Evaluation of Using Local Coarse Aggregate of Kerbala Quarries in Production of High Strength Concrete

Najah M.L. Al-Maimuri  Mohammed K. Al Khafaji
Babil Tech. Institute, Babylon
Jabbar A. J. Al Khafaji
Babil Tech.

Abstract:
The use of White Crushed Gravel from Kerbela Quarries in the design of high strength concrete mixes is evaluated through this research. Two grades of mixes are undertaken; they are A (40 Mpa) and B (60 Mpa) of compressive strength. The mixes proportion is used for the design in these mixes are (0.35 and 0.3 water/cement ratio), (446kg/m$^3$ and 550kg/m$^3$ cement), (0.8 liter/kg super plasticizer) for each A and B mixes respectively.

The fresh concrete tests results indicate that mixes made of the Crushed White Gravel characterized with slump value of 57 and 52 mm and compaction factor of (0.95, 0.92) for the mixes type A and B respectively.

The maximum compressive strength of (43.6 and 62.2) Mpa, the modulus of elasticity of (40.5 and 43.4) Gpa, the modulus of rupture of (6.3 and 6.7) Mpa, the splitting tensile strength of (4.5 and 4.9 Mpa, the Ultra Sonic Pulse velocity of (4.25 and 4.58) Km/s for both A and B mixes respectively at 28 days.

Introduction

Construction industry is using natural resources of preliminary minerals necessary for it in neighboring regions. Frequently projects managers faces constantly the problems of concrete mixes failures in most civil engineering problems enterprises; these problems surely are issued by many factors, among them the badness of the coarse aggregate. Searching for the best alternative is always the dominant phenomena. Extensive researches are frequently deals with enhancement of concrete mixes characteristics, but actually researchers develop materials occupy the zone of mortar structure. Many attempts are made for this purpose. In general in UK the HSC mixes include concrete with a characteristic compressive strength of 60 MPa or more.

John and Ban (2003) confine the factors govern the strength of concrete mixes as; aggregate properties, cement paste properties, properties of the transition zone between cement paste and the aggregate, and relative proportion of constituent materials. In this research, it is focused on the coarse aggregate effect in the industry of HSC mixes technology. Bing et al (2001) tested the effect of coarse aggregate type on the compressive strength, splitting, tensile strength, fracture energy, characteristic length and elastic modulus of concrete. They concluded that HSC can be made by
selecting high-strength aggregate. Yaguband Imran (2006) described the effect of aggregate size on the compressive strength of HSC. Five course aggregate sizes were used; 37.5, 25, 20, 10, and 5mm with natural sand of 3.48mm of maximum sizeas fine aggregate and Portland Cement. It is accordingly concluded that 10mm and 5mm showed higher compressive strength than other sizes of aggregates. Bing and Juanyu (2004) investigated the effect of aggregate size distributions and the volume fraction of aggregate on the fracture parameters of HSC with strength 50-80 Mpa under three-point bending test. Chee and Wan (2011) indicates that most investigations on HSC used coarse aggregates in order the amount of free-water content for hydration is not reduced. They focused on the effect of free-water being absorbed by the coarse aggregate. The results show that the slump values are drastically reduced more than 80% and considerable increments of 3% and 16% for the compressive strength and modulus of rupture respectively. Paramasivam(2006) used a suitable mix to develop HSC using crushed sandstone coarse and fine aggregates. Three types of curing conditions have been employed to investigate the effect of curing on strength and durability. It was found a combination of silica fume and fly ash as partial replacement of cement with crush sandstone aggregates offers synergistic effect on workability, strength, and durability. Finally, he concludes that sandstone aggregates can be used in HSC production. Badawy et al (2007) used the dolomite and basalt (obtained from different location in Egypt) as a partial replacement of coarse aggregate in normal strength concrete NSC and HSC. The results show that the compressive strength of dolomite concrete is higher than that of basalt and gravel concretes. Aitcin and Mehta (1990) indicate that transferring process of transition zone is weakened by smooth rounded gravel rather than rough and crushed gravels. They indicate that crushed aggregate particles may be severely micro-cracked; moreover it is associated with high number of microcracks in large particles. Consequently, the common sizes (5-10mm nominal size) are recommended to be used in HSC mixes. They also indicated that the coarse aggregate must be stressed to select the appropriate sources which are much more critical for HSC than for conventional concrete.

