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DEMOLITION AGGREGATE CONCRETE: MODELING AND OPTIMIZATION OF SOME SHORT TERM PROPERTIES

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ABSTRACT

Building waste becamea serious problem that forces the researchers and professionals to focus on its control. For this purpose, sustainable waste management strategies have been implanted to provide effective and efficientplans for waste collection, diversion and disposal, as well as its reusing.The recent work deals with using demolishing concrete waste as coarse aggregate in concrete for the purpose of reduction the natural resource exploitation and associated costs, as well as minimization waste landfill. A 2-operating parameter central composite design (with 2*2=4 factorial points, 2*2 star-points and 2 repetitions of central point) was adopted to optimize and model the impact of demolition aggregate content (8.6-86.4) wt.%, and water/cement ratio (0.43-0.57) for concrete contain demolishing components as coarse aggregate on compressive strength and density. Water absorption characteristics were also investigated. Conventional concrete specimens were prepared and tested for comparison purposes. The results obtained confirmed that the incorporation of the demolition aggregate resulted in decreasing concrete density and water absorption capacity. The model analysis results approved that concrete with lower density and water absorption, and superior compressive strength of 49.70MPa could be manufacturedusing demolishing concrete as coarse aggregate up to 49.3 (wt. %) atwater/cement ratio 0.49.

KEYWORDS: Demolishing concrete, Demolition aggregate, Demolition aggregate concrete, Modeling, Optimization.

I. INTRODUCTION

The increase economic growth and the expansion of urban areas resulted in significant increasein the demand for concrete which became the main material in buildings construction all over the world. However, concrete production consumes a large amount of natural raw materials and energy which haslead to a direct impact on energy consumption, environment and economy, in addition to generating millions of tons of waste concrete every year. The concrete waste isgenerated due to demolition of old structure, destruction of buildings and structures during earthquakes and wars,removal of useless concrete from structures, buildings, road pavements anddestructive testing for concrete specimens[1-3]. To solve the problem of concrete waste, environmental management plans have been established,and researches have been conducted to obtain the best and most promising techniques to restore and reuse building waste [4, 5].

Although reusing and/or recycling of concrete materials arecentral itemsof waste management hierarchy, however, they cannot be applied easily from technical or economical points of view [6]. Therefore, maximizing the lifespan of concrete structures and minimize the waste from concrete structures is considered of top most priorities.

Demolishing concrete wastes are heterogeneous materials. They consist of a high percentage of inert material, as brick, sand and concrete, other constituents are present in smaller amounts including metals, wood, gypsum, papers, glass, and plastics [7]. Without any processing, construction and demolishing concrete have been used for road construction, fill and raising areas, bank protection, noise barriers and embankments [8].

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The most environmentally favorite method for managing concrete and demolition waste is recycling concrete rubble as aggregates. However, in establishing a recycling program, the most important step is finding a market for a recycled waste product. Demolition aggregate (DA) or recycled concrete aggregates (RCA) found a potential use ingeotechnical applications, such as filling materials and in unbound pavement layers [9]. Also, they are used in base or sub base road construction [10].RCA generally consists of natural coarse aggregate and adhered mortar which makes it porous, inhomogeneous and less dense [11]. It was reported that volume of residual mortar in recycled aggregate varies from 25% to 60% according to the size of aggregate [12]. For particle size range from 20 to 30 mm, it was demonstrated that around 20% of cement paste is found attached to the surface of recycled aggregate [13].

Processing the demolition concrete needs a preliminarycleaning stage through separation to eliminate impurities e.g. wood, plastic, gypsum, and paper. Removing of steel and iron is conducted usually by magnetic separation. Crushing is carried outafterwards to reduce the debris dimensions to achieve the required grading. Washing stage may be done; nevertheless, washing is not common owing to the difficulties of disposal the mud produced[14].

On the other hand, it has been demonstrated that quality of the recycled concrete aggregate depends on the content of the porous and cement mortar attached to the recycled aggregate [15].Therefore, enhancing the properties of RCA can be performed by removing and strengthening the adhered mortar[16].It was noted thatparticlebreakageof recycledconcreteaggregatedepends on differentfactorsmainlyparticle size, and particleshape. It wasdocumentedthatbrittleconstruction and demolitiongranularmaterialswithhigherdegree of sphericity and lowerflakiness index would show higherresistance to breakage[17]. Various mineral dressing operations for improving the quality of recycled aggregate by removing the attached cement paste have been developedand documented [16, 18].

Considerable research work has been carriedout up to date to evaluate the possibility to replace cement [19], natural fine and/ or coarse aggregate in concrete [20-26]. However, dearth of investigations on incorporating aggregates from demolished wastes in Kurdistan region of Iraq. Thus was the reason to carry out the present work.The emphasis is on the assessment of the influence of demolished aggregates on some short term properties of concrete, more particularly, the compressive strength, density and water absorption. The impact of the demolition aggregate content and water/cement ratio on demolition aggregate concrete properties is studied, modeled and optimized using Response Surface Methodology.

II. MATERIALS & METHOD

1. Materials

Ordinary Portland Cement and conventional aggregates were purchased from Soran local market. Demolished aggregates were prepared by grinding demolished concrete blocks collected from landfill sites in Soran city-Kurdistan region of Iraq. The demolition concrete was crushed, then similar to the grading of conventional aggregates, they were screened by means of sieve analysis and used as standard coarse aggregates with grading (4.75-20) mm. Tap water was used for preparation the concrete pastes.

