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# Evaluation of the Use of Volcanic Tuff in concrete block production

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**Abstract**

Jordanian volcanic tuff has low specific gravity and density compared to ordinary limestone aggregate and sandstone used in concrete block production. The current study had considered volcanic tuff from Jabal Al Halain Tafila to be tested in concrete block production. Concrete mixes were designed by using volcanic tuff as the whole part of specific size gradation and in ratios of ordinary materials applying manual and vibration compaction. Volcanic tuff gives less density for concrete block compared to ordinary materials. Density reduction can reach 20-30% for all mixes on manual compaction, while it was increased by 20-30% when VEBE compaction was used. Compressive strength of volcanic tuff at 28-day age of concrete block can attain 40-50% of that for ordinary materials using manual compaction, and up to 50-60 of compressive strength using VEBE compaction. Regarding permeability, volcanic tuff has a noticed increase in permeability when compared with the permeability of ordinary materials. Increasing fine materials in concrete block mix and plastering of block walls' during construction can solve the problem of permeability. Therefore, it is recommended to use volcanic tuff in concrete block production in building construction widely.



**Keywords:** volcanic tuff, lightweight aggregate, compressive strength, concrete block production.

## 1. Introduction

In Jordan, the use of natural materials such as Tripoli, Basalt and Oil shale ashes in concrete and as cement replacing materials was studied by many (e.g. El-Hasan and Al-Hamaideh, 2012; Abdelhadi et al., 2014; El-Hasan et al., 2015, Al-Sekhaneh and El-Hasan, 2021). Also, the investigation and use of natural resources such as basaltic rocks that extend on 18% of Jordan area (Al Smadi et al., 2018; Ibrahim et al., 2014) required analysis, testing and employment in construction operations as materials that can add new properties for construction materials. Lime stone in Jordan was studied by Moh'd (2015) to investigate the skeleton structure of pores in lime stone and its different state and effect on stone structure, The use of natural lightweight aggregate in concrete production results in reducing the density and weight of concrete structure produced. This will influence the total dead load of the structure significantly. This allows structural designers to immensely reduce the size of load-bearing elements such as columns, walls and footings. The implementation of such natural resources will lead to lowering the cost in construction by reducing the load of structure and the required quantity of steel reinforcement (Fredrick, 2014) and Sarireh (2015).

Volcanic tuff is a natural reserve resource of aggregate that can be found in Jabal Al-Hala located in Tafila in the Southern part of Jordan (Sarireh, 2020). As the volcanic tuff is a volcanic rock containing natural mineral zeolite (aluminium silicate alkaline) with a mainly vitreous structure, the high reactive silica content determined by chemical analysis gives Măcicaş quarry tuff pozzolanic character and hydraulic properties (Bedelean et al., 2010). The advantages of volcanic tuff include its highly porous structure, high surface area, and low density that gives less weight for structures. It is available in different types, sizes, and colors, and can reduce concrete dead weight in structure when it is used. Similarly, to other volcanic tuff materials, such as silica fumes and fly ash, replacement with zeolite can help in improving the strength of concrete through the volcanic tuff reaction with $Ca(OH)_2$ compound with cement gel and its compounds of calcium, phosphate, and ferrous materials (Negis, 1999). A similar conclusion was reached by using the mixtures of oil ash with Red soil and phosphogypsum (El-Hasan et al., 2019). Also, depending on the mineralogical composition and physical-mechanical characteristics of zeolitic tuffs, they have many uses in other areas: wastewater treatment, as a lightweight aggregate for fertilizers in agriculture and horticulture, for the minimization of heavy elements in the soil, in animal husbandry, fisheries, for the separation of nitrogen from the air, elimination of radioactive elements (Cs and Sr) of nuclear waste, supplements in animal diets, deodorants (Dipayan, 2007).

Pozolana can be prepared in different sizes and gradations and can be used as a light aggregate that fits into all parts of aggregate production and for the production of cement as additives in the form of fine and ground pozolana.

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10% to 30% is added before incarnating of the weight to correct the mixture components in terms of iron content, as well as the proportion of added 30% to clinker, helps in increased strength of concrete. There is a very large reserve in North-Eastern part of Jordan estimated at 470 Millions of Tons. Featuring pozolanic cement by the resistance to the impact of fresh and salt water that is usually rich in sulfate, leads to dioxide interaction. Calcium surplus with article pozolanic reduces the permeability of concrete and absorb excess water in addition to mobilizing cracks resulting from hydration (Alnawafleh et al., 2013). Also, Abali et al. (2006) and Augenti and Parisi (2010) pointed that volcanic tuff has an important role in keeping an intermediate compressive strength of the concrete mix, and in decreasing the weight of the concrete structure. Volcanic tuff can be used to produce workable concrete, light-weight concrete with reasonable concrete strength.

Abdelhadi et al. (2009), had utilized the bituminous limestone ash in the production of lightweight concrete masonry block. This step was produced to reduce the environmental impact by the waste of production of oil shale treatment process. And the utilization process for the oil shale residuals after extraction will give and lead to the production of 52% by weight of original rock as solid waste (fly ash) material. The compressive strength of the ash-mixes has a range of 1.9 – 7.6 Mpa. And the compressive strength of ash-aggregate mixes has a range of 5.4 – 6.3 Mpa, all at 28 days. The ash-polyester gave 2.1 Mpa as compressive strength at 28 days. Furthermore, the compressive strength and permeability parameters were improved by adding the Red soil to the bituminous limestone ash (El-Hasan et al., 2019).

