EFFECT OF MAXIMUM SIZE OF AGGREGATE AND FINENESS OF SAND ON COST OF CONCRETE

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Abstract - This research presents an analytical calculation using the American Concrete Institute (ACI 211.1) and British methods (Department of the Environment) used for mix design of normal concrete to assess the difference in produced concrete cost due to difference in maximum size of aggregate, fineness of sand in Babylon local market. Four concrete targeted design strengths were designed (15, 20, 25 and 40) MPa. The design variables for each value of compressive strength were; maximum aggregate size, fineness of sand. The results obtained show that the cost of concrete using crushed aggregate is greater than uncrushed for all compressive strengths and the difference in cost increases directly with maximum size of aggregate (MSA),. The concrete cost will decrease with the increase of maximum size of aggregate value, and there is no effect of fineness modulus on concrete cost what so ever. In general, when designing a concrete mix with a specified compressive strength and fixing all other variables the ACI method gives a lower cost compared with British method for (15, 20, and 25 MPa) and higher cost for 40 MPa strength.

Keywords - Maximum Size of Aggregate, Fineness of Sand, Cost of Concrete, Slump, Compressive Strength.

I. INTRODUCTION

Concrete is composed principally of aggregates, Portland or blended cement, and water, and may contain other cementitious materials and/or chemical admixtures. It will contain some amount of entrapped air and may contain purposely-entrained air obtained by use of an admixture or air-entraining cement [1]. The selection of concrete proportions involves a balance between economy and requirements for place ability, strength, durability, density, and appearance. The required characteristics are governed by the use to which the concrete will be put and by conditions expected to be encountered at the time of placement. These characteristics should be listed in the job specifications. (ACI 211.1- 91) [2] (Dixon, Prestrera et al. 1991) [3].

Concrete mix design is the procedure by which the proportions of constituent materials are suitably selected so as to produce concrete satisfying all the required properties for the minimum cost. Many attempts have been made to develop a reliable method for normal concrete mix design in various parts of the world ever since usage of concrete began as a structural material. Among all available methods, the ACI 211.1, the British Road Note Number 4, and the British method DoE of mix design are the most widely used ones in the Middle East. Many of the Middle East countries adapted one or more of these methods as the basis for their concrete mix proportioning (examples are Iraq, Kuwaiti, Saudi, and Jordanian specifications). (Qasrawi 2016) [4], Khalid et al 2007 [5], Kozul & Darwin 1997 [6].

Because of the variations of the available materials (in many countries) from the American or the British specifications, the use of the American or the British method of mix design requires special care, individual experience, and special judgments in order to achieve the optimum design. The most common variations of the available materials are aggregate grading, shape, fineness, and texture (Qasrawi 2016) [4], (Dixon, Prestrera et al. 1991)[3].

The procedure of ACI 211.1 for selection of mix proportions is applicable to normal weight concrete and it can be accomplished through seven steps. While the current British method is that of the Department of the Environment (DoE) revised in 1997.14.11 similarly to the ACI approach, the British method explicitly recognizes the durability requirements in the mix selection. The method is applicable to normal weight concrete made with Portland cement only or also incorporating ground granulated blast furnace slag or fly ash, but it does not cover flowing concrete or pumped concrete; nor does it deal with lightweight aggregate concrete. The British method consists of 5 steps [7].

II. COMPUTER PROGRAM

A computer program was designed specially to calculate concrete mix proportions and the cost of $1m^3$ of normal weight concrete.

The program consist of two main types of data;, the input which is represented by the following values; compressive strength (designed or required) (cube or cylinder), slump, maximum size of aggregate MSA, fineness of sand, type of exposure, type of structure, dry density of aggregate, specific gravity for coarse aggregate and (cement, coarse aggregate and fine aggregate) cost. While the output is the required strength, concrete mix proportions by (weight and volume) and the cost for $1m^3$ by Iraqi Denair.

III. RESULT AND DISCUSSION

This section shows the calculations of concrete mix proportions and concrete cost by using ACI & DoE mix design methods with slump, maximum size of aggregate, fineness modulus, compressive strength and their effect on the concrete cost as variables.

