Al-Khafaji, ZS, Falah, MW, Shubbar, AAF, Nasr, MS, Al-Mamoori, SF, Alkhayyat, A, Al-Rifaie, A, Eissa, A, Latif Al-Mufti, RA and Hashim, KS

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The Impact of Using Different Ratios of Latex Rubber on the Characteristics of Mortars Made with GGBS and Portland Cement

Zainab S. Al-Khafaji [1], Mayadah W. Falah [2], Ali A. Shubbar [3,*], Mohammed Salah Nasr [4], Shahad F. Al-Mamoori [5], Ahmed Alkhayyat [6], Ali Al-Rifaie [7], Abdulhadi Eissa [3], Rafal Latif Al-Mufti [3] and Khalid Hashim [3]

[1] Al-Furrat Al-Awsat Distribution Foundation \ Ministry of Oil \ Babylon, Iraq.
[2] Building and Construction Engineering Technology Department, AL-Mustaqbal University College, Babylon, Iraq
[3] Department of Civil Engineering, Liverpool John Moores University, UK.
[4] Babylon Technical Institute, Al-Furat Al-Awsat Technical University, 51015 Babylon, Iraq.
[5] Department of Civil Engineering, College of Engineering, University of Babylon, Iraq
[6] Department of Building and Construction Technical Engineering, College of Technical Engineering, the Islamic University, 54001 Najaf, Iraq.
[7] College of Engineering, Al-Muthanna University, Samawah, 66001, Iraq.

* Corresponding author: alishubbar993@gmail.com , A.A.Shubbar@2014.ljmu.ac.uk

Abstract. Preserving natural resources and implementing the concepts of sustainable engineering to approach the zero waste concept helped in reducing the detrimental environmental effects in the last two-decade. Proposed re-using of Ground Granulated Blast Furnace Slag (GGBS) as an alternate solution is to get rid of them and profit from them concurrently. In this process, GGBS is used as cement substitute material to enhance mortar characteristics. On the other hand, the required water for concrete mixture should be characterized by several characters, which similar to drinkable water, therefore, using of Latex Rubber as a water substitution reduces the demand for such water in the construction industry. In this project, percentages of GGBS that have been used were 0%, 10%, 30%, and 50% which compatible with (0, 10, 20 and 30) % of Latex Rubber. Suitable tests were performed to measure properties of mortar by GGBS and Latex Rubber such as setting time, compressive strength and Permeability test (Electrical resistivity). The results obtained indicate that the setting time reduced with increasing Rubber Latex in spite of increasing the proportion of water to binder. Additionally, increasing the Latex Rubber amount leads to decrease the compressive strength and electrical resistivity of mortars.

1. Introduction

In construction the applying of mortar as a binding material is essential. Elements of construction such as concrete masonry unit, stones, bricks rely on the cementitious binding material for stability and durability [1]. Mortar is composed of cement, sand and water. Cement is being one of the most demanded produced materials. However, it is causing heavy drawbacks on the environment which also associated with its high cost of production. It was estimated that for every 1.5 tonne of raw materials to make Ordinary Portland cement (OPC), one tonne in return is produced [2]. Also, it is worth to note that the energy intensive process of producing cement reflect back on the cost of composing mortar [3]. Moreover, a high amount of green-house gases is emitted during the manufacturing process of the cement [4–12]. The emissions of carbon dioxide connected with the cement manufacturing account for about 7% of that manufacture globally [13–22]. Therefore, CO_2 release should be reduced to enhance the environment [23]. Alternatives therefore have been investigated to offer a substitution to OPC. Alternatives that would provide similar and better properties in terms of strength, resistance to the harsh environment wearing conditions that would weaken the conventional cement utilized in the mix of concrete or mortar [24]. For decades, researchers have experimented by-product materials from different industries to achieve such goal, materials such as Ground Granulated Blast Furnace Slag (GGBS) from the steel industry, Rice Husk Ash (RHA) that could be obtained from agriculture industries, etc. The literature shows that the use of these by products and others could develop the durability and improve the strength of concrete and mortar mixes in the long run [25,26].

GGBS is a supplementary cementitious material that is extracted in the process of making pig iron in blast furnace. The lime stone, coke and Iron-ore mixture are poured into the blast furnace and heated to 1500 C^o, molten slag and molten iron are the outcomes of this burning process. Once the slag and iron are separated, a rapid quenching of the slag by pressurized water jet that will turn the slag into small particles will take place, subsequently these particles are waited to be dried and crushed further to be utilized as a substitution of cement in the mix of the concrete and mortar [27,28].

