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Testing of Rounded Valley Aggregate in Concrete Mix in Comparison with Crushed Limestone Aggregate

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ABSTRACT

Round valley aggregate RVA is a natural source of aggregate that is found in Tafila in Jordan. For current research, RVA from Al-Hasa valley was considered for testing with crushed limestone aggregate (CLA) from Karak and Tafila sources. 39 samples were collected through the valley at the joint with the lake of Al-Tanour Dam in Tafila. Samples of RVA and CLA were tested and concrete mix at 15, 20, and 25 MPa. ANOVA analysis was conducted to test means' differences in aggregate and concrete properties. Results showed that RVVA has no significant difference in means' properties. While RVA has significant differences when with CLA from Karak and Tafila. Results of ANOVA showed that there is a significant difference in the properties of fresh and hardened concrete for 15 and 25 MPa concrete grades. While significant difference is neglected for 20 MPa concrete grade. Consequently, RVA can be used for concrete mix as CLA.

Keywords: rounded valley aggregate, concrete mix design, density, strength

INTRODUCTION

Aggregate occupies 75% of concrete volume and gives volumes stability to concrete and responsible mainly for strength. Concrete mix in all its grades consumes crushed limestone aggregate (CLA) that mined in a continuous operation from local stations and plants in huge quantities and transported to farther sites, so rounded valley aggregate (RVA) becomes an important source for aggregate surface mining and concrete production [1]. The use of RVA is more economical and effective in achieving the desired concrete compressive strength and other properties of concrete. RVA is more effective in mining that has less production waste, and can be transported locally for short-trip distances. RVA has competitive properties such as the less absorption and less abrasion and more uniform fineness modulus.

The trials to improve concrete performance and quality are essential steps for the whole development of building and construction process through technology and materials to avoid overruns in time and cost [2]. The development process can be achieved through the development on cement the binder agent, natural and/or artificial fibers, or through the use of coarse and fine aggregates from new sources. The effect of mineralogical nature, and/or the effect of aggregate shape and texture are highly affect concrete properties. Several studies had showed that the effect of physical and mineralogical properties of aggregate, also affect directly the properties of some mixture types such as cementacious (cement and concrete) and asphaltic mixture [3, 4, 5, 6].

Even CLA contributes higher in concrete compressive strength, but RVA also contributes more in other properties of fresh concrete such as workability and considerable high slump value at low w/c ratio, and low water absorption [7] that will use less mixing water to improve compressive strength and other strength parameters of concrete. RVA can improve compressive strength, flexural tensile and splitting strengths when elaborated in laboratory conditions by (26%, 46%, 38%) respectively. And economically, RVA is cost less than crushed aggregate, so concrete produced will be cheaper [8].

The current study aims to test the use of RVA as a local construction material in concrete and construction industry through the elaboration of RVA properties according considering the specific size gradation that can suit different uses [9]. A comparable methodology for testing RVA and CLA is employed using ANOVA analysis for properties of aggregate and concrete mix. Specific gravity, absorption, abrasion, in addition to the fresh and hardened properties of concrete on 15, 20, and 25 MPa grades.

One-way ANOVA analysis can be employed with the purpose of comparing means of population of several independent groups or samples. Statistical parameters such level of significance alpha(α), degree of freedom, means standard deviations, and size of groups or samples are essential information in ANOVA test or analysis [10].

MATERIALS AND METHODS

Cement

According to [11], ordinary Portland cement type I (OPC-I) is used in normal applications for concrete production. Lafarge Cement Cooperation Factory in Tafila at South of Jordan produces cement and concrete for different uses and applications. The hydraulic (OPC-I) cement produced by pulverizing clinker primarily consisting of hydraulic calcium silicates, and containing one or more types of calcium sulphate as an interground addition. Also, blended cement refers to other materials which may be added or blended in the production of hydraulic cement. [12] uses the term for a hydraulic cement consisting of Portland cement and other appropriate of inorganic materials. Lafarge cement has the chemical analysis that is shown in Table 1.

