INVESTIGATION THE EFFECT OF ARABIC GUM ON THE PHYSICAL AND MECHANICAL PROPERTIES OF ORDINARY CEMENT

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Abstract: The presented study examined the impact of Arabic gum (AG) on physical and mechanical properties related to ordinary cement mortar by cement's partial replacement via various quantities of Arabic gum (0.1%, 0.3%, 0.5%, 0.7%, 0.9%), the sample mortar's preparation was achieved with using 1:2 ratio of cement to sand by weight, with a (0.5) water to binder ratio. The compressive strength, flexural strength, and Workability tests were carried out on these five groups (G₁, G₂, G₃, G₄, G₅) in addition to a reference group G₀ that not contain Arabic gum, compressive as well as flexural strength tests were achieved after curing at early and standard age 7 and 28 days, respectively. The results specified that the compressive in addition to flexural strengths of samples of groups G₁, G₂, G₃ mortars were increasing with the increase of replacement's ratio (0.1%, 0.3%, 0.5%) and then decreased at G₄ and G₅ (0.7% and 0.9%) and The best results were recorded at G₃ (0.5% replacement ratio) where enhancement of compressive strength 17% and 16% for early and standard age respectively and enhancement of flexural strength 11% and 10% for early standard age respectively, the results of workability test refers to that the increase of the ratio of Arabic gum (AG) in the mortar increase its workability, from SEM analysis indicated in sample G₃ were more homogeneous microstructure in comparison to the microstructure of G₀.

Keywords: Arabic gum, compressive strength, flexural strength, microstructural analysis, Workability, scanning electron microscopy (SEM).

1. Introduction

The Arabic Gum or the Acacia gum was considered as edible biopolymer that

was acquired as exudates related to the mature trees of Acacia seyal as well as the Acacia Senegal that principally grow in the African region of Sudan's Sahel. Chemically, Arabic Gum was defined as a complex mixture related to macromolecules with various compositions and sizes (majorly proteins and carbohydrates). The features and properties related to AG were extensively examined and developed, also being applied in a lot of industrial sectors, including food, pharmaceuticals, lithography, ceramics, textiles, cosmetics, encapsulation, food, and so on. [1,2]. Arabic Gum was chosen in this work as it is a biopolymer available in the local markets in Iraq and has a lower cost than other polymers. Numerous works were conducted using Arabic gum (AG) to study its impact on the physical and mechanical properties of cement mortars.

Khayat et al. [3] Studied the influence of Arabic gum (AG) as viscosity modifying agent (VMA) on rheological properties related to water and cement paste. The VMAs were specified as polysaccharides that are enhancing the stability and cohesion of cement-based systems. Also, there is an increase in the water retention capacity, where as the bleeding and segregation characteristics were enhanced, also there is an increase in the mortar's flowability, performance,

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and homogeneity of the hardened concrete were enhanced. They were utilized together with the superplasticizers in the Self Compacting Concrete (SCC) to improve the workability and ensure the high deform-ability. Furthermore, the initial, as well as the final setting time regarding the mortar, was prolonged in the case when such admixtures are applied. The AG found some applications in the construction industry, particularly in the hot weather climates as they are prolonging concrete's plastic state, therefore allow time for transportation, placing as well as finishing.

C. Zhao et al. [4] Examined the dispersion impact related to the AG and the factors impacting holding capacity related to AG in the cement throughout hydration, the cement paste's rheological properties with the added AG powder. The results indicating that the 0.10–0.60 wt% regarding AG positively impacting the dispersion, while the low dosage has an insignificant impact. The high-speed mixing was needed for maintaining the AG's dispersion stability in the cement's paste. The optimal dosage related to AG for achieving optimum disperse-holding capacity regarding the cement paste was 0.30wt%, also the minimal water-cement ratio which is required for obtaining dispersion impact was 0.28.

P. Zakka et al. [5] examined AG's suitability in terms of the capability for acting as a plasticizer in the concrete was put to test with the target of creating self-compacting concretes. Also, the fresh concrete's self-compacting properties were put to test, also the compressive strength related to concrete created. Furthermore, utilized 2 concrete mixes with various ratios of water/powder were applied. Concrete (normal) which were serving as control had a ratio of water/cement (W/C) = 0.50, whereas Self Compacting concrete that had AG as plasticizer at 2 distinctive percentage values had a ratio of water/powder 0.45. The study indicated that AG

was optimum plasticizer in addition to excellent viscosity modifying agent to be utilized in the inexpensive self-compacting concretes.