A. British method (Department of the Environment) DoE mix design B.S. 5328.2.

During this research four values were taken for compressive strength as follow: (15, 20, 25 and 40) MPa and for each value of compressive strength four different values of slump were taken (0-10, 10-30, 30-60, 60-180) mm, and by using five deferent sand zones: (15%, 40%, 60%, 80% and 100%). The sand zone values represent the percent of passing through sieve size 600µm.

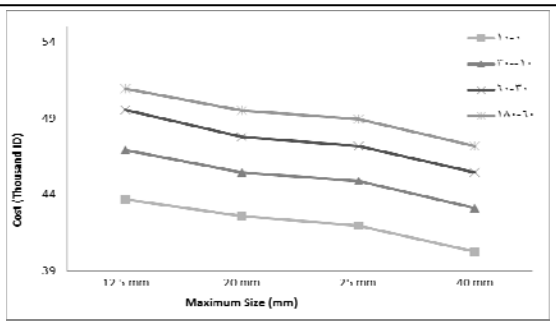
Figures (1) represent the effect of maximum uncrushed size of aggregate on cost for different compressive strength and slump values. Whereas Figures (2) represent the effect of maximum crushed size of aggregate on cost for different compressive strength and slump values of concrete.

From the previous figures, it can see that for the same compressive strength and all other variables the cost of concrete containing crushed aggregate is higher than that containing uncrushed aggregate due to the increase in the quantity of water, which leads to undeniable increase in cement amounts that would lead to an increase in concrete cost.

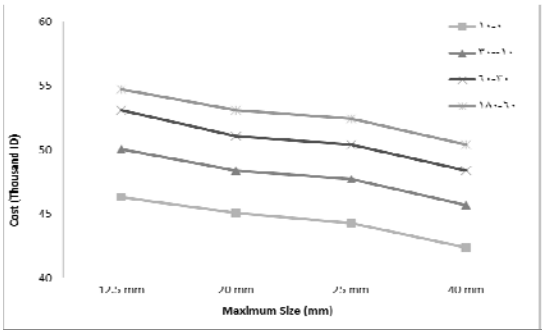
Furthermore, with the increase of slump value for the same compressive strength, type of aggregate (crushed, uncrushed), and maximum size of aggregate, the cost of concrete increases. Due to this increased cement content, slight increase in fine aggregate and noticeable decrease in coarse aggregate content.

For the same value of compressive strength and all other variables, the increase in maximum size of aggregate decreases concrete cost because of decreasing in water content, which results in decrease in cement content.

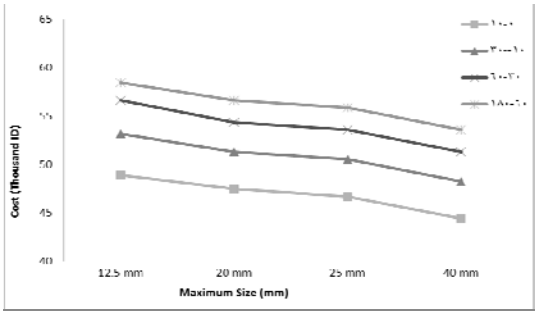
Regarding the fineness of sand, there is no change in concrete cost for the same compressive strength and all other variables. The change occurs in the amount of coarse aggregate that would increase due to an increase in fineness of sand. The cost is not affected by this change since the fine and coarse aggregate cost are almost the same.



