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Applying of No-fines concretes as a porous concrete in different construction application

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ABSTRACT

Recently, the demands on the concretes with no fines aggregate has been increased as a results of the industry revolution. Many researchers are trying to recycle the concretes and rubble. In addition, the increase in noise in the surrounding environment as a result of the growing population and cars has generated an urgent need to produce concretes characterized by good sound insulation. No-fines concretes is considered as a kind of porous lightweight concretes, gained by removing the sand from the ordinary concrete mixture. The aim of this study is replacing the coarse aggregate by waste ceramics in order to reduce the wastes as well as investigate strengths against compression s, density and porosity of No-fines concretes before and after substitution the coarse aggregate by waste ceramics. The methodology of this research paper has been mainly depending on strengths against compression s test and the measured ultrasonic pulse velocity as well as the density. The investigational research has been implemented by 54 samples cast by six various blending proportion consisting of (cement, coarse aggregate, water) utilizing ceramic wastes (CWs) as a substation ratio of coarse aggregates in making concretes free of fine aggregate, so that the proportions of ceramic residues are (0, 10%, 20, 30, 40, 50) as a partial substation of the coarse aggregates and examined at the ages of (7, 28 and 90) days. The mechanism of failure has been detected and categorized beside the concrete's density and void percentage have been collected. The results show that, the increasing the substitution ratio for waste ceramic within the no-fine mixtures cause a decrease in the density with increasing the strengths against compression s for the specimens.

Keywords: Porous Concrete, Mechanical and Physical features, ceramic waste (CWs), Voids, Density.