It is pronounced that aggregate strength becomes increasingly important as target strength increases. The suitability of crushed white aggregate for use in HSC meeting the requirements for various applications, namely foundations, paving reinforced and prestressed concrete, has examined by the authors and reported elsewhere next.

Research Significance

In the middle and south of Iraq, civil engineering enterprises suffer the problems of coarse aggregate discrepancy of compatible specifications to standards. The main origin of a common type of the coarse aggregate is Tigris River Arm in Samarra County. Unfortunately, these areas are infected by the terroristic war which extremely affects the coarse aggregate material transportation activity in recent few years; the later problem accordingly increases the costs of black aggregate at the destination they are requested.

The purpose of this research is to evaluate the use a local type of coarse aggregate (white gravel) of Kerbala Quarries in production of HSC mixes and to investigate their physical properties and mechanical performance.

Materials and Experimental Work

Before navigation in this manipulation of HSC Mixes Design, it must obviously be recognized, that there is no unique constituent for HSC. John and Ban (2003)
indicated that HSC can be made of a wide range of materials and mix proportions which correspondingly produce a slight variation in the properties.

I) Cement

Ordinary Portland cement (Tasluja) is used in this research. Table (1) and Table (2) Show the physio-chemical properties of cement which conforms to IQS No.5/1984

Table (1) Physical Properties of Cement

<table>
<thead>
<tr>
<th>Test</th>
<th>Results</th>
<th>Allowable Limits According to IQS No.5/1984</th>
</tr>
</thead>
<tbody>
<tr>
<td>Settin Time, Min,</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Initial</td>
<td>135</td>
<td>≥ 45 min</td>
</tr>
<tr>
<td>Final</td>
<td>240</td>
<td>≤ 600 min</td>
</tr>
<tr>
<td>Fineness (Blaine), m²/kg</td>
<td>280</td>
<td>≥ 230</td>
</tr>
<tr>
<td>Compressive Strength, MN/m²</td>
<td></td>
<td></td>
</tr>
<tr>
<td>at 3days</td>
<td>20</td>
<td>≥ 15</td>
</tr>
<tr>
<td>7days</td>
<td>30.5</td>
<td>≥ 23</td>
</tr>
<tr>
<td>Soundness (Auto Clave), %</td>
<td>0.028</td>
<td>≤ 0.8</td>
</tr>
</tbody>
</table>

Table (2) Chemical Properties of Cement

<table>
<thead>
<tr>
<th>Oxide</th>
<th>% by Weight</th>
<th>Allowable Limits According to IQS No.5/1984</th>
</tr>
</thead>
<tbody>
<tr>
<td>CaO</td>
<td>64.16</td>
<td></td>
</tr>
<tr>
<td>SiO₂</td>
<td>20.59</td>
<td></td>
</tr>
<tr>
<td>Al₂O₃</td>
<td>5.92</td>
<td></td>
</tr>
<tr>
<td>Fe₂O₃</td>
<td>3.29</td>
<td></td>
</tr>
<tr>
<td>MgO</td>
<td>2.20</td>
<td>≤4</td>
</tr>
<tr>
<td>SO₃</td>
<td>2.21</td>
<td>≤2.5 if C₃A &lt;5% ≤2.8 if C₃A &gt;5%</td>
</tr>
<tr>
<td>Free Lime</td>
<td>0.76</td>
<td></td>
</tr>
<tr>
<td>Loss on Ignition</td>
<td>0.8</td>
<td>≤4%</td>
</tr>
<tr>
<td>Insoluble Residue</td>
<td>1.75</td>
<td>≤1.5%</td>
</tr>
<tr>
<td>C₃S</td>
<td>61.684</td>
<td></td>
</tr>
<tr>
<td>C₂S</td>
<td>23.2</td>
<td></td>
</tr>
<tr>
<td>C₃A</td>
<td>5.146</td>
<td></td>
</tr>
<tr>
<td>C₄AF%</td>
<td>9.97</td>
<td></td>
</tr>
</tbody>
</table>

