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Study and Evaluation of Fiber Cement Board Using Waste Basalt Fibers in with Polyvinyl Acetate and Poly Urethane

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Abstract

In this work, the remnants of rock wool available in large quantities in the State Company for Mining Industries in Iraq were used as reinforcing materials for the production of fiber cement panels, polyvinyl acetate and polyurethane were used as a water-soluble polymeric mixture. Different percentages of this polymer were used: 2.5%, 5%, 10, 15%, 20%. All percentages of these polymers were added to the cement/water mixture, which were in proportions of 1.5, 1.25, 1, 0.75, 0.5 as a percentage, as it was observed The best polymer ratio is 15% as a binder after studying the mechanical and physical properties. The physical and mechanical properties tests were performed according to ASTM c-1185. Where it was observed that the density ranged between 812 kg / m3 - 1847 kg / m3, the bending resistance of fiber cement boards ranged from 0.43 MPa to 1.79 MPa, the percentage of water absorption was 16.07% - 69.42%, the thermal conductivity was tested depending on American specification ASTM-C1113-90, ranging from 0.1138 W / (m. K) - 0.47 W / (m. K), and finally the compressive strength was tested and it was in the range of 2.7 MPa - 13.48 MPa.

Keywords: Cement fiber board, Fiber reinforcement, Cement reinforcement, Basalt fiber board, Construction building.

1 Introduction

In recent years, Alternative components used in building materials has become a global concern, as the cost of building materials increases day by day due to the high demand, scarcity of raw materials and the high energy prices. Therefore, intensive research and development is exploring new ingredients required for sustainable production [1]. Many cement boards have been used as building partitions for over one century [2]. However, the unit weight of cement boards is still high, more than 2000 kg. /m3. In order to adapt the varieties of the functions and the space for high-rise structure, the partitions to separate building space demand to be lightweight, easy to construct fast and assembled simple.

Fiber –cement products are the fiber-reinforced construction materials for roof, ceiling, wall, and floor applications. Asbestos fibers were normally the reinforcement phase for these products. However, asbestos fibers were considered as carcinogen by International Agency for Research on Cancer (IARC), and were banned in many countries. Although, cellulose fibers and synthetic fibers are commonly used in non-asbestos fiber-cement products, the strength of these fibers is significantly lower than asbestos fiber. [3, 4] Wollastonite is another material considered as the asbestos substitute material. However, its availability in the nature is limited. [5, 6] Basalt is the volcanic rock that is widely available. It can be melted and drawn into fibers. According to [4, 17], the strength of basalt fibers is equivalent to the strength of carbon fiber and asbestos . Moreover, basalt fibers are not easy to break into the size that is considered carcinogen [8].

many countries around the world, especially where natural reserves of asbestos are lacked, research related to the partial or complete replacement of asbestos with other types of organic or inorganic fibers remains relevant. In this regard, the use of environmentally friendly raw materials of low cost required technical properties should be taken into account in the attempt to develop new cement-fiber composite materials. The most significant effect can be achieved with the introduction of new asbestosfree cement-fiber materials on existing traditional production lines for the production of asbestos cement sheets with maximum use of existing equipment. There are studies of fiber-cement materials based on alkali resistant glass grades (S-15GT) and basalt fibers [9], according to which the complete exclusion of asbestos from the composition and their replacing with glass or basalt fiber with respect to existing round-grid machines is practically impossible. It is caused by low cement-holding capacity of such fibers. Zone dispersed reinforcement with metal fibers, despite its effectiveness, does not provide the required corrosion resistance of thin-walled materials that are operated in humid environments [10]. The experience of using carbon fibers in fiber-cement boards is known, but high cost does not allow them to be fully utilized [11]. The use of basalt and glass fibers in cement systems is limited due to their low resistance to cement hydration products. However, currently this problem is being solved by modifying the surface of such fibers [12, 13]. Z. Canan Girgin and Mehtap Tak Yıldırım study fiber reinforced cement compounds and how to use basalt fibers in them. Only cement was used in this research as a binder to achieve variation of bending strength under extreme conditions [14]. Barabanshchikov, Y and Gutskalov, I study Strength and Deformability of Fiber Reinforced Cement Paste on the Basis of Basalt Fiber. Increasing water-cement ratio to obtain a certain workability with increasing the fiber content reduces the compressibility solidity of the samples [15]. Parinya Chakartnarodom et al Demonstrate the importance of obtaining building materials that are reinforced with fibers and used in floor, wall and ceiling applications by using basalt fibers as a strengthening stage in fiber cement [16]. Agamveer Singh et al used demonstrates of untreated coir fibers to produce fiber cement boards which can be used for building partitions. The samples were analyzed after 28 days of curing and it was observed that the density of the boards decreased with percentage increase in fiber content, the impact resistance and the amount of water absorbed by the boards increased with increase in fiber content. The boards also showed good drilling characteristics [17]. Na Zhang et al assessed dynamic mechanical properties of a Strain-Hardening Cementitious Composite (SHCC) Reinforced with inorganic fibers of basalt and steel for different stress rates (101 to 102 seconds - 1) using a 50 mm Hopkinson split pressure bar. The results showed that all mechanical indicators increase with increasing stress rate [18]. Małgorzata Wydra et al summarized results of bending tests of basalt fiber cement mortar in terms of bending strength and appearance of bridging effect. Regarding the effect of an alkaline environment on the performance of basalt fibers [19].

