	Cement	Sand	Gravel
C	Weights (kg/m3)	172.36	416.7	539.65	1236
	Percentages	0.413	1.000	1.295	2.966
	Original mix proportions are (1 : 1.205 : 2.966 , w/c = 0.480)				
	Adjusted mix proportions are (1 : 1.295 : 2.966 , w/c = 0.413)				

Table (4.4): Adjusted materials and mix proportions for case (D)

Case	Constituents	Adjusted quantities of:			
		Water	Cement	Sand	Gravel
D	Weights (kg/m3)	194.60	416.7	502	1264.43
	Percentages	0.467	1.000	1.205	3.034
	Original mix proportions are (1 : 1.205 : 2.966 , w/c = 0.480)				
	Adjusted mix proportions are (1 : 1.205 : 3.034 , w/c = 0.467)				

Table (4.5): Adjusted materials and mix proportions for case (E)

Case	Constituents	Adjusted quantities of:			
		Water	Cement	Sand	Gravel
E	Weights (kg/m3)	167.02	416.7	539.65	1264.43
	Percentages	0.401	1.000	1.295	3.034
	Original mix proportions are (1 : 1.205 : 2.966 , w/c = 0.480)				
	Adjusted mix proportions are (1 : 1.295 : 3.034 , w/c = 0.401)				

Table (4.6): Adjusted materials and mix proportions for case (F)

Case	Constituents	Adjusted quantities of:			
		Water	Cement	Sand	Gravel
F	Weights (kg/m3)	143.93	416.7	539.65	1264.43
	Percentages	0.345	1.000	1.295	3.034
	Original mix proportions are (1 : 1.205 : 2.966 , w/c = 0.480)				
	Adjusted mix proportions are (1 : 1.295 : 3.034 , w/c = 0.345)				

Table (4.7): Adjusted materials and mix proportions for case (G)

Case	Constituents	Adjusted quantities of:			
		Water	Cement	Sand	Gravel
G	Weights (kg/m3)	157.01	416.7	539.65	1264.43
	Percentages	0.376	1.000	1.295	3.034
	Original mix proportions are (1 : 1.205 : 2.966 , w/c = 0.480)				
	Adjusted mix proportions are (1 : 1.295 : 3.034 , w/c = 0.376)				

Table (4.8): Adjusted materials and mix proportions for case (H)

Case	Constituents	Adjusted quantities of:			
		Water	Cement	Sand	Gravel
H	Weights (kg/m3)	158.49	416.7	502	1264.43
	Percentages	0.380	1.000	1.205	3.034
	Original mix proportions are (1 : 1.205 : 2.966 , w/c = 0.480)				
	Adjusted mix proportions are (1 : 1.205 : 3.034 , w/c = 0.380)				

Table (4.9): Adjusted materials and mix proportions for case (I)

Case	Constituents	Adjusted quantities of:			
		Water	Cement	Sand	Gravel
I	Weights (kg/m3)	195.45	416.7	539.65	1236
	Percentages	0.469	1.000	1.295	2.966
	Original mix proportions are (1 : 1.205 : 2.966 , w/c = 0.480)				
	Adjusted mix proportions are (1 : 1.295 : 2.966 , w/c = 0.469)				

Therefore, for comparison purposes, the adjusted mix proportions can be summarized, depending upon the moisture conditions and absorption capacity of the used aggregates and tabulated in Table (4.10).

Table (4.10): Adjusted mix proportions obtained for different cases of aggregates

Cases	Moisture Conditions		Adjusted Mix Proportions
	SAND	GRAVEL	
Reference mix	S.S.D.	S.S.D.	1 : 1.205 : 2.966 , w/c = 0.480
A	Moist	Moist	1 : 1.295 : 3.034 , w/c = 0.321
B	Air-Dry	Air-Dry	1 : 1.034 : 2.545 , w/c = 0.480
C	Moist	Air-Dry	1 : 1.295 : 2.966 , w/c = 0.413
D	Air-Dry	Moist	1 : 1.205 : 3.034 , w/c = 0.467
E	Moist with absorption capacity	Moist with absorption capacity	1 : 1.295 : 3.034 , w/c = 0.401
F	Moist	Moist with absorption capacity	1 : 1.295 : 3.034 , w/c = 0.345
G	Moist with absorption capacity	Moist	1 : 1.295 : 3.034 , w/c = 0.376
H	Air-Dry	Moist with absorption capacity	1 : 1.205 : 3.034 , w/c = 0.380
I	Moist with absorption capacity	Air-Dry	1 : 1.295 : 2.966 , w/c = 0.469

2-Effect of moisture conditions of aggregates on workability and compressive strength of concrete[3,6]:

The adjusted mix proportions tabulated in Table (4.10) for different cases of moisture content and absorption capacity of aggregates are used experimentally in preparing concrete mixes in the laboratory, the workability (slump test) of fresh concrete and the 7 and 28 days compressive strengths of the hardened concrete are measured for each case. Results of slumps and strengths are shown in Table (4.11).