2. Methodology

Response Surface Methodology (RSM) isused to investigate the interaction between several illustrative variables and one or more response variables. The process of RSM includes designing of a series of experiments for sufficient and reliable measurement of the response and developing a mathematical model of the second order response surface with the best fittings. The Software portable stat graphics centurion 15.2.11.0.exe was used to analyze the data. The mathematical empirical model is defined as:

$$Y = \beta_0 + \beta_1\chi_1 + \beta_2\chi_2 + \beta_{11}\chi_1^2 + \beta_{22}\chi_2^2 + \beta_{12}\chi_1\chi_2 \qquad (1)$$

Where: Y: is the response or dependent variable; χ_1 and χ_2 are the independent variables; and,β_0,β_1. β_2. β_{11}. β_{22}. $\beta_{12}$are the regression coefficients.

The analyses of variance (ANOVA) are used to determine significant differences between the effects of independent variables ($p<0.05$). Pareto chart is used to identify the impact level of the independent variables on each considered response. The vertical line (significant front) in Pareto chart determines the effects that are statistically significant at 95% as confidence level. Main Trends and Surface Response, as well as the empirical

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regression model can be used to optimize the dependent parameter (responses). RSM was used to modeling and optimization the effect of replacing the conventional coarse aggregate by demolished aggregate on compressive strength and density. Details on using RSM in processes design are highlighted in literature [27, 28].

3. Experimental Design

A 2-factorial central composite design (with 2*2=4 factorial points, 2*2 star-points and 2 repetitions of central point) was adopted to study the effect of demolition aggregate (DA) content and water/cement ratio of demolition aggregate concrete (DAC) as independent variables using RSM software. The experimental design including the coded and actual levels of the independent variables is presented in Table 1.

Table1.The experimental design including the coded and actual levels of the independent variables

Coded level	-α	-1	0	1	+α
Water / Cement	0.43	0.45	0.50	0.55	0.57
Demolished Coarse Aggregate Content (wt. %)	8.6	20	47.5	75	86.4

Exp. No.	Water/Cement	Demolished Coarse Aggregate (DA) Content (wt. %)
1	0.5	86.4
2	0.45	75
3	0.45	20
2*	0.5	47.5
6	0.57	47.5
7	0.43	47.5
8	0.55	75
9	0.55	20
10	0.5	8.6
11	0.5	100
2* : The two repetitions of central point (experiments 4 and 5)		

4. Preparation of concrete mixes

Demolishing concrete was collected from Soran city (Delizian site) all from the same place which was deconstructed before a year. The demolished concrete blocks were broken, crushed and sieved. The shape of the crusheddemolitionaggregatewasgenerallyirregularowing to contain a sizeablelevel of oldmortarlayerattached to virginaggregate. The fraction matched with the standard size of coarse aggregate (the fineness falls within the grading limits for coarse aggregate) was separated by sieving and used in different concrete mixes according to the experimental design based on standard procedure. For each experiment nine cubes (3 cubes for each test) were prepared.The concrete mix proportionused was (1.15: 2.3: 4.6).

The cement was mixed with the aggregate; water was then added and mixed with the other constituents of the mix. The concrete slurry was compacted in three layers in steel molds which were cleaned and oiled properly. The specimens were de-molded after 24 hours and placed in the curing tank at ambient temperature for curing to 28 days.Figures 1 and 2 show a typical concrete mix, and the casted cubes respectively. Table 2 listed the concrete mixes constituents.

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Table 2.The mix proportions of the concrete mix constituents

Exp. No.	Water/Cement	Demolition aggregate (DA) (wt.%)	Water (ml)	Cement (kg)	Demolition aggregate (DA) (kg)	Natural coarse aggregate (kg)
1	0.5	86.4	2300	4.6	16	2.50
2	0.45	75	2070	4.6	13.8	4.6
3	0.45	20	2070	4.6	3.68	14.72
*2	0.5	47.5	2300	4.6	8.74	9.66
6	0.57	47.5	2622	4.6	8.74	9.66
7	0.43	47.5	1978	4.6	8.74	9.66
8	0.55	75	2530	4.6	13.8	4.6
9	0.55	20	2530	4.6	8.74	14.72
10	0.5	8.6	2300	4.6	1.5	16.82
11	0.5	100	2300	4.6	18.4	0

2*: Two central points; experiments 4 and 5, α is the (axial distance) =$\sqrt[4]{2^k}$, k is the number of orthogonal design variables (in this case, k=2).

5. Initial and Total Surface Water Absorption

The initial and total surface water absorption test was conducted on the 28 days cured specimens by drying the specimens at 110°C until the mass became constant, then following the change in weight of the specimens after immersion in water for (30, 60, 120) minute, and 28 days.

6. Concrete Density Test

The density test was carried out on the dried concrete cubes after 28 days water curing. The cubes weighted and its volume was accurately measured.

7. Compression Strength Test

A 150*150*150 mm concrete cube were prepared and tested bycompressive strength machine controls model 50-C23C02 with a 2000 KN load capacity.The cube testingwas carried out by applying the load at a constant rate until the specimen failed. The failure load was recorded and an average of three test results was taken as the compressive strength of concrete.