As a result, polymer was used in this work in an attempt to moisten surface of basalt fibers, and physical and mechanical properties were studied, through which satisfactory results were obtained that led to the creation of fiber board cement panels of different densities, which can be found on building panels with low weights per kg / M3. Basalt fibers use in construction industry reduces work effort, reduces materials cost and trouble.

2 experimental part

2.1 Materials

2. 1.1 Cement(C)

An Iraqi type cement was used in this study, produce (Um Qaser-Basrah), which has a hardness test of 5 mm and smoothness of sieve used with a diameter of 90 micrometers and carries the number 170. So cement must be replaced within a short period after opening and use not exceeding three days as exposure to moisture and hardening during use, Tap water is used as a base ingredient.

2. 1. 2 Basalt fibers(BF)

A large amount of basalt fiber was provided in this study from waste available in General Company for Mining Industries (Basrah – Iraq). Basalt fibers were prepared from basalt rocks by melting rocks at 1500 ° C and pulling them into fibers.

2. 1. 3 Polymers

The polymer is classified in this study into two parts:

First. Poly Vinyl Acetate (PVA): it is a polymer with a high molecular weight, and it a transparent glass solid substance that soluble in a number of organic solvents such as water. It amorphous and softens at relatively low temperatures. It produced from Waha Company (Tehran, Iran), it available in Iraqi market.

Second. Poly Urethane(PU): It is a product of polyol reaction, which is an alcohol that contains multiple hydroxyl groups, it comes in liquid state and gives flexibility to polymers, it has several molecular weights makes it different uses, with poly toluene diisocyanate, it organic compounds, which an aromatic substance, Its color white, highly toxic, so care must by taken dealing with it, as polyurethane is a sponge material with high porosity and flexibility or considered as an insulator to give durability and protection to bodies as covers from heat and cold or from corrosion due to intensive uses, it was supplied from General Company of Petrochemical Industries (Basra-Iraq).

2. 1. 4 Water(W)

Water is the basic element for the reaction of the components

2. 2 Mixing and Sample Preparation

Several mixtures cement fiber board have been studied, mention them in detail as following: Cement fiber board consists of a fixed rock wool amount of 30g and study several ratios for polymer %2.5, %5, %10, %15, %20, for each of these proportions were added cement as ratios: 1.5, 1.25, 1, 0.75, 0.5, as a ratio water/cement and all these percentages, whether polymer or *cement, are a ratio to water that remains constant throughout experiment 200 ml as listed in table no. (   ).Mix polymer first with water, where polyvinyl acetate is mixed with poly-teluen-diisocyanate, mix well, add a small amount of water for purpose of dissolution and mix well, then add polyol and mix well, add remaining water gradually with mixing for purpose of homogeneity, then add cement and stir well and put entire mixture.*

*Basalt fibers is immersed in mixture, but immersion is done in batches to make sure that mixture permeates rock wool completely and wool must be immersed in one direction and not randomly to avoid the clumping of wool and the formation of balls inside rock wool, which ultimately leads to the inconsistency here lies Difficulty in work, then placed in a wooden mold with dimensions of 30 mm * 30 mm * 12 mm. Leave for 24 hours in mold until it solidifies after which leave cement fiber board for 48 hours to dry in primary, leave another seven days to dry completely after which cut by An electric machine*

3 Tests procedure

3. 1 Compression test

A piston electrolysis U. S origin of type (HUMBOLDT) used to calculate compressive strength; it has been shed load gradually on simple dimension (50mm*50mm*50mm) according to international standard ASTM-D1037-06a.Data read until the failure of sample.