R. Mbugua et al. [6] examined the impact of the Gum from Acacia Karroo (GAK) as set-retarding admixtures in the cement's paste. The potential to use the GAK as water decreasing admixture in the mortar of the cement was examined. The cement pastes were prepared for measuring setting time with the use of various dosages related to GAK, were conducted through mixed. There are 500 grams regarding OPC with the GAK at 0, 0.30%, 0.40%, 0.50%, 0.60%, 0.70%, 0.80%, 0.90% and 1%wt (cement's weight). The trade CE (commercial admixture) with dosages of 0.30%, 0.40%, 0.50%, 0.60% as well as 0.70%wt was utilized based on manufactures instruction Control was the neat cement paste. The flow test, bleeding, and compressive strength was examined on the cement's mortars with control being the cement mortar with no admixtures. GAK was indicated for increasing the final time of the setting by six hours over control. The compressive strength is increasing with a decrease in W/C from 0.50 to 0.40. Thermogravimetric analysis indicated an elevated dose of GAK decreased rate of hydration.

A.U. Elinwa et al. [7] examined the compressive strengths related to AG increased over control (M-0.00) with the increase in dosage. The maximum strength was done at a dosage of 0.50%. The properties related to tobermorite, osumulite, and certain other minerals in the AG samples were considered as factors that contribute to optimal strength which is accomplished at such dose. The osumulite, defined as potassium magnesium aluminium silicate, and chemical formula $\text{KMg}_2\text{Al}_3(\text{Si}_{10}\text{Al}_2)\text{O}_{30}$, and a hexagonal crystal structure, and tobermorite, which is a calcium silicate hydrate, represented as $\text{CaSi}_6(\text{O}, \text{OH})_{18.5}\text{H}_2\text{O}$, exist in AG samples at a 0.50% dose. The

tobermorite has mono-clinic crystal structures and it's anisotropic in the character with fairly high resistance to the external Isostatic compressions. Furthermore, minerals were comparable to C-S-H phases (Calcium Silicates Hydrates) created in the process of hydration related to Portland cement. The minerals such as Wollastonite, Mordenite, and Sepiolite were also indicated in the samples of AG at the dosage of 0.50%, also they affect mechanical strength as well as the physical characteristics regarding concrete. The wollastonite minerals were indicated for enhancing concrete's compressive and flexural strengths. The aims of this work

1. obtain a new cement formula in dry form can be easily prepared by partial replacement of cement by Arabic Gum (AG) in suitable ratio, the new formula has higher physical and mechanical properties than that of ordinary Portland cement.

2. Studying the effect of biopolymer (AG) in different ratios on the cement properties.

3. Detect the effect of Arabic gum (AG) on the microstructure of the new cement by using scanning electron microscopy (SEM).

2. Materials

2.1. Ordinary Portland cement

About the presented study, the cement that was used is the type 1 of the Ordinary Portland Cement (OPC) that is commercially referred to as (MASS), manufactured in Al-Sulaimaniya, Iraq, stored in a dry place to protect it from atmospheric conditions.

The chemical and physical analysis were conducted via Laboratories of the University of Baghdad / Department of Engineering Affairs. The test results are specifying that the sample complies with the Iraqi specification (IQS No. 5 / 1984) [8].

2.2. sand

AL- Ukhaider, in Karbala, Iraq, natural sand [that was used in this study that has a fineness modulus (FM) equal to 2.74, bulk specific gravity (Sp. gr.) which is equal to 2.6 and (0.39%) sulfate content (SO₃%) by the sand weight, which conforms with IQS limit No. 45 / 1984 [9]. in the present study, only sand < (4.75mm) was utilized for the achievement of mixing characteristics and requirements.

2.3. Arabic Gum (AG)

Typical properties of Arabic gum (AG) given in table 1 [10].

