DOI: 10.24996/ijs.2022.63.10.15

ISSN: 0067-2904

Study and Evaluation of Rock Wool Board by using PVA/PU as a Polymer Blend Binder

Moayad Abdullah Mohammed*[1], Mohammed Ali Jaber[2], Abbas Fadel Essa Al-Maamouri[1]

[1]*College of Science, Wasit University, Wasit, Iraq*
[2]*Polymer Research Center, Basra University, Basra, Iraq*

Received: 30/5/2021 Accepted: 9/1/2022 Published: 30/10/2022

Abstract

The Rock Wool Board (RWB) is widely used in the building exterior insulation all over world. As polymer affects hardening of plate, meaning it acted as a basic binder in this work and gave a smooth texture, ease of carrying and workmanship in different sizes and shapes. PVA was studied at the rates of PVA %4, %5, %6.66, %10, %20, results showed that 6.66% is the best percentage, through tensile and bending tests, this percentage was use with polyurethane with rates of PU 1, 0.5, 0.333, 0.25, 0.2 It is found that the ratio 0.333 is the best ratio to give good mechanical properties of bending, tensile and elongation. This percentage was fixed on different percentages of polymer (PU/PVA) as %2.5, %5, %10, %15, %20 and examinations were performed on these percentages and percentage %10 was best, this percentage was adopted. Another study in change of the rock wool with rates of %5, %7.5, %10, %12.5, where it was found that best percentage of the rock wool is 12.5% after studying mechanical and physical properties.

Keywords: Thermal insolating, Polymer fiber board, Fiber reinforcement, external insolating, Basalt fiber board.

دراسة وتقييم لوح الصوف الصخري باستخدام مزيج البوليمر الرابط PVA / PU

مؤيد عبدالله محمد[1]*, محمد علي جابر[2], عباس فاضل عيسى[1]

[1]كلية العلوم، جامعة واسط، واسط، العراق
[2] كلية العلوم، جامعة البصرة، البصرة، العراق

الخلاصه

تستخدم ألواح الصوف الصخري (RWB) على نطاق واسع في بناء العزل الخارجي في جميع أنحاء العالم ، حيث يؤثر البوليمر على تصلب اللوح ، مما يعني أنه يعمل بمثابة مادة رابطة أساسية في هذا العمل ويمنح ملمسًا ناعمًا ويسهل حمله وصنعة بأحجام وأشكال مختلفة. تمت دراسة PVA بنسب٪ 4، ٪5، ٪6.66، ٪10، ٪20 وأظهرت النتائج أن ٪6.66 هي أفضل نسبة من خلال اختبارات الشد والانحناء وقد استخدمت هذه النسبة مع البولي يوريثين بنسب 1، 0.5، 0.333 ، 0.25، 0.2 وجد أن النسبة 0.333 هي أفضل نسبة لإعطاء خصائص ميكانيكية جيدة للانحناء والشد والاستطالة. تم تثبيت هذه النسبة على نسب مختلفة من البوليمر (PU / PVA) بنسبة ٪2.5، ٪ 5، ٪ 10، ٪ 15، ٪ 20 وتم إجراء الفحوصات على

*Email: mmoayedali65@yahoo.com

هذه النسب المئوية وكانت النسبة المئوية 10 هي الأفضل ، وتم اعتماد هذه النسبة المئوية. دراسة أخرى في تغير الصوف الصخري بنسب 5٪ ، 7.5٪ ، 10٪ ، 12.5٪ ، حيث تبين أن أفضل نسبة للصوف الصخري هي 12.5٪ بعد دراسة الخواص الميكانيكية والفيزيائية.

1 Introduction

Spread of polymer composite construction materials allowed development of products in all areas of applications to meet the technical requirements in a most effective way. Increasing economic and environmental demands for reinforcement of the polymer-bearing construction materials are encouraging researches to develop new, high-strength reinforcement materials and structures. As a result, in recent years, extensive research has begun worldwide regarding applicability of various types of organic and inorganic reinforcement materials in polymer matrixes. Basalt of mineral origin has gained increased interest as a stiffening material compared with the traditional glass and carbon plants [1].

Basalt comes from the basalt rock which is an above-ground igneous rock saturated with 45-52% SiO2. As a consequence of this formation, basalt has many beneficial properties such as elastic modulus, excellent heat resistance, high heat resistance capacity, acoustic resistance and outstanding vibration isolators. Because of its insulation property, it is used an insulation material in the construction industry in the form of rock wool, which is produced as follows: using the centrifugal blowing process, the basalt rocks are knocked into threads with a diameter of 7-13 microns and a length of 60-100 mm and of a melting temperature higher than 1500 ° C. This material is used as an insulator in construction due to fact that it is an excellent sound and thermal insulation and vibration damping, as well as non-slip, chemically indifferent, corrosion resistant and biologically stable. Several materials dealing with glass- and carbon-reinforced polymers indicate the significance of basalt as a potential new reinforcement material [2, 3].