3. 2 Bending tests before and after immersion

Bending test before immersion is performed accordance specification ASTM-C1185-99, dimensions (300 mmx75 mmx12 mm) ,. For bending test after immersion, it done by immersing samples in water for 48 hours, after which tests are procedure with same specifications, dimensions, and method above.

3. 3 density Tests

For this testing, the mold dimension of (100 mm x100 mm x 12mm) was used. Mass of the sample was first determined in kg. Then, Volume of the sample was measured by knowing its dimensions in m^3 and calculated according to density formula, which is mass divided by volume, result of density test can be obtained in k g/m^3.

3. 4 Water absorption Tests

Sample size for water absorption tests was (100mm x 100mm x 12mm) coordinate to ASTM – C1185-99. Samples were immersed in water for 24 hours and difference in weight before and after immersion were measured by the formula:

$$\text{Water absorption}=(w_2-w_1/w_1)\ x100\%$$

Where w_2 weight before immersion of sample
W_1 weight after immersion of sample

3. 5 Moisture content Tests

Moisture content test procedure from bending test dry with dimension (150mmx75mmx12mm) according ASTM – C1185-99. where by straightly carried out after samples were taken out from curing tank. Initial weight of sample was determined for first times. Then, it was inserted in oven. Oven was preheated for about 15 minutes at temperature of (90± 2) C^0. Sample was then left in oven for a period of 24 hours. After 24 hours, sample was then weighed again. Weight difference of sample is weight of moisture inside sample, according to equation:

$$M=100[(w-F)/F]$$

Where M moisture content
W initial weight
F final weight

3. 6 Thermal Conductivity Tests

Examination was procedure according to requirements of American standard ASTM-C1113-90 with dimensions (100mmx50mmx50mm) at National Center for Laboratories and Structural Research (Baghdad Central Laboratory) in Iraq, which is a Japanese device. Thermal conductivity coefficient was examined using QTM-500 technology, which is a Japanese technique based on platinum wire method sensor consists of two wires, heated wire and a sensitive wire when device is turned on, which shedding a current proportional with density of sample to heat surface of sample and when there is an equilibrium between temperature of wire generated as a result of passage of current with surface of sample touching it, the sensor wire senses speed of heat transfer through surface of sample as well.

4 Results and Discussion

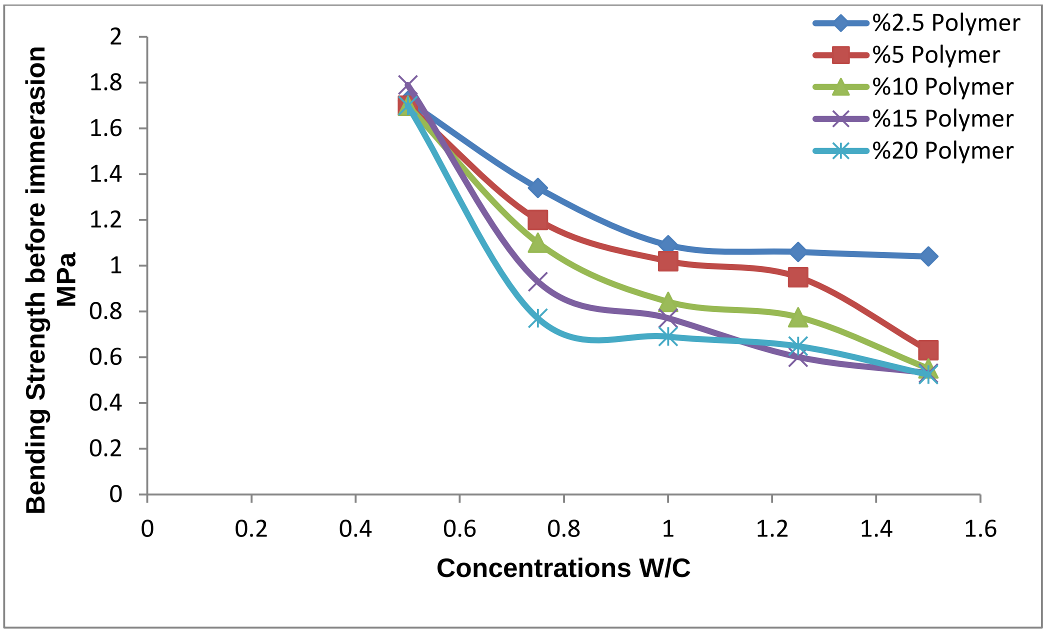


Figure-1 Effect Concentrations of polymer on bending strength before immersion of cement fiber board with basalt fibers 30g.