Table 1. Typical properties of AG

Density	1.35 g/cm ³
Colour	White to yellow-beige
form	fine powder
Stability	Stable, not compatible with the alcohols and the oxidizing agents.
Water Solubility	Water-soluble. An aqueous solution is acidic to the litmus.

The XRF analysis was performed for obtaining the chemical composition of the Arabic gum was used in this work, the results shown in table 2

Table 2. Chemical composition of Arabic

Element	Concentration m/m %
Na ₂ O	0.017
MgO	0.241
Al ₂ O ₃	0.116
P ₂ O ₅	0.025
K ₂ O	1.142
CaO	4.032
TiO ₂	0.028
MnO	0.015

Fe ₂ O ₃	0.068
Cl	0.0436
Ba	0.0339
Cu	0.0053
Pb	0.0137
Zn	0.0084

3. Mixtures

mixtures were produced as 6 mixture groups, each one of those groups consists of 6 cubic samples (50mm*50mm*50mm) for compressive strength test and 6 prism samples (100mm*2.5mm*2.5mm) for flexural strength test. First group G₀ mixtures were Prepared as a reference group only contain sand, cement, and water. Groups G₁, G₂, G₃, G₄, G₅ represent 0.1%, 0.3%, 0.5%, 0.7%, 0.9% respectively (ratio of AG to cement). For each one of the mixtures, the ratio of the sand to the cement was maintained at (2:1), and water to cement ratio was kept at (0.5). Table 3 presents the mixture proportions.

Table 3. The proportions of the mixtures

Sample	Cement%	AG%	Water to cement ratio	Sand to cement ratio
G ₀	100	00	00.5	2:1
G ₁	99.9	00.1	00.5	2:1
G ₂	99.7	00.3	00.5	2:1
G ₃	99.5	00.5	00.5	2:1
G ₄	99.3	00.7	00.5	2:1
G ₅	99.1	00.9	00.5	2:1

4. Preparation of test specimens

After the weighing of elements with 0.01gm sensitive digital balance, Arabic gum dry mixing with the cement for the G₁, G₂, G₃, G₄, G₅ for obtaining homogenous binder, binder and Sand are mixed for approximately 2 minutes by hand, water was added to the mixer and then mixed for four minutes according to ASTM C305 [11] after

that it was poured into clean oiled moulds, the densification of the samples was carried out on a vibrating table in two layers, and each layer was vibrated for (1min to 1.5min) until there aren't any bubbles that emerge to the surface of the casting. The surface finish of the samples was performed with the use of spatula. Moulds were covered with plastic sheets to preserve the moisture and those samples were kept in the labat room temperature, for 24 hours, ultimately, those samples were demoulded and cured in water, in which they were until the testing time.

5. Tests:

5.1. The Test of the Compressive Strength:

The test which is related to mortar's compressive strength was conducted based on (ASTM: C109-02) [12]. Compressive strengths for each mixture were characterized from the average of three cubic samples (50x50x50)mm were tested at 7 days of age (i.e. in early age) and 28 days (i.e. the standard age) following curing.

5.2. Flexural strength Test:

Based on the (ASTM C-293) [13] test approach was performed. A rectangular cross-section block of dimensions (100x25x25mm) is resting upon a pair of the supports and was loaded with the use of a loading nose which is in the middle of the distance between the support (1 point load). Flexural strength for each mixture was identified from a mean value of three prism specimens that were tested at seven days of age and 28 days (i.e. the standard age) following curing.

5.3. Workability:

Workability test was estimated based on Flow Table Test of Hydraulic Cement ASTM C-230 [14], also the mortar poured at 2 layers, each of them approximately with a thickness of 25mm

in a mould and tamp 20 times with the tamper, also the tamping pressure must be adequate for obtaining uniform mass in the mould, then pour the second layer in a similar process for the layer, after that cutoff mortar for obtaining plane surface flues with mould's top via drawing straightedge or towel's edge with sawing motion across mould's top. Following 1 minute from completing the pouring operation of mortar lift mould from the mortar. Right after that, the table is dropped 25 times in 15sec., the mortar diameter is measured along 4 lines, and every one of the diameters is recorded to the nearest millimeters.

5.4. SEM analysis:

Small specimens from the crushed samples in mechanical tests (flexural and compressive strength tests) were used in the SEM analysis.

