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Testing the Properties of Concrete Using Natural and Local Aggregates

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Abstract
The use of natural resources in concrete mix assured that they are environmental friendly and cost effectively and increasing material and structure durability. Even though, there are no plenty of structures were built using natural resources in concrete, but studies are in progress and different and there is a need for further studies and experimental works. This paper aims to use basalt aggregate to produce dense, high strength, and durable concrete compared to crushed limestone aggregate and rounded valley aggregate concrete. Results showed that the use of basalt aggregate improves concrete properties. An improvement in density is noticed to be about 5-8.7% more for all grades of concrete. The improvement in compressive strength of 15-40% more for different grades of concrete using basalt. And the improvement in tensile strength of 35-50% more, with an improvement of modulus of rupture of 11-17% on different grades of concrete. In addition to the improvement of permeability loads of 20% more when basalt aggregate is used in concrete mix. The statistical analysis showed that the properties of concrete are significantly different in their means when employing ANOVA analysis. As a result, the use of basalt in concrete mix shows a distinguished performance of concrete in fresh and hardened properties.
Keywords: *high strength; basalt; density; tensile, rupture; permeability; ANOVA*

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I. Introduction

Strength of material (ex. concrete) is based on the structure of the original material and components, such as the parent rock for the aggregate and the Portland cement type used in the concrete mix. Considering a specific water/cement ratio in addition to concrete mix components, high strength, high durability, and high quality concrete can be achieved through the use of natural sources of aggregate [1] and [2]. Concrete is the most desired material for construction, especially the high strength concrete that is required for casing of footing, columns, walls, slabs, and beams. Construction is seeking for the concrete strength on short and long time basis [3] and [4]. The use of admixtures and additives in concrete mix can improve concrete strength. The cementatius material content of 600 kg/m3 in addition to the admixtures and fillers enhance the concrete strength. High strength concrete can exhibit a strength of 100-120 Mpa. Also, the standards for specifications and tests should be reviewed to accommodate the use of the new material in concrete construction (high strength or performance concrete). The condition of design, mixing, and curing of high strength concrete should be prepared, handled, and examined to give the satisfying result of high strength, performance and durability of concrete [5]. The strength of the stone itself that comprises the most weight for concrete strength is not considered. Basalt stone can attain 150-170 Mpa in compression test, while limestone can attain 70-90 Mpa using 15 cm of stone cubes of both materials. While cement and sand cubes (6 cm) can attain 6 Mpa in the same test. As basalt has high soundness, low abrasion and absorption, it will add more than 30-35% for strength Also, density of concrete made of basalt will be around 2500 kg/m3, which is greater than of ordinary normal concrete. Basalt is found in Jordan, in Tafila area in plenty quantities, in Jurf Al-Daraweesh area [6]. The ordinary normal aggregate can be replaced by basalt aggregate in all sizes except for the size of sand and fine materials that are less than 2 mm. and all ingredients are mixed to produce concrete at 15, 20, and 25 Mpa grades. And the results of density, and strength of concrete is compared to that of crushed limestone aggregate (angular) and rounded or granular (Valley or Wadi aggregate) designed and tested at the same grades of concrete [7] and [8]. So, the use of different texture of aggregate sources can add more in concrete strength [9] and improve adherence of cement paste to the aggregate texture [10]. The benefits of high strength concrete are seen in improving durability and increasing the service life of the structure, decreasing maintenance cost and time of construction, and increasing space, span, and comfort in high rise buildings. Also it saves cement, aggregate, and other ingredients in the mix which contributes to sustainable development. Also it is a desire for shields, thin walls, and nuclear sites and plants for storage of waste and power against terrorist attacks and natural damages [11]. Normal concrete strength and high concrete strength. Were examined by heating concrete specimens up to 400, 600, 800, and 1200℃ and kept for 1 hour, then they tested for compressive strength and tensile splitting strength. The concrete specimens of high strength showed slightly better performance and less loss in its mechanical performance. The main function for fire resistance in concrete is to keep the heat from reaching the embedded reinforcement and to withstand against heating and cooling by water and still has the capacity to insulate reinforcement away from the effect of heating and cooling. [12]. So, durability of concrete could be improved when natural aggregate is used in concrete mix [13].

The current research presents the work in four sections start with the literature reviews of aggregate and concrete properties and its constituents, and the possible statistical comparison. The materials and methods are discussed according to the specifications for aggregate and concrete. The results are organized in the third section for the properties of concrete. And finally, the discussion and conclusions are organized in brief reading and summarizing for the results.

II. Materials And Methods

Exploratory work

Table 1 presents the X-Ray Fluorescence Analysis (XRF) for the basalt sample from Tafila area. The table shows the per cent of the oxides exist in the sample of basalt material.

Table 1. The XRF analysis for basalt oxides per cent content (Royal Scientific Society Labs, 2/2021)

Description: Basalt								
2/2021	MgO	Fe_2O_3	TiO_2	SiO_2	CaO	K_2O	P_2O_5	Al_2O_3
Result (%)	9.6535	11.6379	3.3584	38.7966	9.9000	0.7457	0.6679	10.7451

Figure 1 shows the X-Ray Diffraction Analysis (XRD) spectra for basalt. basalt is available in Tafila area in many continuous sites, Figure 2 represents the extent of basalt material in Tafila area.