With the use of such low density, solid compounds instead of metallic raw materials, for example in manufacture of mechanical problems of rotating fluid machines those related to fan blades [4,5] can be overcome. There are only a few researchers who have been able to create composite basaltic compounds in a polymer matrix [6] because of the interface interaction problem between matrix and high fracture sensitivity of the basalt. The use of basalt FRP (BFRP) reinforcement and development phase of composites are currently in the top research interest [7, 8]. Mechanical properties of the basalt fibers are very close or even better than remaining fibers (aramid, carbon, glass, etc.) [2]. Properties of the basalt fiber generally depend on the source and the type of basalt rock and method of production. Basalt fibers have high temperature resistance and are much cheaper than rest of composite fibers [3. 9].

Zhang et al. fabricated basalt fiber (BF) reinforced poly (butylene succinate) (PBS) composites with different fiber contents by the injection molding method. Their tensile, flexural and impact properties, as well as thermal stability have been investigated [10]. Wang et al. investigated the creep behavior of newly developed basalt fiber reinforced polymer (BFRP) tendons for prestressing applications. Furthermore, the creep rupture stress was predicted based on statistical analysis [5]. Li et al. studied rock wool board (RWB) in construction of exterior insulation worldwide. Fiber diameter, solid volume fraction (SVF), and contact degree among the fibers significantly influence the RWB physical properties [11]. Chakartnarodom et al. studied mechanical and physical properties, and performance of the texture roof tiles reinforced with basalt fibers. Samples of basalt-fiber reinforced texture roof

tiles were produced on industrial scale using the filter pressing method. After forming, as-molded samples were air cured and characterized based on ASTM C1185 standard for their mechanical properties and physical properties [12]. Arora et al. studied the effect of different basalt fiber contents (0%, 10%, 20%, 30%, 100% by binder mass) as a replacement of rice husk ash on the fresh hardened and microstructural properties of geopolymer paste [13].
In this work, damaged rock wool, which is present in large quantities in the General Company for Mining Industries in Iraq, was used to manufacture insulating panels for ceilings, walls and surfaces as sound, heat and fireproof panels. Aim of this research is to study applicability of the basalt as a reinforcing material in polymers, to determine properties of basalt and to define a model for production of basalt.

2 Materials

The basalt fibers wastes (made by General Company for Mining Industries,Iraq - Basra), in rock wool form, were used. It is treated with a polymer matrix and used as a binder in this work, and which consists of:
1- Poly Vinyl Acetate (PVA) from Waha Company (Iran - Tehran), which a product of the reaction of acetic acid with estylene, and this reaction takes place either in a liquid phase or a gas phase.
2. Polyurethane is a solid foam formed from the two main compounds, namely Polyols and Poly Toluene Diisocyanite (TDIS). Polyol is an alcohol that contains multiple hydroxyl groups. It comes in a liquid form, gives flexibility to polymers, it has several molecular weights and this makes its uses different. As for (TDIS) is white in color with an aromatic substance. It has a pungent odor it causes irritation of the respiratory system and the eye when inhaled. Moreover, it is very toxic. Therefore, utmost care and caution must be taken when dealing with it or when storing it, and it is preferable to use oxygen masks.
3. Water is considered good solution for reaction matrix and binding material.

3 Methods and Samples Preparation

PVA was used alone as a binder for the rock wool. Subsequently, Polyurethene (with different weight ratios) was used with PVA as Polymeric blends. The rock wool fibers were dipped in PVA dissolved in water, then it was placed in a mold with dimensions of 300mm x300mm x12mm and left for two days to dry. The same method was repeated, but this time PU (of different weight ratios) was added to the PVA, and the homogeneous mixture was poured into a molds of size of 300mm x300mm x12mm. The models were left for 48 hours to dry. The models were taken out of the mold and exposed to a temperature of 40℃ for a period of 24 hours until they solidify. The molds were cut according to the specifications(ASTM 1185, 2013). Physical and mechanical properties, density, parallel tensile strength, bending and elongation were studied.

4 Result and discussion

4.1 Tensile Tests

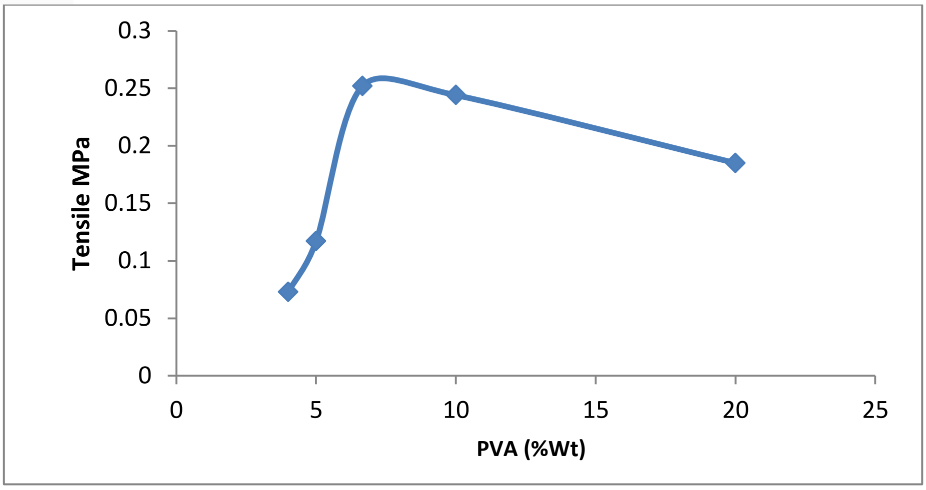

Figure 1: Effect PVA % concentration in water on tensile strength .