In the late 1800s, many allocations consisted of rubber latex were utilized. The latex is naturally extracted by “Tapping”, a process that would involve controlled cutting or wounding the outer layer (bark) of rubber tree, thus the latex would flow out into containers by channels [2]. Scientists since the 1920s have introduced the use of polymers latexes into the mix of concrete and/or mortar [29]. The natural rubber latex has shown benefits when utilized in the mixture of concrete and mortar as a partial substitution of water, such as enhancement in strengths of flexural, compressive, and splitting tensile in concrete [30]. Furthermore, latex has wider dispersion or types, synthetic latex that are depending on ethylene/vinyl-acetate, acrylate chemistry or styrene/butadiene and are manufactured via emulsion polymerization is conventionally utilized as a chemical admixture in construction [31].

As pointed out previously that, scientists have found that GGBS and rubber latexes were beneficial when utilized to replace cement and water or utilized as additives partially in the making of concrete and mortar mixes due to their chemical compositions. However, there is a lack in the literature in the investigation of combining use of both GGBS and latex rubber in the mix. Therefore, the overall research aim is to explore the feasibility of incorporating GGBS as a substitution for cement as well as replacing the water by different Latex Rubber proportions on different properties of mortar.

2. Materials and Methodology

2.1. Materials

2.1.1. Binder Material.

The utilized binder materials in this project were GGBS and Portland Cement (PC). The cement was PC kind CEM-II/A/LL 32.5-N that provided from the company of CEMEX ltd that located in Warwickshire, United Kingdom. GGBS has been brought from Group Hanson Heidelberg Cement.

The elemental compositions of PC and GGBS was investigated by an Energy Dispersive X-ray Florescence Spectrometer (EDXRF) kind Shimadzu EDX-720. Table 1 demonstrates the chemical compositions of the PC and GGBS.

Table 1. Chemical analysis of PC and GGBS

Item	PC	GGBS
Ca0 %	$6521x10^{-2}$	$4251x10^{-2}$
$Si0_2$ %	$2456x10^{-2}$	$4106x10^{-2}$
Al_20_3 %	$170x10^{-2}$	$512x10^{-2}$
Fe_20_3 %	$164x10^{-2}$	-
Mg0 %	$130x10^{-2}$	$425x10^{-2}$
Na_20 %	$134x10^{-2}$	$309x10^{-2}$
K_20 %	$82x10^{-2}$	$69x10^{-2}$
$S0_3$ %	$262x10^{-2}$	$127x10^{-2}$
$Ti0_2$ %	-	$98x10^{-2}$
LOI %	$28x10^{-2}$	$37x10^{-2}$
pH	$1273x10^{-2}$	$1102x10^{-2}$
Specific Gravity	$294x10^{-2}$	$290x10^{-2}$

2.1.2. Fine aggregates. Natural fine aggregate (sand) used in the present work. Figure 1 shows the full sieve analysis of the sand.

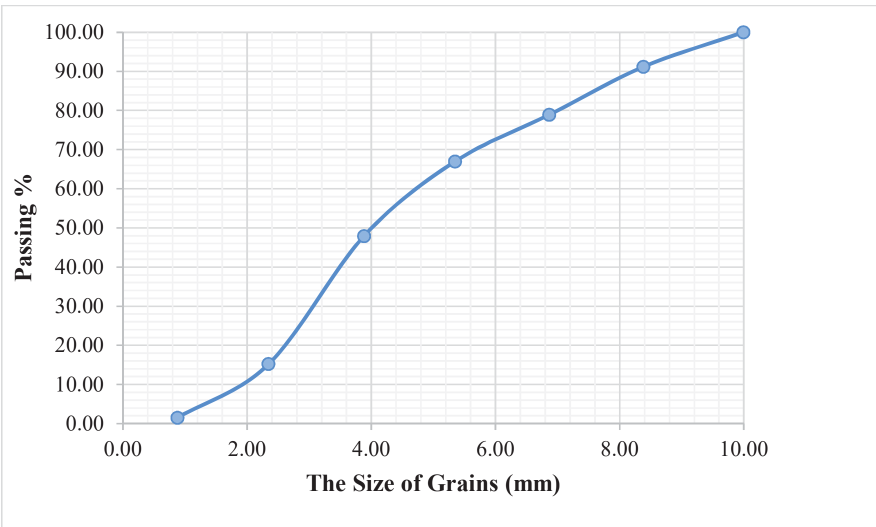

Figure 1. Sieve analysis for utilized Sand

2.1.3. Water. Fresh water has been utilized to cast and cure all selected samples.

2.1.4. Latex rubber. The admixture utilized were latex rubber, high performance agent for decreasing water and anti-form. The latex rubber was Polycraft Liquid Latex that meet the requirements of German Bundesgesundheitsamt (BGA) Recommendation.

