

Appendix 1 XRF, BET, and Specific Gravity Results

Figure 1. BET for OPC

Quantachrome NovaWin - Data Acquisition and Reduction
for NOVA instruments
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version 11.0j

Analysis
Operator:alex Date:2007/01/01 Report Operator:alex Date:7/21/2024
Sample ID: OPC-42.5R Filename: C:\QCdata\Physisorb\des OPC.qps
Sample Desc: sample Comment: TEST
Sample weight: 0.08 g Sample Volume: 0.02051 cc Sample Density:3.9 g/cc
Outgas Time: 8.0 hrs OutgasTemp: 300.0 C
Analysis gas: Nitrogen Bath Temp: 77.3 K
Press. Tolerance:0.100/0.100 (ads/des) Equil time: 60/60 sec (ads/des) Equil timeout: 240/240 sec (ads/des)
Analysis Time: 48.4 min End of run: 2007/01/01 3:53:39 Instrument: Nova Station B
Cell ID: 2 F/W version: 0.00
Adsorbate Nitrogen Temperature 77.350K
Molec. Wt.: 28.013 g Cross Section: 16.200 Å² Liquid Density: 0.808 g/cc

Relative Pressure P/Po	Volume @ STP cc/g	1 / [W((Po/P) - 1)]
5.27240e-02	11.6002	3.8390e+00
1.22613e-01	26.6187	4.2006e+00
1.95518e-01	41.9589	4.6344e+00
2.84893e-01	60.6397	5.2566e+00
3.51047e-01	74.7514	5.7901e+00

BET summary
Slope = 6.539
Intercept = 3.428e+00
Correlation coefficient, r = 0.996766
C constant= 2.908
Surface Area = 349.437 m²/g

Figure 3. XRF for WPA



Geological Institute of Ethiopia
Mineralogy & Physical Laboratory Desk
Result Form

Geoscience Laboratory		Lab section: - Mineralogy ☐ Physical ☒	
Client /Originator Name: - Desalegne Ayenew			
Client Category: - Institute		Gov. ☐	Pvt. ☐
File name: - 1348/24PVT		Area Ref: -	No of Samples:- 02
Sample Type: - Waste Paper Ash/Rice Husk Ash		Lab No: -	Sample No.: -
Type of Analysis: - Specific gravity		Preparation required: -	Date Submitted: - 30/09/2016 E.C

Coll.No.	Lab. No.	Pycnometer No.	m ₂ Mass of pycnometer in g	m ₃ Mass of test solution in the pycnometer without test sample in g	Q ₂ Density of test solution in g/cm ³	m ₄ Mass of pycnom. plus test sample in g	m ₄ -m ₂ mass of test sample in g	m ₅ mass of pycnom. test sample and test solution in g	m ₃ +m ₄ - m ₅ volume of test sample in g/cm ³	Specific Gravity in g/cm ³	Average
WPA-750°C-2hr	1348/24	4/4	34.9939	85.0234	1 g/cm ³	42.2753	7.2814	88.8552	3.4496	2.11	2.10
		5/5	34.7787	84.7996	1 g/cm ³	41.581	6.8023	88.3522	3.2497	2.09	
RHA-750°C-5hr	1349/24	4/4	34.9939	85.0234	1 g/cm ³	42.687	7.6931	88.7857	3.9308	1.95	1.94
		5/5	34.7787	84.7996	1 g/cm ³	42.2253	7.4466	88.4196	3.8266	1.94	

Described By / Analysts: - Aregahagn Kefelegn	Checked by: - Abdu Ebrahim	Date Completed: - 03/07/24
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	GEOLOGICAL INSTITUTE OF ETHIOPIA	Doc. Number: GLD/F5.10.2	Version No: 1
	Geochemical Laboratory Desk		Page 1 of 1
Document Title:-	Complete Silicate Analysis Report	Effective date:	Nov. 2022

Customer Name:-Dessalegn Ayenew

Sample type :- Powder

Sample Preparation:-200 Mesh

Date Submitted:-7/06/2024

Analytical Result: In percent (%) Element to be determined Major Oxides & Minor Oxides.