Figure 1. The concrete mix components

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Figure 2.Casted concrete cubes

III. RESULTS AND DISCUSSION

1. Results of compressive strength test

The mean results (from testing three specimens) forcompressive strength and density for all mixes prepared and cured for 28 days are shown in table 3.

Table 3.Experimental design with the mean values of the responses(compressive strength and density)

Exp. No.	W/C	Demolition aggregate (DA) (wt. %)	Compressive strength (MPa)		Density (Kg/m^3)	
			DAC	Control	DAC	Control
1	0.50	86.4	36.38	26.29	2290	2390
2	0.45	75	31.43	27.43	2230	2470
3	0.45	20	37.30	27.43	2270	2470
*2	0.5	47.5	49.25	26.29	2320	2390
6	0.57	47.5	45.72	25.46	2410	2370
7	0.43	47.5	42.29	34.96	2330	2470
8	0.55	75	22.10	18.39	2360	2360
9	0.55	20	21.36	18.39	2350	2360
10	0.50	8.6	21.25	26.29	2350	2390
11	0.50	100	17.71	26.29	2200	2390
DAC: Demolition Aggregate Concrete						

Concrete strength is the key mechanical property of structural concrete. Theexperimental results for experiments (1, *2, 10, and 11) including DAC mixes prepared with identical water/ cement ratio (0.5) were analyzed to identify the effect of DA content on compressive strength. The variation in compressive strength of the hardened mixes (28 dayscured) withdemolition aggregate content (wt.%)is illustrated inFigure 3. It is obvious to note that compressive strength is affected by the level of demolition aggregate replacement of natural coarse aggregates.Interestingly, it is evident that concrete with demolition aggregate seemed to attain more compressive strength exceeding that of control concrete at certain demolition aggregate levels. DAC mixes contain 47.5 and 86.8 (wt. %) demolition aggregate were of higher compressive strength compared to the control specimens. DAC mixes contain 47.5 (wt. %) demolition aggregate were of maximum compressive strength (49.25 MPa), accounted for 1.87 timesthe compressive strength value of control concrete (26.29 MPa).However, DAC mixes of highest DA content (86.8 %) exhibited lower compressive strength (36.38 MPa) which still higher than that of control concrete.For more clear view, the variation in compressive strengthwith

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DA replacement levelsisillustratedgraphically in Figure 4.The resultsseemedcoherentwiththoserecordedin a studyconcerningusingrecycled fine aggregates in concrete [29].

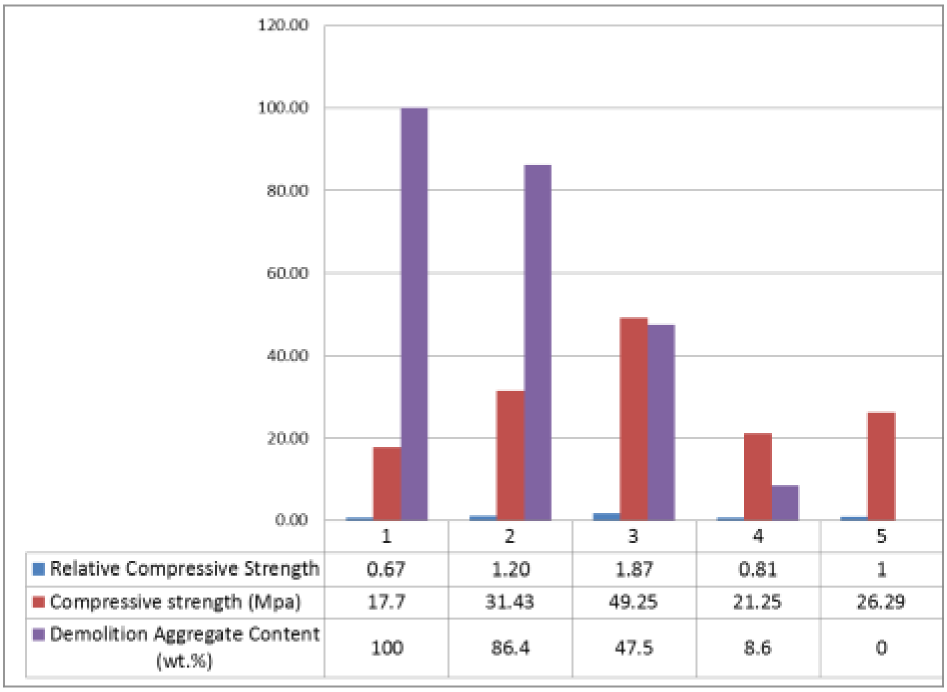

Figure 3.Compressive strength versus content of demolished aggregate for concrete mixes (W/C = 0.5)

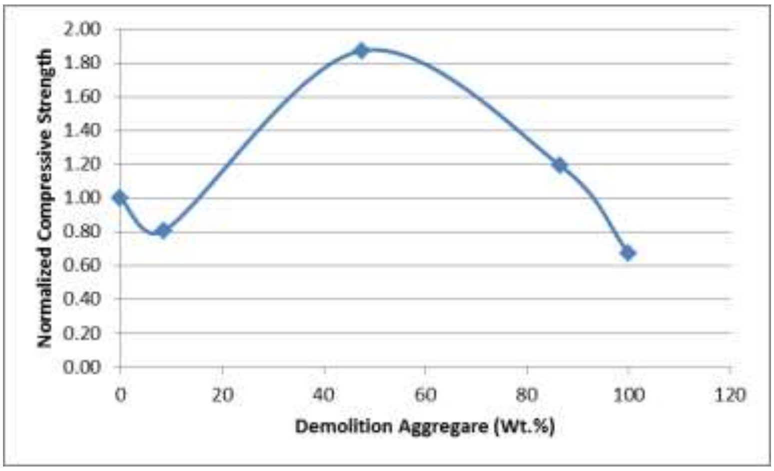

Figure 4.Compressive strength of demolition aggregate concrete (DAC)normalized to control concrete