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1. Introduction

No-fines concretes, also known as porous or open textured concrete, is made up of cement, water, and coarse aggregate (sizes ranging from 19.0-9.5mm) but no fine aggregate. As a result, there are cavities throughout the concretes matrix [1]–[7]. A lightweight concrete is made when fine aggregate is not utilized. It's an aggregation of coarse aggregate particles encased in a 1.3mm thick covering of cement paste. As a result, huge holes may be found throughout the concretes body, and these pores are a key reason in the material's low strength, poor heat conductivity, and light weights. The huge size of these holes prevents water from passing through the concretes matrix through capillary features [8]. No-fines concretes is often used in the production of precast concretes and the construction of building units' interior and external walls (bearing and non-bearing). It's also utilized in the building of partitions and insulation. In 1924, the United Kingdom employed No-fines concretes for commercial purposes. Throughout the second World War, research and studies on No-fines concretes began to grow and expand, resulting in around 130000 buildings in the United Kingdom utilizing this form of concretes between 1945 and 1961 [3], [7], [9]–[12]. Desai [13] investigated the influence of aggregate size and cement, additives, and water ratios on the no-fines concretes porosity. Due to the enormous spaces in the cement slurry settled down, he determined that the specimens with aggregates larger than 2 cm have not been porous from the base. The cement slurry sank down in all of the cubes that were compacted, resulting in a level bottom surface. As a result, the ultimate decision has been to employ aggregates with a max size of 10-19mm and not compress them when filling. Furthermore, since fine aggregate had not been utilized, the concrete's density has been lower comparison with regular concretes, and the strengths has been lower comparison with normal concretes. Yehia, [14], [15] conducted a detailed examination into the features of porous concretes in order to expand its applications in structural engineering. Physical features including porosity, permeability, and density, as well as mechanical features like strengths against compression s, indirect tensile strengths, and flexural strength have been examined. Moreover, three polymers impregnated porous slabs of concretes have been investigated under pure bending force to study the chosen resin's Influence liveness to integrate concretes particle in establishing a novel generation in structural engineering utilizing porous concretes. According to the findings, adding more than 200 kg/m3 of cement seems to have no Influence on the max deflections or maximum loading of polymers impregnated porous slabs of concretes. The impact of recycled aggregate and hydrophilic additives on both physical, mechanical and durability features of no-fines concretes has been investigated by Tittarelli et al. [16]. The researchers discovered that changing the water/cement proportion from 0.41 to 0.34 and the aggregates/cement proportion from 8 to 4 optimizes no-fines concretes strengths against compression s in the ranging of 7–30 MPa after 28 days of curing. To investigate the influence of durability, many combinations were duplicated by applying a hydrophilic additive and preparing them by replacing the standard aggregates with recycled aggregates. Carbonation susceptibility has been found in all of the no-fines blends tested. Eventually, they discovered that employing recycled aggregates enhances capillary water absorption by around 50 percent; however, the corresponding decrease in durability may readily be offset by applying a hydrophilic additive. According to Sriravindrarajah et al. [17], No-Fines mixture of Recycled Concretes Aggregates should be planned (RCA). The right quantity of Recycled Concretes Aggregates (RCA) has been achieved by crushing concretes block and waste concretes in crusher and separating the aggregate on mechanical vibration screen. Once the aggregates to cement ratio is 4:1, RCA get an overall strength against compression s of 12 MPa. They also discovered that when porosity increases, compressive intensity decreases. RCA also have a lower Influence magnitude and a higher abrasion magnitude that is a major drawback. As a consequence, compared to typical aggregates, recovered aggregates have worse mechanical features. Natural resource depletion is a regular occurrence in emerging nations such as third world countries as a result of fast industrialization and urbanization, which includes the creation of infrastructure and other amenities. As a result, people have been looking for acceptable and feasible substitution concretes materials so that current natural resources may be protected to the greatest degree possible for future generations. The strength qualities of concretes constructed from waste materials, such as ceramic tiles, ceramics insulator trash, and shattered glass pieces, were studied in this research. [18] utilizing industrial wastes, a total of 24 cubes, 24 cylinders, and 24 beams have been produced and evaluated for strengths against compression s, splitting tensile strengths, and flexural strengths. It had been discovered that wastes ceramics tiles aggregate concretes had higher compression, split tensile, and flexure strength comparison with ceramics insulator trash and broken glass material. Waste ceramic tiles, according to this research, may be utilized as an alternative to coarse aggregates in concretes building. Millions of tons of these waste products are readily accessible and dumped every year across the globe, depending on [19]. Recycling these wastes as a building material looks to be a realistic alternative not just for reducing pollution, but also as a cost-Influenced choice in green building design. Today's growing concern for environmental preservation and energy saving with little economic Influence has prompted academics to hunt for new coarse aggregate options in the concretes industry [20]. Various industrial waste materials, including waste aggregate, broken glass waste, brick, tile waste, quarry dust, blast furnace slag, fly ashes from structure demolition, ceramics insulator waste, and so on, were studied as potential viable substitution products for conventional concretes materials. Over the past several decades, the relevance of recycling and sustainability has grown more recognized and appreciated in academics and business. Recycling building and debris trash is one of several options for reducing the construction industry's dependency on diminishing natural resource supply and preventing waste from entering landfills [3], [21]–[24]. Anderson et al. [25] looked at the mechanical characteristics of concretes that used discarded ceramic as coarse aggregate. With three distinct wastes ceramics tile materials in substitution proportions of 20, 25, 35, 50, 65, 75, 80, and 100 percent, a coarse aggregate substitution method in concretes is examined. The results suggest that waste ceramic may be used as a natural coarse aggregate substitute material with little mechanical characteristics modifications. Road construction often use industrial waste materials. Crushed ceramic waste aggregates (CWAs) have been used in this investigation and mixed into asphalt mixes to see whether they may be useful. The influence of materials thermal conductivity on the temp gradient of the pavement structure has been initially investigated utilizing a finite-element technique (FEM). In model simulations, a considerable influence of the surface layer's conductivity on the temps (at the bottom and top locations of the middle layer) has been discovered. The mix for asphalt mixes containing various percentages of CWAs had just been established, and the thermal characteristics of these mixtures have been examined. It has been determined that asphalt mixes containing an acceptable amount of CWA may meet pavement performance standards [26]. CWAs may diminish the asphalt mixes thermal conductivity that has been demonstrated to help minimize pavement temp gradients. Eventually, because of the influence on combination performance, it is advised that less than 40% CWA be used to substitute coarse aggregates in asphalt mixes. The aim of this work is to see what happens when waste ceramics are used to substitute coarse aggregate in no-fines concretes in various amounts while altering the coarse aggregates weights to find the best substitution ratio. The research also looked at hardened concretes parameters such as density, void percentage, and strengths against compression s of no-fines concrete. To evaluate the voids proportion before and after adding waste ceramics, an ultrasonic wave velocity testing has been implemented as a non-destructive testing.