Physical properties such as fineness of cement, soundness or expansion, and initial setting time of cement are presented in Table 2 for Lafarge cement that was used in concrete production.

Table 1. Chemical properties of ordinary Portland cement [11, 13]

Chemical requirements	Results	
	Min.	Max.
Ignition loss	0.89	1.94
Insoluble residue	0.49	1.7
MgO	1.83	3.83
SO_3	2.67	3.5
Chloride content	0.01	0.03
CaO	60.89	64.9
SiO_2	17.81	20.77
Al_2O_3	4.12	6.02
Fe_2O_3	2.97	5.44
K_2O	0.6	1.02
Free lime	0.75	2.56

Table 2. Physical properties of ordinary Portland cement [13]

Physical requirements	Results	
	Min.	Max.
Fineness (Blaine) (cm^2/g)	4188	5020
Soundness (expansion) (mm)	1.5	2.5
Initial setting time (min)	120	180

Mixing water

Mixing water is the tap water that is usually used in concrete mix depending on w/c ratio for specific concrete strength [14]. There is a relation between the 28-day compressive strength and w/c ratio that is highly affect the compressive strength of concrete [15].

Aggregate

Since aggregate composes about 75% of concrete volume, aggregate affects the properties of concrete [16]. The shape of aggregate affects concrete workability in fresh stage and compressive strength in hardened stage and finally durability of concrete [2]. Elongation flatness factors, shape factor, sphericity, and roundness are factors affect mostly concrete properties. The behavior of fresh concrete is measured by slump test and density of concrete. In addition to water and cement contents that affect concrete strength also [17].

Coarse and fine CLA were chosen to be transferred from local crusher-plants in Tafila and Karak at South of Jordan. Coarse and fine RVA were chosen from Al-Hasa valley at the point of intersection Al-Hasa valley with the lake of Tanour Dam at Tafila. CLA and RVA were separated to the coarse size of (19–10 mm) size ([18] and [19]. Medium size of CLA and RVA also selected from the same source of local surface mining plants in Karak and Tafila with the size of (10–4.75 mm) [20]. Natural fine sand was used in all concrete mixes of size gradation of (2.36–0.3 mm) [21]. Sieve analysis for coarse and medium aggregate and fine sand is covered by [22]. Concrete mix design and analysis were conducted in order to find the appropriate ratio of mixing materials of water, cement, and aggregate [23] and [24]. Table 3 presents the approximate concrete mix proportions in concrete mix design on 15, 20, and 25 MPa. Specific gravity was considered to calculate the volumes of aggregate of CLA and RVA.

Methods

Current research bases on testing the physical and mechanical properties of aggregate samples that were collected to produce concrete mix. CLA was collected from local crusher-plants in Tafila and Karak, and RVA was collected from AL-Hasa valley at the joint with the lake of Tanour Dam at Tafila. Aggregate tests included specific gravity, fineness modulus, absorption, and abrasion. Concrete tests included slump, density, compressive strength, tensile strength, and modulus of rupture. Means, standard deviations, and sum of squared errors were calculated in order to use ANOVA analysis test to evaluate the significance difference in means between properties of aggregate and concrete samples. ANOVA test for independent measures is designed to compare the means of three or more independent samples (treatments). The analysis can be successfully employed to test the effect of treatment on properties of aggregate and concrete mix considering CLA from Tafila and Karak, and RVA. The 15, 20, and 25 MPa grades of concrete mix were designed on the appropriate w/c ratio, cement content, and aggregate properties and its gradation for CLA and RVA. Concrete properties were tested on fresh-phase and on hardened phase at 7-, 14-, and 28-day [26] and [27]. Representatives of 39 samples of fine and coarse RVA were tested for specific gravity, abrasion, and absorption. Then samples of CLA and RVA were tested and compared using ANOVA analysis technique considering the three sources as levels of treatment [28]. ANOVA analysis can be applied successfully to predict differences in means of processes, operations, and products depending on levels of treatment [29] and [30].