6. Result and Discussions:

The compressive strength test results represent the average results of 3 samples for each replacement ratio. These results are shown in figure 1.

Figure 1. Results of compressive strength

From figure 1, it can be determined that for the early age and the standard age mixtures (G_1 , G_2 , G_3 , and G_4) have a compressive strength which is greater than the compressive strength of the control mix (G_0), the compressive strength gradually increases with an increase of AG ratio until reaches G_3 after that there was a decrease in

the value of the compressive strength with the increase in the AG ratio at (G_4 and G_5), at G_5 the compressive strength becomes lower than that at G_1 . For early and standard ages, the maximum Values of compressive strength are 28.9MPa and 32.78Mpa for G_3 mixture which is (0.5% AG) for 7 and 28 days respectively. The percentage of Enhancement in compressive strength reached approximately 17% at an early age and 16% at the standard age. The compressive strength value increases because of viscosity modifying the effect of AG that leads to improving the stability and cohesion of the microstructure of mortar [3] [7]. The decreased in compressive strength value following the G_3 for the standard as well as the early ages because of increasing the AG ratio to cement higher than 0.5% cause disserve C_3S hydration and that lead to delaying C_3S and C_3A reaction as a result of water retention effect of AG [6], the overdosage of AG may because segregation that has a direct effect on cohesive and uniformity of mortar. The Flexural strength test results for all samples shown in figure 2.

Figure 2. The results of the Flexural strength

From this figure it may be determined that for the standard age and the early age, the mixtures (G_1 , G_2 , G_3 , G_4 , and G_5) have flexural strength value which is greater than the flexural strength value of the control mix (G_0), the strength gradually increase with the increase of AG ratio until

reaches G_3 then at G_4 and G_5 the flexural strength decreased with the increase of AG ratio. For early and standard ages, G_3 have a higher value where recorded 10.26 MPa and 11.76 MPa respectively for the early age and the standard age. The percentage of Enhancement of flexural strength increased by approximately 11% at an early age and just 10% for standard age. Increasing the flexural strength value was because of the viscosity modifying effect related to AG that lead to improving the stability and cohesion of the microstructure of mortar [3][7]. The decreased in flexural strength value after G_3 for early age and the standard age due to increasing the AG ratio to cement higher than 0.5% cause disserve C_3S hydration and that lead to delaying the C_3S and C_3A reaction as a result of water retention effect of AG [6], the overdosage of AG may because segregation that has a direct effect on cohesive and uniformity of mortar .the effect of AG on workability for all groups as compared with G_0 represented in figure(3)

Figure 3. Effect of AG on workability

From this figure were observed that the increase in AG ratio increases the workability. The increasing in workability due to the presence of Soluble polysaccharides that caused increasing the water retention capacity as well as improving the workability [6]. The maximum value at G_5 (Contain 0.9% AG) higher than G_0 by

approximately 62%. SEM analysis was performed for a sample from G_3 (have the best results of mechanical tests as compared with other groups) and G_0 (reference group). As indicated in figures (4a&4b) for a standard sample of the (G_0) group, the micro-structure includes large crystals and it is possible to observe empty spaces and pores between crystals.

As can be seen in the figures (5a and 5b) for the sample of G_3 , micro-structure is more homogeneous as compared with that of G_0 where the crystals are finer and the pores disappeared, that may be as a result of the viscosity modifying effect of AG that lead to spacing the cement particles from each other and form fine crystals that lead to filling the empty spaces and reduce the pores in the microstructure.

Figure 4a, 4b .the microstructure of standard sample of G_0

Figure 5a,5b.the microstructure of the sample of G3

7. Conclusions

Based on the experimental results that are related to workability, flexural strength, as well as compressive strength it was indicated that using AG in ordinary cement mortar in suitable replacement ratio enhanced the flexural and compressive strengths and improved the mortar's workability, group G_3 (contain 0.5% AG) was recorded as the optimal result in mechanical tests in comparison to other groups, the presence of AG in ordinary cement mortar increased the workability, from SEM analysis observed the effect of AG on forming more homogeneous microstructure in G_3 in comparison to the microstructure related to G_0 .

Conflict of interest

The authors confirm that there's no conflict of interest.

8. References

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