Figure 1 shows that increasing the concentration of PVA in water led to an increase in tensile strength parallel to the surface, as it increased from 0.0727 to 0.252 MPa; reaching a maximum at a PVA concentration of 6.66%; tensile strength started to decrease at 10% PVA concentration and continued to decrease to the highest level of PVA in water. The reason for this behavior is that an increase in PVA, leads to a strong cohesion between fibers (rock wool) due to its adhesion properties, but when it reaches a saturation state at the ratio 20% of PVA, then percentage of PVA is more than that of the rock wool. Where at the ratio (20%) tensile strength decreased until it reached 0.185 MPa.

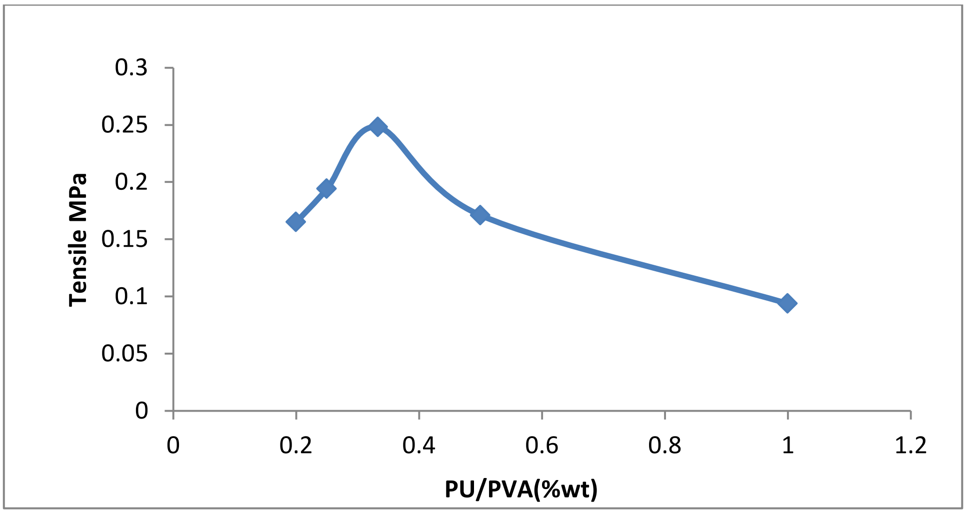

Figure 2: The effect of %6,66 polymer as concentrations PU/PVA on tensile strength.

Figure 2 two materials were used in the form of a polymer blend, which are PU and PVA, with various ratios of PU:PVA where the PVA was changed: 1:1, 1:2, 1:3, 1:4,1:5, then making cement fiber board at a ratio the rock wool %15, after tests. Figure 2 shows the effect of adding PU on the efficiency of PVA as a bonding force for rock wool panels, where it is noticed that when adding PU with increasing PVA led to an increase in tensile strength parallel to the surface until it reached a maximum value of 0.248 Mpa at a ratio of 1:3 which is best ratio. Tensile strength decreased with further increase of PVA indicating that the PVA quantity is more than required. The ratio of 1:3 was chosen as the best ratio because it is more resistant to moisture and PU large porosity allows the control of the lightness of the panels, thus giving a lower density and higher thermal insulation.

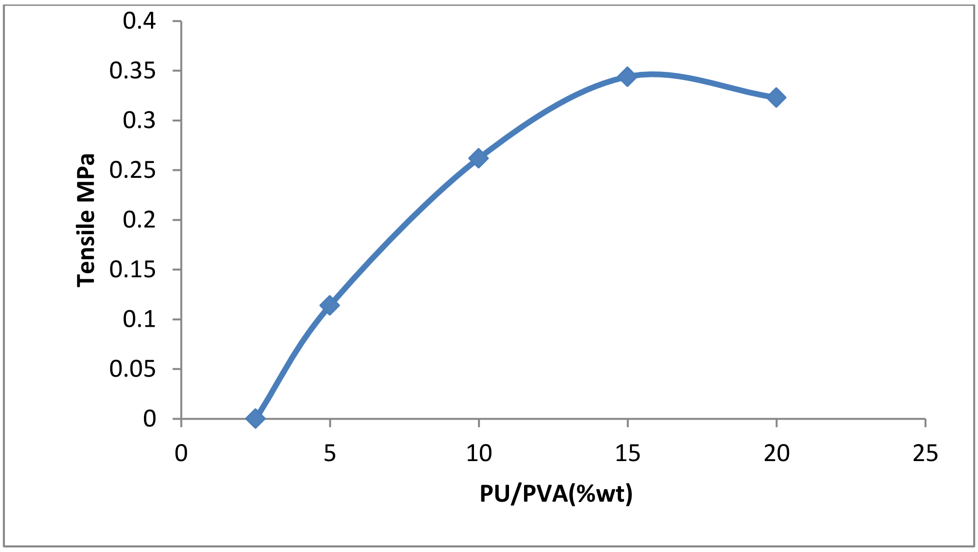

Figure 3: The effect of % concentration of polymer in water as 1/3 (PU/PVA) on tensile strength.