RESULTS

Tests of fine aggregates

Dry specific gravity

Table 4 presents dry density values of fine RVA that were collected from left, middle, and right sides of valley through 13 stations in a total number of 39 samples. Results showed means, standard deviation, and required parameters to conduct ANOVA analysis. Results of ANOVA showed that samples of fine RVA are uniform, and there is no difference in dry specific gravity and the samples are representative.

ANOVA analysis was applied to test differences in the results of dry specific gravity of fine aggregate samples (RVA, CLA from Karak and

Table 3. Concrete mix proportions [25]

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

Table 4. Statistical analysis of dry specific gravity of fine RVA

Statistical parameters	Right	Mid	Left	Total
N	13	13	13	39
Σx	30.483	31.229	30.382	92.093
Mean	2.345	2.402	2.337	2.361
Σx2	71.56	75.093	71.075	217.727
Standard Deviation	0.083	0.079	0.077	0.083
Results Details				
Source	SS	df	MS	
Between treatments	0.033	2	0.017	F = 2.6
Within treatment	0.228	36	0.006	
Total	0.261	38		

* The f-ratio value is 2.6. The p-value is 0.0882. The result is not significant at $p < 0.05$.

Tafila), they are significantly different depending on their means, standard deviation considering significance level α = 0.05. Each type of aggregate can be used significantly in concrete mix production. So, the null hypothesis Ho that specifies (μ1 = μ2 = μ3) is rejected, and the alternate hypothesis Ha (μ1 ≠ μ2 ≠ μ3) is accepted. Results are shown in Table 5.

Saturated surface dry specific gravity

Table 6 presents the statistical parameters of saturated surface dry (SSD) specific gravity of fine RVA, 39 samples were collected from the valley for 13 stations on right, middle, and left sides of the valley. ANOVA analysis showed that there is no significant difference between SSD specific gravity of the fine RVA.

By applying ANOVA analysis to test differences in SSD specific gravity of fine RVA and CLA for Karak and Tafila, considering significance level α = 0.05, the null hypothesis H0 (μ1 = μ2 = μ3) is rejected, and the alternate hypothesis H1 (μ1 ≠ μ2 ≠ μ3) is accepted. Table 7 presents the statistical parameters for the three groups.

Apparent specific gravity

Table 8 presents the statistical calculations for the apparent specific gravity of fine RVA for the 13 stations (39 samples) that extended on the right, middle, and left sides of the valley. ANOVA analysis showed that the means of samples have no significant differences and all samples are representative to be used as fine RVA in concrete mix.

Also, differences between means of RVA and CLA were tested and results showed that considering significance level α = 0.05, each type of aggregate can be used significantly in concrete mix production. The null hypothesis H0 (μ1 = μ2 = μ3) is rejected, and the alternate hypothesis Ha (μ1 ≠ μ2 ≠ μ3) is accepted. Results are presented in Table 9.

Tests of coarse aggregate

Dry specific gravity

Table 10 presents data and test for dry specific gravity of coarse RVA that were collected from the valley. Coarse aggregates were collected and taken from aggregate passes 3/4” sieve size and retains on 3/8” sieve size. Results showed that there is no significant difference between means of samples collected and all samples are representative for coarse RVA to be used in concrete mix.

By applying ANOVA analysis on the three groups of coarse aggregate samples (RVA, CLA /

Table 5. Dry specific gravity of fine RVA and CL A

RVA			CLA /Karak			CLA /Tafila		
Average	Std.	N	Average	Std.	N	Average	Std.	N
2.361	0.083	13	2.664	0.076	10	2.566	0.065	10

Table 6. Statistical values of SSD specific gravity of fine RVA

Statistical parameters	Right	Mid	Left	Total
N	13	13	13	39
Σx	32.012	32.224	32.208	96.264
Mean	2.462	2.479	2.464	2.468
Σx2	78.868	79.898	78.931	237.696
Standard Deviation	0.059	0.042	0.043	0.048
Results details				
Source	SS	df	MS	
Between treatments	0.002	2	0.001	F=0.454
Within treatment	0.085	36	0.0024	
Total	0.088	38		

* The f-ratio value is 0.454. The p-value is 0.639. The result is not significant at $p < 0.05$.