Semsettin (2011) indicates that the use of volcanic tuff in concrete mix preparation and constituents can help in improving the properties of fresh and hardened concrete. Workability is an important property of fresh concrete that will improve with the use of volcanic tuff. Bleeding and segregation can be less when volcanic tuff is used in concrete mix (Al-Zou'by and Al-Zboon, 2014). Permeability, compressive strength, and durability can be increased also with the increase of volcanic tuff constituents in concrete mix (Ababneh and Matalkah, 2018). Kan and Gul (2008) pointed that volcanic tuff can increase the adhesion of cement gel in the concrete mix, in addition to the increase of durability and strength of the concrete structure. Kilic et al. (2009) pointed that volcanic tuff aggregate can affect the properties of the concrete in unit weight and strength if used in the mix, which will lead to a decrease in unit weight, with a remarkable increase in compressive strength.

Haddad and Shannag (2008) in their study for masonry cement for construction purposes, identify the optimum mortar mixes best suited to different masonry applications. The study indicated that masonry mortar mixtures proposed in this investigation met the European and American standard needs for water retention and air content. The use of hydrated lime in these mixes causes reductions in compressive strength and flexural strengths without developing an increase in the workability of the mix. The compressive strength test also indicated that masonry mortars, prepared as an aggregate to cement ratio equal to or less than 4 on a loose volume basis, can be successfully used for different masonry applications in Jordan. Considering shrinkage and volume stability and also economic feasibility, it was found that to use an aggregate cement ratio not less than 3.

Al-Zou'by and Al-Zboon (2014) studied the effect of the use of fine volcanic tuff on the characteristics of cement mortar. Fine volcanic tuff was mixed at ratios of 0, 25. 50, 75, and 100% with ordinary fine sandstone to form the mix of mortar. The samples were tested for compressive strength, flexural strength, and unit weight at 3, 7, 28, and 56 days. The compressive and flexural strengths had increased up to 75% through the use of fine volcanic tuff in mortar mix, and unit weight, as usual, was decreased with the increase of mixing ratio of fine volcanic tuff.

Balog et al. (2014) in the valorization of volcanic tuff in construction materials andmanufacturing industry, introduced the use of zeolitic volcanic tuffs as a local source for construction in the building materials industry for rock embankment, aggregate, for the preparation of mortar for masonry, and the production of lightweight concrete or autoclaved aerated concrete. The study was based on using the zeolitic volcanic tuff as a substitute for cement or aggregate. The study aimed to obtain a new building material made from local resources that can be used to realize new masonry works and to rehabilitate the old structures. Tests included physical properties of aggregate and compressive strength of mortar. The results showed that strength can be improved by using the volcanic tuff as fine and coarse aggregate materials for mortar construction. In addition, volcanic tuff has no production waste through mining, sieving, preparation, and during transportation for concrete block production or any construction and structural work (Al-Tabal and Al-Zboon, 2019), so it has no environmental impact on the surrounding environment and species during its production operations( Al-Tabal and Al-Zboon, 2012).

The current study aims to introduce the use of volcanic tuff as a construction material in the industry of block production by employing volcanic tuff materials in the form of powder, sandstone, and aggregate gradation in the concrete mix for block production. The size variations aim to notice an adequate improvement in compressive strength and decrease in the weight of block that met the acceptable allowable limits.

## 2. Materials and Methods

### *2.1 Materials*

A sufficient of grey-colored volcanic tuff material was obtained from Jabal-Alhala in Tafila governorate, south of Jordan.In addition to aggregate materials of screened crushed granular material consisting of well-graded gravel, crushed stone or crushed gravel for the use in concrete block production, and fine limestone powder materials. It is required to define the source area for the material sample and to describe the material by conducting physical tests (El-Hasan and Al-Tarawneh, 2019). Also, natural sources of materials can be helpful in the case of construction and concrete and mortar production, or rehabilitation of old and ancient sites. Abdelhadi et al. (2012) utilized El-Lajjun bituminous limestone ash in the rehabilitation works for the weathered and eroded mortar and plaster of Al-Shawbak castle in South of Jordan. The use of natural sources for construction materials adds sustainability, environmental, and cost effectiveness for construction process and operations.

*2.1.1 Material characterization and description*

Volcanic tuff from Jabal Al Halal is highly found as grey colored material with a thickness of more than 50m. The volcanic tuff in Jabal Al Halal location is of Paleocene to Neogene age (Gradstein, 2012). Limestone was obtained from a local quarry in Tafila. X-ray diffraction (XRD) spectra were used to characterize the volcanic tuff materials. Figure 1 illustrates the XRD spectra for the volcanic tuff sample.

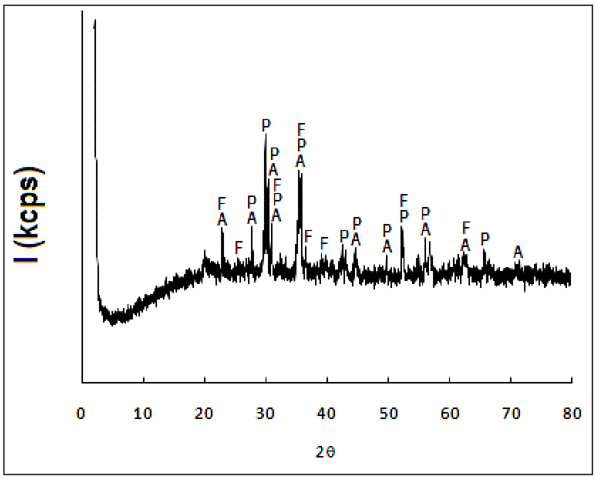


**Figure 1.** XRD spectra for Volcanic Tuff samples. Where A: Plagioclase feldspar (Anorthite), F: Olivine (Forsterite) and P: Pyroxene (Augite). Royal Society Laboratory, 2019.