On another hand, it was reported that strength of DAC isdirectlyproportional to strength of the blendedaggregate[26]. Furthermore, the extent to which the properties of concrete are affected by the use of recycledaggregatedepends on the water absorption, crushing value and soundness of the recycledaggregates[30]. Nevertheless, several researches pointed that compressive strength of DAC is generally lower than that of conventional concrete made from similar mix proportions. The extent of the reduction is dependent on factors such as the type of concrete used for obtaining the recycled aggregate whether high, medium or low strength, the replacement ratio, water-cement ratio and the moisture condition of the recycled aggregate [20, 22]. However,a study pointedthat demolished aggregate concrete gave strength closer to the strength of plain concrete and strength retention was recorded in the range of 86.84-94.74% for recycled concrete mix[31].Similar findings were reported by other researchers[32].Accordingly, literature reflected lack of agreement amongstresearchersregardingthistheme. Yet, the observed fashion of development in compressive

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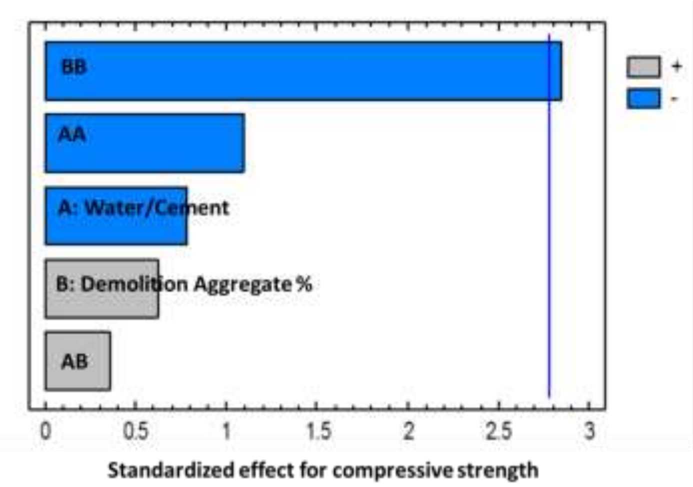
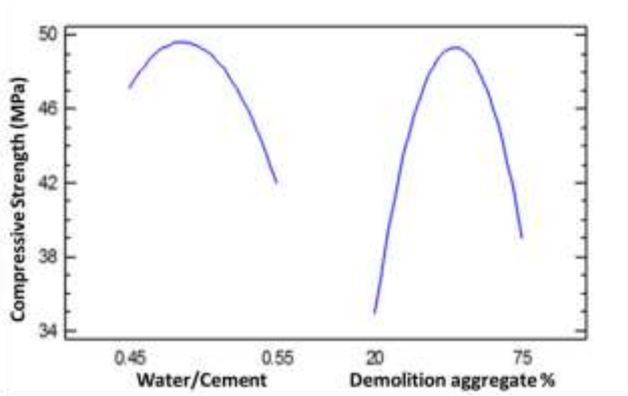
strength in the current study looks interested and applicable. The trend of results for the current study is quite similar to that reported by some other researchers worked onrecycled construction waste [33].

The development in compressive strength obtained in the current work at certain levels of DA may be attributed to the presence of some unreacted cement attached to the mortar layer of the DA. The unreacted cement enhance the creation of a strong residual mortar layer capable to form strong bonds with the conventional coarse aggregate.However, at higher DA levels, the old mortar layer may create lot of voids in the concrete leading to weakening the bonds with conventional coarse aggregates, thus resulted in decreasing the compressive strength afterwards.

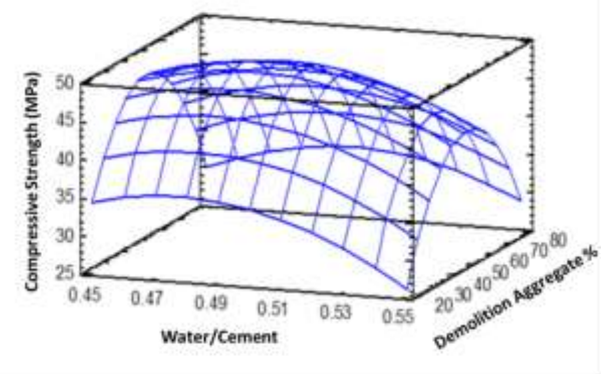
To model and optimize the effects of the independent variables, and to identify their interaction effect on compressive strength, the experimental results of all experiments for DAC were analyzed by RSM software. The estimated results of Response Surface Analysis (RSA) for compressive strength are shown in Figure 5.The standardized Pareto chart (Figure 5A) confirms that the quadratic effect of demolition aggregate content has a significant effect that govern compressive strength, at the same time,water/cement ratio seemed not significant with a negative effect, i.e. the lower the water/cement ratio, the higher the compressive strength.