2.2. *The Mixing Ratios*. In the current empirical work, four proportions of GGBS (0, 10, 30 and 50%) were utilized as replacement to cement. This substitution was combined with replacing the water by Latex rubber in ratios of (0, 10, 20 and 30%). The sand to binder (S/B) proportion that utilized in this research was fixed to be (2.5), whereas water to binder (W/B) proportions were changeable from 0.4 to 0.7 as demonstrated in Table 2. Table 2 demonstrates the proportions of mixing materials utilized in this research.

Table 2. Proportions of Mixture

Mortar mix	Cement %	GGBS%	Latex %	Water %	S/B	W/B
M1	100	0	0	100	2.5	0.4
M2	90	10	10	90	2.5	0.6
M3	70	30	20	80	2.5	0.65
M4	50	50	30	70	2.5	0.7

2.3. Experiments and Tests

1) Vicat apparatus has been utilized to determine the initial time of setting depending on BS EN 196–3 [32].
2) The compressive strength test for all selected samples have been done according to BS EN 196-1 [33] (Two specimens with measurements of 40x40x160 mm were cast for each blending proportion at each curing time. Every sample was split into two parts by three points prism samples loading and four parts have been tested to reflect the final compressive strength magnitudes).
3) Using a Resipod Proceq meter, the electrical resistivity test has been conducted according to AASHTO T358 [34]. This test is specifically related to concrete and mortar corrosion possibilities attributable to chloride diffusion. After curing, three cylinders with diameter=10 cm and height= 20 cm were prepared and evaluated. The readings were gained 8 times per sample and an average of 24 measurements were obtained to reflect the final electrical resistivity magnitudes.

3. Results and discussion

3.1. Setting Time

Figure 2 demonstrates that the setting time reduced with the addition of GGBS and latex rubber comparative to the control samples. Additionally, increasing the amount of GGBS and latex rubber resulted in extending the setting time for samples incorporated such materials. In the control mixture (M1) the initial setting time was 270 min, while in M2 the initial setting time was 105 min which is the lowest time for setting among all selected mixture. In samples M3 and M4 the initial setting time were (108 and 120) min in spite of increasing w/b ratio relative to M2. This could be attributed to several parameters such as quantity of GGBS used, type and amount of cement, w/b ratio, type and amount of chemical admixtures may impact on the setting behavior of the concrete containing GGBS.

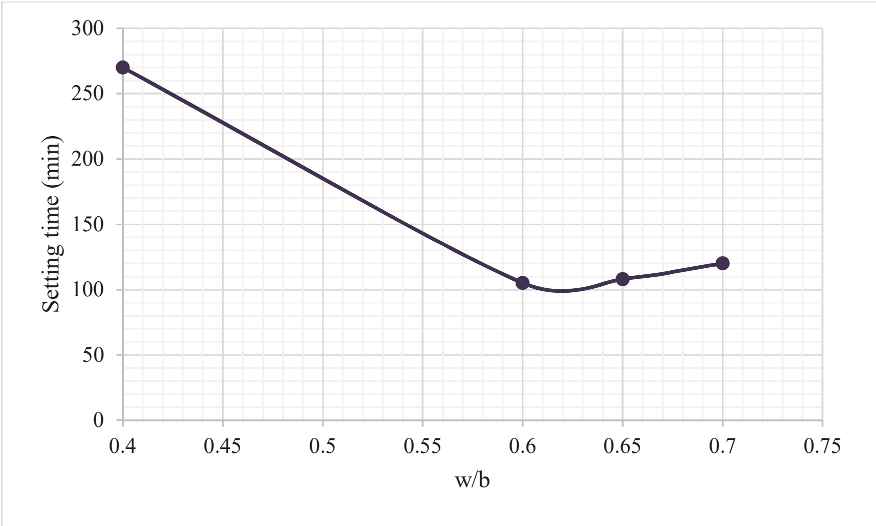

Figure 2. The initial setting time for samples M1, M2, M3 and M4

3.2. Compressive strength

The findings of compressive strength are presented in Figure 3 at ages 7, 14 and 28 days for samples M1, M2, M3 and M4. The compressive strength for sample M2 increased as compared with the reference mix at both 7 and 14 curing days and approximately same compressive strength as control sample was obtained after 28 days of curing. In the other samples (M3 and M4), the compressive strength decreased with increasing the substitution proportions from (30 and 50) % GGBS and (20 and 30) % latex rubber for all curing ages. There are many reasons behind that decreasing, one of them increasing the w/b ratio and the other effects that compatible with that increasing such as increasing the voids and reduce the density of the samples.