Analytical Method: LiBO₂ FUSION, HF attack, GRAVIMETRIC, COLORIMETRIC and AAS

Issue Date:-27/06/2024

Request No:- GLD/RQ/1449/24

Report No:- GLD/RN/3472/24

Number of Sample:- One(01)

Collector's code	SiO ₂	Al ₂ O ₃	Fe ₂ O ₃	CaO	MgO	Na ₂ O	K ₂ O	MnO	P ₂ O ₅	TiO ₂	H ₂ O	LOI	Weight of Sample
WPA	7.10	1.64	1.56	57.22	1.52	<0.01	<0.01	<0.01	<0.01	0.08	0.40	29.27	200gm

Note:- This result represent only for the sample submitted to the laboratory.

➤ LOI = Loss on Ignition

Analysts

Haimanot Bayeh

Kindie Kasahun

Melkamu Debalka

Shashe Haile

Checked By

Nigist Fikadu

Approved By

Lidet Engdeshaw



Source: (Dessalegn Ayenew 2024)

Figure 4. XRF for CP

GEOCHEMICAL INSTITUTE OF ETHIOPIA		Doc. Number:	Version No: 1
Geochemical Laboratory Desk		GLD/F5.10.2	
Document Title:-	Complete Silicate Analysis Report	Effective date:	Nov. 2022

Customer Name:- Yihenew Assefa
Sample type :- Ceramic powder
Sample Preparation:- 200 Mesh
Date Submitted :- 10/04/2025
Analytical Result: In percent (%) Element to be determined Major Oxides & Minor Oxides.
Analytical Method: LiBO₂ FUSION, HF attack, GRAVIMETRIC, COLORIMETRIC and AAS

Issue Date:- 02/05/2025
Request No:- GLD/RO/1222/25
Report No:- GLD/RN/4698/25
Number of Sample: One(01)

Collector's code	SiO ₂	Al ₂ O ₃	Fe ₂ O ₃	CaO	MgO	Na ₂ O	K ₂ O	MnO	P ₂ O ₅	TiO ₂	H ₂ O	LOI	weight Of sample
Y.A.02	90.00	1.12	0.98	0.66	0.68	<0.02	1.93	0.14	0.14	0.06	1.70	4.05	500gm

Note:- This result represent only for the sample submitted to the laboratory.
➤ LOI = Loss on Ignition

Analysts
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Geochemical Laboratory Desk

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Source: (Yihenew Assefa)

Figure 4. BET for CP

Quantachrome NovaWin - Data Acquisition and Reduction
for NOVA instruments
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Analysis Report
Operator:alex Date:2025/05/2 Operator:alex Date:2/05/2025
Sample ID: ceramic Filename: C:\QCdata\Physisorb\YHN WCP ceramic.qps
Sample Desc: sample Comment: TEST
Sample weight: 0.1 g Sample Volume: 0.02564 cc Sample Density:3.9 g/cc
Outgas Time: 8.0 hrs OutgasTemp: 300.0 C
Analysis gas: Nitrogen Bath Temp: 77.3 K
Press. Tolerance:0.100/0.100 (ads/des)Equil time: 60/60 sec (ads/des) Equil timeout: 240/240 sec (ads/des)
Analysis Time: 46.3 min End of run: 2007/01/01 1:01:15 Instrument: Nova Station B
Cell ID: 2 F/W version: 0.00
Adsorbate Nitrogen Temperature 77.350K
Molec. Wt.: 28.013 g Cross Section: 16.200 Å² Liquid Density: 0.808 g/cc
Relative Pressure P/Po Volume @ STP 1 / [W((Po/P) - 1)]
cc/g

5.37500e-02	9.2536	4.9115e+00
1.23334e-01	21.0223	5.3545e+00
1.97123e-01	33.3866	5.8839e+00
2.70634e-01	45.5314	6.5204e+00
3.47767e-01	58.2007	7.3301e+00

BET summary
Slope = 8.178
Intercept = 4.377e+00
Correlation coefficient, r = 0.994816
C constant= 2.868
Surface Area = 277.396 m²/g