Figure 3 shows the effect of polymeric mixture PU: PVA from (2.5 - 20)%, where it was observed that at a ratio of 2.5%, tensile strength was zero due to the weakness of bonding material between pores of rock wool represented by PU:PVA, but when percentage of polymer increased tensile strength gradually increased until it reached 0.344 MPa at rate of polymer 15%, which represents the highest tensile strength, after which tensile strength started to decrease at the rate of 20%. The reason is that increase in polymer ratio leads to an increase in crosslinking between the rock wool fibers until it reached state of saturation, after that amount of polymer when it is more than the amount of rock wool, tensile strength begins to decrease and porosity increases between the rock wool[14].

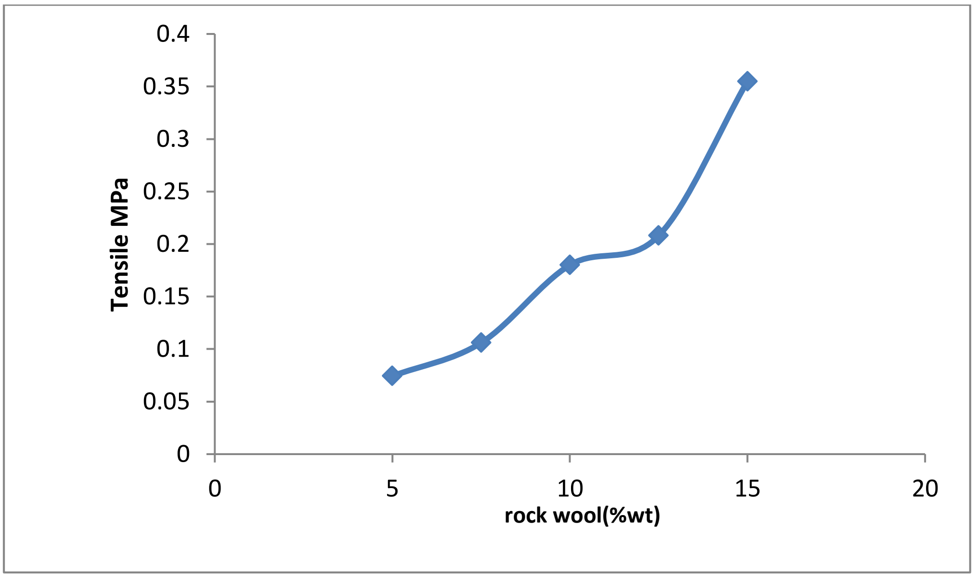

Figure 4: The effect of content rock wool at %15 polymer and 1:3 PU/PVA ratio on tensile strength.

From Figure 4, It is noticed that there is an increase in tensile strength, according of the standard (ASTM 1185, 2013) when increasing the percentage of fibers in water, as tensile strength increased from (0.0743 to 0.355) MPa when increasing weight percentage of fibers in the water from 5% to 15%. The reason for this increase in tensile strength is due to the the increase in the durability of the board as result the increase of rock wool. Thus, the density increases density and closes intervals (as a result of the increase in mass and according to the relationship density equals mass to volume), which leads to an increase in strength and durability of the board, and consequently an increase in compaction force inside matrix, this increased tensile strength vertical of surface, which leads to an increase a strength of bond between the rock wool[15].

4. 2 Bending Tests

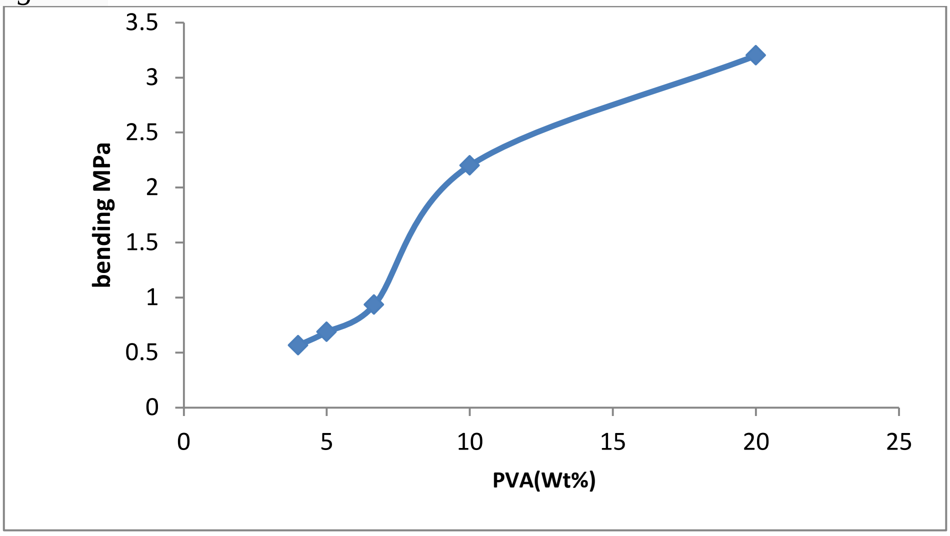

Figure 5: The effect of PVA % concentration in water on flexural strength.