2. The No-fines concretes Applications

The use of NFC in the area of civil engineering is demonstrated by the use of this concretes in several domains like as [27]:

Despite its excellent thermal insulation features, NFC is frequently used in construction. NFC, on the other hand, is built up entirely of cement and coarse aggregates, with no fine aggregates present. NFC may be designed with a specified amount of voids to promote thermal insulation.

Non-pavement applications of NFC, according to Harber et al. [28], include dwellings, tennis courts, drainage, and drainage tiles, while pavement applications include pavement edge drainage system, low volume surface roads, and plenty of parking. Ravenling occurs 10 years after construction, and excessive uplift pore compression may be reduced by utilizing NFC as a (stiff pavement) that can also serve as a storm water management system. There may have been a cost reduction as compared to standard concrete. NFC pavements seems to have a 20–40-year life expectancy, depending on the Southern California Blending Concretes Society. Because NFCs are light in color, they help to reduce ground-level ozone.

Since capillary action, the voids should be adequate to prevent rainwater from migrating into the concretes part. Rains that fall on the surfaces of outside walls will only travel a short distance horizontally before dropping to the base of the walls, therefore no fines will be produced. Exterior walls in constructions are often made of concrete. Figure 1 shows permeable concretes, which is a kind of concretes that allows water to pass through it. As a consequence, heavy rain might be absorbed by permeable concrete's porous nature, allowing water to flow (faster than its surfaces outflow) into a covering of gravel into a network of tubes designed for this purpose, minimizing the influence of stormwater runoff and the flood risk and its implications. Reduce the requirement for rainwater treatment facilities whereas improving the efficacy of surface water discharge. Decrease the number of required installations, construction expenses, and maintenance costs. Provide for groundwater replenishment. It's the simplest technique to deal with flooding and heavy rainfall. Water can flow through the porous gravel layer because it contains holes (15-30%). In compact concretes, large granulated grains with or without microscopic particles are employed. However, a concretes mixture has been used to fill it, allowing water to flow through. Figure 2 shows the difference between regular concretes and NFC.


Figure 1. No-Fines Concretes (NFCs) structures and applications in a wall.


Figure 2. The variances between the normal Concretes and No-fines concretes.

3. Experimental Part

3.1. Materials

3.1.1. Cement

In this investigation, ordinary Port-lands cements (kind 1) from Iraq's Al-Najaf, KAR mill has been utilized. Tables (1) and (2) demonstrate the chemically and physically parameters of that cement, respectively. According to tests findings, the chosen cement complies with Iraqi standard No. 5/1984 [29], [30].

Table 1. Composition and Chemical analyzing of KAR Cements

Oxide Compositions	OPC %	Limit of IQS No.5/1984 [31]
SiO_2	20.58	---
Al_2O_3	5.6	---
Fe_2O_3	3.28	---
CaO	62.79	---
SO_3	2.35	2.5 if C3A ≤5 2.8 if C3A >5
K2O+Na2O		
L.O.I.	1.94	5% max
CI	0.02	≤ 0.10 %
CaO(free)	1.00	---
Lime Saturation Factor (L.S.F.)	0.9	---
Magnesia (MgO)	2.79	5% max

Table 2. Physical features of and KAR Cement [29], [32]