Figure 1: Represents bending resistance before immersion, where it is noticed from figure that addition of polymer at rates ranging from 2.5% to 20% weakens bending resistance. At ratio of 2.5% polymer, bending resistance is much highest and gradually weakened when increasing percentage of polymer until it becomes much less than at percentage of polymer 20%, the reason for this is due to flexibility of polymer chains, as it is thermoplastic, and bending resistance improves when cement is added as a bonding material for polymer it is noticed that at a concentration of 2.5% polymer with increased cement concentrationss from 1.5 to 0.5, bending resistance increases from 1.04 MPa to 1.72 MPa, where noticed from curves that at cement concentrationss 1.5, 1.25, 1, 0.75 bending resistance varies, where noticed difference clearly with increase in polymer ratio, as for cement concentration of 0.5, it is noticed that bending resistance meets at all polymer s, which represent highest bending resistance, reason in this, that is increase in cement leads to permeation of polymer particles and works on cohesion and bonding between rock wool and polymer.

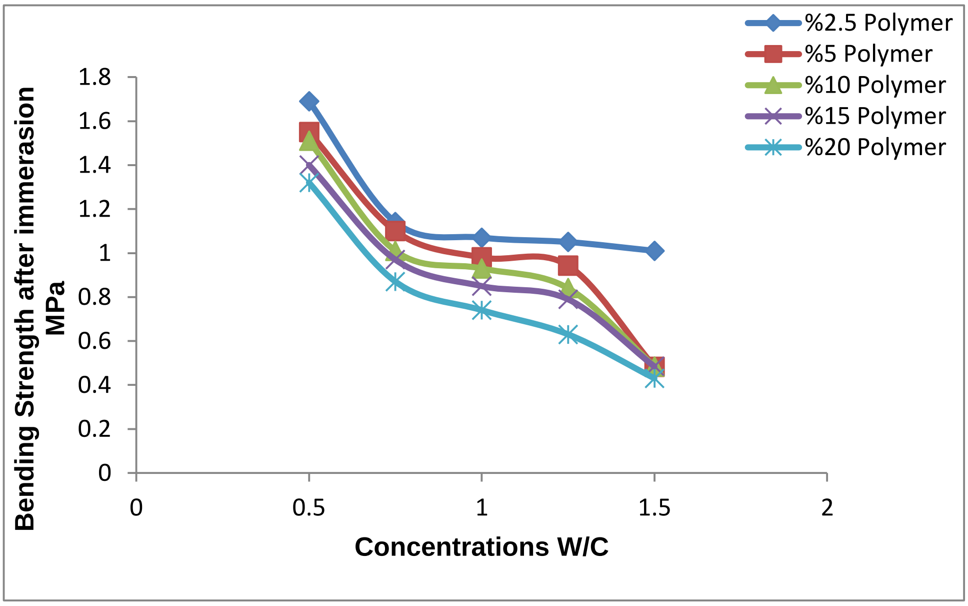


Figure-2 Effect Concentrations of polymer on Bending strength after immersion of cement fiber board with basalt fiber 30g.

Figure 2: Shows bending resistance after immersion after effect of adding polymer on refractive properties of models, where bending strength decreases from 1.8MPa to 0.4 MPa when increasing Water /cement from 0.5 to 1.5. This means that an increase in amount of water / cement leads to an increase in porosity of composition, which leads to decreased bending resistance It is also noticed that increasing polymer concentrations from 2.5% to 20% leads to a decrease in bending resistance. In addition that, It can also be observed from curve as increasing polymer also increases porosity of polymer structure, which leads to more flexibility and leads to a decrease in polymer stiffness, than leads to decrease in bending resistance.