Figure 5 shows gradual increase in the bending resistance with the increase of PVA, as it rises from 0.564 MPa until it reached 3.2 MPa reaching almost the highest value of 3.5 Mpa at 20% from PVA.. The reason is because PVA material has a high adhesion force that works on the cohesion between the rock wool fibers.

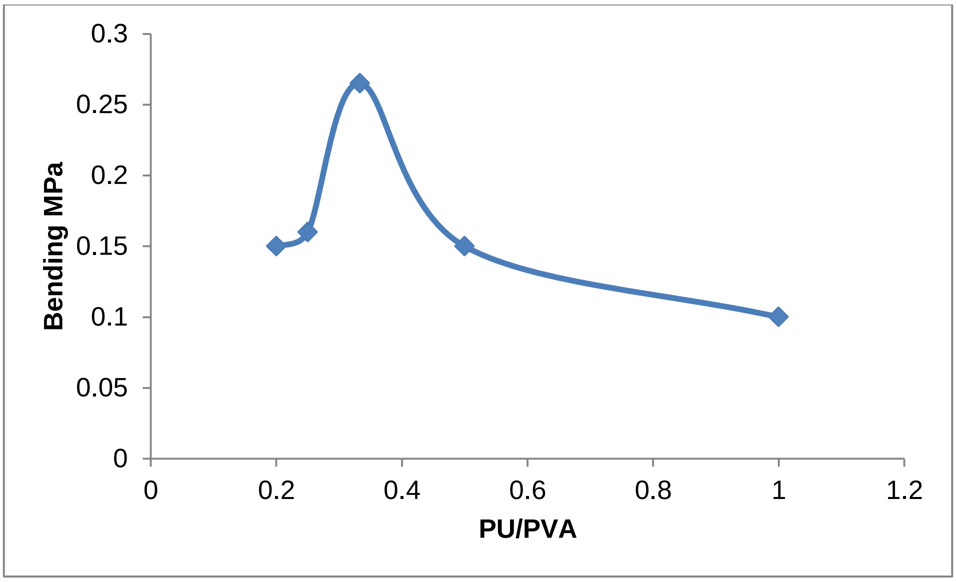

Figure 6: The effect of %7.5 polymer as Concentrations PU/PVA on flexural strength

Figure 6 shows the effect of PU on the bending strength, where it is noticed that bending resistance begins to increase until it reached 0.817 MPa at a ratio of 1: 3, after this ratio the increase in PVA will decrease bending resistance until it reaches 0.4 Mpa. Where the increase in PVA affects the binder, as a result, the best ratio of the binder is 1:3 as a ratio PU: PVA.

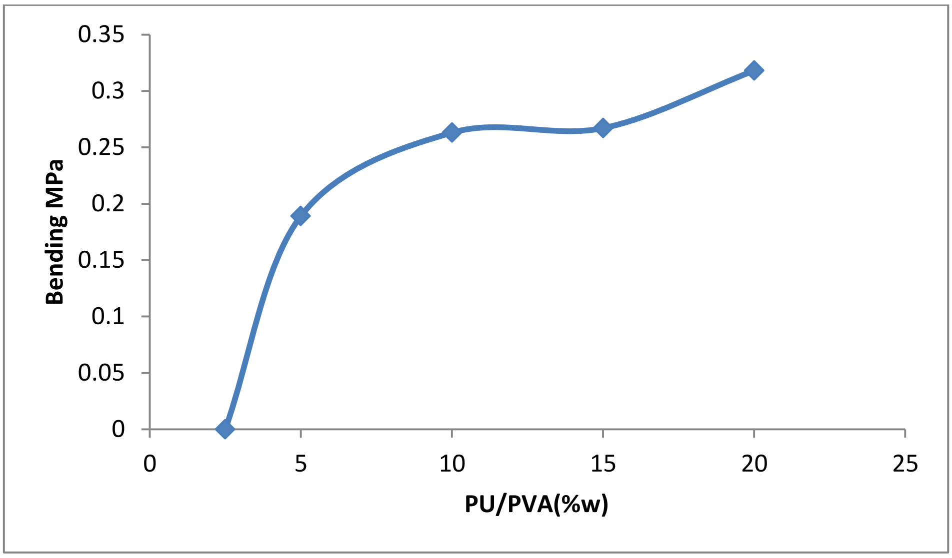

Figure 7: The effect of % concentrations of polymer in water at 1:3 PU/PVA ratio on flexural strength.

Figure 7 shows that bending resistance increased with the increase of bond material (polymeric mixture), as it increased from (0 to 0.318) MPa when polymer percentage increased from (2.5 to 20) %, and the reason for this is that increase in bending material leads to an increase in bond strength between pores of the rock wool[15].