Physical features	Cements	Limit of IQS NO. 5/1984 [31]
Specific Surfaces Areas (Blaine Technique) m^2/kg	314	-
Initially Setting duration, (mins)	22	≥ 45 min
Finally setting duration, (mins)	193	≤ 10 hrs.
Soundness Utilizing Autoclave Technique	0.61	≤ 10 mm
Specific Surface, Min, (m^2/g)	-	-
Retained amount Percent on sieve 45µm (No.325), max, Percent	-	-
Specifical Surfaces, Mins, (m2/g)	-	-
Strengths against compression s at:		
3 Days (MPa)	21.0	Higher than 20
28 Days (MPa)	45.8	≤ 42.5

3.1.2. Coarse aggregate

Rounded normal coarse aggregates with a max size of 1.4 cm have been utilized. The chemical and physical features are listed in **Table 3**. It has been separated by sieve analysis and substantial the classifying depending on Iraqi requirement [33], [34].

Table 3. Coarse aggregates Physical features

Physical features	Tests finding	Iraqi requirement Limit No.45/1984
Specifical gravity	2.62	/
Sulfates amount percent	0.01	≤0.1%
Absorption percent	0.22	/
Bulk density kg/m^3	1625	/

3.1.3. Waste Ceramic

The discarded grounds ceramics utilized in this research came from Iran, which offered recycled ceramics grounds tile. A jaw crusher has been utilized to smash broken portions of grounds tiles. Figure 3 depicts the ground ceramic preparation procedure.

Figure 3. Waste ceramics utilized in this investigation

3.1.4. Water

Water utilized for blending or healing shall be fairly oil-free and clean, salt-free, acid or alkali-free, sugar or vegetable-free or other harmful substances. Water will therefore be screened according to the suggested criteria of AASHTO T-26 and will once more be satisfied. Without testing, water known to be of drinking quality could be utilized. Specific gravity and hydrometer experiments use distilled water. Tap water has been utilized for other tests and healing. Table (4) indicates the tap water's chemical features.

Table 4. Tap water chemically analyzing

Characteristic	**Units** (mg.L^{-1})	**Value**
PH	-	7.6
EC	-	963Mus
Turbidity	-	1.6 N.T.U Nephelometic Turbidity
Total Hardness (T.H)	*	278
Chloride	*	112
Mg	*	12.44
Ca	*	216
SO4	*	182
PO4	*	0.31
Na	*	75
K	*	3.9
TDS	*	480

3.2. Research Methodology

Pour 54 cube samples with sizes 1.50 x 1.50 x 1.50 cm to study the strengths against compression , separated into six sets depending on the proportion of aggregate residues in concretes mixtures, and every group is examined at the age of (7, 14, 28) days to study the Influence of the age of the test on strengths against compression according to different proportions of waste materials. aggregates.

The cubes are examined in a non-destructive way utilizing the (UPV) and then they are examined in a destructive way to find the difference between the two methods.

Figure 4. Blending methodology and No-fines concretes after casting

3.3. Blending proportion

In the current empirical work, six proportions of waste ceramic (0, 10, 20, 30, 40 and 50%) were utilized as substitution to coarse aggregates. The water/cements (W/C) proportions were fixed 0.4 as demonstrated in Table 5. Table 5 demonstrates the proportions of blending materials utilized in this research.

Table 5. Concretes Mix Design Proportions.

Samples ID	**CWs %**	**CWs (Kg/m^3)**	**Coarse Aggregates (Kg/m^3)**	**W/C Proportion**	**Cements (Kg/m^3)**	**Water (kg/m^3)**
1	0%	0	2400	0.4	300	120
2	10%	240	2160	0.4	300	120
3	20%	480	1920	0.4	300	120
4	30%	720	1680	0.4	300	120
5	40%	960	1440	0.4	300	120
6	50%	1200	1200	0.4	300	120

3.4. Test method

3.4.1. Strengths against compression

The cubes strengths against compression have been obtained via utilizing a worldwide machine measurement (EVERY DENISON) of 2000 KN capacity, the rate of loading has been approximately 0.9 MPa/sec. The average finding of three fabricated concretes cubic samples with dimensions (150*150*150) mm according to ASTM C109 has been reported for every concrete cubic specimen that has been conducted for 7, 28 and 90 days. This inspection has been carried out in the Laboratory of the Department of Building and Constructions Engineering at the University of Al-Mustaqbal.