Appendix 2 Tests for Fine Aggregate and Cement

1. Gradation and Fineness Modulus of Fine Aggregate ASTM C33

Table 1. Gradation for Fine Aggregate

Sieve size (mm)	Weight of sieve(gm)	Weight of sieve+samplel(gm)	Weight of retained(gm)	Percentage retained(gm)	Cumulative % retained	Percentage passing	ASTM C - 33 Limit	
							Min	Max
9.5	691	691.00	0.00	0.00	0.00	100.00	100	100
4.75	717.5	717.50	0.00	0.00	0.00	100.00	95	100
2.36	731.5	1054.00	322.50	8.57	8.57	91.43	80	100
1.18	613	1224.60	611.60	16.26	24.83	75.17	50	85
0.6	603	1743.00	1140.00	30.30	55.13	44.87	25	60

0.3	575.5	1575.30	999.80	26.57	81.70	18.30	10	30
0.15	573	1025.70	452.70	12.03	93.74	6.26	2	10
0.075	535	694.40	159.40	4.24	97.97	2.03		
0	209	285.20	76.20	2.03	100.00	0.00	-	-
Total mass		3762.2	F.M=	2.64				

$$\text{Fineness Modulus} = \frac{\sum \text{Cumulative \% Retained}}{100}$$

$$FM = \frac{264}{100} = 2.64$$

2. Specific Gravity, Absorption, and Moisture Contents of Fine Aggregate

Table 2. Determination for Specific Gravity, Absorption, and Moisture Contents of Fine Aggregate

No.	Descriptions	Measured value in gram
1	Mass of SSD sample in air (D)	500
2	Mass of water + pycnometer (B)	1588
3	Weight of sand + water + pycnometer (C)	1904
4	Mass of oven-dry sample (A)	486.5
Moisture Contents for sand		
1	Mass initial sample	1500
2	Mass of oven-dry sample	1475.3

$$\text{Bulk specific gravity (SSD)} = \frac{D}{(D+B-C)} = \frac{500}{(500+1588-1904)} = 2.72$$

$$\text{Water absorption (\%)} = \frac{(D-A)}{A} * 100 = \left(\frac{500-486.5}{486.5} \right) * 100 = 2.8\%$$

$$\text{Moisture content (\%)} = \left(\frac{1500-1475.3}{1475.3} \right) * 100 = 1.7\%$$

Table 3. Unit Weight (Dry rodded Density) of Fine Aggregate

	mold weight	(mold +sample)weight		
Trials	(M1)	M2	Volume	Unit Weight
	(kg)	(kg)	(m ³)	(kg/m ³)
1	2.97	7.53	0.003	1520.33
2	2.97	7.60	0.003	1543.67
			Average	1532.00

3. Silt Content of Fine Aggregates (ASTM C117)

A = Mass of oven-dried sample of sand before wash = 1500 g

B = Mass of oven-dried sample of sand after washing using 75 μ m = 1445 g

Calculation

$$\text{Silt Content (\%)} = (A - B)/B = (1500 - 1445)/1445 = 3.67\%$$

5. Consistency, Setting Time, and Soundness of Cement

Table 4. Consistency and Soundness of Cement Containing WPACP

Mix code	Cement (gm)	WPACP (gm)	Water demand (%)	Water (ml)	Consistency (mm)	Soundness (mm)
WPACP0	650.0	0	26.5	172.3	11.0	1.0
WPACP5	617.5	32.5	27.5	178.8	10.5	1.0
WPACP10	585.0	65	28	182.0	10.5	1.5
WPACP15	552.5	97.5	28.5	185.3	10.0	1.5
WPACP20	520.0	130	29	188.5	9.5	1.5

Table 5. Initial and Final Setting Time

Mix code	Cement (gm)	Initial setting time (minutes)	Final setting time (minutes)	ASTM C150 Limit	
				Initial setting time (minutes)	Final setting time (minutes)
WPACP0	650.0	188	325	45	375
WPACP5	617.5	183	310	45	375
WPACP10	585.0	165	280	45	375
WPACP15	552.5	156	265	45	375
WPACP20	520.0	150	244	45	375