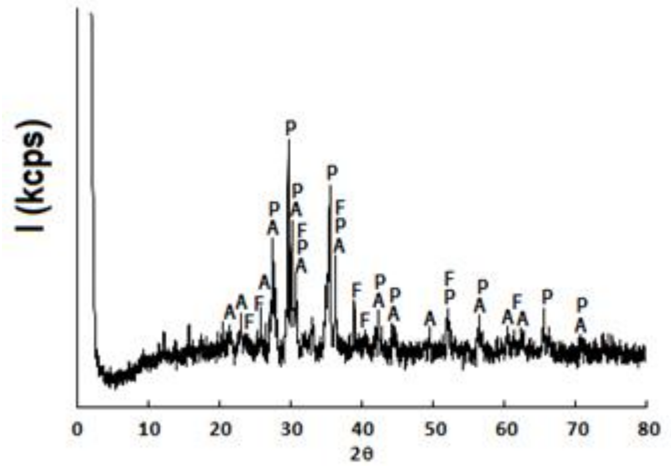

Figure 1. XRD spectra for Basalt, Where A: Plagioclase feldspar (Anorthite), F: Olivine (Forsterite) and P: Pyroxene (Augite) (Source: Royal Scientific Society Labs, 2/2021)

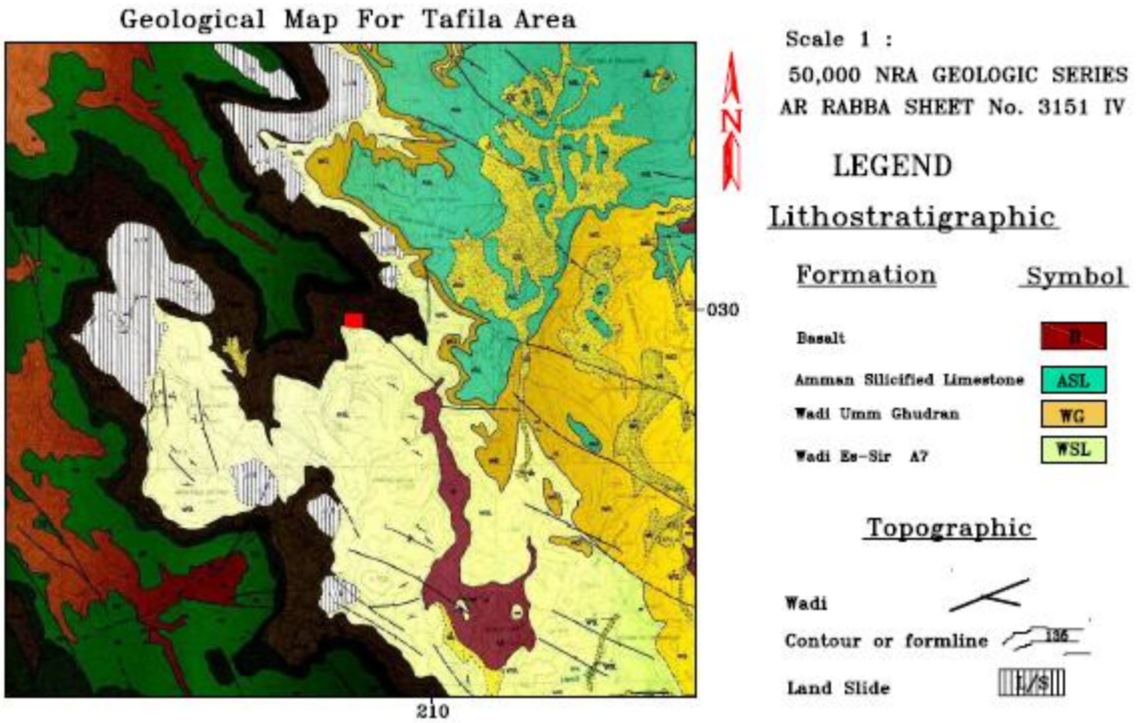

Figure 2. The extent of basalt in Tafila area (Source: Natural Resources Authority Maps in Jordan)

Basalt aggregate can be described by gray to black material in color, with specific gravity of 2.9 gm/cm^3 [11] as presented in Table 2 that explains the XRF for basalt sample which conforms with the analytical local sample from Tafila area presented in Table 1 earlier.

Table 2. Chemical composition of basalt
(Royal Scientific Society, 2/2021)

Compound	Percent
Silicon Dioxide	48
Alumina Oxide	14.4
Iron Oxide	15.1
Calcium Oxide	6.18
Magnesium Oxide	5.95
Sodium Oxide	4.05
Potassium Oxide	2.29
Titanium Oxide	2.29
Other Oxides	1.74

Also, moisture content test is conducted on basalt samples, and results are presented in Table 3. Basalt has a water content about 1.93% in average in its natural case. The value is less because basalt has a sound structure and impermeable texture that has less water absorption also. This property give basalt a preferable use in concrete as it needs less water content and less /c ratio for concrete mix and contributes in increasing strength parameters of concrete in general as basalt in the form of aggregate will occupy 70-80% of concrete volume in the structural elements.

Table 3. Moisture content for basalt samples from Tafila mining source

Sample	Description	mass of dish	total mass before	total mass after	mass before	mass after	water mass	% water content	% Average water content
2/2021	Basalt	3.001	169.21	165.94	166.2	162.9	3.27	1.97	1.93
		3.004	160.97	157.99	157.9	154.9	2.98	1.88	

Design of concrete mix

The proportional constituents of the materials used in the three grades of concrete mix 15Mpa, 20Mpa, and 25Mpa are presented in Table 4. The difference in constituents leads to the difference in the results of strength parameters such as compressive strength, tensile strength, modulus of rupture and permeability of concrete. 6 cubes are used to mold the concrete specimens for each test at 7, 14, and 28 days. All concrete specimens are kept in curing water tank for the required age of concrete in days until testing.