Figure 5. It shows the compressive test machine.

$\sigma = P/A$ …………………………………………………………………… (1)

Whereas,

σ: Strengths against compression s, (MPa)

P: Max compressive loading, (N)

A: Specimen areas, (mm^2).

3.4.2. Density test

The concrete's density has been determined utilizing a 150x150x 150 mm cubes and the ASTM C 642-13 [35]. The dry density can be calculated for concretes cubes by taking the dry weights of the samples after drying them in the oven at a temp of 110 degree centigrade for one day, then the samples submerged in water for one day and then weighed again after the stability of the model to weigh again to take the wet weights and then take the weights submerged in the water. The research has been carried out at the age of 7 and 28 days. The percent of total water absorption, porosity and density for concretes cubic samples can be calculated by utilizing the equations as follows [36].

Absorption of Water = $(W2 - W1)/W1 * 100$ % …. ………………......(2)

Whereas,
W1: The dry-weights of Specimen (g).
W2: The wetted weights of Specimen (g).

Porosity = (W2-W1) / (W2-W3) *100 % …………………………….. (3)

Whereas,
W1: The dry-weights of Specimen (g).
W2: The wet-weights of Specimen (g).
W3: The immersed Specimen weights in water (g).

Dry density (g/cm3) = W1/ (W2-W3) *Pw …………………………. (4)

Whereas,
W1: The dry-weights of Specimen (g).
W2: The wet-weights of Specimen (g).
W3: The immersed Specimen weights in water (g).
Pw: The water density that equal to (1 g/cm^3).

Figure 6. It shows the samples preparation for tests.

3.4.3. Velocity Pulse Ultra-sound (UPV)

By measuring traveling of the ultrasonic wave attenuation and speed through the element being examined, (UPV) testing may be utilized to verify the stone or structures of concretes integrity and quality. In comparison to high-velocity zones, lesser-velocity areas have reduced strength and density. Tomographic pictures of flaws may be created utilizing data gathered along various testing paths [37]. The UPV test has been implemented for all blending No-fines concretes proportions. The test has been implemented depending on BS EN1881-203 [38]. Cubic moulds (150 x 150 x 150 mm) have been utilized to implement this testing. Three trials specimens cast for every blending proportions and for every curing duration, which experienced after 7, 28, and 90 days from starting the curing process [39].