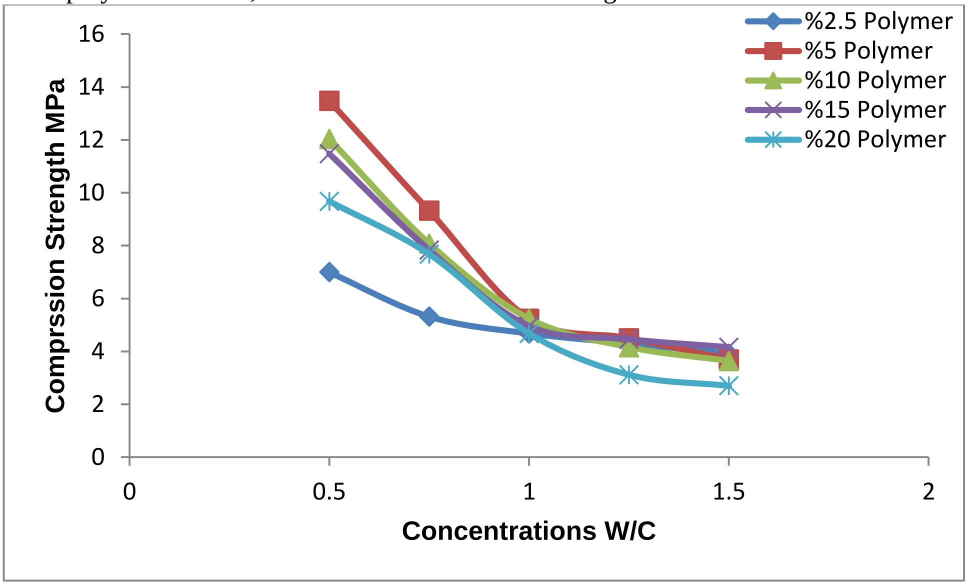


Figure-3 Effect Concentrations of polymer on Compression strength of cement fiber board with basalt fiber 30g.

Figure 3: Shows effect of adding polymer on compressive properties of board different concentrations of polymer are added, ranging from 2.5% to 20% of prepared board, where it is noticed that polymer concentration when it is 2.5%, compressive strength is a little equal to 6 MPa, and when it is increased to 5% it rises to 14 MPa after that it begins to decrease when increasing polymer from 15% to 20% until it reaches approximately 9 MPa, but at concentration water/cement is equal to 0.75, and at polymer concentration is 2.5%, compressive strength decreases to reach 5.5 MPa, but at concentration of polymer is increased to 5%, compressive strength is equal to 10 MPa, and so it begins to decrease when polymer is increased, and this can be interpreted as a per concentration water/ cement a certain concentrations of polymer can be determined through curves. Moreover, it is noticed that effect of adding water has a great effect on compressive strength, when increasing concentrations of water/cement from 0.5 to 1.5, compressive strength decreases from 14 MPa to 2 MPa, and this decrease results from increase in water concentration, which leads to an increase in porosity in internal structure of sample prepared and due to this reason compressive strength is decreases.

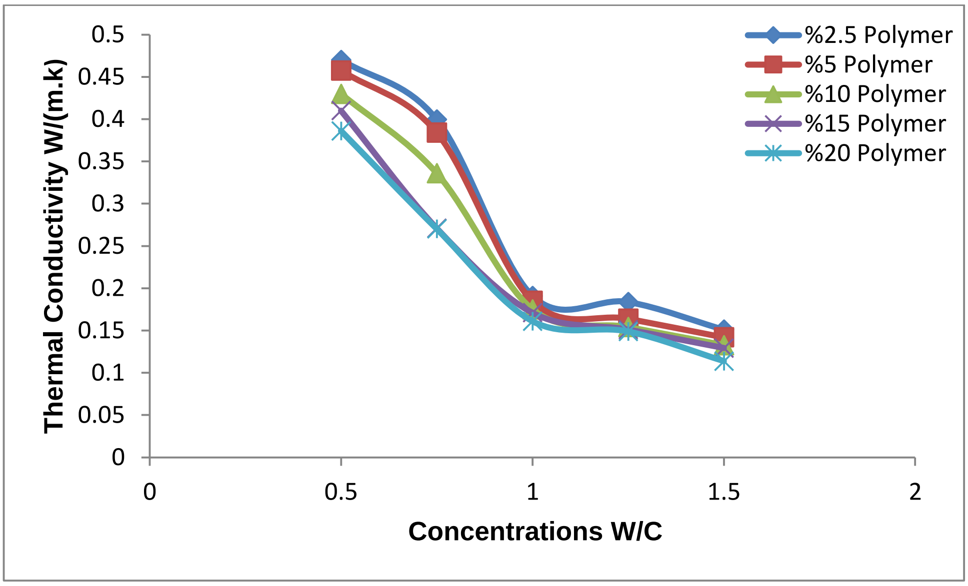


Figure-4 Effect Concentrations of polymer on thermal conductivity of cement fiber board with basalt fiber 30g.