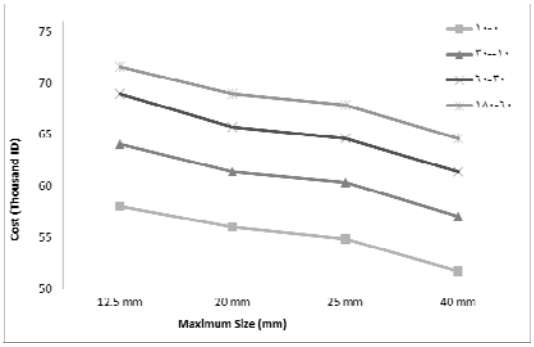
compressive strength 15 MPa



compressive strength 20 MPa



compressive strength 25 MPa

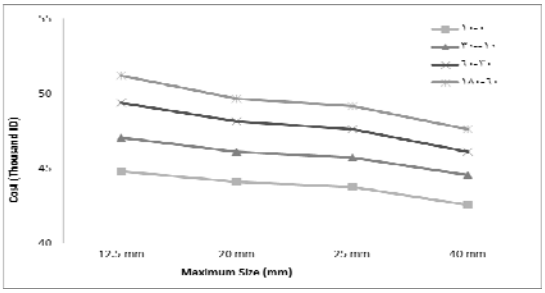


compressive strength 40 MPa

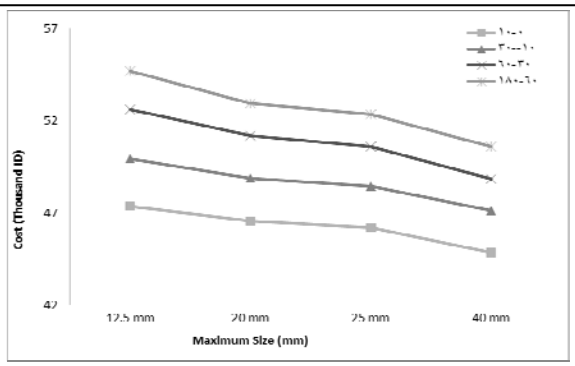
Figure (1) Effect of maximum size of uncrushed aggregate on cost of concrete with different slump values (DoE).

B. ACI mix design method ACI 211.1 [2].

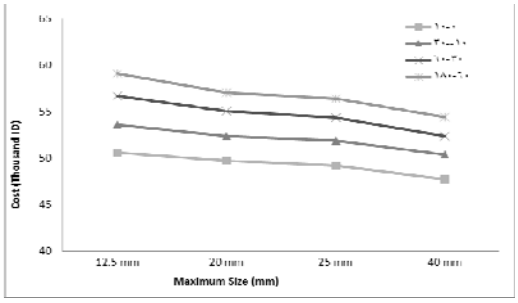
In this section, four values were taken for compressive strength as follow: (15, 20, 25 and 40) MPa and for each value of compressive strength, three different values of slump were taken (low, medium, and high), and by using five deferent sand zones: (2.4, 2.6, 2.8, and 3.0) represent the fineness modulus.



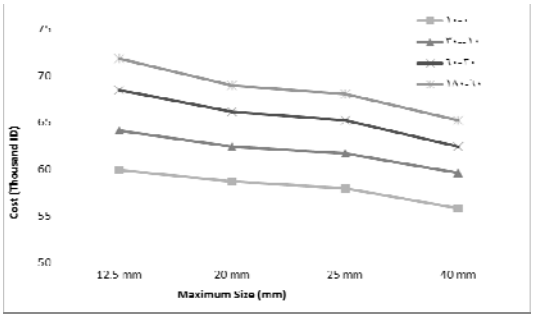
compressive strength 15 MPa



compressive strength 20 MPa



compressive strength 25 MPa

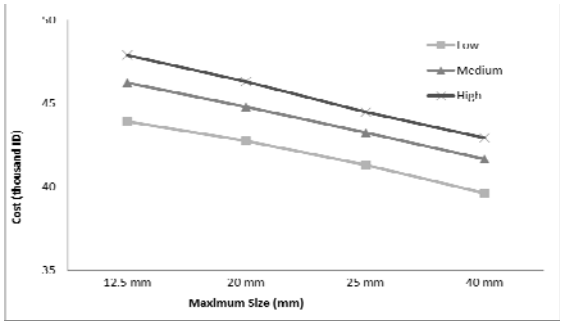


compressive strength 40 MPa

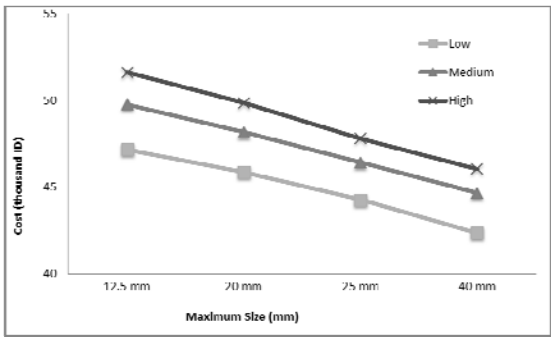
Figure (2) Effect of maximum size of crushed aggregate on cost of concrete with different slump values (DoE).