Table 7. SSD specific gravity of fine RVA and CLA

RVA			CLA /Karak			CLA /Tafila		
Average	Std.	N	Average	Std.	N	Average	Std.	N
2.468	0.048	13	2.683	0.057	11	2.546	0.078	11

Table 8. Statistical data and calculation for apparent specific gravity of fine RVA

Statistical parameters	Right	Mid	Left	Total
N	13	13	13	39
Σx	34.442	34.290	34.578	103.310
Mean	2.649	2.638	2.660	2.649
Σx2	91.292	90.457	92.178	273.927
Standard Deviation	0.060	0.032	0.031	0.083
Results details				
Source	SS	df	MS	
Between treatments	0.003	2	0.002	F=0.222
Within treatment	0.26	36	0.007	
Total	0.263	38		

* The f-ratio value is 0.222. The p-value is 0.802. The result is not significant at $p < 0.05$.

Table 9. Apparent specific gravity of fine RVA and CLA

RVA			CLA /Karak			CLA /Tafila		
Average	Std.	N	Average	Std.	N	Average	Std.	N
2.649	0.083	13	2.694	0.071	11	2.676	0.079	11

Table 10. Statistical data and calculation for dry specific gravity of coarse RVA

Statistical parameters	Right	Mid	Left	Total
N	13	13	13	39
Σx	29.657	29.525	30.427	89.609
Mean	2.281	2.271	2.341	2.298
Σx2	67.742	67.067	71.606	206.415
Standard Deviation	0.084	0.032	0.181	0.118
Results details				
Source	SS	df	MS	
Between treatments	0.037	2	0.018	F=1.346
Within treatment	0.488	36	0.014	
Total	0.525	38		

* The f-ratio value is 1.346. The p-value is 0.273. The result is not significant at $p < 0.05$.

Table 11. dry specific gravity of coarse RVA and CLA

RVA			CLA /Karak			CLA /Tafila		
Average	Std.	N	Average	Std.	N	Average	Std.	N
2.298	0.118	13	2.645	0.079	11	2.506	0.068	11

Karak, and CLA /Tafila) as presented in Table 11, they are significantly different depending on their means, standard deviation, and size of samples considering significance level $\alpha = 0.05$. Each type of aggregate can be used significantly in concrete mix production. So, the null hypothesis H0 ($\mu1 = \mu2 = \mu3$) is rejected, and the alternate hypothesis Ha ($\mu1 \neq \mu2 \neq \mu3$) is accepted.

Saturated surface dry specific gravity

Table 12 presents the SSD specific gravity of coarse RVA that were collected from the valley. Results showed that samples' means are not significantly difference and all RVA are similar and representative to be used in concrete mix production.

Table 13 showed ANOVA analysis on the three groups of coarse aggregate samples (RVA, CLA /Karak, and CLA /Tafila). they are significantly different in means considering significance level $\alpha = 0.05$. Each type of aggregate can be use significantly in concrete mix production. The null hypothesis H0 ($\mu1 = \mu2 = \mu3$) is rejected, and the alternate hypothesis Ha ($\mu1 \neq \mu2 \neq \mu3$) is accepted.

Table 12. Statistical data and calculation for SSD specific gravity of coarse RVA

Statistical parameters	Right	Mid	Left	Total
N	13	13	13	39
Σx	30.558	30.412	31.274	92.244
Mean	2.351	2.339	2.406	2.365
Σx2	71.918	71.156	75.652	218.725
Standard Deviation	0.083	0.031	0.186	0.119
Results details				
Source	SS	df	MS	
Between treatments	0.033	2	0.016	F=1.157
Within treatment	0.509	36	0.014	
Total	0.542	38		

* The f-ratio value is 1.157. The p-value is 0.326. The result is not significant at $p < 0.05$.