***2.2 Methodology***

All materials were classified by sieve analysis using the sieve sizes that include sieve 3/8”, and the sieves # 4, No. 6, No. 14, and No. 40). The volcanic material was tested for specific gravity, absorption, and density. Ordinary limestone aggregate that is used in block production was obtained from Tafila crusher query for limestone, the aggregate is called Adasyiah (3/8”-No. 4 sieves), sandstone (swaileh), and fine lime (boudrah). Ordinary materials were tested for specific gravity, absorption, and density. Mixes were prepared in concrete technology laboratory using Ordinary Portland Cement type I (OPC-1) and distilled water at the designed ratio of volcanic tuff materials including 10, 20, 30, 40, 60, and 80%. Concrete samples and specimens were prepared using wooden molds of cubes (15 cm and 20 cm cubes) and solid block (10 cm and 15 cm solid block) and tested at 7, 14, and 28 days for mass (Kg) and compressive strength (N/mm$^2$). Also, density was calculated considering their mass and dimensions of specimens. Results were compared for mass, density and compressive strength.

Trial Mix #1 constitutes of concrete mixes for solid block molds and concrete cubes were prepared from the original materials (Adasyiah, Boudrah, and Swaileh) at the volume ratios (9:4:1.5 in volume) as the control mix sample, then it was tested for mass, density, and compressive strength of concrete and block specimens. Samples of fresh concrete molds were prepared according to the ASTM C 192/C 192M -00 and ASTM C 31 / C 31 M. Specimens were prepared in the lab in dimensions of concrete cubes: (150x150x150 mm) and (200x200x200mm) (Sarireh and Al-Baijat, 2019a), and in solid block molds: (400x200x100mm and 400x200x150mm). In mix #2 original Adasyiah was replaced by pozolanic (volcanic tuff) of the same aggregate size. Similarly, in mix #3 swaileh was replaced by pozolanic (volcanic tuff) of the same aggregate size. Mix #4 fine boudrah was replaced by pozolanic (volcanic tuff) of the same aggregate size.

As expected the use of pozolanic materials reduced the mass of specimens, as volcanic tuff has less density and specific gravity. Using Adasyiah size from Pozolana (Volcanic Tuff Aggregate) cause a decrease in mass in all specimens, followed by swaileh size from Pozolana (Volcanic Tuff Aggregate) to a lesser extent. A recommendation was made based on the obtained results.

*2.2.1 Volume relation and ratios*

Table (1) shows the volume relation between components of concrete mix for the block using ordinary and volcanic tuff materials and water-related to (OPC-1). Ordinary materials were replaced by volcanic tuff at (10, 20, 30, 40, 60, and 80%) ratios in the mix for concrete block production.

**Table 1.** The volume of ordinary and volcanic tuff materials related to cement volume.

| Material | Volume Ratio concerning cement volume |
|---|---|
| Ordinary Adasyiah (4-8 mm) | 4.2 |
| Tuff Adasyiah (4-8 mm) | Will be replaced on specific ratio (10, 20, 30, 40, 60, and 80 %) |
| Fine Tuff (4-0.075 µm) | Will be replaced on specific ratio (10, 20, 30, 40, 60, and 80 %) |
| Ordinary Swaileh | 2.2 |
| Ordinary Boudrah | 0.7 |
| Cement | 1 |
| Water | 2.3 |

## 3. Results

***3.1 Specific gravity, density and absorption of production materials***

Specific gravity and absorption of coarse aggregate that used is called (Adasyiah ) (4-8 mm particle diameter) were tested according to the AASHTO T 85. Specific gravity and absorption of fine aggregate (Boudrah, and Swaileh). (4-0.075 µm) were tested according to the AASHTO T 84-93 I and ASTM C 128-88. Table (2) presents the specific gravity and absorption of the tested materials. It is shown that volcanic tuff materials have less specific gravity than ordinary aggregate materials of Adasyiah and boudrah and swileh of the same size gradation.

The density of materials used in block production was determined for coarse aggregate according to ASTM C 127. Density for fine aggregate was determined according to ASTM C 128. Results of density showed that volcanic tuff materials have less density than ordinary material in the same size gradation, and the density decreases with the increase of aggregate size in both types of aggregates (Sarireh, 2017).

**Table 2.** Specific gravity, absorption, and density of materials in concrete and volcanic tuff block production.

| Materials | Bulk Specific Gravity | SSD Specific Gravity | Density (g/cm$^3$) | Absorption% |
|---|---|---|---|---|
| Ordinary Adasyiah (4-8 mm) | 2.453 | 2.587 | 1.29 | 5.48 |
| Tuff Adasyiah (4-8 mm) | 2.391 | 2.556 | 1.04 | 6.88 |
| Fine Tuff (4-0.075 µm) | 2.349 | 2.54 | 1.35 | 8.11 |
| Ordinary Swaileh | 2.615 | 2.653 | 1.68 | 1.42 |
| Ordinary Boudrah | 2.554 | 2.573 | 1.52 | 0.72 |

5 Mixes were prepared using ordinary and volcanic tuff materials as presented in Table (3) including the required mixes for block production to test mix and block properties.

**Table 3.** Concrete mix materials for block production

| Mix Type | | Components |
|---|---|---|
| Mix #1 control sample | | Original or ordinary materials (Adasyiah and boudrah and swaileh) |
| Mix #2 | | Pozolanic addasiah with ordinary materials of (boudrah and swileh) |
| Mix #3 | | Pozolanic Swaileh with ordinary materials of (Adasyiah and boudrah) |
| Mix #4 | | Pozolanic boudrah with ordinary materials of (Adasyiah and swileh) |
| Mix #5 Trial Mix | 1- rich cement-content | 50 kg of cement with volcanic tuff mixed on 10, 20, 30, 40, 60, and 80% of ordinary original materials on manual compaction |
| | 2- low cement-content with manual compaction | 33 kg of cement with volcanic tuff mixed on 10, 20, 30, 40, 60, and 80% of ordinary original materials on manual compaction |
| | 3- Low cement-content with VEBE compaction | 33 kg of cement with volcanic tuff mixed on 10, 20, 30, 40, 60, and 80% of ordinary original materials on VEBE compaction |

### 3.2 Results of concrete samples for block production

12 specimens were prepared for each mix (i.e. 12 molds and cubes). Then results were obtained at 28 days age of concrete samples to observe and test the concrete hardened properties.