Table 4. Concrete mix design constituents

Concrete grade (Mpa)	Constituents content (kg/m^3)				
	Cement	Fine Sand	Medium agg.	Coarse agg.	Water
15	265	761	571	572	240
20	306	745	559	560	267
25	360	723	542	543	344

The calculations of the volumes and weighs of materials in the concrete mix are prepared according to its specific gravities of these materials for basalt, rounded valley and crushed limestone aggregates.

Testing of results of concrete tests

Means, standard deviations, and sum of squared errors are calculated in ANOVA analysis to test the significant difference in means [14] between the results of concrete samples. The analysis is successfully employed to test the effect of treatment (type of aggregate) on properties of concrete mix considering basalt, rounded valley and crushed limestone aggregates from Tafila area on the 15Mpa, 20Mpa, and 25Mpa.

Employing basalt aggregate in concrete

Basalt is sued as aggregate in concrete mix in designing the concrete mix the concrete grades that include 15Mpa, 20Mpa, and 25Mpa [15] in comparison with the concrete made of crushed limestone and rounded valley aggregates using the testing of significance of means differences for the parameters of concrete [16]. The required mechanical properties and size gradation were determined for crushed, round, and basalt aggregate according to [17] and [18]. Specific gravity values for coarse and fine aggregates were determined according to [19], [20], [17], [22], [22], {23], [4], and respectively. Absorption of aggregate was determined considering to [25], and [22]. Aggregate abrasion value was determined by Los Angeles in accordance with [26], and [27] as discussed in [28]. Also, [21] [29] are considered to determine the aggregate impact value. Most of tests for aggregate and concrete were covered in accordance with [26].

Table 5 presents the physical properties of aggregate of crushed limestone, rounded valley, and basalt aggregate. The physical properties included the bulk, saturated surface dry, and apparent specific gravities, in addition to the absorption, aggregate impact value, and aggregate abrasion by Los Angeles.

Table 5. Physical properties of crushed, rounded, and basalt aggregates

Aggregate		Physical Properties					
Type	Size	Specific Gravity			Absorption	AIV	Abrasion Los Angeles
		Bulk	SSD	App.			
Crushed	Coarse	2.635	2.67	2.72	1.267% 7.09%	24.9	28.78 18.56%
	Fine	2.53	2.54	2.55	0.28%	----	----
Rounded	Coarse	2.571	2.621	2.705	1.925% 6.84%	15.5	33.9 17.914
	Fine	2.52	2.53	2.55	0.14%	----	----
Basalt	Coarse	2.611	2.664	2.761	2.12%	21.22%	14.54
	Fine	2.62	2.38	2.39	2.8%	----	----

III. Results Of Concrete Tests

The employing and comparing of concrete strengths considering basalt, crushed limestone, and rounded valley aggregates are two targets were implemented during the experimental work in current research. This section presents the properties of the fresh and hardened concrete mixes that were made of different aggregate from local sources in Tafila area in the South of Jordan. The use of basalt as aggregate is examined in concrete mix at ratios of 0, 25, 50, 75, and 100%. The tests included the physical properties of basalt, chemical composition, permeability, compressive strength, modulus of rupture, tensile splitting [30].

Slump value

Table 6 presents the slump values for concrete types that were made using in crushed limestone, rounded valley, and basalt aggregates. Slump test was conducted according to the [31] and [32]. It is shown that the concrete made of basalt and crushed limestone aggregates has a close value of (155mm and 160mm), (150mm and 140mm) and (160mm and 150mm) for the 25, 20, and 15 Mpa concrete grades, respectively. While, the concrete that was made of rounded valley aggregate has a larger value of slump (175mm) and this is because this type of aggregate has less angularity and crushed faces than other aggregates and makes concrete more workable. Also, the slump is seen to be high in low grade of concrete and this because of the high w/c ratio in concrete mix.

Table 6. Slump values for basalt, crushed limestone, and rounded aggregates

Aggregate Type	Slump Value (mm)for Concrete Grade		
	Class 25	Class 20	Class 15
Basalt	160	150	160
Crushed	155	140	150
Rounded	175	160	180

Density of concrete

Figure 3 presents the density of concrete (kg/m^3) using basalt, crushed lime stone, and rounded valley aggregates for the 15 Mpa design grade of concrete. The basalt aggregate has the largest value of density averaging (2,520kg/m^3) compared to the density of concrete made of crushed limestone aggregate averaging (2,310kg/m^3) and (2,330kg/m^3) for that made of rounded valley aggregate.

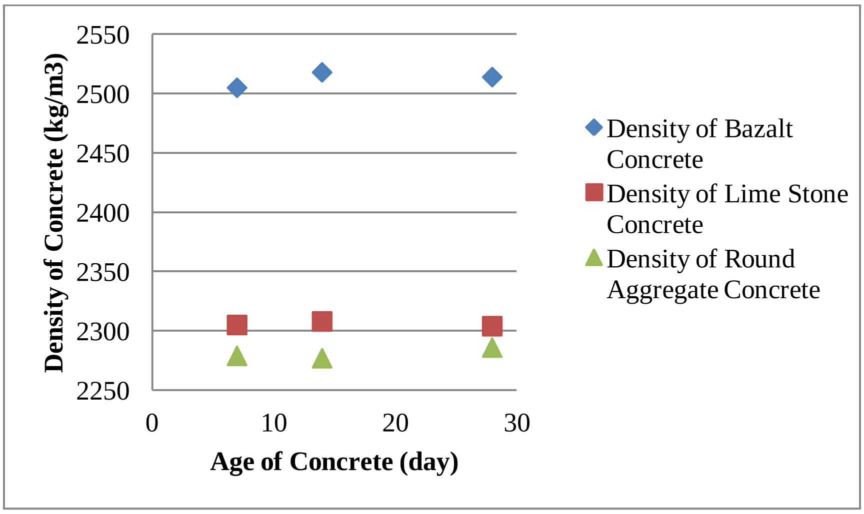

Figure 3. Density of 15 Mpa concrete (kg/m3) for basalt, crushed limestone, and rounded aggregate