Figure 4: Shows effect of polymer concentration in water on thermal conductivity of prepared samples, where it is noticed that thermal conductivity decreases if polymer increases. This means that polymer is an insulating material. On other hand, it is seen that when concentration water / cement increases significantly, thermal conductivity decreases, as is evident from curves. When concentrations more than 1, water will increase at expense of cement, where when water increases, porosity inside boards increases, and when porosity of boards increases, spatial structures or porosity will decrease, as a result thermal conductivity.

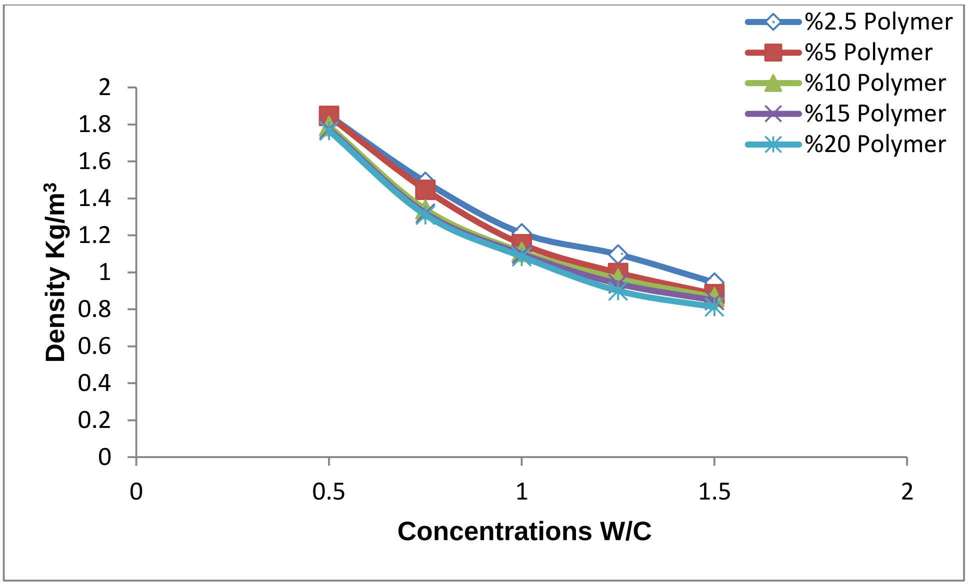


Figure-5 Effect Concentrations of polymer on density of cement fiber board with basalt fiber 30g.

Figure 5: Shown of polymer effect on density, where it is noticed from curves that higher concentrations of polymer become lower density. It is also noted that higher concentration water / cement , be lower density and inverse relationship between them, meaning that lower cement gives higher water concentration in board composition, explanation for this it that with increase concentration of water / cement that porosity between internal composition board it decreases as a result of increase in water, and this leads to an increase in interfacial holes of board strictures.