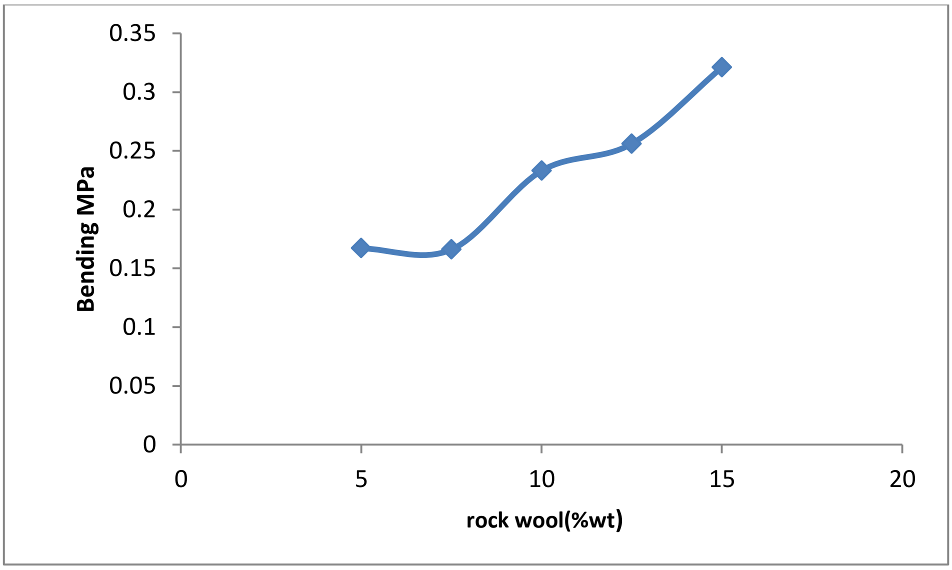

Figure 8: The effect of rock wool content at %15 polymer at 1:3 PU/PVA ratio on flexural strength.

It is noted from Figure 8 that bending resistance increased when weight ratios of the rock wool increased; as bending resistance increased from (0.166 to 0.321) Mpa, when fiber percentage increased from 5% to 15%. The reason for this is that increasing weight ratios of fiber leads to a reduction in voids and pores within the matrix and increase in its density, which leads to an increase in cohesion of components of board leading to an increase in resistance to fracture[16]. This is evident in Figure 5, where the bending resistance gradually increased with the increase of PVA, reaching almost the greatest value of 3.5 Mpa at 20% from PVA.

4. 3 Density Tests

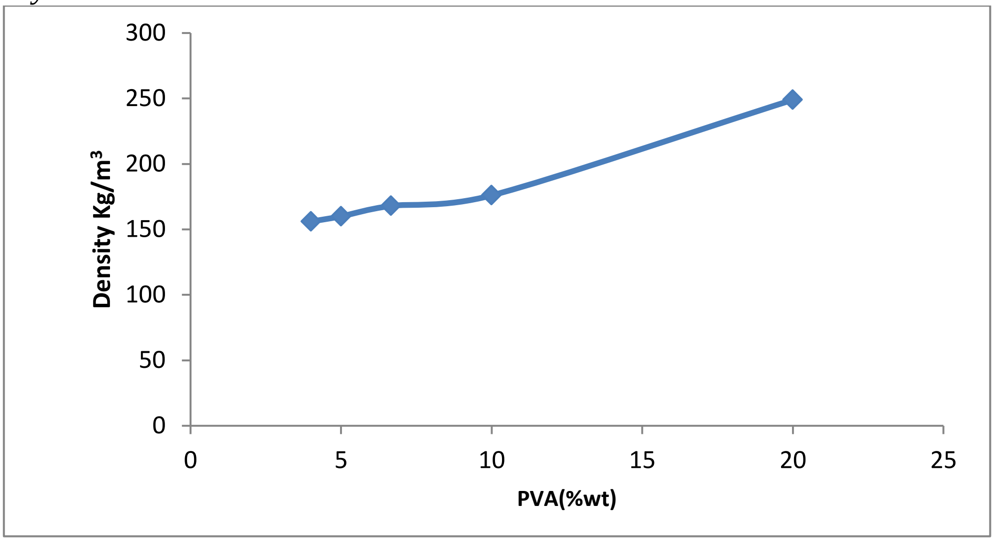

Figure 9: The effect of PVA % concentration in water on the density boards.

Figure 9 shows that density increased with the increase in the concentration of PVA in water.Density increased from 156 kg / m^3 to 249 kg / m^3 due to the nature of properties that PVA has in water, where it is characterized by its heavy weight and gives characteristic of stacking with components of the mixture.