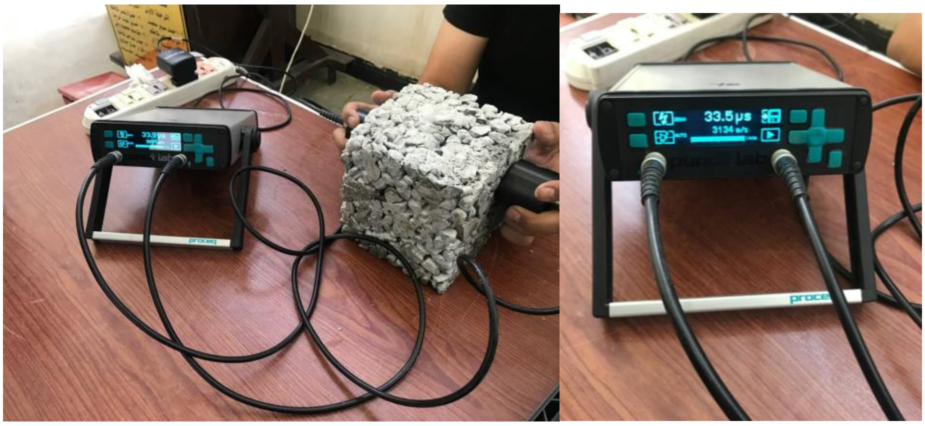

Figure 7. Ultrasonic Pulse Velocity (UPV) testing

4. Results and discussion

4.1. Influence s of CWs on strengths against compression s of no-fines concretes

The strengths against compression of no-fines concretes samples for various CWs percentages are demonstrated in Figure 8 and Table 6. It has been detected that the strengths against compression of No-fines concretes with and without CWs has been fluctuated depending on the substitution ratio and the curing age. At 7 curing age, the strengths against compression of No-fines concretes have been increased after replacing (10 and 20) % of coarse aggregates by waste ceramics, but the increasing of waste ceramics waste to 30 and 40% lead to decrease strengths against compression by 2 % and 35%, respectively comparison with strengths against compression of control sample without CWs that has been (5.75 MPa). Increasing the curing duration to 28 curing days cause a decreasing in the strengths against compression compatible with increasing the coarse aggregate replacing ratio. In spite of that the No-fines concretes sample with 20% is considered the best one with only 7% decrease in the strengths against compression comparison with controlling sample with (8.33 MPa). All in all, the expanded of curing age to 90 days, give same indication as 29 days, with development of strengths against compression and increase the decrease in strengths against compression with increasing the coarse aggregates substitution proportion by CWs.

Table 6. Strengths against compression results for No-fines concretes with waste ceramic.

Sample ID	Strengths against compression MPa		
	7 days	28 days	90 days
cont.	5.75	8.33	7.83
10%	6.48	6.45	6.41
20%	6.65	7.77	6.15
30%	5.61	3.23	5.47
40%	3.71	4.83	5.22
50%	5.87	5.26	5.31

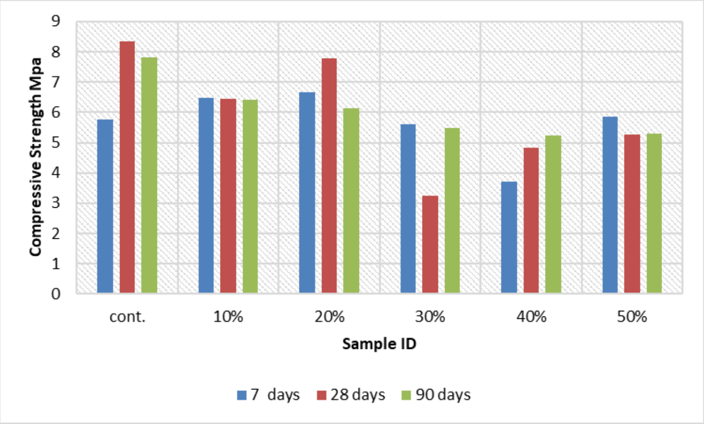

Figure 8. Strengths against compression s results for No-fines concretes with waste ceramic at different curing ages

4.2. Influence of CWs on no-fines concretes's density

The concrete's density is a measuring of the solidity of the material. For various curing ages, Figure 10 depicts the influence of CWs concentration on the mass density of hardened No-fines concretes. The density of concretes grew significantly as the cure time increased. In addition, when the amount of CWs in the concretes rose, the density of the concretes reduced. Because the CWs has been lighter than the conventional coarse aggregate, the loosely packed inner matrix may have contributed to the lower density. According to [40-49], the magnitudes of all the densities at all sustainable intensities have been in the 2200–2550kg/m3 density ranging for typical concretes. As a result, substituting regular coarse aggregates with CWs reduces the self-weights of concretes buildings. Figures 11 and 12 demonstrate the Absorption percentage and Porosity percentage for six different No-fines concretes mixture before and after substitution coarse aggregate with waste ceramics at different curing ages (7, 28 and 90) days. Absorption percentage and Porosity percentage increased with increasing the substitution proportion due to the behavior of the ceramic materials that increased the voids as demonstrated in figure 9.

Figure 9. No-fines concretes structure and porosity

Table 7. Absorption%, Porosity % and Density g/cm3 results for No-fines concretes with waste ceramic.