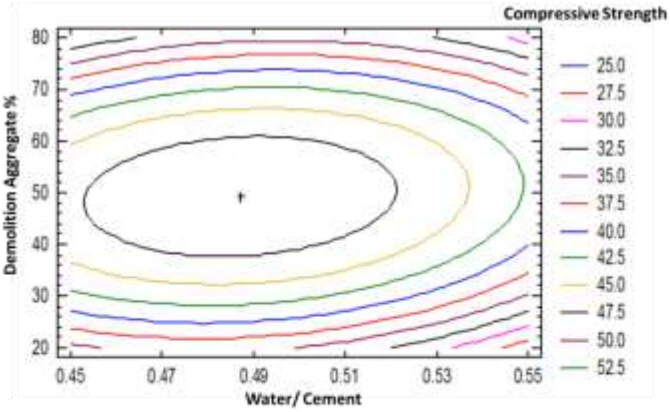
(A). Pareto chart for comprssive srength



(B).Main effects plot for compressive strength



(C).The estimated response surface



(D). Countersfor estimated response surface for compressive strength

Figure5. Pareto chart (A), Main effects Plot (B), the estimated response surface (C), and counters plots (D) for compressive strength

The main effects plot (Figure 5B) shows that the compressive strength increases till a maxima in term of the twoindependent variables (DA content and W/C ratio),then declines, predicting that there is a maximum limit for the two independent variables for optimum compressive strength.The RSA results are in line with those estimated from the conventional analysis of the experimental results shown in Figures 3 and 4.

The response surface analysis (RSA) predicted that the value of the regression factor estimated from the model analysis (R-squared = 69.872 %) is relatively acceptable, it reflects that the model is capable relatively to explain the compressive strength experimental results.

The mathematical modelgoverns the effect of DA content and water/cement ratio is shown in the second order polynomial equation (equation 2) estimated from the adopted model:

$$\text{Compressive strength} = -409.906 + 1783.8*W + 1.0211*D - 1891.97*W^2 + 1.2018*W*D - 0.0163*D^2 \quad (2)$$

Where W =W/C, D= Demolition aggregate content (wt. %)

An optimum compressive strength value = 49.68MPa was estimated from the model analysis corresponds to concrete mixof 0.49 W/C ratio, contains 49.30 (wt. %) of the demolition aggregate. The estimated response surface plot Figure 4D, and contours plots Figure 4C clarify the situation.The high value of compressive strength estimated from the model is promising for the encouragement to use the demolishing concrete as coarse aggregate up to 49.3 % for manufacture high strength concrete at W/C= 0.49.

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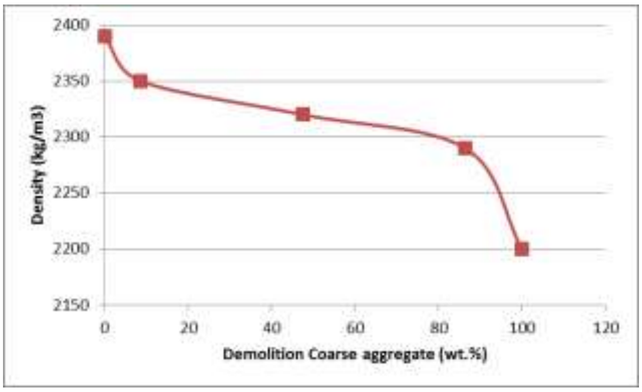
2. Result of Density Test

The experimental results of density test for control and the concrete samples contain demolition aggregate are illustrated in table 2.

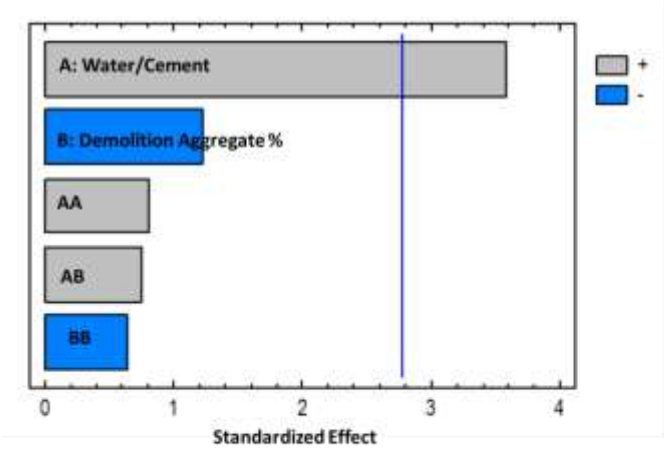
In general, theexperimental resultsof the current study revealed that concrete contains the demolition aggregate is relatively of lower density (mass) compared toconcretemade with natural coarse aggregates.

It was reported that concretes madewith demolished aggregates had lower densities due to the higher air void content[20]. Figure 6 shows the variation of DAC mean density values with demolition aggregate content for DACs of identical water/cement ratio (0.5). DAC of 100% demolition aggregates seemed to exhibit the lowest density(about 8% decrease) compared to control concrete which has the highest density. This finding is almost certainly due to the higher amount of porous and less dence mortar attached to the demolition aggregate replaced natural coarse aggregate in concrete specimems. The trend of the results seemed quite similar to that observed by other researchersusedrecycled aggregates derived from crushed concrete [34, 35].



Figue 6. Density versus content of demolition coarse aggregate in concrete

More detailed information were estimated from analysis the experimental results of the DAC using RSM.Figure 7 shows the RSM analysis results of density for the DACs . It is well noticed that water/cement ratio has significant effect on density, while the demolition aggregate content seemed not significant as shown in the Pareto chart of Figure 7A.