Mix proportions and concrete cost were calculated as represented in the Fig. (3) to Fig. (5). It is obvious from these figures that the increase in maximum size of aggregate decreases concrete cost because of decreasing water content, which results in a decrease in cement content. Regarding the fineness of sand, there is no change in concrete cost for the same compressive strength and all other variables. The change occurs in the amount of coarse aggregate that would increase due to an increase in fineness of sand. The cost is not affected by this change since the fine and coarse aggregate cost are almost the same in Hilla city. Furthermore with the increase of slump value for the same compressive strength, type of aggregate (crushed, uncrushed), and maximum size of aggregate, the cost of concrete also increases. Figures from (1) to (3) represent the effect of maximum size of aggregate on concrete cost for different slump values and compressive strength using the ACI & DoE both (crushed and uncrushed aggregate) The increase of maximum size of aggregate leads to decrease the cost for different compressive strength and slump values.

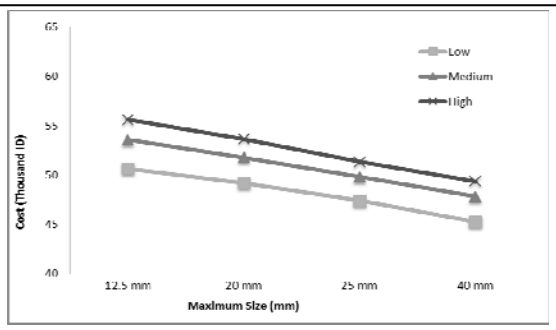
The concrete cost decreases due to the decrease in water demand for aggregate with the same value of porosity because the aggregate with greater max size have less surface area. Figure (4) represent the effect of fineness of sand on concrete cost for different slump values and compressive strength using the ACI method. The DoE both (crushed and uncrushed aggregate) has the same trend. The fineness of sand does not affect the concrete cost in both ACI & DoE mix design methods. The increase in the value of sand fineness would increase the amount of coarse aggregate in DoE method and decrease the amount of coarse aggregate in ACI method. Figure (5) represent the effect of slump on concrete cost for different slump values and compressive strength using the ACI method. The DoE both (crushed and uncrushed aggregate) has the same trend. The concrete cost will increase with the increase of slump value for different maximum size of aggregate and compressive strength using the ACI & DoE both (crushed and uncrushed aggregate) due to the noticeable increase in water, which lead to an increase in cement content and an associated decrease in coarse aggregate quantity. Figure (6) present a comparison for maximum size of aggregate effect on concrete cost between ACI and DoE (crushed and uncrushed aggregate) mix design methods, for compressive strength values (15MPa & 40MPa) and slump values (0-10 & 60-180) In general using DoE method the cost of concrete with crushed aggregate is greater that concrete with uncrushed aggregate when designing (15, 20, 25, 40) MPa compressive strength and the difference in cost increase directly with maximum size of aggregate values and indirectly with slump values and the margin is about (0.3-5.5) %.