#### *3.2.1 Mass of solid concrete blocks and cubes*

Figure (2) illustrates the results for the average mass of concrete and block specimens. Concrete block of mix #1 that was prepared using the ordinary aggregate materials (Adasyiah , swaileh, and fine boudrah at the volume ratios (9:4:1.5 in volume). In mix #2, ordinary addasyiah was replaced by volcanic tuff addasyiah, In mix #3, ordinary swaileh sand was replaced by fine volcanic tuff sand of similar size gradation, and in mix #4 ordinary fine boudrah was replaced by fine volcanic tuff of similar size gradation.

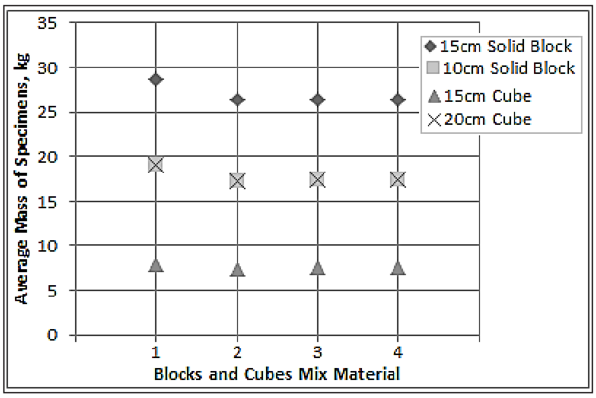


**Figure 2.** Mass of concrete cubes and solid block materials: Mix#1: Ordinary Materials, Mix #2: Pozolanic Addasiah, Mix #3: Pozolanic Swaileh, and Mix #4: Pozolanic Boudrah.

#### *3.2.2 Density of solid concrete blocks and cubes*

Concrete mixes were prepared in concrete cubes and solid block molds and cured until 28 days age (Al-Baijat and Sarireh, 2019a). Figure (3) illustrates the results of density (kg/m$^3$) for these samples. The results showed that pozzolanic or volcanic tuff can reduce the density of produced concrete block with lighter mass and weight. It is obvious the difference in results between original ordinary materials and volcanic tuff materials. But the use of Addasiah size volcanic tuff has the largest effect to give lighter material with lower density ranges between 2,150 to 2,200 kg/m$^3$ in mix #2. Then, mix #4 that used volcanic tuff boudrah instead of ordinary boudrah achieved an average density of 2250 kg/m$^3$. While the use of total swaileh as volcanic tuff in mix #3 achieved an average density of 2300 kg/m$^3$.While the average density for ordinary materials was 2350 kg/m$^3$.

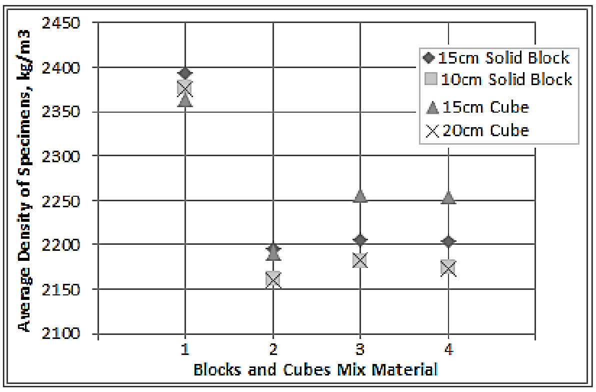


**Figure 3.** Density of block materials: Mix#1: Ordinary Materials, Mix#2: Pozolanic Addasiah, Mix#3: Pozolanic Swaileh, and Mix#4: Pozolanic Boudrah.

*3.2.3 Compressive strength of concrete blocks and cubes*

For compressive strength, specimens were prepared according to (BS EN 12390-2:2009) for making and curing specimens for compressive strength test, block specimens were prepared according to IS: 2185 (part-I) (1979-1987-1998) and IS : 2185 (part-II)- 1985 and tested according to (ASTM : C 140-03),and were tested according to (BS EN 12390-3:2009) for compressive strength of test specimens, and (BS EN 12390-4:2009) for compressive strength specification of test machines (Sarireh and Al-Baijat, 2019b). The results are presented in Figure (4). All specimens have achieved the required compressive strength of concrete block samples. It is showed that pozolanic of addasyah size and pozzolanic fine materials have the lowest compressive strength after 28-day. Pozolanic addasiah size has compressive strength in the range between 9 to 11 N/mm$^2$ in concrete block mix #2, and the pozolanic fine (boudrah size) material has the range of compressive strength of 9 to 12 N/mm$^2$ in concrete block mix #4. While the compressive strength of swaileh volcanic tuff has the range 10-14 Mpa in concrete block mix #3According to the term 603/2-Non-bearing block, the minimum compressive strength of block is 3.5 N/mm$^2$ (Technical Specifications for General Buildings, 1996).