Table (4.11): Results of the experimental work

Cases	Moisture conditions		Adjusted mix proportions	Slump (mm.)	Compressive strength (MPa)	
	SAND	GRAVEL			7-day	28-day
Reference mix (Theoretical)	S.S.D.	S.S.D.	1 : 1.205 : 2.966 , w/c = 0.480	80 – 130	--	34.00
Reference mix (Practical)	S.S.D.	S.S.D.	1 : 1.205 : 2.966 , w/c = 0.480	126	27.10	38.74
A	Moist	Moist	1 : 1.295 : 3.034 , w/c = 0.321	115	24.34	36.60
B	Air-Dry	Air-Dry	1 : 1.034 : 2.545 , w/c = 0.480	127	23.89	35.62
C	Moist	Air-Dry	1 : 1.295 : 2.966 , w/c = 0.413	122	24.00	36.93
D	Air-Dry	Moist	1 : 1.205 : 3.034 , w/c = 0.467	128	26.35	34.28
E	Moist with absorption capacity	Moist with absorption capacity	1 : 1.295 : 3.034 , w/c = 0.401	120	25.29	35.46
F	Moist	Moist with absorption capacity	1 : 1.295 : 3.034 , w/c = 0.345	117	27.04	35.92
G	Moist with absorption capacity	Moist	1 : 1.295 : 3.034 , w/c = 0.376	119	26.41	35.77
H	Air-Dry	Moist with absorption capacity	1 : 1.205 : 3.034 , w/c = 0.380	121	24.99	36.24
I	Moist with absorption capacity	Air-Dry	1 : 1.295 : 2.966 , w/c = 0.469	129	25.26	35.39

Experimental results show that the saturated-surface dry (S.S.D.) aggregates (both sand and gravel) is the best case, with relation to moisture conditions, when used in preparing the reference mix, since the 7 and 28 days compressive strengths are (27.10) and (38.74) MPa respectively. This is due to the aggregates in this case are in the ideal condition with relation to moisture conditions, i.e. the mixing water is used directly in hydration of cement and no water will used by aggregates[1,7]. S.S.D. aggregates can be controlled in the laboratory, but in the field, it is impossible to obtain S.S.D. aggregates practically. Examining the results obtained using the nine moisture condition cases, it is clear that all the adjusted mix proportions can be used practically, because they gave good results, the average 28-day compressive strength is (35.80) MPa, and this value is acceptable comparing with the 28-day characteristic strength (34.00) MPa obtained using the ACI method[5]. Therefore, field adjustment with relation to moisture condition of aggregates must be taken into account when the concrete constituents were put in the mixer.

Here, certain attention should be taken especially when the mix proportions are taken without adjustment. In this case, some water will be added to the original mixing water used for hydration, and this will affect adversely (reduce) the compressive strength, especially when the unadjusted aggregates are in the moist case, and moist with absorption capacity case, since strength is related inversely with the water content of the mix[1,7]. On the other hand, some water is deduced from the original mixing water used for hydration when the unadjusted aggregates are used in the air-dry case, and this will reduce the workability since workability is related directly with the water content of the mix.

3- Expressions to calculate the adjusted concrete constituents:
At this stage, it is better to prepare general expressions to give the adjusted quantity of all concrete constituents for any mix proportion of known surface moisture and absorption capacity. The following formulas can be derived, and are shown in Tables (4.12 to 4.20):

Notations:
Ws = weight of sand (kg)
Wg = weight of gravel (kg)
Ww = weight of water (kg)
Wc = weight of cement (kg)
sws % = percentage of surface moisture on sand
swg % = percentage of surface moisture on gravel
acs % = percentage of absorption capacity of sand
acg % = percentage of absorption capacity of gravel
Wsws = weight of surface moisture on sand (kg) = sws % * Ws
Wswg = weight of surface moisture on gravel (kg) = swg % * Wg
Wacs = weight of absorbed water by sand (kg) = acs % * Ws
Wacg = weight of absorbed water by gravel (kg) = acg % * Wg
Therefore, weights of the adjusted materials are:
Wss = weight of moist sand (kg) = Ws + Wsws
Wsg = weight of moist gravel (kg) = Wg + Wswg
Wds = weight of air-dry sand (kg)
Wdg = weight of air-dry gravel (kg)
Wnw = net (effective) weight of mixing water (kg)
Wnc = weight of the adjusted cement

Table (4.12): Expressions for the adjusted materials for case (A)