Table 6. Summary of Test Result for Mix Design

No.	Type of test	Test results
1	Specific gravity of sand	2.7
2	Unit weight of sand	1532 kg/m ³
3	Fineness modulus of sand	2.64
4	Silt content of sand	3.67%
5	Absorption of sand	2.8%
6	Moisture content of sand	1.7%
7	Specific gravity of cement	3.15
8	Specific gravity of water	1

Appendix 3 Mortar Properties

1. Compressive Strength Test Results

Table 1. 3 Days of Compressive Strength Curing in Water

Mix Code	Sample No.	Mass (gm)	Average Mass (gm)	Load (KN)	Average Load (KN)	Compressive Strength (Mpa)	Average Compressive Strength (Mpa)
WPACP0	1	344.55	345.7	38.95	40.65	15.58	16.26
	2	347		40.9		16.36	
	3	345.5		42.1		16.84	
WPACP5	1	346.95	349.5	44.05	43.05	17.62	17.22
	2	350		42.1		16.84	
	3	351.5		43		17.20	
WPACP10	1	357.5	356.2	46.6	45.13	18.64	18.05
	2	355.0		43.5		17.40	
	3	356.1		45.3		18.12	
WPACP15	1	356.55	358.6	46.65	47.57	18.66	19.03
	2	358		48.5		19.40	
	3	361.25		47.55		19.02	
WPACP20	1	340	340.5	36.3	37.53	14.52	15.01
	2	340.7		37.8		15.12	
	3	340.65		38.5		15.40	
	2	332.65		32.75		13.10	
	3	330.5		31.3		12.52	
	2	334.1		30.2		12.08	
	3	333.8		26.1		10.44	

Table 2. 7 Days of Compressive Strength Curing in Water

Mix Code	Sample No.	Mass (gm)	Average Mass (gm)	Load (KN)	Average Load (KN)	Compressive Strength (Mpa)	Average Compressive Strength (Mpa)
WPACP0	1	355.5	354.3	52.8	49.57	21.12	19.83
	2	354.3		48.8		19.52	
	3	353		47.1		18.84	
WPACP5	1	349.5	355.7	53.6	52.70	21.44	21.08
	2	358		53.8		21.52	
	3	359.5		50.7		20.28	
WPACP10	1	362	358.1	57.3	56.30	22.92	22.52
	2	356.8		56.8		22.72	
	3	355.5		54.8		21.92	
WPACP15	1	357.2	361.5	60.8	59.93	24.32	23.97
	2	364.6		60.4		24.16	
	3	362.7		58.6		23.44	
WPACP20	1	347	348.2	44.8	43.48	17.92	17.39
	2	347.2		43		17.20	
	3	350.5		42.65		17.06	
	2	341.8		41.1		16.44	
	3	339.3		37.9		15.16	
	2	340.5		40.4		16.16	
	3	337.2		38.4		15.36	

Table 3. 28 Days of Compressive Strength Curing in Water

Mix Code	Sample No.	Mass (gm)	Average Mass (gm)	Load (KN)	Average Load (KN)	Compressive Strength (Mpa)	Average Compressive Strength (Mpa)
WPACP0	1	359	358.1	66.8	69.37	26.72	27.75
	2	356.8		71.3		28.52	
	3	358.5		70		28.00	
WPACP5	1	357.4	357.1	71.9	71.67	28.76	28.67
	2	355.8		69		27.60	
	3	358		74.1		29.64	
WPACP10	1	359.2	359.1	79.9	78.60	31.96	31.44
	2	358		76.6		30.64	
	3	360		79.3		31.72	
WPACP15	1	364.1	365.9	87	86.93	34.80	34.77
	2	368.5		87.7		35.08	
	3	365		86.1		34.44	
WPACP20	1	349.9	351.6	64.2	64.20	25.68	25.68
	2	353.5		65		26.00	
	3	351.3		63.4		25.36	
	2	350.7		58.1		23.24	
	3	343.4		59		23.60	
	2	344.2		54.9		21.96	
	3	340.1		60.8		24.32	