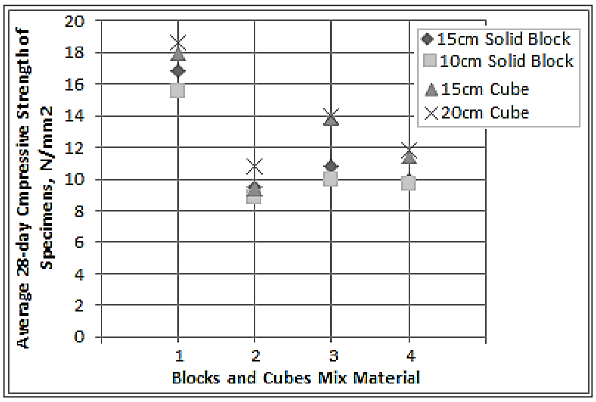


**Figure 4.** Compressive strength of block material: Mix #1: Ordinary Materials, Mix #2: Pozolanic Addasiah, Mix #3: Pozolanic Swailleh, and Mix #4: Pozolanic Boudrah.

***3.3 Trial mix with rich cement content and replacement ratios of original materials***

The mix was prepared by mixing (100) kg of block materials, with(20) Liter of water, and (50) kg of OPC-I. Pozolana (Volcanic Tuff) were mixed at 20, 30, 40, 60, and 80% replacing the original materials. And samples were formed in block molds of (400x200x100mm and 400x200x150mm), and in concrete cubes molds of (150x150x150 mm and 200x200x200 mm) (Al-Baijat and Sarireh, 2019b).

*3.3.1 Mass of solid concrete block and cubes*

As presented in Figure (5), the mass of the specimen was reduced by the increase of volcanic tuff (Pozolana) ratio in the concrete block mix. It is clear that the addition of volcanic tuff in replacing original materials, cause a decrease in the mass of specimens. But, the mass cannot be considered to judge the results because the specimens have different dimensions and shapes. So, in each mix or step the density will be considered for the judgement and compare with the control samples mix of ordinary materials that has 0-content of volcanic tuff. When volcanic tuff was used on 60-80%, the mass was decreased by 10-15% respectively compared to volcanic tuff of 10% replacement of ordinary.

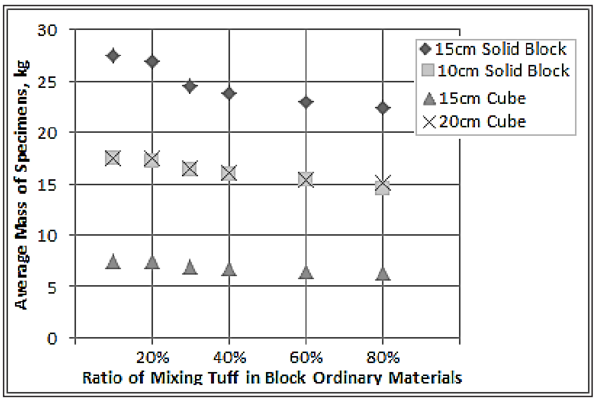


**Figure 5.** Mass reduction based on volcanic tuff ratios.

*3.3.2 Density of block specimens and concrete cubes*

Figure (6) presents the density (kg/m$^3$) of concrete specimens and block molds after pouring and casting in solid block molds. The addition of volcanic tuff to the concrete block mix will decrease the density, to reach the lowest density of 1857.7 kg/m$^3$ with the ratio of 80% of replacement. The reduction in density can reach 15.6% between 10% and 80% of volcanic tuff when used in material of concrete block production. Ordinary materials give an average density of 2,380 kg/m$^3$, compared to 1,900 kg/m$^3$ at 60%, and 1,800 kg/m$^3$ at 80%.

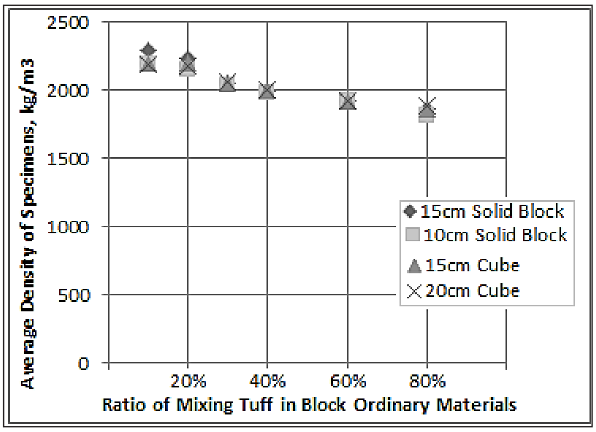


**Figure 6.** Density reduction based on volcanic tuff ratios.

*3.3.3 Compressive strength of block specimens and concrete cubes*

The specimens compressive strength of the mixes were prepared in block molds and cubes and tested after28-day age, results are presented in Figure (7). The addition of volcanic tuff decreases the compressive strength of concrete block mix at 28-day. The lowest value was obvious at an 80% replacement ratio, which can also be acceptable. 80% ratio can attain a compressive strength of range (6.5.5-8N/mm$^2$), and this result is acceptable for block production as the minimum value of compressive strength is 3.5 N/mm$^2$ for non-bearing block (Technical Specifications for General Buildings, 1996). Ordinary material gives an average compressive strength of 17.5 Mpa, while the compressive strength was reduced to 8.25 Mpa at 60%, and reduced to 7.5 Mpa at 80%, but still acceptable as discussed previously.