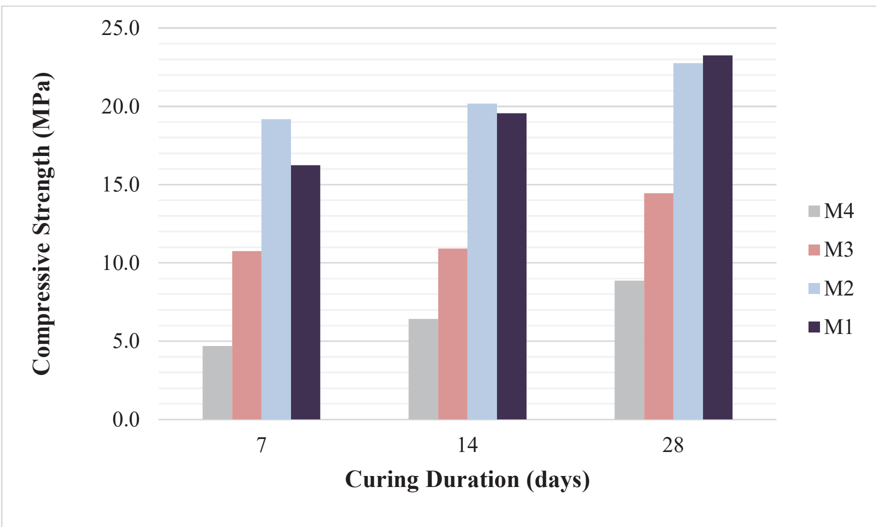

Figure 3. The Compressive strength for samples during (7, 14 & 28) curing days.

3.3. Electrical resistivity

The concrete's electrical resistivity results demonstrate an idea about the interlinked pores and therefore the permeability of concrete [35]. Consequently, concrete sample electrical resistivity characterizes the capability to limit the internally current motion. From Figure 4 it could be observed that the electrical resistivity improved with increasing the curing period from 7 to 28 days, where it has greater comparison with the control samples at 7 curing days. Increasing the curing period to 14 and 28 days caused in lower electrical resistivity values for samples incorporated GGBS and latex rubber. Additionally, the higher presence of GGBS and latex rubber resulted in higher electrical resistivity values for samples incorporated such materials.

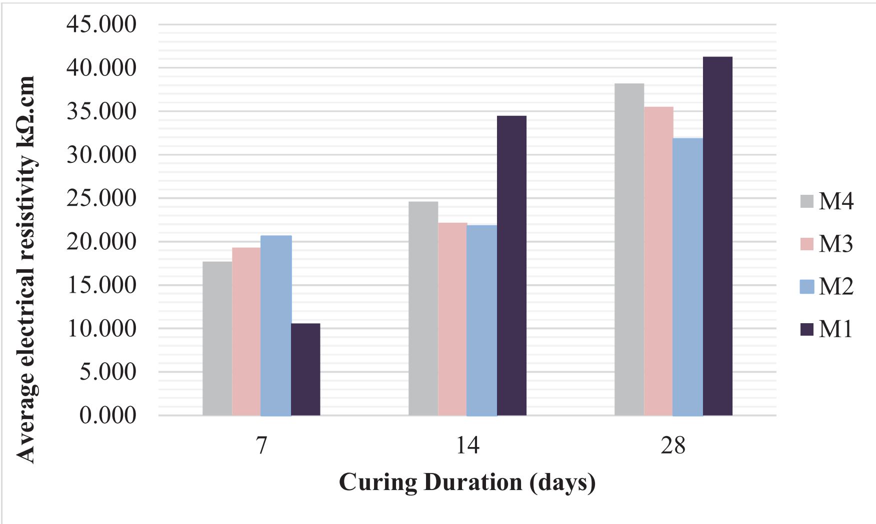

Figure 4. The Electrical resistivity for various samples during (7, 14 & 28) curing days

4. Conclusion

The findings of this study showed various effects of different proportions of GGBS and latex rubber as a cement and water substitution, respectively, which could be concluded as following:

- The setting time has been decreased for samples incorporated GGBS and latex rubber relative to the control sample.
- The compressive strength results indicated that replacing the cement and water by 10% GGBS and 10% latex rubber, respectively could provide similar performance relative to the control mixture.
- The electrical resistivity values for samples incorporated GGBS and latex rubber decreased after 14 and 28 days of curing relative to the control sample.

Other by-products or waste materials (for instance: ground granulated blast furnace slag, fly ash, stainless steel powder, silica fume, fly ash, crude oil wastes, agricultural waste [36–57], municipal solid wastes [58], industrial wastes [59,60] and wastewater (or water) planes waste [61–64]) are recommended to be applied to develop the different characteristics of the produced concrete or mortar.

In addition, the use of such materials in reinforced structural members [65,66] may improve their mechanical and durability properties.

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