Table 13. SSD specific gravity of coarse RVA and CLA

RVA			CLA /Karak			CLA /Tafila		
Average	Std.	N	Average	Std.	N	Average	Std.	N
2.365	0.119	13	2.663	0.076	11	2.556	0.073	11

Apparent specific gravity

Table 14 presents the apparent specific gravity of coarse RVA that were collected from the valley among 13 stations of overall 39 samples. Results showed that there is no difference between means of samples. So, samples of RVA are representative to be used in concrete mix.

By applying ANOVA analysis on the three groups of coarse aggregate samples (RVA, CLA /Karak, and CLA /Tafila), they are significantly different considering significance level α=0.05. So, the null hypothesis Ho (μ1 = μ2 = μ3) is rejected, and the alternate hypothesis Ha (μ1 ≠ μ2 ≠ μ3) is accepted. Table 15 showed the required results.

Fineness modulus of RVA

Table 16 presents the statistical calculations for the fineness modulus of the RVA for the 39 samples from the 13 stations that extend from right, middle, left sides of the valley. Results showed that fineness modulus has no difference between means of samples for RVA valley aggregate.

ANOVA analysis conducted on the three groups of coarse aggregate samples (RVA, CLA /Karak, and CLA /Tafila), they are significantly different considering significance level α = 0.05. So, the null hypothesis Ho (μ1 = μ2 = μ3) is rejected, and the alternate hypothesis Ha (μ1 ≠ μ2 ≠ μ3) is accepted. Table 17 showed statistical parameters for ANOVA testing.

Absorption of coarse RVA

Table 18 presents the statistical calculations for the absorption of the coarse RVA for the 13 stations that extend from the right bank to the

Table 14. Statistical data and calculation for apparent specific gravity of coarse RVA

Statistical parameters	Right	Mid	Left	Total
N	13	13	13	39
Σx	31.893	31.549	32.620	96.062
Mean	2.453	2.427	2.509	2.463
Σx2	78.343	76.604	82.391	237.338
Standard Deviation	0.092	0.056	0.212	0.138
Results Details				
Source	SS	df	MS	
Between treatments	0.046	2	0.023	F=1.222
Within treatment	0.678	36	0.019	
Total	0.724	38		

* The f-ratio value is 1.222. The p-value is 0.307. The result is not significant at $p < 0.05$.

Table 15. Apparent specific gravity of coarse RVA and CLA

RVA			CLA /Karak			CLA /Tafila		
Average	Std.	N	Average	Std.	N	Average	Std.	N
2.463	0.138	13	2.674	0.081	11	2.638	0.069	11

Table 16. Statistical data and calculation for the fineness modulus of RVA

Statistical parameters	Right	Mid	Left	Total
N	13	13	13	39
Σx	75.679	73.922	75.884	225.485
Mean	5.822	5.686	5.837	5.782
Σx2	440.863	421.792	443.047	1305.701
Standard Deviation	0.157	0.348	0.090	0.231
Results Details				
Source	SS	df	MS	
Between treatments	0.179	2	0.091	F=1.745
Within treatment	1.847	36	0.051	
Total	2.026	38		

* The f-ratio value is 1.222. The p-value is 1.892. The result is not significant at $p < 0.05$.

Table 17. Fineness modulus of coarse RVA and CLA

RVA	Std.	N	CLA /Karak	Std.	N	CLA /Tafila	Std.	N
5.78	0.23	13	5.26	0.19	11	5.842	0.18	11

mid of the valley and the left bank of the valley. ANOVA analysis showed that samples' means of absorption for rounded and crushed aggregate are not significantly different and can be used in concrete mix as representative sample.

Also, ANOVA analysis as conducted on the three groups of coarse aggregate samples (RVA, CLA /Karak, and CLA /Tafila) to test the absorption of coarse aggregate, they are significantly different considering significance level $\alpha=0.05$. So, the null hypothesis Ho ($\mu 1 = \mu 2 = \mu 3$) is rejected, and the alternate hypothesis Ha ($\mu 1 \neq \mu 2 \neq \mu 3$) is accepted. Table 19 showed the conducted results.