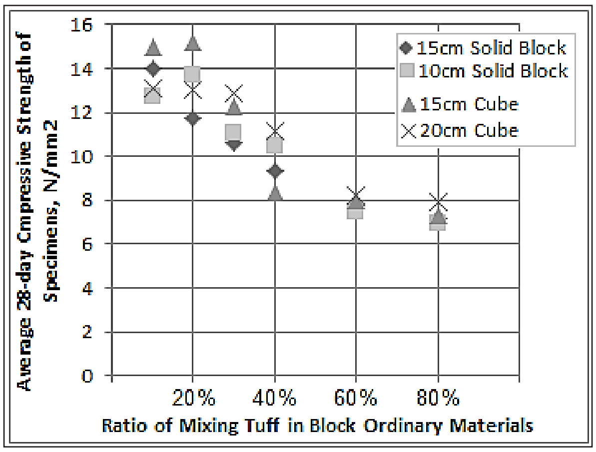


**Figure 7.** Compressive strength of block concrete specimens and cubes Mpa.

### *3.4 Trial mix with less cement content (Local Recipe) for local production plants*

The 2nd trial for block mixes was prepared by mixing of block original materials(100) kg with Volcanic Tuff (Pozolana) in ratios including 20, 40, 60, 80, and 100% and 33 kg of cement.The concrete mix was poured into block molds andcubes, also cured for 28-day age.

*3.4.1 Mass of concrete block and cubes*

Figure (8) presents the results of specimens' mass on the designed mixing ratios of volcanic tuff. The results showed a decrease in the mass of specimens with an increase of volcanic tuff mixing ratio in mix. A 25% reduction in mass can be attained at 80%, while a reduction of 31.25% can be achieved when using volcanic tuff on 100%.

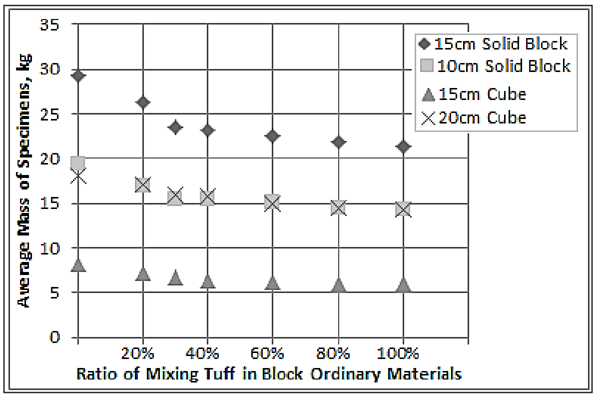


**Figure 8.** Mass of concrete block and cubes for volcanic tuff ratios.

3.4.2 Density of block and cube specimens

Figure (9) presents the values of density of concrete blocks and cubes using volcanic tuff materials in ratios for 10%-100% of production materials of blocks. The addition of volcanic tuff decreases the density of block density from 2400 kg/m$^3$ of original materials to 1800 kg/m$^3$ for 100% replacement. The ratio of 80% of volcanic tuff can reduce the density of block by 25% compared to original materials of zero content of volcanic tuff. While the use of 100% of materials from volcanic tuff can reduce the density of block by 29%. Ordinary materials give an average density of 2,380 kg/m$^3$, compared to 1,850 kg/m$^3$ at 60% and to 1,775 kg/m$^3$ at 80%. While the use of volcanic tuff materials by 100% reduced the density to 1,750 kg/m$^3$.

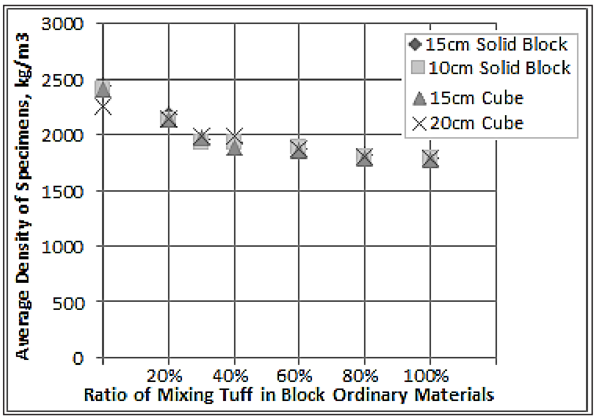


**Figure 9.** Density of concrete block and cubes for volcanic tuff ratios.

*3.4.3 Compressive strength of block and cube specimens*

Block and cube specimens were tested for compressive strength, the results are presented in Figure (10). The addition of volcanic tuff decreases the compressive strength of specimens. The least compressive strength of 100% replacement is equal to (5.5-7.25 N/mm2), although it is low it is still acceptable for a concrete block in construction (Technical Specifications for General Buildings, 1996). Ordinary materials give about 16 Mpa compressive strength, while the use of volcanic tuff materials by 60% reduced the compressive strength to7.35 Mpa, and to 7 Mpa at 80%. The use of volcanic tuff materials by 100% reduced the compressive strength to 6 Mpa, and this compressive strength is acceptable as discussed previously.

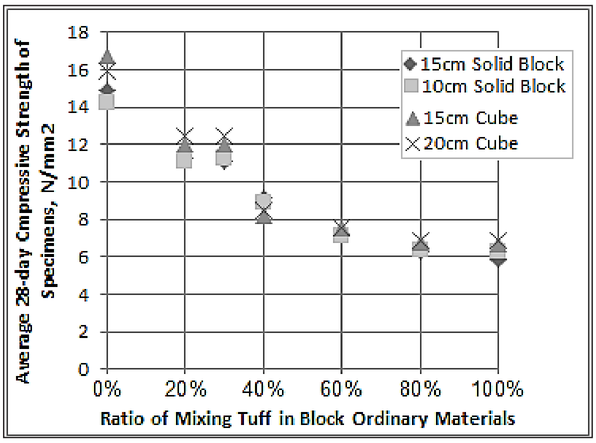


**Figure 10.** Compressive strength of concrete block and cubes for volcanic tuff ratios.

### *3.5 Preparation of block and cube specimens by VEBE-table for compaction*

Block sand cube specimens were prepared using the VEBE-table for compaction instead of a 16 mm – diameter compaction rod.