II) Coarse Aggregate

White Crushed gravel of Kerbala quarries are used as coarse aggregate with a maximum aggregate size and sulfate content of (20mm) and 0.02% respectively. Table (3) shows its gradation which conforms to (IQS No 45/1984).

Table (3) Gradation of Coarse Aggregate (Crushed White Gravel)

<table>
<thead>
<tr>
<th>d</th>
<th>% Passing by Weight</th>
<th>Allowable Limits According to IQS No.5/1984 to IQS No.45/1984</th>
</tr>
</thead>
<tbody>
<tr>
<td>37.5</td>
<td>100</td>
<td>100</td>
</tr>
<tr>
<td>20</td>
<td>100</td>
<td>95-100</td>
</tr>
<tr>
<td>10</td>
<td>59</td>
<td>30-60</td>
</tr>
<tr>
<td>5</td>
<td>0.4</td>
<td>0-10</td>
</tr>
</tbody>
</table>
Table (4) presents the results of specific gravity, Loss Angles (abrasion), and absorption tests for the white crushed gravel.

<table>
<thead>
<tr>
<th>Property</th>
<th>Max Allowable limit According to IQS 45</th>
<th>1984</th>
<th>Crushed White Gravel</th>
</tr>
</thead>
<tbody>
<tr>
<td>Specific Gravity Test</td>
<td>2.6 (Typical Value)</td>
<td>2.55</td>
<td></td>
</tr>
<tr>
<td>Loss Angles Test (%)</td>
<td>30%</td>
<td>25.50</td>
<td></td>
</tr>
<tr>
<td>Absorption Test (%)</td>
<td>5%</td>
<td>2.22</td>
<td></td>
</tr>
</tbody>
</table>

**Fine Aggregate**

The local type of Kerbala Sand is used for its rounded grains, specific gravity of 2.64, the ratio of sulfate content is 0.23% and fineness modulus of 2.915. Table (5) includes the grading of the used sand.

<table>
<thead>
<tr>
<th>Sieve Size, mm</th>
<th>%Passing by Weight</th>
<th>Allowable Limits According to IQS 45</th>
<th>1984, Zone 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>10</td>
<td>100</td>
<td>100</td>
<td></td>
</tr>
<tr>
<td>4.75</td>
<td>95</td>
<td>90-100</td>
<td></td>
</tr>
<tr>
<td>2.36</td>
<td>78</td>
<td>75-100</td>
<td></td>
</tr>
<tr>
<td>1.18</td>
<td>63</td>
<td>55-100</td>
<td></td>
</tr>
<tr>
<td>0.6</td>
<td>40</td>
<td>35-59</td>
<td></td>
</tr>
<tr>
<td>0.3</td>
<td>30</td>
<td>8-30</td>
<td></td>
</tr>
<tr>
<td>0.15</td>
<td>2.5</td>
<td>0-10</td>
<td></td>
</tr>
</tbody>
</table>

III) Superplasticizer

*Floretesuperplasticizer (SP905)* is used to reduce W/C, slump loss, to offer excellent workability, increase the compressive strength, high ability against bleeding or segregation, low resistance and easy for pumping, suitable bubble content, no bad influence on concrete modulus of elasticity, good freeze resistance, high compatibility, compatibly with many cement types and mineral admixtures, particularly fit for high durability concrete and self- compacting concrete. Table (6) presents the physiochemical properties of this superplasticizer according to ASTM C494 Type B and G.