Figure 4 presents the density of concrete (kg/m3) using basalt aggregate, crushed lime stone, and rounded aggregate for the 20 Mpa design grade. Concrete made of basalt aggregate has a largest density averaging (2,480kg/m^3), compared to the concrete made rounded valley aggregate averaging (2,374kg/m^3), and to that made of crushed limestone aggregate averaging (2,367kg/m^3). Usually, aggregate of higher specific density such as basalt makes concrete more dense.

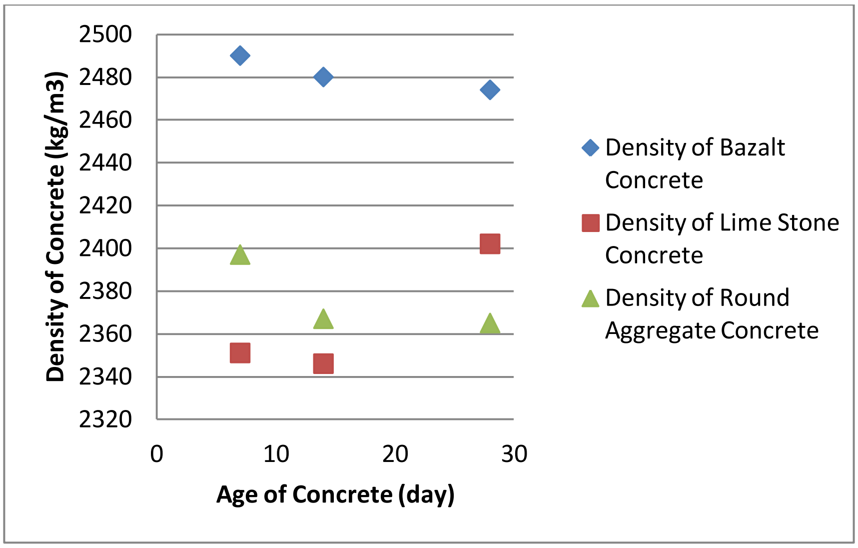

Figure 4. Density of 20 Mpa concrete (kg/m3) for basalt, crushed limestone, and rounded aggregates

Figure 5 presents the density of 25 Mpa concrete mix for basalt, crushed lime stone, and rounded aggregate. The concrete made of basalt has density of (2,475kg/m^3), compared to that made of crushed limestone aggregate (2,377kg/m^3), and that made of rounded valley aggregate (2,360kg/m^3). Also, higher grade of concrete has higher concrete density. In addition to the reason that the higher the density of the aggregate, the higher the density of concrete.

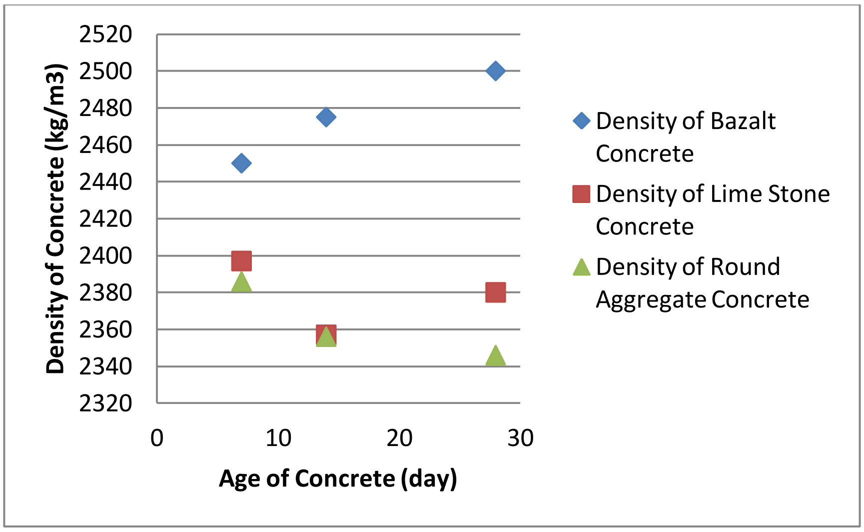

Figure 5. Density of 25 Mpa concrete grade using basalt, crushed lime stone, and rounded aggregates

Table 7 presents the results of the statistical analysis conducted using ANOVA analysis for the density of concrete at 28 days' age of concrete for the concrete samples of basalt, crushed limestone, and rounded valley aggregates. The results of analysis show that the difference in means of the density is significant for all grades of concrete that were tested in the current research. The type of aggregate affect the density as a main property of the concrete.

Table 7. Density of concrete made of basalt, rounded valley and crushed limestone aggregates

Age (days)	Basalt	Std.	N.	crushed limestone	Std.	N	rounded valley	Std.	N
					15Mpa				
28	2510	8.5	6	2305	12	6	2280	13	6
					20Mpa				
28	2475	12	6	2405	22	6	2362	14	6
					25Mpa				
28	2500	20	6	2380	28	6	2345	10	6

*28 days concrete age and concrete grade 15Mpa, for basalt, crushed limestone and rounded valley aggregates, the result is significant at $p < 0.05$.
*For basalt, crushed limestone and rounded valley aggregates at 20Mpa, the result is significant $p < 0.05$.
*For basalt, crushed limestone and rounded valley aggregates at 25Mpa, the result is significant $p < 0.05$.