Sample ID	7 days			28 days			90 days		
	Absorption %	Porosity %	Density g/cm3	Absorption %	Porosity %	Density g/cm3	Absorption %	Porosity %	Density g/cm3
cont.	0.10	0.24	2.45	0.43	1.07	2.46	1.44	3.67	2.57
10%	1.10	2.60	2.37	0.88	2.10	2.39	1.29	3.29	2.54
20%	3.04	6.69	2.23	0.73	1.67	2.31	2.84	6.37	2.39
30%	6.10	12.42	2.08	1.96	4.34	2.22	2.89	6.68	2.32
40%	0.33	0.76	2.33	0.73	1.67	2.28	4.27	9.59	2.25
50%	1.93	4.21	2.19	0.89	1.95	2.21	3.29	7.23	2.23

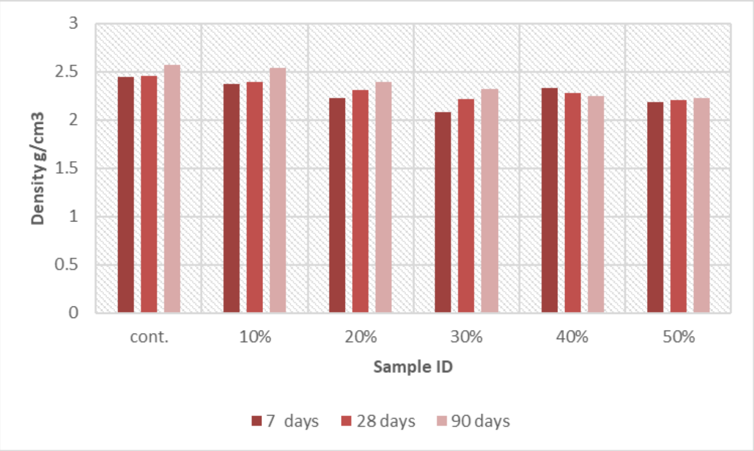

Figure 10. Density g/cm3 results for No-fines concretes with waste ceramic at different curing ages

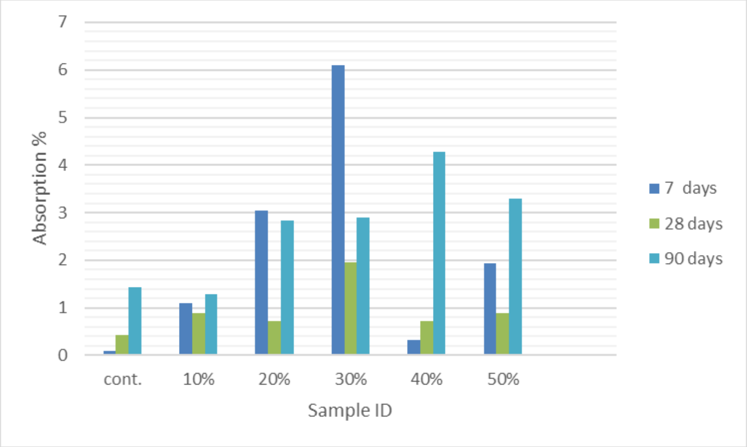

Figure 11. Absorption% results for No-fines concretes with waste ceramic at different curing ages