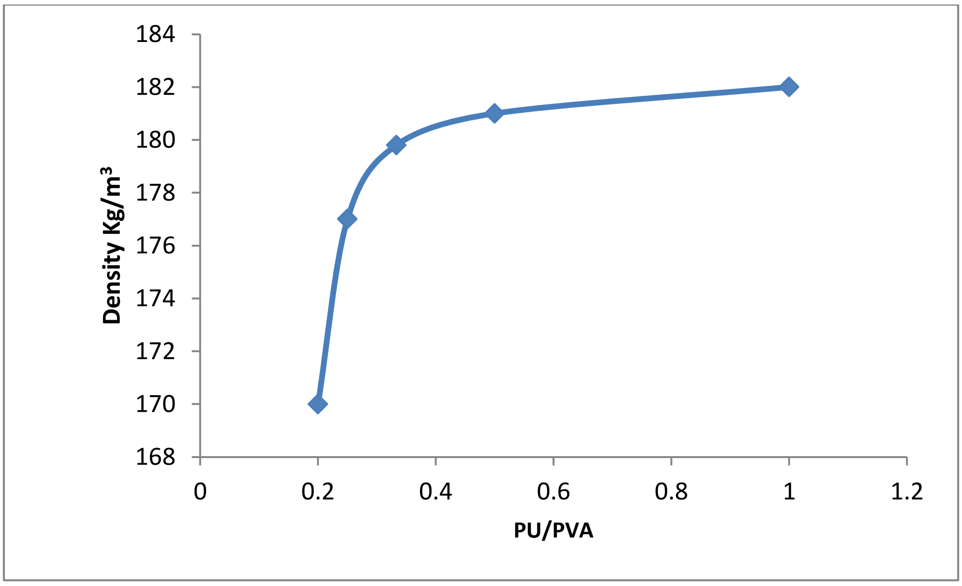

Figure 10: The effect PU/PVA concentrations at % 6.66 polymer on the density boards

Figure 10 shows that density increased from 170 kg/m^3 to 182 kg/m^3 when increasing PU:PVA ratio 1:1, 1:2, 1:3, 1:4, 1:5. It is worth noting that density in this board is less than density of the board in Fig. 8, due to entry of PU material into this mixture, this is explained by the fact that density of PU is less than density of PVA because it contains a foamy substance with lower densities.

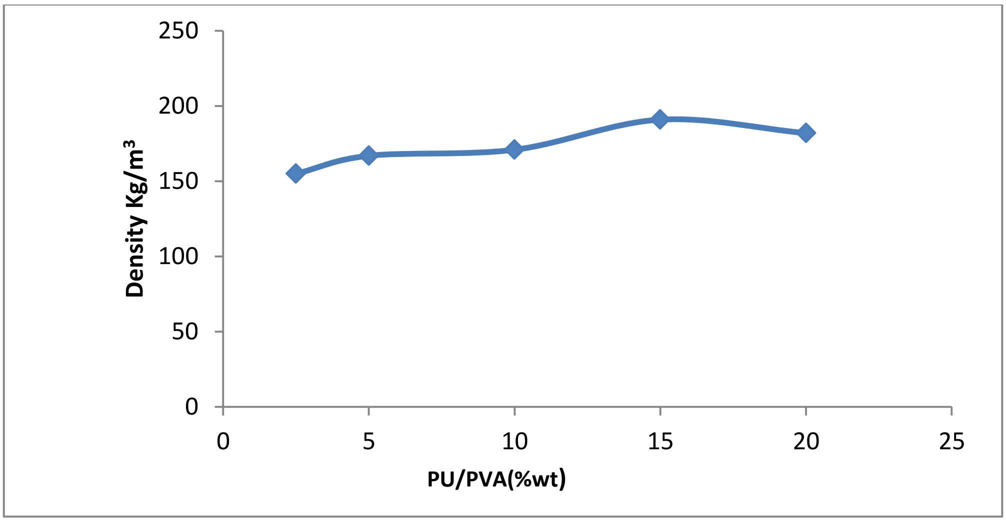

Figure 11: The effect of % concentration of polymer in water at 1:3 PU/PVA ratio on the density boards.

From Figure 1, it is noted that density increased gradually when increasing concentration of the polymer in water, where density begins to rise from 155 kg/m^3 to 211 kg/m^3 at polymer ratios ranging from%2.5 to %20, which is as a ratio 1:3 (PU: PVA) where it is constant for all polymer blends, and the reason for this increase in density is due to the increase in the ratios of PVA, which is heavier than PU which considered a foamy and inflating the material.

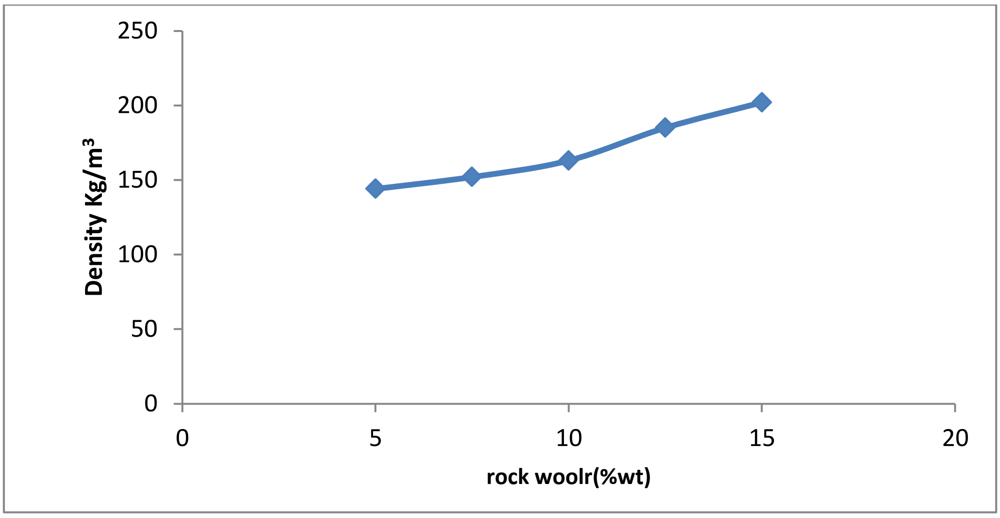

Figure 12: The effect of rock wool at %15 polymer and 1:3 PU/PVA ratio on the density board.