Compressive strength of concrete

Figure 6 presents the actual strength gain by basalt aggregate at 15, 20, and 25 Mpa design grade for concrete mix during the age of concrete at the periods 7, 14, and 28 days. The compressive strength of concrete made of basalt aggregate is improving fast with the age of concrete in days.

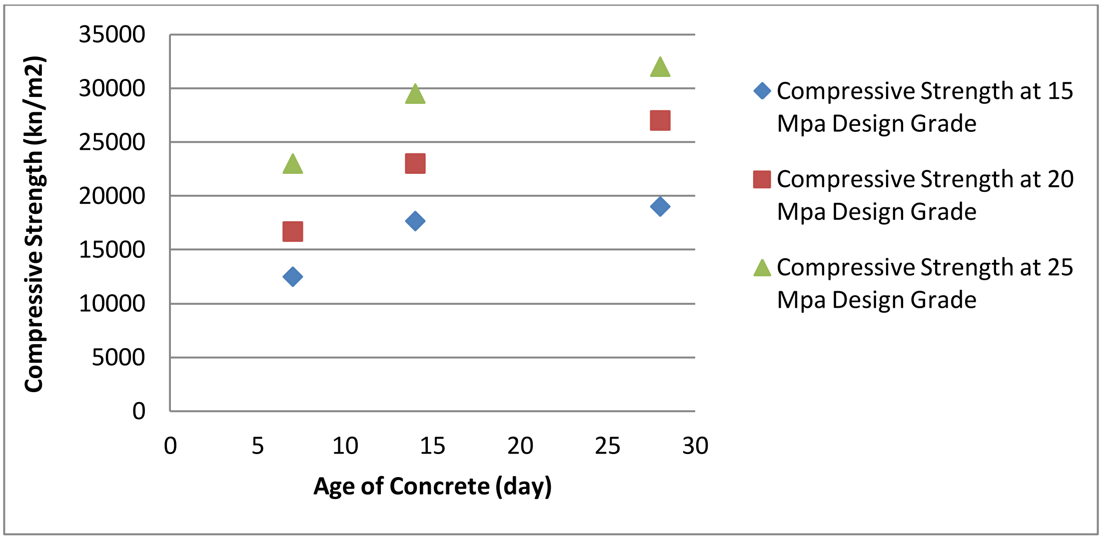

Figure 6. Compressive strength of basalt aggregate concrete at 15, 20, 25 Mpa design grade vs. age of concrete (days)

Also, figure 7 presents the specified design strength for basalt aggregate at 28 days for the 15, 20, and 25 Mpa design grade compared to the compressive strength of concrete made using crushed limestone and rounded valley aggregates. Basalt aggregate gives more concrete strength than crushed limestone and rounded valley aggregates as basalt has higher density and more soundness and less absorption and abrasion values when tested for physical tests.

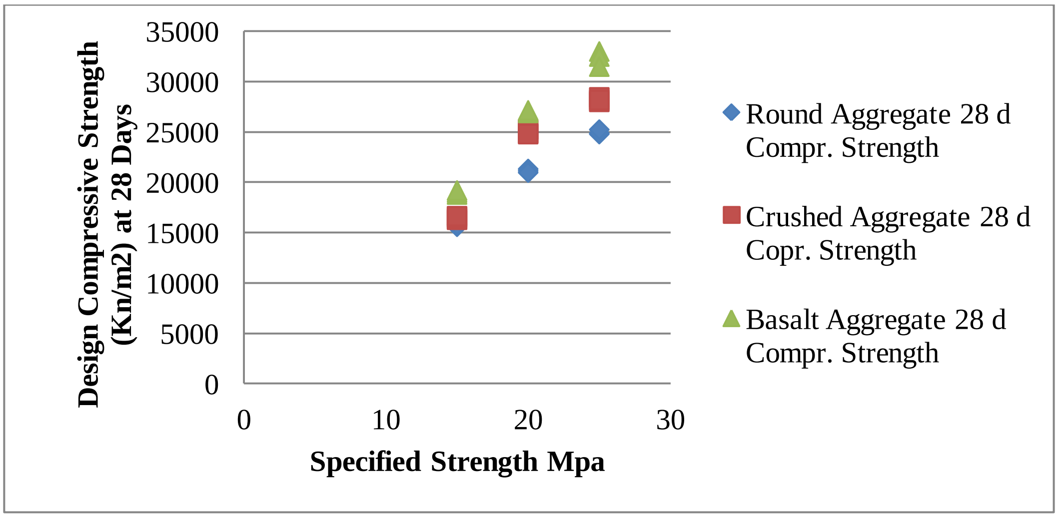

Figure 7. Compressive strength of basalt, crushed lime stone, and rounded aggregates

Table 8 presents the results of the statistical analysis of the compressive strength of concrete made of basalt, crushed limestone, and rounded valley aggregates at 28 days' age of concrete. The results that were obtained by ANOVA analysis showed that the difference in means of the 28-day compressive strength is significant for all grades of concrete that were tested in the current research.