*3.5.1 Mass of concrete block and cube specimens*

Figure (11) presents the results for a mass of concrete specimens, although there is a decrease in mass with increasing mixing ratios. But the compaction using VEBE-table can increase and maintain specific mass for specimens compared to the similar ratio and shape of the specimen. i.e. VEBE compaction has a moderate slope of decreasing in mass. VEBE- table compaction can increase the mass of concrete cubes and solid block specimens made of original material by 20%, while it increased the mass of these cubes and specimens by 10-15% when volcanic tuff was used.

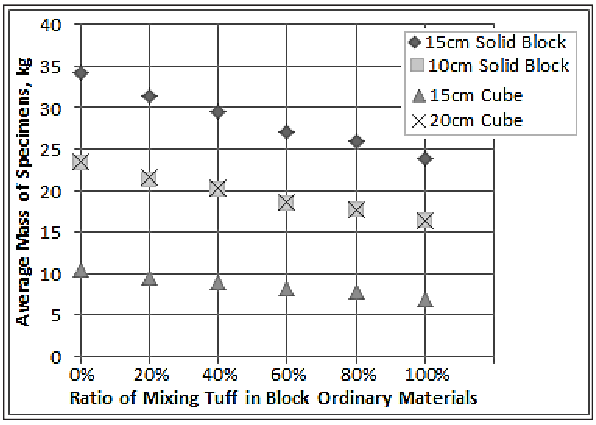


**Figure 11.** Mass of concrete block and cubes forvolcanic tuff ratios compacted by VEBE- table.

*3.5.2 Density of concrete specimens using VEBE-table*

Concrete block and cube specimens were prepared by compaction using VEBE-table to give more compaction for the density of specimens. Figure (12) presents the density test of concrete block and cube specimens compacted by VEBE-table. Results showed that the density of block materials can be smoothly decreased as the volcanic tuff is used and cause decreasing in density when mixed with original block materials. Using VEBE-table for compaction increased the density for original materials to 2,900 kg/m$^3$, while for 60% volcanic tuff the density was increased to 2,350 kg/m$^3$, and to 2,300 kg/m$^3$ at 80% volcanic tuff. While the use of volcanic tuff by 100% had increased the density to 2,000 kg/m$^3$.

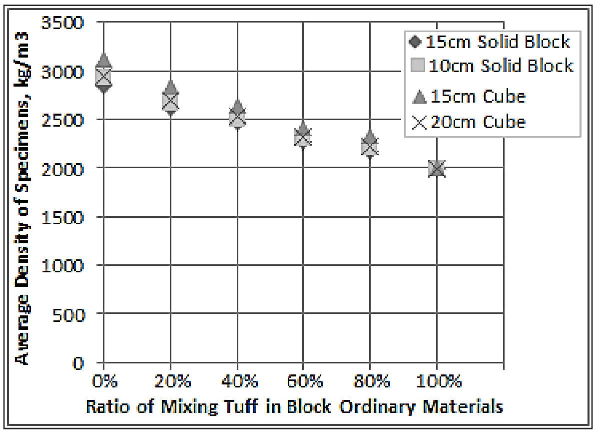


**Figure 12.** Density of concrete block and cubes for volcanic tuff ratios compacted by VEBE- table.

*3.5.3 Compressive strength of VEBE-table compacted specimens*

Figure (13) presents values of compressive strength for production materials of block compacted by VEBE-Table. The vibrated specimens by VEBE-table have cause an increase in compressive strength, even if volcanic tuff materials are used in 100% compared with compressive strength using original materials or any other ratio of volcanic tuff. The compaction effort by VEBE-table increases the compressive strength in a noticeable range. Ordinary materials increased the compressive strength to 22.5 Mpa when compacted by VEBE-table. Also, 60% as volcanic tuff increased compressive strength to 14 Mpa, and to 9.5 Mpa when used at 80%. The use of volcanic tuff by 100% increased the compressive strength to 8 Mpa. VEBE-table compaction can be effective in increasing compressive strength for block production.

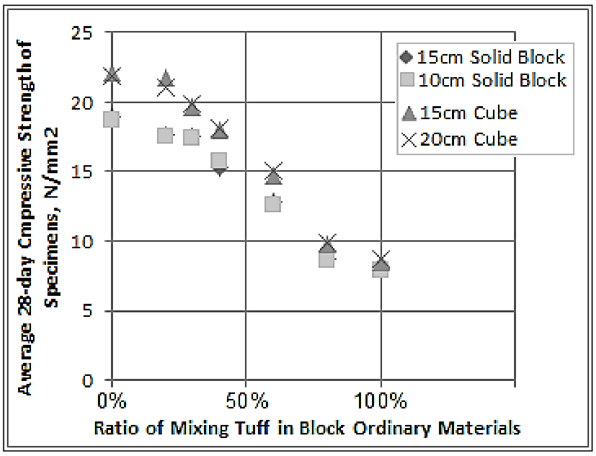


**Figure 13.** Compressive strength of concrete block and cubes for volcanic tuff ratios compacted by VEBE- table.

***3.6 Permeability of block materials using volcanic tuff***

Permeability of concrete block is another important test, Table (4) presents the values for permeability of waterfall for control specimens (ordinary block materials) and those of volcanic tuff based on designed mixing ratios with ordinary materials. Because of the higher porosity of volcanic tuff material, the block specimens of high mixing ratio have a noticeable and maximum waterfall and increase of seepage through volcanic tuff materials. Permeability increased when volcanic tuff used in concrete mix for block production, especially on 80-100%. While permeability seemed to be moderate when volcanic tuff was used on 60% in the concrete mix.