<table>
<thead>
<tr>
<th>items</th>
<th>index</th>
</tr>
</thead>
<tbody>
<tr>
<td>Appearance</td>
<td>light brown liquid</td>
</tr>
<tr>
<td>Freezing Point</td>
<td>-2 C°</td>
</tr>
<tr>
<td>Cement paste fluidity (cement base) (mm)</td>
<td>250 (W/C=0.29)</td>
</tr>
<tr>
<td>pH</td>
<td>6-8</td>
</tr>
<tr>
<td>Chloride %</td>
<td>Nile</td>
</tr>
</tbody>
</table>
Mixes Design Proportion and Issues
The mix design in this research is based on the following general basic considerations for HSC mixes design John and Ban (2003):
1- W/C ratio will typically be in the range 0.25 – 0.35
2- The proportion of fine aggregate to the total aggregate is about 45% and 40% for mixes A and B respectively.
In general, two types of mixes have been attempted of concrete cubes according to British Method (BS 5328 Part2: 1997). The mixes proportion has been estimated and listed in Table (7).

<table>
<thead>
<tr>
<th>Mix Notation</th>
<th>Cement, kg/m³</th>
<th>Fine Aggregate, kg/m³</th>
<th>Gravel, kg/m³</th>
<th>Water, kg/m³</th>
<th>SP905, Liter</th>
<th>W/C</th>
<th>Designed Compressive Strength, Mpa</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>446</td>
<td>830</td>
<td>975</td>
<td>183</td>
<td>0.8 for each 100kg of Cement</td>
<td>0.35</td>
<td>40</td>
</tr>
<tr>
<td>B</td>
<td>550</td>
<td>660</td>
<td>990</td>
<td>165</td>
<td>0.8 for each 100kg of Cement</td>
<td>0.3</td>
<td>60</td>
</tr>
</tbody>
</table>

Laboratorial Tests
In this research, the fresh and hard concrete tests have been carried out to check the potential performance of the prepared samples for the foregoing A and B mixes as follows:
I) Fresh Concrete Test
The slump and the compaction factor tests have been conducted for both A and B mixes according to ACI 116R-90, ASTM C143-90, and BSEN 12350-2000, the results are listed in Table (8).
II) Hardened Concrete Test
Cylindrical samples of concrete with dimensions of (150 mm in diameter and 300 mm in height) are prepared and cured in fresh water to be tested later on for both A and B mixes.
A) Density Evaluation
The density of the concrete samples are measured when the sample are wet. The concrete density is investigated for ages in between 7-90 days.
B) Compressive Strength
The strength test results, cubes specimens (150*150*150)mm are used. The standard Practice prescribed by {BS 1881 Part:108-1983} and BS 1881 Part: 116-1983.
After(7,28,56, and 90) days of curred in water at 25°C⁰, the load on the cubes should be applied at constant rate of stress equal to 0.2-0.4 Mpa/second until failure.
C) Splitting Tensile Strength
The most commonly used test for estimating the tensile strength of concrete are the (ASTM C496), splitting tensile test (150*300) mm Concrete cylinder is subjected to compression load along twp axial lines which are diametrically opposite.
D) Flexural Strength
The beams with dimensions (150*150*520) mm are casted according to BS 1881 part: 118, 1983. By using two points loading machine with capacity of 200 tons. The
tensile strength is usually calculated by using indirect measurements such as the measurements of the modulus of rupture (MOR) according to ASTM C78-1983).

E) Elastic Modulus
The measurement of vthe elastic modulus if HSC can be done in the same way as for usual concrete. The use of set-up reduces considerably the time devoted the measurement of the elastic modulus. The set-up is composed of two Yokes separated by a distance equal to half length of the spacers to be tested. Before loading, the specimen, the temporary supports are removed and the load and the relative displacement of the two rings are recorded simultaneously.

F) Stress-Strain
A cylindrical samples of (150*300) mm are places in the compression machine and tested under an axial load. The compressive strength is recorded for each deformation of dial gauge reading. The test is continued until failure of concrete cylinder. This proportion is prescribed in BS 1881 part: 121-1983 and ASTM C494-94.