Table 8. Compressive strength of concrete made of basalt, rounded valley and crushed limestone aggregates

Age (days)	Basalt	Std.	N.	Rounded valley	Std.	N	crushed limestone	Std.	N
				15Mpa					
28	21	0.32	6	16	0.33	6	18	0.12	6
				20Mpa					
28	28	0.27	6	21	0.28	6	24	0.31	6
				25Mpa					
28	32	0.27	6	26	.37	6	28	0.27	6

* 28 days concrete age and concrete grade 15Mpa, for basalt, crushed limestone and rounded valley aggregates, the result is significant at $p < 0.05$.
*For basalt, crushed limestone and rounded valley aggregates at 20Mpa, the result is significant at $p < 0.05$.
*For basalt, crushed limestone and rounded valley aggregates at 25Mpa, the result is significant at $p < 0.05$.

Tensile strength of concrete

Figure 8 presents the splitting tensile strength of concrete made of basalt, crushed limestone and rounded valley aggregates on the concrete grades 15, 20, and 25Mpa. The concrete made of basalt gains higher tensile strength of 2, 3, and 3.6Mpa at the concrete grades 15, 20, 25Mpa respectively. Compared to values of crushed limestone and rounded valley aggregates, basalt gains also higher tensile strength for concrete.

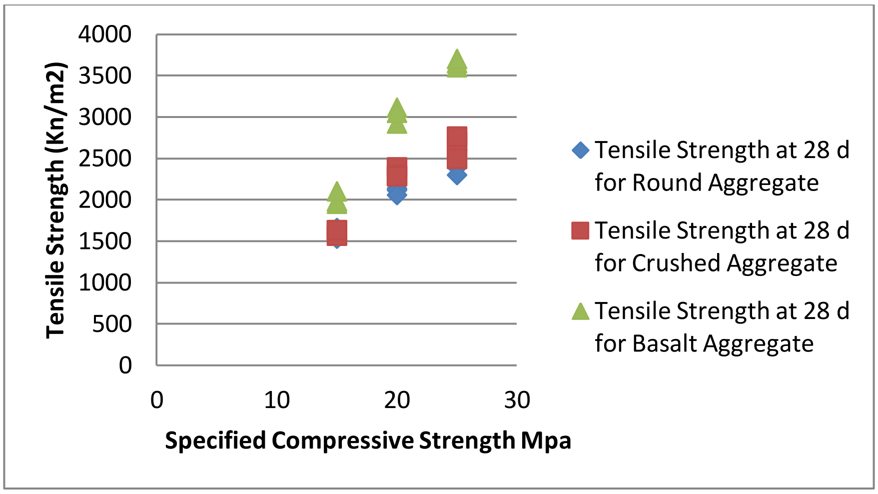

Figure 8. Tensile strength of basalt, crushed limestone, and rounded valley aggregates

Table 9 presents the results of the statistical analysis conducted by ANOVA for the tensile strength of concrete samples made of basalt, crushed limestone, and rounded valley aggregates. The results of statistical analysis showed that difference in means of tensile strength is significant. The type of aggregate and its properties is proposed to lead to the significant difference in concrete properties such as tensile strength.

Table 9. Tensile strength of concrete made of basalt, rounded valley and crushed limestone aggregates

Age (day)	Basalt	Std.	N.	crushed limestone	Std.	N	Rounded valley	Std.	N
				15Mpa					
28	2	0.12	6	1.75	0.08	6	1.6	0.111	6
				20Mpa					
28	3	0.10	6	2.4	0.14	6	2.2	0.07	6
				25Mpa					
28	3.6	0.14	6	2.7	0.09	6	2.3	0.13	6

* 28 days concrete age and concrete grade 15Mpa, for basalt, crushed limestone, and rounded valley aggregate, the result is significant at $p < 0.05$.
*For basalt, crushed limestone and rounded valley aggregate at 20Mpa, the result is significant at $p < 0.05$.
*For basalt, crushed limestone and rounded valley aggregate at 25Mpa, the result is significant at $p < 0.05$.

Modulus of rupture

Figure 9 presents the modulus of rupture of concrete for basalt aggregate at specified strength of 15, 20, and 25 Mpa at 28 days compared to crushed lime stone and rounded aggregate. The concrete made of basalt has modulus of rupture of 2.6, 3.2, and 3.7Mpa on 15, 20, and 25Mpa the grades of concrete respectively. these values are higher than those for concrete made of crushed limestone and rounded valley aggregates.

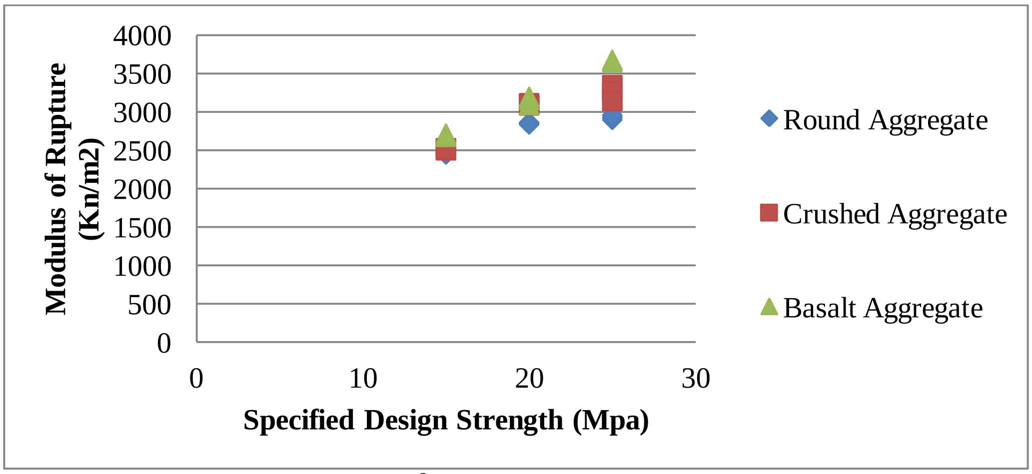

Figure 9. Modulus of rupture (kN/m^2) for basalt, crushed limestone and rounded aggregates

Table 10 presents the statistical analysis of modulus of rupture of concrete conducted by ANOVA analysis at 28 days results. The results showed that difference in means of the modulus of rupture is significant. The difference in aggregate type and its properties leads to the difference in concrete properties such as the modulus of rupture.