ANOVA analysis was conducted on the absorption of the three groups of fine aggregate samples (VA, CLA /Karak, and CLA /Tafila), they are significantly different considering significance level $\alpha=0.05$. So, the null hypothesis Ho ($\mu 1 = \mu 2 = \mu 3$) is rejected, and the alternative hypothesis Ha ($\mu 1 \neq \mu 2 \neq \mu 3$) is accepted. Table 20 showed the conducted results.

Table 18. Statistical data and calculation for the absorption of coarse RVA

Statistical parameters	Right	Mid	Left	Total
N	13	13	13	39
Σx	0.373	0.394	0.375	1.142
Mean	0.029	0.030	0.029	0.029
Σx2	0.011	0.013	0.0113	0.035
Standard Deviation	0.005	0.009	0.006	0.007
Results details				
Source	SS	df	MS	
Between treatments	0.000	2	0.000	F=0.233
Within treatment	0.002	36	0.000	
Total	0.002	38		

* The f-ratio value is 0.233. The p-value is 0.794. The result is not significant at $p < 0.05$.

Table 19. Absorption of coarse RVA and CLA

RVA	Std.	N	Karak CLA	Std.	N	Tafila CLA	Std.	N
0.021	0.007	13	0.023	0.0051	11	0.025	0.0046	11

Table 20. Absorption of fine RVA and CLA

RVA	Std.	N	Karak CLA	Std.	N	Tafila CLA	Std.	N
0.015	0.004	13	0.026	0.0046	11	0.027	0.0053	11

Aggregate impact value

Aggregate impact value test (AIV) [31] was applied on RVA and CLA of Tafila and Karak areas. Table 20 shows the statistical parameters of the test on types of aggregate. The means of the three groups of aggregate samples (RVA, CLA / Karak, and CLA /Tafila) are significantly different considering significance level α=0.05. So, the null hypothesis Ho (μ1 = μ2 = μ3) is rejected, and the alternate hypothesis Ha (μ1 ≠ μ2 ≠ μ3) is accepted. Results are presented in Table 21.

Aggregate abrasion

Aggregate abrasion is covered by [32] and conducted using Los Angeles machine. Test as applied on RVA and Karak and Tafila CLA. Table 22 showed the statistical parameters of the test. ANOVA analysis showed that the means of the three samples are significantly different considering significance level α=0.05. The null hypothesis Ho (μ1 = μ2 = μ3) is rejected, and the alternate hypothesis Ha (μ1 ≠ μ2 ≠ μ3) is accepted.

Concrete properties

Slump of concrete mix

Slump test is an important indicator on workability of concrete mix. The type and shape of aggregate have a great effect on mix workability. Slump test is applied under [33] specification. Table 23 presents slump value for RVA and CLA. ANOVA analysis showed that the means of the three samples of aggregate are significantly different considering significance level α=0.05. So, the null hypothesis Ho (μ1 = μ2 = μ3) is rejected, and the alternative hypothesis Ha (μ1 ≠ μ2 ≠ μ3) is accepted. Slump test was applied for 15, 20, and 25 MPa grades of concrete mix.

Density of concrete

Density of concrete is an indicator on the mass, weight, and strength of concrete. Density test is covered by [34]. density of concrete is measured on 7, 14, and on 28 day as shown in Table 23 for the concrete grades 15, 20, and 25 MPa. ANOVA analysis here is conducted on two-way of treatments that included the age of concrete and the type of aggregate. Results are significantly different for 15 MPa and 20 MPa. While the results are not significantly different for 25 MPa grade of concrete. Density of concrete gives significant difference considering the age of concrete and the type of aggregate. Table 24 showed the results of concrete density.

Compressive strength of concrete

Table 25 presents the compressive strength of concrete using RVA and CLA at 7-, 14-, and 28-day for the grades of concrete mix 15, 20, and 25 MPa. Compressive strength test is conducted according to [35]. Results of ANOVA analysis results showed that difference is significant for concrete compressive strength grades of 15 and 25 MPa. While difference is not significant in the compressive strength of crushed and round aggregate. The effect of age of concrete is significant for all grades of concrete. Also, grades of concrete gives significant difference considering type of aggregate for results.