G) Ultra-Sonic Pulse Velocity Test (UPV)
UPV gives direct information about the concrete. This is along-established non-destructive test method which determines the velocity of longitudinal waves. This determination consists of measurement of the time taken by pulse-hence the name of the method to travel a measured distance. The test method is prescribed by (ASTM C597-1991 and by BS 1881 part: 203-1986).

Results &Discussion
1- The results of slump and compaction factor have been conducted for both A and B mixes are listed in Table (8). It has been found that high strength concrete slump often appears to require more efforts to compact than more conventional concrete of similar slump; this is probably due to a combination of high cement content and high levels of admixture, this agree with held Aitcin & Mehta (1990).

2- The average density of six standard concrete cylinder, the density increased with age, it can be seen that from Fig. (1), the density values are in the range from (2452-2460) Kg/m³. For mix A and in the range from (2456-2463) kg/m³ for mix B. This is concerned to the ages (7-90) days.

The effect of Kerbala coarse aggregate on the compressive strength for both mixes A and B are shown in Fig.(2). It is observed that a compressive strength is increased from (20-50) Mpa and (25-70) Mpa for both A and B mixes for the ages 7-90 days respectively. In addition the splitting tensile strength is increased from (4.1-5.4) Mpa and (4.2-5.8) Mpa for the ages 7-90 days. This is shown in Fig.(3).

Fig.(4) presents the rupture modulus variation with the ages modulus of rupture increased with ages of both mixes A and B from (5-7.5) Mpa and (5.3-8) Mpa respectively. The variation in the modulus of rupture for A and B mixes is about 10% reduction which is agreed with Aitcin (1998).

View which is saying that the crushed rock aggregates are generally preferred to smooth gravels as there is some evidence that the strength of transition zone and improved the transfer of stresses from the best to the aggregate particles become more effective.

3- The stress-strain curves are represented graphically in in Fig.(5) and Fig. (6) for A and B mixes respectively. The trends of the curves are as expected. The trend of the curve B mix is more ascent as compared with that of curve A. This indicates that mix B offers more strength than mix A.

4- Fig.(7) shows the variation of the elastic modulus with curing time advance from (32-46)Gpa and from (33-50)Gpa for both mixes A and B respectively which is
agreed with Neville (2000). View which saying that the effect of the shape and mineralogy of the coarse aggregate offer a significant influence over elastic modulus and stiffer aggregate will achieve a much higher modulus than softer granular aggregate.

5- Fig.(8) shows the UPV versus age. The variations are noticed for all ages which are fallen within 5% for early and late ages for both mixes.

<table>
<thead>
<tr>
<th>Table (8) Fresh Concrete Tests Results</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mix Notation</td>
</tr>
<tr>
<td>---------------</td>
</tr>
<tr>
<td>A</td>
</tr>
<tr>
<td>B</td>
</tr>
</tbody>
</table>

Fig.(1) Bulk Density of the resulting Mixes

Fig.(2) Compressive Strength Versus Age
Fig. (3) Splitting Tensile Strength Versus Age

Fig. (4) Rupture Modulus Variation Versus Age
Fig. (5) Stress-Strain Curves of A Mix

Fig. (6) Stress-Strain Curves of B Mix
Conclusions
Several conclusions may be extracted:
1- An acceptable compressive strength up to 70.4Mpa after 90 days curing age is obtained by the use of the Crushed White Gravel of Kerbala Quarries in the concrete mixes design.
2- Since the current mixes which are made of Crushed White Gravel of Kerbala Quarries characterized with low workability, thus more plasticizer should be used during mixes design.
3- The resulting mixes offer an acceptable modulus of elasticity values up to 50 Gpa.

Recommendations
It is recommended to use the White Crushed Gravel of Kerbala quarries in the manufacturing of high strength concrete mixes is possible in the middle and south of Iraq under the highlight of this research.
References