Table 10. Modulus of rupture of concrete made of basalt, rounded valley and crushed limestone aggregates

Age (day)	Basalt	Std.	N.	crushed limestone	Std.	N	rounded valley	Std.	N
				15Mpa					
28	2.7	0.23	6	2.6	0.15	6	2.5	0.17	6
				20Mpa					
28	3.2	0.12	6	3.15	0.18	6	2.8	0.21	6
				25Mpa					
28	3.7	0.16	6	3.3	0.11	6	2.9	0.21	6

* At all levels of treatments (age of concrete in days) and grade of concrete (15Mpa), for basalt, crushed limestone and rounded valley aggregate, the result is not significant at $p < 0.05$.
*For basalt, crushed limestone and round aggregate at 20 Mpa, the result is significant at $p < 0.05$.
*For basalt, crushed limestone and round aggregate at 25 Mpa, the result is significant at $p < 0.05$.

Permeability of concrete

Permeability test can be used as an indication for concrete durability. For each mix, three specimens were casted, cured and tested at the age of 28 days according to [33]. Impermeability of concrete surface and masses is an important characteristic, and it can affect the short- and long-term properties of concrete. Table 7 presents the permeability of Basalt concrete and ordinary crushed limestone aggregate as control sample, in addition to rounded valley aggregate. It can be clearly seen that concrete permeability was reduced by about 25% by using basalt aggregate in the concrete mix and can experience higher force of 219.4 kN. Also the results of statistical analysis conducted by ANOVA analysis for the force attained by concrete samples for permeability test have significant difference. As it is showed that the force attained by basalt is the largest value when tested for permeability.

Table 7. Permeability of basalt and rounded valley concrete vs. control sample of crushed lime stone concrete

Sample ID	Water Distance (cm)	Sample high (cm)	Force (KN)
Control Cube (crushed limestone)	4	14.2	176
Basalt	3.0	14.1	219.4
Rounded Valley	3.5	14.1	187

*Results are significant for the force attained by concrete samples made using basalt, crushed limestone, and rounded valley aggregates

IV. Discussion

The improving of concrete properties is an important step in improving the durability of concrete and the ability to hold loads and forces. Basalt aggregate has higher specific gravity and less absorption and AIV and abrasion. The improvement starts with the properties of concrete mix in fresh stage, slump is maintained at acceptable values of 160mm to attain acceptable workability of the concrete mix without losing strength in using basalt aggregate. Also, the improvement of density reaches 8.7%, 5%, and 5.2% for 15Mpa, 20Mpa, and 25Mpa respectively when basalt is used as coarse and medium aggregate in concrete mix. And the improvement in concrete compressive strength reaches 20-30%, 15-22%, and 30-40% for 15Mpa, 20Mpa, and 25Mpa respectively when basalt aggregate is used in concrete mix. And related to tensile strength the improvement in this property reaches 35%, 50%, and 40% at 15Mpa, 20Mpa, and 25Mpa respectively when basalt is used in concrete mix. And the modulus of rupture is improved by 12%, 11%, and 17% more at 15Mpa, 20Mpa, and 25Mpa respectively when basalt is used in concrete mix. Also the use of basalt aggregate in concrete mix helps concrete to hold 20% increase in load in case of permeability. Conducting statistical analysis by ANOVA analysis on the properties of concrete showed that the difference in means of density, compressive strength, tensile strength, modulus of rupture, and permeability is significant. The achieved properties of slump, density, in addition to the compressive, tensile, and rupture strengths and permeability enable the concrete mix of natural resources of basalt to be used safely in structural buildings. Results of basalt aggregate give more in comparison to crushed limestone and rounded valley aggregate.

V. Conclusions

The current research focuses on introducing the use of basalt aggregate as natural resource in concrete mix to improve its properties of concrete. Density, and strength parameters of concrete (compressive, tensile, and modulus of rupture), and permeability can be improved by using basalt aggregate.

1. Specific gravity and density of basalt aggregate are higher than that of crushed limestone aggregate.
2. The AIV and Los Angeles abrasion values were reduced by 25% for aggregate of basalt.
3. The density of basalt concrete mix is higher by 8.7%, 5%, and 5.2% for 15Mpa, 20Mpa, and 25Mpa grades of concrete than those of crushed limestone and rounded valley aggregate.
4. The strength of concrete exhibits an improvement for compressive, tensile, modulus of rupture, and permeability. The improvement in concrete compressive strength using basalt aggregate reaches 20-30%, 15-22%, and 30-40% for 15Mpa, 20Mpa, and 25Mpa respectively.
5. The improvement in concrete tensile strength reaches 35%, 50%, and 40% more at 15Mpa, 20Mpa, and 25Mpa respectively when basalt aggregate is used in concrete mix.
6. The modulus of rupture is improved by 12%, 11%, and 17% more at 15Mpa, 20Mpa, and 25Mpa respectively when basalt aggregate is used in concrete mix.
7. The permeability load, basalt aggregate can attain 20% more when used in concrete mix.
8. Testing of means of density, compressive strength, tensile strength, modulus of rupture, and permeability testing load showed that the difference in means is significant.