Tensile stress of concrete

Table 26 presents the tensile stress of concrete using RVA and CLA at the main ages of concrete (7-, 14-, and 28-day) on concrete mix grades (15, 20, and 25 MPa). Tensile strength of concrete is conducted according to [36] for testing cylindrical concrete specimens by splitting. ANOVA analysis was conducted on two-way of treatment,

Table 21. AIV of Coarse RVA and CLA statistical parameters

RVA	Std.	N	Karak CLA	Std.	N	Tafila CLA	Std.	N
15.5	2.6	13	23	3.4	11	25	2.9	11

Table 22. Abrasion value of Coarse RVA and CLA statistical parameters

RVA	Std.	N	Karak CLA	Std.	N	Tafila CLA	Std.	N
18.5	3.7	13	27	3.4	11	29	4.1	11

Table 23. Slump value of concrete mix produced using RVA and CLA, statistical parameters

RVA	Std.	N	Karak CLA	Std.	N	Tafila CLA	Std.	N
15 MPa								
180	3.21	6	152	3,16	6	150	2.65	6
20 MPa								
165	3.2	6	144	3.35	6	145	2.07	6
25 MPa								
173	6.025	6	155	3.74	6	156	4.09	6

* For RVA and CLA at 15 MPa, the f-ratio value is 19.023. The p-value is 0.0024. The result is significant at $p < 0.05$.
* For RVA and CLA at 20 MPa, the f-ratio value is 77.055. The p-value is 0.000022. The result is significant at $p < 0.05$.
* For RVA and CLA at 25 MPa, the f-ratio value is 70.335. The p-value is 0.000031. The result is significant at $p < 0.05$.

Table 24. Density of concrete for RVA and CLA

Age (days)	RVA	Std.	N	Karak CLA	Std.	N	Tafila CLA	Std.	N
15 MPa									
7	2284	1.09	6	2296	10.15	6	2283	14.98	6
14	2282	16.12	6	2289	13.89	6	2279	26.21	6
28	2292	10.50	6	2294	4.51	6	2285	13.64	6
20 MPa									
7	2384	64.48	6	2398	11.59	6	2352	18.49	6
14	2368	13.69	6	2389	47.72	6	2346	57.14	6
28	2366	7.46	6	2394	57.81	6	2366	48.32	6
25 MPa									
7	2334	59.03	6	2384	27.39	6	2380	46.03	6
14	2358	21.04	6	2378	58.05	6	2357	68.47	6
28	2380	11.22	6	2361	24.54	6	2346	34.09	6

* At all levels of treatments (age of concrete in days) and grade of concrete (15 MPa), for RVA and CLA, the result is significant at $p < 0.05$.
* For RVA and CLA at 20 MPa, the result is not significant $p < 0.05$.
* For RVA and CLA at 25 MPa, the result not significant $p < 0.05$.

Table 25. Density of concrete for RVA and CLA

Age (days)	RVA	Std.	N	Karak CLA	Std.	N	Tafila CLA	Std.	N
15 MPa									
7	11	0.173	6	13	0.701	6	13	0.11	6
14	14	0.175	6	15	0.521	6	14	0.301	6
28	17	0.396	6	18	0.51	6	17	0.178	6
20 MPa									
7	14	0.138	6	16	0.551	6	14	0.18	6
14	18	0.476	6	21	0.34	6	19	0.143	6
28	22	0.229	6	25	0.666	6	23	0.175	6
25 MPa									
7	18	0.222	6	21	0.436	6	19	0.136	6
14	22	0.221	6	24	0.333	6	23	0.138	6
28	26	0.221	6	28	1.341	6	27	0.138	6

* At all level of treatments (age of concrete in days) and grade of concrete 15 MPa, for RVA and CLA, the result is significant at $p < 0.05$.
* For RVA and CLA at 20MPa, the result is not significant at $p < 0.05$.
* For RVA and CLA at 25MPa, the result is significant at $p < 0.05$.

and results showed that the difference is significant for the concrete grades 15 and 25 MPa. While, difference is not significant for results on the concrete grades. Difference according to the effect of age of concrete is significant for all concrete grades.