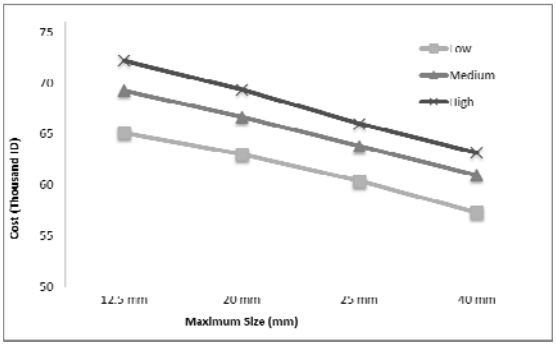
compressive strength 15 MPa



compressive strength 20 MPa

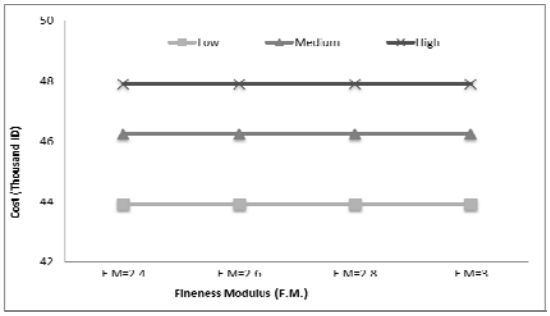


compressive strength 25 MPa

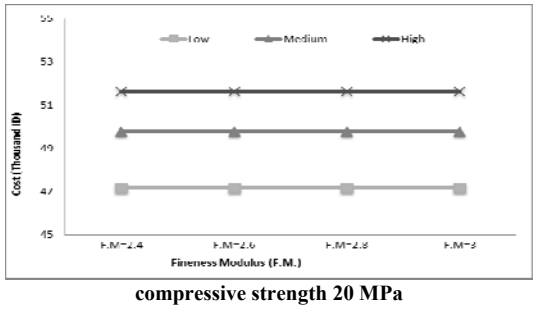


compressive strength 40 MPa

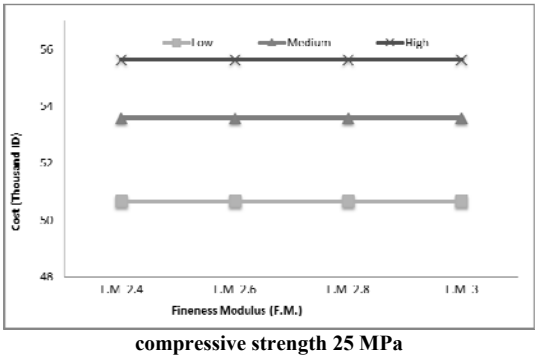
Figure (3) Effect of maximum size of aggregate on cost of concrete with different slump values (ACI).



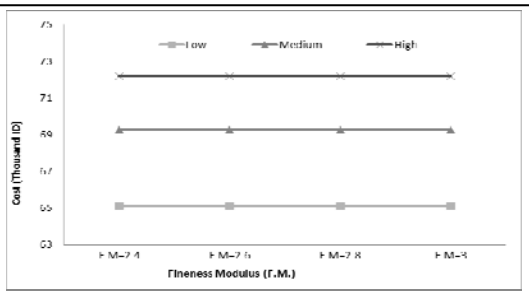
compressive strength 15 MPa



compressive strength 20 MPa

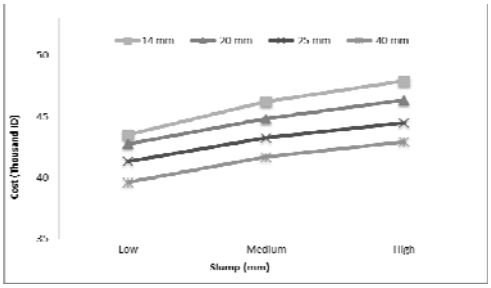


compressive strength 25 MPa

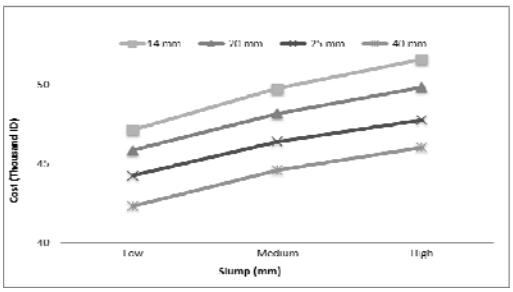


compressive strength 40 MPa

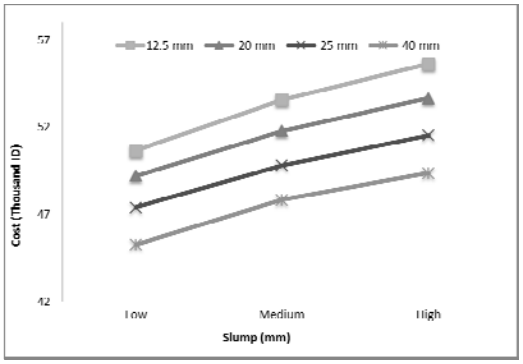
Figure (4) Effect of fineness modulus on cost of concrete with different slump values (ACI).