(A).Standardized Pareto chart for density

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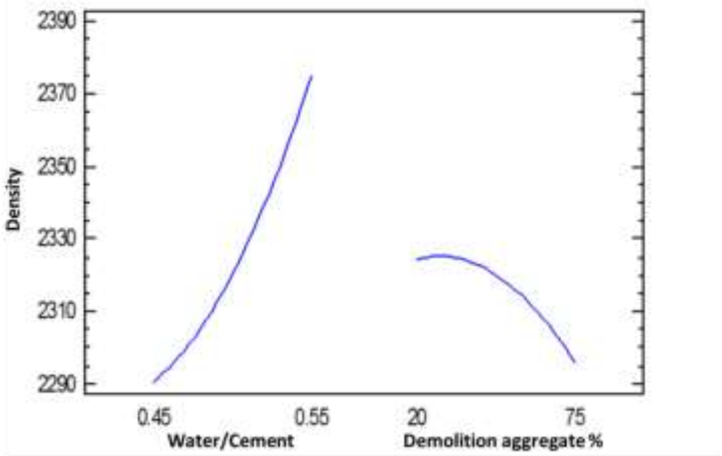
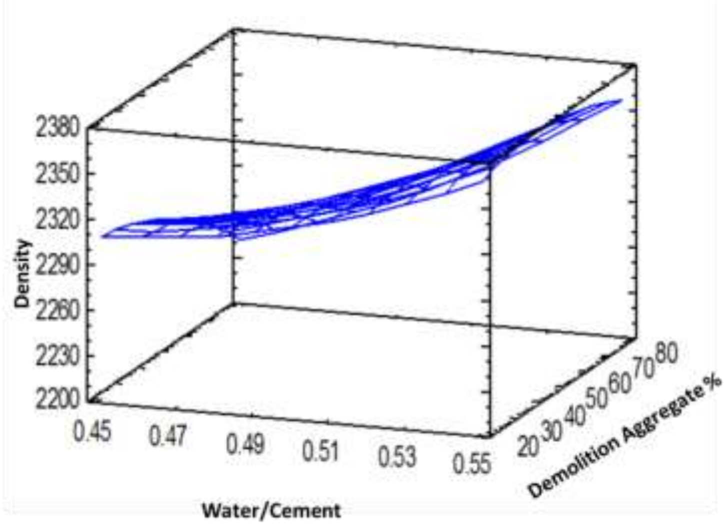
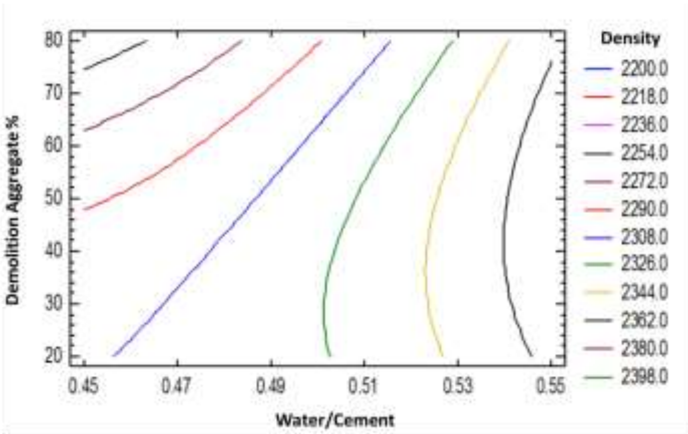


(B).Main effects plot for density



(C). Response Surface for density



(D). Contoursfor estimated response surface for density

Figure 7. Pareto chart (A), Main effects plot (B), the estimated response surface (C), and counters plots (D) for Density of DACs

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Density seemed to increase significantly with increasing water/cement ratio. The negative effect of demolitionaggregate content as reflected from the negative sign of the effect in the Pareto chart (Figure 7A) revealed that as demolition aggregate content increases density decreases. The effect is well clarified in the main effects plot (Figure 7B), the density of DACs increases with increasing water/ cement ratio, and decreases with increasing DA content. The response surface and the counters for the estimated response surface show more clear view about how density changes with the two independent variables on 3-dimentional surface.On the other hand, the coefficient of determination (R^2) computed by ANOVA indicates that the model explains80.70 % of the variability observed in density.The mathematical model estimated is presented by the second order polynomial equation (equation 3) that governs the effect of the two variables:

$$Density = 3359.28 - 4588.65*W - 3.81*D + 5000.03*W^2 + 9.09*W*D - 0.013*D^2 \quad (3)$$

Where, W =W/C, D= Demolition aggregate content (wt. %)
Anoptimumvalue of density was estimated = 2404.9 kg/m^3 for a concert mix of W/C = 0.57 contains demolition aggregate 52.06(wt. %).