Figure 12 shows that increasing weight ratios of rock wool leads to density increase, where density increased from 144 kg/m^3 to 202.9 kg/m^3 when increasing rock wool from %5 to %12.5 in water, for as the rock wool weight increases, density increases as a result of the increase in mass and according to the relationship density equals mass to volume.

5 Conclusion

1. The rock wool is submerged in one batch and in a large quantity better than if it was in

batches so that wool does not clump and leave breaks between the matrix and binding material which affects internal composition of sample, then affects study on the mechanical and physical properties during casting, i.e. large quantity and one batch by immersion makes the rock wool is intertwined and forms a single lump with bonding the material.
2. Increase in the polymer ratios leads to the weak mechanical and physical properties but helps adhesion to the rock wool surface. Therefore, best percentage polymer 10% to seek adequate the mechanical properties and adhesion.
3.Increasing the rock wool ratios leads to a decrease the moisture content and absorption but improves the thermal conductivity, the compression resisting, the elongation percentage and the bending resistance before and after immersion.

References

[1] X. Wang, Z. Wu, G. Wu, H. Zhu, and F. Zen, “Enhancement of basalt FRP by hybridization for long-span cable-stayed bridge,” *Composites Part B: Engineering*, vol. 44, part: 1, pp. 184–192, 2013.
[2] V. Kostikov, “Fibre Science and Technology.” Soviet Advances Composites Technology Series, *Russian Academy of Sciences. Dordrecht: Springer*, p. 694, 1995.
[3] Y. Kim, “Advanced Composites in Bridge Construction and Repair,” *Cambridge, Woodhead Publishing* (Elsevier), p 351, 2014.
[4] J. Sim, C. Park and D. Moon, “Characteristics of basalt fiber as a strengthening material for concrete structures,” *Composites Part B: Engineering*, vol. 36, no.7, pp. 504–512, 2005.
[5] X. Wang, J. Shi, S. Liu, L. Yang and Z. Wu, “Creep behavior of basalt fiber reinforced polymer tendons for prestressing application,” *Materials and Design*, vol. 59, pp 558–564, 2014.
[6] M. Pearson, T. Donchev, and J. Salazar, “Long – term behaviour of prestressed basalt fibre reinforced polymer bars,” *Procoedia Engineering*, vol. 54, pp. 261–269, 2013.
[7] X. Wang, G. Wu, Z. Dong and Z. Xie, “Evaluation of prestressed basalt fiber and hybrid fiber reinforced polymer tendons under marine environment,” *Materials and Design*, vol. 64, pp. 721–728, 2014.
[8] X. Wang, J. Shi, Z. Wu and Z. Zhu, “Fatigue Behavior of Basalt Fiber-Reinforced Polymer Tendons for Prestressing Applications,” *ASCE Journal of Composites for Construction*, vol. 20, no.3, pp. 1–10, 2016.
[9] M. Zoghi, “The International Handbook of FRP Composites in Civil Engineering,” *CRC Press*. P. 692, 2014.
[10] Y. Zhang, Y. Chunxiao, P. Chu, L. Fengzhu, Z. Changan, J. Junhui, R. Zhang and H. Wang, “Mechanical and thermal properties of basalt fiber reinforced poly (butylene succinate) composites,” *Materials Chemistry and Physics*, vol. 133, pp. 845–849, 2012.
[11] X. Li, J. Liu, X. Fan, J. Qin, R. Zhang, R. Cao, P. Wang and X. Huo, “Simulating Study on Mechanical Properties of Rock Wool Board for Thermal Insulation on External Walls,” *Advances in Materials Science and Engineering,* vol. 2020, Article ID 4028941, 2020.
[12] C. Parinya, C. Nutthita, L. Edward and P. Wichit, “Properties and performance of the basalt-fiber reinforced texture roof tiles,*” Case studies in Construction Materials*, vol. 13, 2020.
[13] A. Saloni, J. Parveen and P. Thong , “Enhanced Properties of High-silica Rice Husk Ash-Based Geopolymer Paste by Incorporating Fine Basalt Fibers,” *Construction and Building Materials*, vol. 245, 2020.
[14] X. Xu, P. Rawat, Y. Shi, and D. Zhu, “Tensile mechanical properties of basalt fiber reinforced polymer tendons at low to intermediate strain rates,” *Compos. Part B: engineering*, vol. 177, no. 107., p. 442, Sep. 2019.
[15] S. Khandelwal and K. Y. Rhee, “Recent advances in basalt-fiber-reinforced composites: Tailoring the fiber-matrix interface,” Composites Part B: Engineering, vol. 192, 2020.
[16] T. Afiq, S. Sapuan and R. Ilyas, "Mechanical properties of basalt fiber reinforced polymer composites," Conference: Seminar on Advanced Bio- and Mineral based Natural Fibre Composites (SBMC2021), ISBN: pp. 978-983, 2021.