Cases	Moisture conditions		Adjustments	
	SAND	GRAVEL		
A	Moist	Moist	Water	Wnw = Ww – Wsws – Wswg
			Cement	Wnc = Wc
			Sand	Wss = Ws + Wsws
			Gravel	Wsg = Wg + Wswg

Table (4.13): Expressions for the adjusted materials for case (B)

Cases	Moisture conditions		Adjustments	
	SAND	GRAVEL		
B	Air-Dry	Air-Dry	Water	Wnw = Ww + Wacs + Wacg
			Cement	Wnc = Wnw / (W/C)
			Sand	Wds = Ws
			Gravel	Wdg = Wg

Table (4.14): Expressions for the adjusted materials for case (C)

Cases	Moisture conditions		Adjustments	
	SAND	GRAVEL		
C	Moist	Air-Dry	Water	Wnw = Ww – Wsws + Wacg
			Cement	Wnc = Wc
			Sand	Ws + Wsws
			Gravel	Wdg = Wg

Table (4.15): Expressions for the adjusted materials for case (D)

Cases	Moisture conditions		Adjustments	
	SAND	GRAVEL		
D	Air-Dry	Moist	Water	Wnw = Ww + Wacs – Wswg
			Cement	Wnc = Wc
			Sand	Wds = Ws
			Gravel	Wg + Wswg

Table (4.16): Expressions for the adjusted materials for case (E)

Cases	Moisture conditions		Adjustments	
	SAND	GRAVEL		
E	Moist with Absorption Capacity	Moist with Absorption Capacity	Water	Wnw = Ww – [(sws % - acs %) * Ws] – [(swg % - acg %) * Wg]
			Cement	Wnc = Wc
			Sand	Ws + Wsws
			Gravel	Wg + Wswg

Table (4.17): Expressions for the adjusted materials for case (F)

Cases	Moisture conditions		Adjustments	
	SAND	GRAVEL		
F	Moist	Moist with Absorption Capacity	Water	Wnw = Ww – Wsws – [(swg % - acg %) * Wg]
			Cement	Wnc = Wc
			Sand	Ws + Wsws
			Gravel	Wg + Wswg

Table (4.18): Expressions for the adjusted materials for case (G)

Cases	Moisture conditions		Adjustments	
	SAND	GRAVEL		
G	Moist with Absorption Capacity	Moist	Water	Wnw = Ww – [(sws % - acs %) * Ws] – Wswg
			Cement	Wnc = Wc
			Sand	Ws + Wsws
			Gravel	Wg + Wswg

Table (4.19): Expressions for the adjusted materials for case (H)

Cases	Moisture conditions		Adjustments	
	SAND	GRAVEL		
H	Air-Dry	Moist with Absorption Capacity	Water	Wnw = Ww + Wacs – [(swg % - acg %) * Wg]
			Cement	Wnc = Wc
			Sand	Wds = Ws
			Gravel	Wg + Wswg

Table (4.20): Expressions for the adjusted materials for case (I)

Cases	Moisture conditions		Adjustments	
	SAND	GRAVEL		
I	Moist with Absorption Capacity	Air-Dry	Water	Wnw = Ww – [(sws % - acs %) * Ws] + Wacg
			Cement	Wnc = Wc
			Sand	Ws + Wsws
			Gravel	Wdg = Wg

Conclusions:

From the previous results and discussion, the following conclusions may be drawn:

1. Experimental results show that, the 7 and 28 days compressive strengths are (27.10) and (38.74) MPa respectively using the mix proportions of the reference mix, which is designed by the ACI method, with the saturated-surface dry (S.S.D.) aggregates (both sand and gravel), is the best case of the aggregates with relation to moisture conditions. This is because of the aggregates in the S.S.D. condition are in regarded as the ideal condition with relation to moisture conditions.

2. Aggregates in the S.S.D. condition can be controlled in the laboratory, but in the field, this case difficult and impossible to gain it. Therefore, nine probabilities of moisture conditions of the aggregates will be arise, and, in order to overcome this problems, field adjustment with relation to moisture condition of aggregates must be taken into account when the concrete constituents were put in the mixer.

3. Examining the results obtained using the moisture condition cases except the S.S.D. condition, it is clear that all the adjusted mix proportions can be used practically and successfully, because they gave good results, the average 28-day compressive strength is (35.80) MPa, and this value is acceptable, comparing with the 28-day characteristic strength (34.00) MPa of the reference mix obtained using the ACI method.

4. When the mix proportions are taken without adjustment, some water will be added to the original mixing water used for hydration when the unadjusted aggregates are in the moist case, and moist with absorption capacity case and this will reduce the compressive strength. On the other hand, some water is deduced from the original mixing water used for hydration when the unadjusted aggregates are used in the air-dry case, and this will decrease the workability.

5. Finally, empirical expressions are derived to calculate the adjusted quantities of concrete constituents for the nine probable cases of moisture conditions.

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