A summary of the results estimated from the adopted models analysis is shown in table 4

Table 4.Summary of the RSM results

Property	Optimum value	R^2 %	Optimum conditions	Mathematical Model
Compressive strength	49.68	70.0	Water /Cement: 0.49 DA(wt.%): 49.3	Compressive strength = -409.906 + 1783.8*W + 1.0211*D - 1891.97*W^2 + 1.2018*W*D - 0.0163*D^2
Density	2404.9	80.7	Water /cement: 0.57 DA(wt.%):52.06	Density = 3359.28 - 4588.65*W - 3.81*D + 5000.03*W^2 + 9.09*W*D - 0.013*D^2 W: water/ cement ratio, D: DA content (wt.%)

3. Compressive Strength-Density Relationship

It is worthy to mention that in design of concrete structures the most important parameters should be taken into consideration are density and compressive strength. In general, the mechanical properties of concrete are highly influenced by its density. Higher strength concretes have low porosity and few amountsof voids such as the concrete become less permeable to water and aggressive fluids [36].

From the experimental data of the current work, relationship between density and compressive strength has been adopted for DAC mixes prepared with identical W/C (0.5) and different DA content. A direct proportional relationship was obtained up to 47.5 (wt. %)of DA, then a decline in compressive strength has been predictedwith increasing the density as shown in Figure 8.Still, it is apparent that the highest compressive strength (49.25 MPa) obtained is accountedfor an increase in compressive strength (46.62%) compared to that of reference concrete. The highest compressive strength concrete found to haveless density; (about 3 % decreasing) compared to reference concrete of similar W/C ratio (0.5). Figure 8 and 9 illustrate the results of analysis of the experimental data in concern.

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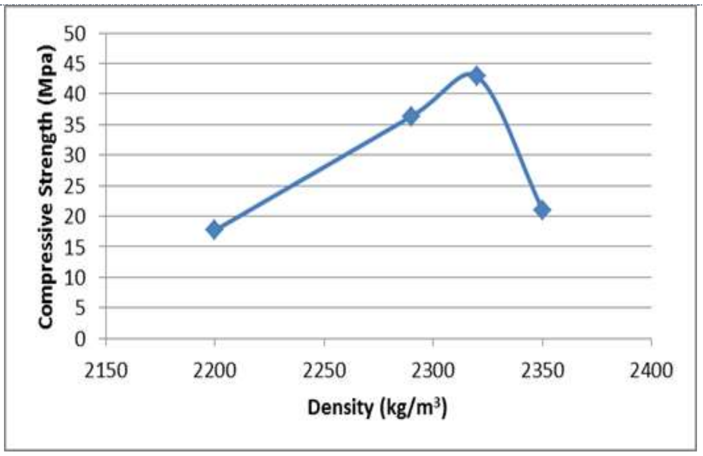

Figure 8. The relation of density and compressive strength for DAC

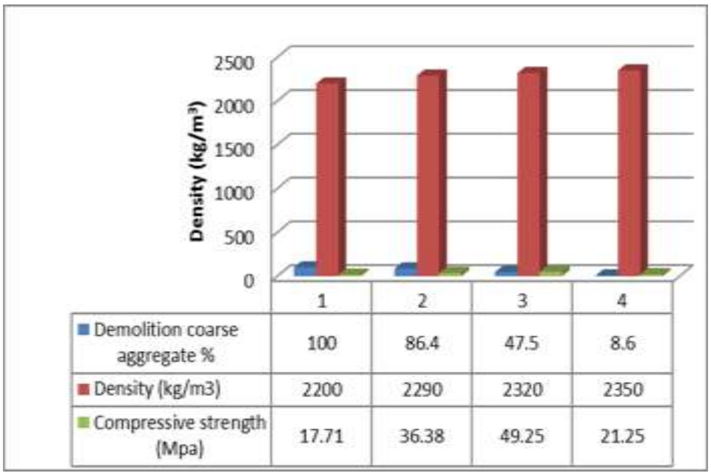

Figure 9. Density and compressive strengrh versus DA content for DACs

4. Results of water absorption test

Septicity is an index expresses the moisture transport into unsaturated concrete, it has also been recognized as an important index of concrete durability. During septicity process, the driving force for water ingress into concrete is capillary suction within the pore spaces of concrete, and not a pressure head [25]. Concretes of high porosity have higher expansion and shrinkage and can not be used outdoors.

Throughout this work, the initial and total absorption test was conducted by following the change in weight of the specimens after each immersion specified period (30, 60, 120 minutes, and 28 days) for 28 age cured specimens). The results are shown in Table 5, and Figures 10 and 11.

Table5. The experimental results for water absorption test

Exp. No.	W/C	Demolition Aggregate DA (wt. %)	Water absorption %							
			30 (min.)		60 (min.)		120 (min.)		28 (day)	
			DAC	C	DAC	C	DAC	C	DAC	C
1	0.5	86.4	0.44	0.05	0.52	0.90	0.58	1.77	0.60	1.89
2	0.45	75	0.91	0.17	0.98	1.17	1.03	1.98	1.73	2.25
*2	0.45	20	0.50	0.17	0.55	1.17	0.59	1.98	0.68	2.25

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5	0.5	47.5	0.14	0.05	0.20	0.90	0.23	1.77	0.62	1.89
6	0.57	47.5	0.17	0.06	0.20	0.42	0.25	1.57	0.38	1.63
7	0.43	47.5	0.63	0.05	0.65	0.50	0.70	0.94	1.06	1.13
8	0.55	75	0.50	0.04	0.53	0.45	0.58	0.99	0.98	1.05
9	0.55	20	0.47	0.04	0.50	0.45	0.52	0.99	0.87	1.05
10	0.5	8.6	0.48	0.05	0.53	0.90	0.57	1.77	0.86	1.89
11	0.5	100	0.83	0.05	0.93	0.90	0.99	1.77	1.21	1.89
DAC: Demolition Aggregate Concrete, C: Control										