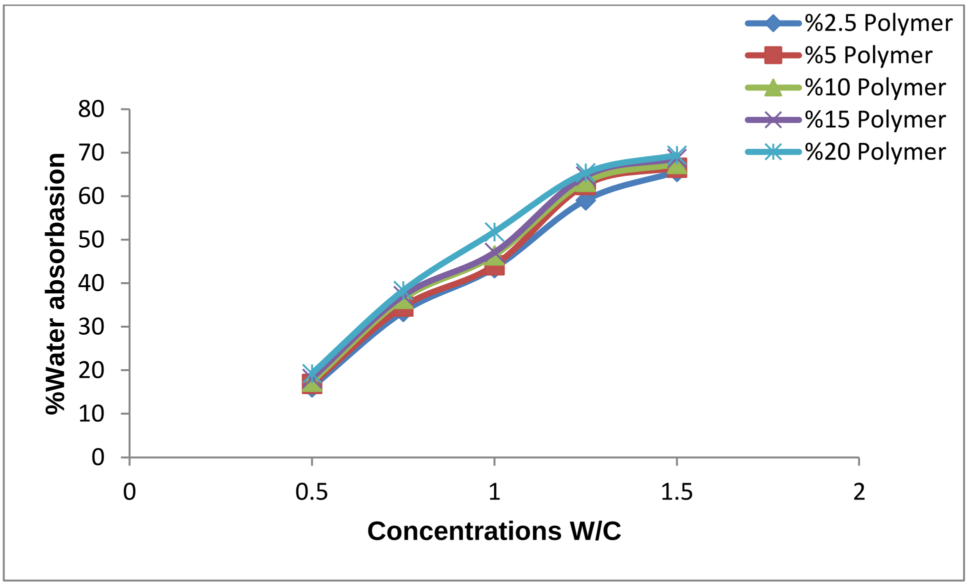


Figure-6 Effect Concentrations of polymer on %water absorption of cement fiber board with basalt fiber 30g.

Figure 6: Explains effect of adding polymer on water absorption, as it is noticed effect of adding polymer on water absorption has a very little effect as observed from curves as if they apply to each other, but effect of adding water to cement from 0.5 to 1.5 on water absorption is very large, as water absorption rate changes from 16.07% to 69.42%. As a result, it is necessary to manufacture board with lowest possible ratio of water/cement in order not to affect water absorption ratio, explanation for this is that when concentration of water/cement increases, porosity of board increases, which leads to an increase in absorption.

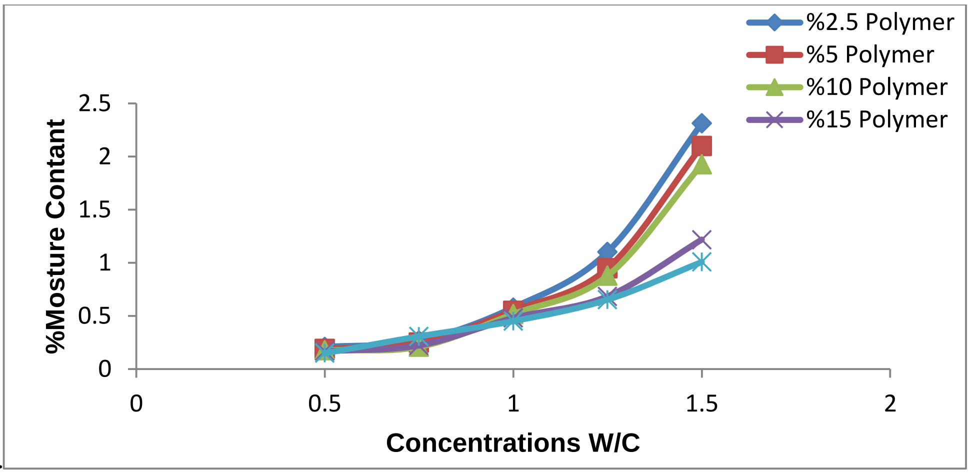
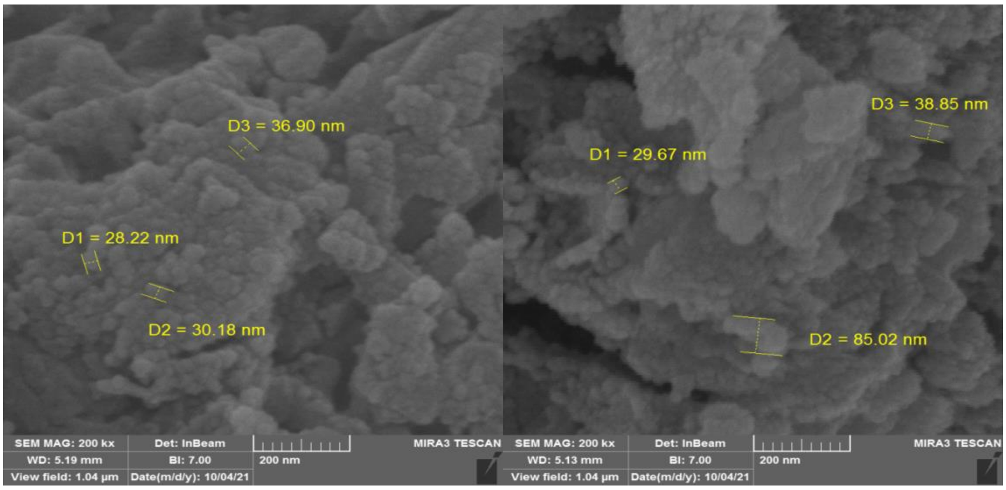
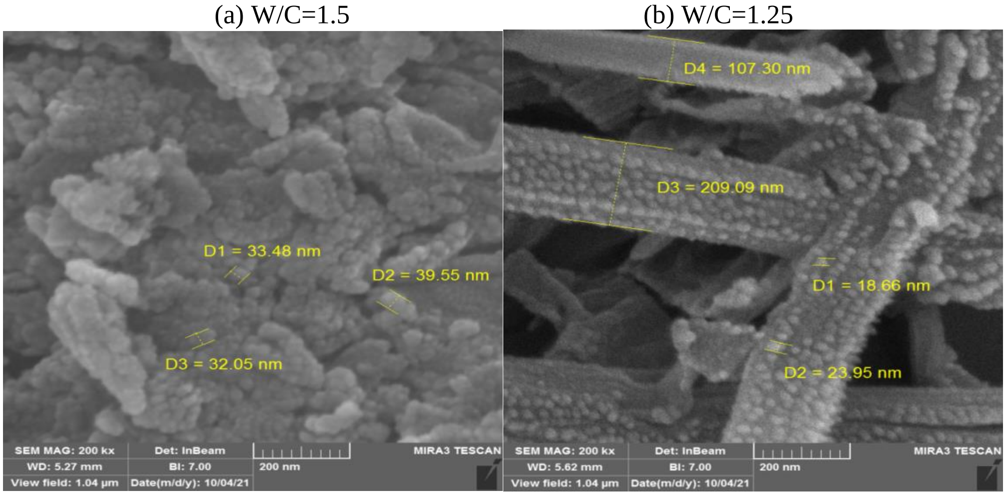