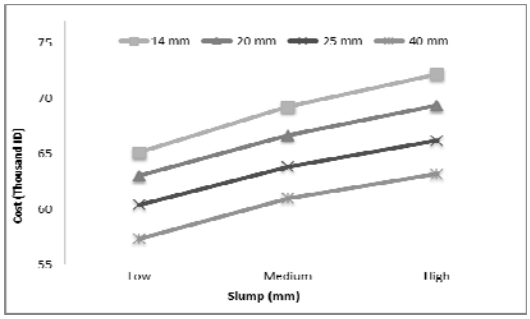
compressive strength 15 MPa



compressive strength 20 MPa

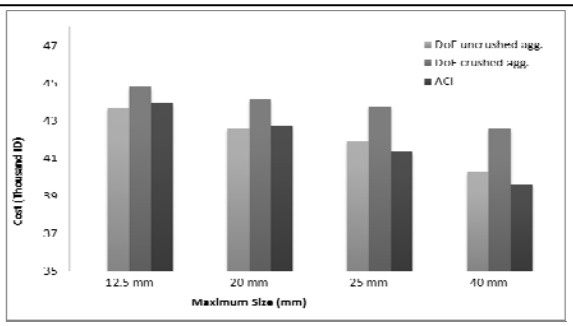


compressive strength 25 MPa

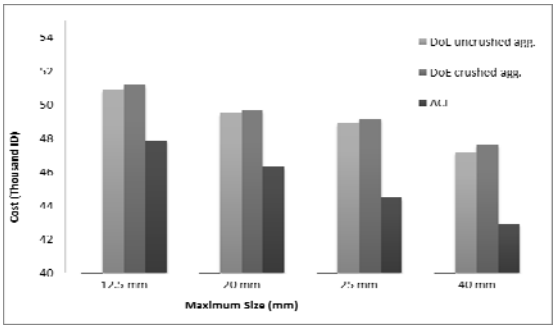


compressive strength 40 MPa

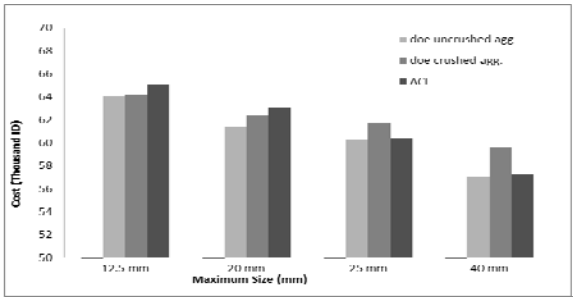
Figure (5) Effect of slump on cost of concrete with different maximum size of aggregate (ACI)



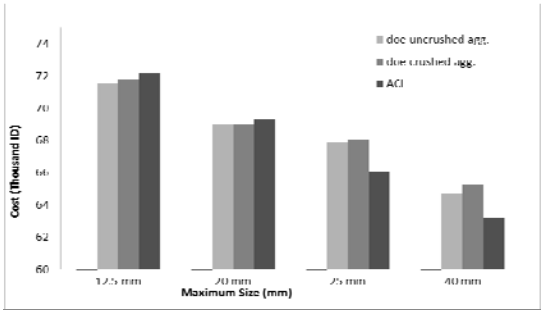
compressive strength 15 MPa, low slump (0-10)



compressive strength 15 MPa, high slump (60-180)



compressive strength 40 MPa, low slump (0-10)



compressive strength 40 MPa, high slump (60-180)

Figure (6) Effect of maximum size of aggregate on cost of concrete by ACI &DoE mix design methods.

When comparing the ACI with DoE cost results the ACI method is economic when designing (15, 20 and 25) MPa and these values increase directly with slump and maximum size of aggregate values and indirectly with compressive strength with a margin (1-9) %, except 40 MPa, the ACI method would be more expensive by (0.4-2.7) %.

IV. CONCLUSIONS

From the results of calculating concrete mix proportions using ACI & DoE mix design methods with the variables; slump, maximum size of aggregate, fineness modulus, compressive strength and their effect on the concrete cost the following conclusions were revealed:

1) Concrete cost will decrease with the increase of maximum size of aggregate value.
2) Concrete cost will increase with the increase of slump value.
3) Concrete cost will increase with the increase of compressive strength value.
4) There is no effect of fineness modulus on concrete cost what so ever.
5) In general when designing a concrete mix with a specified compressive strength and fixing all other variables the ACI method give a lower cost compared with DoE method.
6) When using DoE method the concrete cost will be higher using crushed aggregate compared with uncrushed aggregate.

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