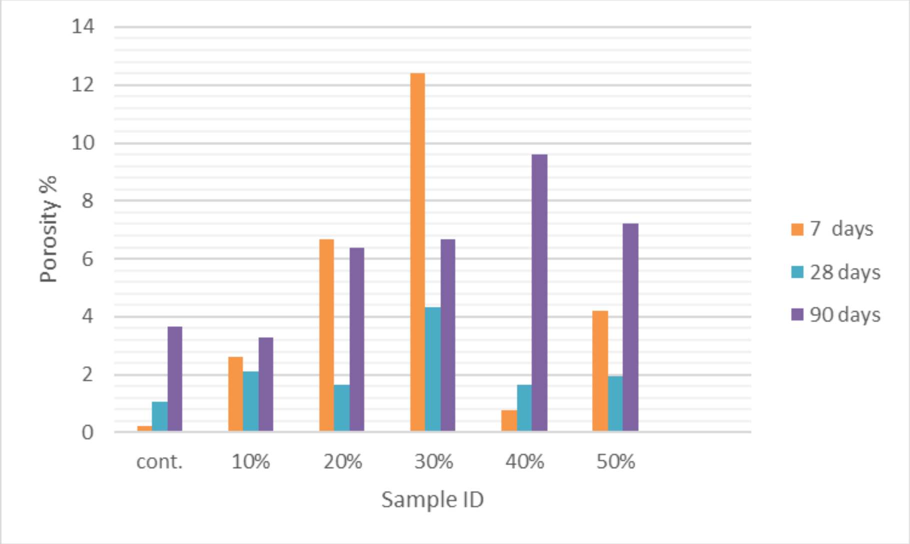

Figure 12. Porosity % results for no-fines concretes with waste ceramic at different curing ages [40]

4.3. Ultrasonic Pulse Velocity (UPV) Testing results for No-fines concretes

The UPV testing findings of No-fines concretes blends with waste ceramics (control, 10%, 20%, 30%, 40% and 50)% at 7, 28, and 90 days from starting the curing process as confirmed in Figure 13 and Table 8. Figure 13 proves that the UPV magnitudes for blends (control, 10%, 20%, 30%, 40% and 50%) rises with expanded the curing durations. As well as, rising the substitution percentage of coarse aggregate with waste ceramics resulted in an increasing of the UPV magnitudes.

Table 8. UPV Testing results for No-fines concretes with waste ceramic at different curing ages.

Sample ID	**UPV Test m/s**		
	7 days	**28 days**	**90 days**
cont.	30	33.40	35.40
10%	32.6	34.40	35.50
20%	34.2	33.27	35.33
30%	33.4	34.70	35.33
40%	32.7	33.17	32.47
50%	36	33.20	33.73

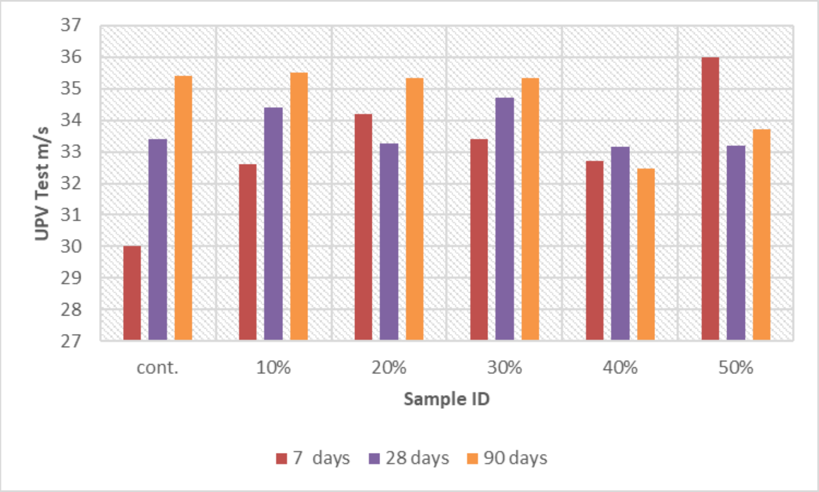

Figure 13. UPV Testing results for No-fines concretes with waste ceramic at different curing ages

5. Conclusions

The findings from the experimental works could be arranged as the following:

1. Due to No-fines concretes recorded lower intensity, it is utilized typically for roads paving. At 28 and 90 days, the compressive strengths of No-fines concretes are reduced highly comparison with standard concretes. However, the using of ceramic waste led to minimizing the compressive strengths of the samples with increasing the substitution ratio due to weak bonds and brittleness of ceramic materials.
2. Du to absence No-fines concretes from fine aggregates, the cost of this kind of concrete will be less and the weight will be lower comparison with normal concrete.
3. Density of No-fines concretes decreased as a result of increasing the coarse aggregates replacing ratios. However, Voids ratio and Absorption ratio have been increased with increment the replacement ratio and that return to two reasons on of them related to the porosity of the ceramic materials and the second one related to the shape of the crashed waste ceramics that usually non-homogeneous or not come in a geometrical shape.

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