**Table 4.** Permeability of control sample and volcanic tuff samples

| Mix Sample | Water height (cm) | Water Fall (cm) | Average Water Fall (cm) |
|---|---|---|---|
| Control (Ordinary Materials) | 16.5 | 0.4, 1, 0.6 | 0.67 |
| 20% volcanic tuff | 16.5 | 0.2, 0.3, 0.5 | 0.33 |
| 30% volcanic tuff | 14.6 | 0.7, 0.5, 0.6 | 0.6 |
| 40% volcanic tuff | 16.4 | 0.7, 0.9, 0.6 | 0.703 |
| 60% volcanic tuff | 14.5 | 0.8, 1.2, 0.9 | 0.967 |
| 80% volcanic tuff | 14.5 | 3.35, 5.55, 3.4 | 3.43 |
| 100% volcanic tuff | 15.6 | 4.65, 5.75, 4.8 | 5.07 |

## 4. Discussion

In concrete and block production, the procedure of analysis implies comparing specimens based on mass, density, compressive strength, and permeability. Volcanic tuff materials were used as a total component of a specific size (Addesiah, Sweileh, and Boudrah) as prepared in mix #2, #3, #4 and compared to original materials in mix #1. Then, volcanic tuff was used on mixing ratios 10% to 80% and 100% of original materials. Also, cement was used on two contents; rich-cement content of 100 kg of cement, and low-cement content of 50 kg of cement with original and volcanic tuff materials at the specified mixing ratio. And finally, the low-cement content mix was prepared by VEBE-table compaction to study the effect of vibration on mass, density, and compressive strength.

The use of volcanic tuff in original material as whole or total part for specific size gradation such as (addasyiah, swaileh, and boudrah) in mix #2, #3, and #4 cause a decrease in mass and density of concrete blocks and cubes. The average density of samples of mix #2 was 2,175. For mix #3, the average density was 2,300. While the average density of mix #4 was 2,250. These values of density were compared to 2350-2400 kg/m$^3$ for ordinary materials.

Compressive strength had an average of 12 Mpa for mix#2, 10 Mpa for mix #3, and 11 Mpa for mix #4. While the concrete mix of ordinary materials had an average of 17.5 Mpa for compressive strength.

Then, volcanic tuff materials were used on mixing ratios consideringthe standard mix (rich-cement content), and the local mix considering(low-cement content). The rich-cement content mixes achieved density of 1,950 kg/m$^3$ at 60% and 1,900 kg/m$^3$ at 80%. While, the low-cement content mixes achieves less density of 1,900 kg/m$^3$ and 1,800 kg/m$^3$ at 60 and 80% respectively. Compared to ordinary materials that achieved 2,450 kg/m$^3$ and 2,380 kg/m$^3$ for rich-cement and low-cement contents for ordinary materials respectively. For compressive strength, rich-cement content mix achieves 8Mpa at 60%, and 7 Mpa at 80% compared to 17 Mpa for ordinary materials. The low-cement content mix achieves 7 Mpa at 60% and 6.5 Mpa at 80%, compared to 16 Mpa of ordinary materials.

Using VEBE-table for compaction, VEBE-table is used to measure the time and effort of compaction on concrete. Here it was used for compaction of specimens of low–cement content mix.VEBE-table raised the average density from 2,400 kg/m$^3$to 3,000 kg/m$^3$ for ordinary materials. While the average density of 60% volcanic tuff raised from 1,900 kg/m$^3$to 2,400 kg/m$^3$. For 80% volcanic tuff, the average density raised from 1,800 kg/m$^3$ to 2,300 kg/m$^3$.For 100% volcanic tuff, the average density raised from 1,750 kg/m$^3$ to 2000 kg/m$^3$.For compressive strength, VEBE-table increased strength from 16 to 21 Mpa of ordinary materials. For volcanic tuff, the compressive strength increased by VEBE compaction from 9.5 to 13.5Mpa, from 7 to 9 Mpa, and from 6 to 8 Mpa for 60, 80, and 100% respectively.

Based on the results of the current study; using volcanic tuff materials on specific mixing ratios in concrete block production can produce a lightweight concrete block that has an acceptable compressive strength. Also, volcanic tuff materials have less waste during miming and transporting, and has less cost for mining and production, which will save other resources such as limestone for other applications of concrete structures that require more density and compressive strength in its structural members such as columns, beams, and footings.

## Conclusions

Based on the results of the current study, the following are the main points that can be concluded in deep:

1-Volcanic tuff has specific gravity and a density less than that for traditional ordinary materials of the same size gradation used for concrete block production, so volcanic tuff can produce less mass and density of concrete and block construction. Also, volcanic tuff has an acceptable concrete compressive strength, and permeability value when it is used when compared with these values of ordinary materials.

2-Volcanic tuff materials have preferable application within production traditional original materials that give less mass for handling, transporting, and loading in concrete structures when used for block work in building and project construction.

3- Volcanic tuff materials can attain 10% less in density when used as a whole part replacement (addaseyah, swieleh, or boudra), and can attain 20% less density when used by80% in rich-cement content mix, and 26% less density in the low-cement content mix at 80% mixing ratio. Compaction by VEBE-table can increase density by 20%.

4- Volcanic tuff when was mixed as a whole part of specific size gradation (such as addaseyah, swaileh, and boudrah), attained 52-57% of 28-day compressive strength of ordinary materials. Also, the compressive strength of 80% volcanic tuff in the low-cement content mix, has the range of 40-45% of compressive strength for ordinary materials.60 and 80% volcanic tuff using VEBE-table compaction, can attain 45-55% of 28-day compressive strength of that for ordinary materials.

5- It is noticed that permeability of specimens increases with the increase of volcanic tuff ratio, this problem can be treated by using more of fine materials and more compaction. Also, concrete block walls usually are coated by plastering (rough and smooth plaster layers) during the construction of buildings.

6- It is recommended to use volcanic tuff in concrete block production for buildings and projects construction in country widely, as the materials can achieve the required density and compressive strength.

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