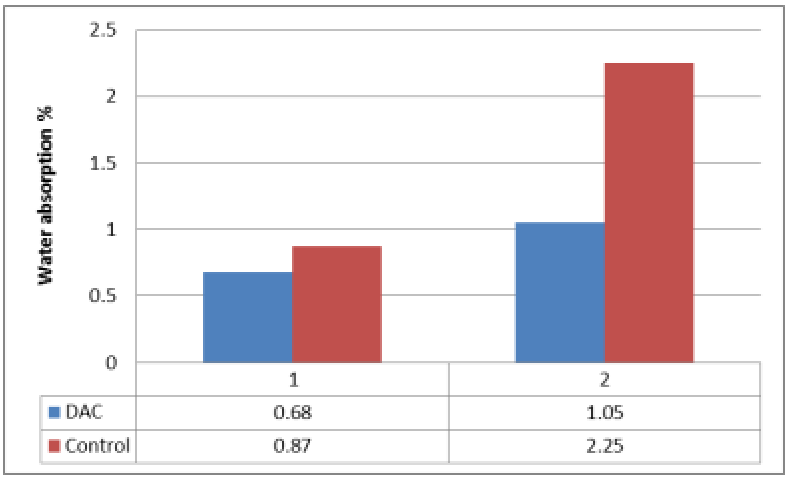

Figure 10. Water absorption % after 28 days immersion for control and DAC (20 wt. % DA) prepared at different W/C ratio(1: 0.45, 2: 0.55)

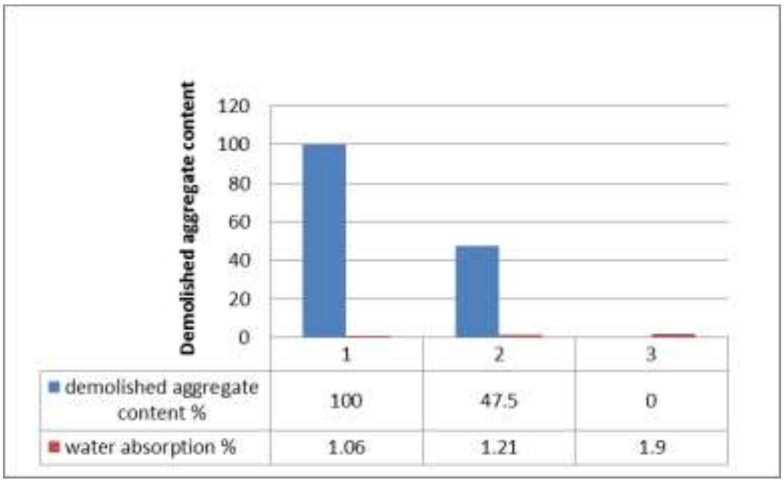

Figure 11: Water absorption % versus demolished aggregate content (W/C =0.5)

The results illustrated in Figure 10revealed that as W/C ratio increases, % water absorption increases for both the control and the mixes contain demolition concrete as coarse aggregate. However, the control samples seemed to absorb more water compared to concrete contains the demolition aggregate. Figure11 shows that as DA wt.% increases in concrete water absorption % decreases. The results approve that concrete with coarse demolition aggregate present lower absorption capacity, hence, it is expected that by incorporation demolition aggregates in concrete mix, less water is necessary to maintain the same workability, therefore, concrete with demolition aggregate have lower drying shrinkage. The findings of the current investigation were in agreement with those reported by Ahmed [38] who observed thatwater absorption decreasesin recycled aggregate concrete as recycled aggregate content increases.However, inverse trend was reported by other researchers [14, 23, and 37]who also utilized demolished waste as coarse aggregate.

The dearth in agreement regarding the water absorption of DACs may be attributed to the quantity and nature of the adhered mortar attached to the virgin aggregates (in the demolition aggregate), which are very important parameters that affect the aggregate-cement matrix interfacial zone. The presence of un-reacted cement particles in the attached mortar make it less porous with respect to the same aggregate-cement matrix interfacial zone in conventional concrete. Also, the cement particles strengthen the bonding between the demolition aggregate and the conventional coarse aggregate in DAC mix. Decreasing the porosity of the concrete mix will lead to decreasing the water absorption capacity as well as the improvement in mechanical properties.Moreover, the rough surface of the demolition aggregate enhances the bonding characteristics in concrete.The collective former effects may be the reasons behind the lower water absorption capacitypredicted for DAC investigated in the current study.

IV. CONCLUSIONS

The conclusions could be drawn from the results of the current study demonstrated that incorporation of demolition concrete aggregate as coarse aggregate in concrete is quite feasible, it resulted in reduction of density and water absorption and enhancing compressive strength of concrete at certain level of demolition aggregate. The observations also led to a conclusion that there is some unreacted cement within the demolition aggregate used. Moreover, central composite design seemed more applicable compared to the conventional concrete design to study, model and optimize the impact of concrete design parameters on DACs properties. The recent work and the future work on other aspects of recycling demolition aggregate concrete may contribute to reducing its negative impact on environment by minimizing waste disposal loads sent to the landfills, and conservation of natural aggregate, in addition to give the opportunity to establishmentof concrete waste recycling plants, as well as the corresponding guidelines for using the demolition concrete waste in concrete industry for structural applications.

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