Table 26. Tensile strength of concrete made of RVA and CLA

Age (days)	RVA	Std.	N	Karak CLA	Std.	N	Tafila CLA	Std.	N
15 MPa									
7	1.19	0.05	6	1.35	0.05	6	1.27	0.045	6
14	1.51	0.032	6	1.71	0.05	6	1.64	0.064	6
28	1.68	0.068	6	1.98	0.032	6	1.82	0.068	6
20 MPa									
7	1.46	0.047	6	1.67	0.021	6	1.54	0.026	6
14	1.89	0.038	6	2.06	0.015	6	1.95	0.01	6
28	2.08	0.057	6	2.42	0.05	6	2.28	0.038	6
25 Mpa									
7	2.23	0.085	6	2.38	0.031	6	2.33	0.031	6
14	2.37	0.04	6	2.59	0.02	6	2.43	0.026	6
28	2.58	0.144	6	2.78	0.142	6	2.62	0.172	6

* At all levels of treatments (age of concrete in days) and grade of concrete 15 MPa, for RVA and CLA, the result is significant at $p < 0.05$.
* For RVA and CLA at 20 MPa, the result is not significant at $p < 0.05$.
* For RVA and CLA at 25 MPa, the result is significant at $p < 0.05$.

Table 27. Modulus of rupture of concrete made of RVA and CLA

Age (days)	RVA	Std.	N	Karak CLA	Std.	N	Tafila CLA	Std.	N
15 MPa									
7	1.99	0.032	6	2.19	0.023	6	2.09	0.042	6
14	2.35	0.038	6	2.7	0.031	6	2.53	0.046	6
28	2.62	0.04	6	2.91	0.081	6	2.76	0.015	6
20 MPa									
7	2.48	0.023	6	2.88	0.1	6	2.75	0.06	6
14	3.1	0.04	6	3.64	0.123	6	3.38	0.03	6
28	3.53	0.051	6	3.96	0.127	6	3.77	0.06	6
25 MPa									
7	4.01	0.127	6	6.09	0.17	6	5.94	0.25	6
14	6.62	0.24	6	7.06	0.199	6	6.79	0.12	6
28	7	0.52	6	8.1	0.22	6	7.05	0.18	6

* At all levels of treatments (age of concrete in days) and grade of concrete 15 MPa, for RVA and CLA, the result is significant at $p < 0.05$.
* For RVA and CLA at 20 MPa, the result is not significant at $p < 0.05$.
* For RVA and CLA at 25 MPa, the result is significant at $p < 0.05$.

Modulus of rupture

Table 27 presents the modulus of rupture for concrete using RVA and CLA on concrete mix grades (15, 20, and 25 MPa). Test of modulus of rupture for concrete was conducted according to [37]. ANOVA analysis applied on two-way process for the age of concrete and the aggregate type the concrete was made of. Results showed that the difference is significant for 15 and 25 MPa for type of aggregate. While, results are not significant for the concrete grade 25 MPa considering type of aggregate. And the effect of age of concrete, the difference is significant on the modulus of rupture for all grades of concrete.

CONCLUSIONS

According to ANOVA analysis that was conducted on the properties of RVA and CLA aggregate and on concrete mix, the study found that RVA has no significant difference on their aggregate properties or concrete properties. While the properties of RVA and CLA from Karak and Tafila sources are significantly different for fine and coarse aggregates. Results of slump value for fresh concrete mixes showed that there is significant difference between values of slumps on 15, 20, and 25 MPa grades of concrete. There were a significant difference in means for hardened concrete mixes for density, compressive strength, tensile stress, and modulus of rupture at 15 and 25 MPa concrete grades at 7, 14, and 28 day age of concrete. While, there is no significant difference between these properties at 20 MPa concrete grade.

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