The results of current research showed an improving in the properties and parameters of strength of concrete without addition of admixtures that they are not available on local levels. It was indicated that the test procedures are correct and successful in measuring the properties and main parameters of aggregate and concrete. Statistical analysis that was conducted in current research by ANOVA analysis showed that the properties of concrete are significantly different between all the properties of concrete designed at the grades 15Mpa, 20Mpa, and 25Mpa.

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References

[1]. Al-Baijat, H., Sarireh, M. 2019-a. The use of fine blast furnace slag in improvement of properties of concrete. Open Journal of Civil Engineering, 9(2), 95-105.

[2]. Güçlüer, K. 2021. An investigation of the effect of different aggregate types on concrete properties with thin section and nondestructive methods. J. Engineering Research, 9(3B): 15-24.

[3]. Sarireh, M,.Al-Baijat H. 2019-a. Local aggregate in production of concrete mix in Jordan. Open Journal of Civil Engineering, 9(2), 81-94.

[4]. Poole, B.A., Sims, I. 2016. Concrete petrography, Second Edition, CRC Press.

[5]. Aitcin, P.C. 2004. Modern concrete technology 5, high performance concrete. Taylor and Francis E-Library,2004.

[6]. Al-Baijat, H. and Sarireh, M. 2019-b. Concrete properties using tripoli. Electronic Journal of Geotechnical Engineering, 24, 2019, Bund.2.
[7]. Al-Baijat, H., Sarireh, M. 2018. The use of basalt aggregate in concrete mixes in Jordan. Jordan Journal of Civil Engineering, 2(1); 2018.
[8]. Sarireh, M., Al-Baijat, H. 2019-b. Cement-tripoli admixture replacement in concrete mix. Electronic Journal of Geotechnical Engineering, 24, 2019, Bund.2.
[9]. Dong, Z., Keru, W. 2001. Fracture properties of high-strength concrete. J. Materials in Civil Engineering, 13(1): February 2001.
[10]. Vishalakshi, K.P., Revathi, V. & Sivamurthy, R.S. 2018. Effect of type of coarse aggregate on the strength properties and fracture energy of normal and high strength concrete. Engineering Fracture Mechanics 194(February): 52-60.
[11]. AGSCO Corporation, Technical Data, online website: http://catalog.agsco.com/Asset/ Basalt.pdf, accessed on Sunday 22/6/2014, 7:57 p.m.
[12]. Limbachiya, M.C., LeelaWat, T., Dhair, R.K. 2000. Use of recycled concrete aggregate in high-strength concrete. J. Materials and Structures, 33, November 2000: 574-580.
[13]. Binici, H., Sbah, T., Aksogan, O., Kaplan, H. 2008. Durability of concrete made with granite and marble as recycle aggregates. J. Material Processing Technology, 208(1): 299-308.
[14]. Ahmad, S., Alghamdi, S. A. 2014. A Statistical Approach to Optimizing Concrete Mixture Design. The Scientific World Journal, 2014.
[15]. Neville, A. M. 2011. Properties of Concrete. Pearson Education Limited Edinburgh Gate Harlow Essex CM20 2JE England.
[16]. Walpole, R. E., Myers, R. H., Myers, S. H., Ye, Keying 2007. Probability and Statistics for Engineers and Scientists. Pearson Prentice Hall, Upper Saddle River, NJ. USA.
[17]. BS 812 and ASTM C136. Mechanical properties of aggregate.
[18]. Sammy Y.N., Chan, G. P., John, K. W. 1996. Comparison between high strength concrete and normal strength concrete subjected to high temperatures. Journal of Materials and Structures, 29, December 1996:616-619.
[19]. ASTM C 127-84. Test for specific gravity and absorption of coarse aggregate.
[20]. Kodur, V.R.K., Sultan, M.A. 2003. Effect of temperature on thermal properties of high-strength concrete. Journal of Materials in Civil Engineering, 15(2): 101-107.
[21]. BS 812: Part 3, 1975. Testing aggregates. method for determination of mechanical properties.
[22]. ASTM C 128-84. Test for specific gravity and absorption of coarse aggregate.
[23]. ASTM C 127-88 Reapproved in 2001. Standard test method for specific gravity and absorption of coarse aggregate.
[24]. ASTM C128-12. Test method for density, relative density (specific gravity), and absorption of fine aggregate.
[25]. BS 8112: Part 107. Absorption of aggregate
[26]. BS 812: Part 113, 1990. Testing aggregates. method for determination of aggregate abrasion value, and BS EN 1097-8:2000.
[27]. ASTM C 131-81 and 06. Standard test method for resistance to degradation of small-size coarse aggregate by abrasion and impact in the Los Angeles machine.
[28]. Sarireh, M. 2020. Examining the suitability of tripoli as admixture in cement paste. International Journal of Construction Management. Accepted 2 November 2020.
[29]. Sarireh, M., Al-Sqoor, S., Ghrair, A.M., Al-Ahmer, A. 2021. Evaluation of the use of volcanic tuff in concrete block production. Jordan Journal of Earth and Environmental Sciences (JJEES), 16 March 2021.
[30]. Sidney M. 2008. Development in the formulation and reinforcement concrete. Wood head Publishing Limited, 2008.
[31]. BS 1881: Part 102, 1983. Testing concrete - method for determination of slump
[32]. BS EN 12350, 2-2000. Testing concrete. method for determination of slump.
[33]. JS 1652-8: 2004. Testing of concrete permeability.