Figure-7 Effect Concentrations of polymer on %moisture content of cement fiber board with basalt fiber 30g.

Figure 7: shows increase in humidity percentage as concentrations water/cement increases in order to increase porosity with increase in water/cement ratio. In addition, it is noticed from curves that at concentrations water/cement from 0.5 to 1 there is no significant effect of polymer on moisture content, but at concentrations greater than 1, there is a noticeable effect of polymer on moisture content, where at higher polymer concentrations, lower moisture content. That is, when concentrations a water/cement is less than one, cement increases at expense of water, which makes cement basic binder material that dominates polymer, except a property which characteristic of polymer, which is wetting surface of the fibers. As for concentrations water/cement greater than one, water will increase at expense of cement, which will give polymer a greater place in working with cement as a binder as well.



(a) W/C=1.5 (b) W/C=1.25



(c) W/C=1 (d) W/C=0.75

Figure -8 SEM Micrographs of the interier structure of cement boards rienforcing of basalt fibers 30g for W/C concentrations 1.5, 1.25, 1, 0.75 contining %10 polymer.

Figure 8: Show images by using a scanning electron microscope for the structure of manufactured cement boards. The images show the effect of the water/cement ratio on the structure and chemical reactions taking place in cement. It is noted from the figure 8 that an increase in the water/cement concentrations leads to an increase in the voids in the structures, as when adding Water to Cement and fiber together, Tri-calcium silicate (C3S) and binary calcium silicate (C2S) react with water and then produce a group of calcium silicate hydrates similar in composition, but they vary in the ratio of calcium / silica with calcium hydroxide and the chemical composition of calcium silicate depends on the water / cement ratio, so the increase in the proportion of water leads to weak structures and an increase in the voids in the structure.

The pictures also show the reaction of basalt fibers with dissolved calcium hydroxide Ca(OH)2 . where by basalt fibers contain 43.24% sio2 and 15.01% Al2o3, so they react with dissolved calcium hydroxide Ca(OH)2 to form compounds of calcium silicate group and tri-calcium aluminate C3A, which It has the ability to resistance acquire, result of its reaction with water/cement to form manufactured hexagonal crystals of hydratiy calcium aluminate C3AH6.

5 Conclusions

1- The study showed that it is possible to use the damaged rock wool available in the General Company for Mining Industries in Iraq in the manufacture of fiber cement panels

2- The study showed that the compressive strength can reach 14 MPa using the polymeric mixture with cement in specific quantities according to the study.

3- It is possible to control the percentage of moisture absorption, resistance to bending and heat conduction of the produced panels by controlling different additives according to the study

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