Table 4. 56 Days of Compressive Strength Curing in Water

Mix Code	Sample No.	Mass (gm)	Average Mass (gm)	Load (KN)	Average Load (KN)	Compressive Strength (Mpa)	Average Compressive Strength (Mpa)
WPACP0	1	364	363.1	83.5	83.80	33.40	33.52
	2	361.8		86.3		34.52	
	3	363.5		81.6		32.64	
WPACP5	1	362.4	362.1	82.7	86.00	33.08	34.40
	2	360.8		89.8		35.92	
	3	363		85.5		34.20	
WPACP10	1	364.2	364.1	88.6	86.90	35.44	34.76
	2	363		82.2		32.88	
	3	365		89.9		35.96	
WPACP15	1	369.1	370.9	95.5	97.27	38.20	38.91
	2	373.5		98.7		39.48	
	3	370		97.6		39.04	
WPACP20	1	354.9	356.6	77.4	76.30	30.96	30.52
	2	358.5		78.7		31.48	
	3	356.3		72.8		29.12	
	2	355.7		68.5		27.40	
	3	348.4		74.2		29.68	
	2	349.2		68.4		27.36	
	3	345.1		65.6		26.24	

Table 5. 91 Days of Compressive Strength Curing in Water

Mix Code	Sample No.	Mass (gm)	Average Mass (gm)	Load (KN)	Average Load (KN)	Compressive Strength (Mpa)	Average Compressive Strength (Mpa)
WPACP0	1	364.5	365.1	86.6	85.93	34.64	34.37
	2	369.3		89.4		35.76	
	3	361.4		81.8		32.72	
WPACP5	1	365.5	366.7	84.4	87.63	33.76	35.05
	2	368.5		91.3		36.52	
	3	366		87.2		34.88	
WPACP10	1	373.1	370.2	82.2	87.70	32.88	35.08
	2	367.3		92.4		36.96	
	3	370.3		88.5		35.40	
WPACP15	1	385.5	385.6	102.6	99.90	41.04	39.96
	2	387.3		100.4		40.16	
	3	384		96.7		38.68	
WPACP20	1	367.5	363.0	79.3	77.30	31.72	30.92
	2	367		77.7		31.08	
	3	354.5		74.9		29.96	
	2	359.5		71.6		28.64	
	3	360		73.2		29.28	
	2	358.2		72.5		29.00	
	3	356.3		68.6		27.44	

Table 6. 3 Days of Compressive Strength Curing in Sulfate Solution

Mix Code	Sample No.	Mass (gm)	Average Mass (gm)	Load (KN)	Average Load (KN)	Compressive Strength (Mpa)	Average Compressive Strength (Mpa)
WPACP0	1	348.4	347.3	35.5	36.20	15.20	15.48
	2	348		35		15.00	
	3	345.5		38.1		16.24	
WPACP5	1	346	352.2	39	39.07	16.60	16.63
	2	353		37.7		16.08	
	3	357.5		40.5		17.20	
WPACP10	1	358.8	354.1	42.5	41.43	18.00	17.57
	2	350.1		40.2		17.08	
	3	353.3		41.6		17.64	
WPACP15	1	349.3	355.9	43.5	44.30	18.40	18.72
	2	358.6		45.1		19.04	
	3	359.7		44.3		18.72	
WPACP20	1	346	339.8	33.2	33.07	14.28	14.23
	2	340		30.8		13.32	
	3	333.5		35.2		15.08	
	2	333.9		29.8		12.92	
	3	344.5		27		11.80	
	2	328		24.5		10.80	
	3	317.5		21.5		9.60	

Table 7. 7 Days of Compressive Strength Curing in Sulfate Solution

Mix Code	Sample No.	Mass (gm)	Average Mass (gm)	Load (KN)	Average Load (KN)	Compressive Strength (Mpa)	Average Compressive Strength (Mpa)
WPACP0	1	346	353.6	48.5	45.87	19.40	18.35
	2	356.8		45.8		18.32	
	3	357.9		43.3		17.32	
WPACP5	1	358.05	360.0	46.2	49.27	18.48	19.71
	2	360		52.7		21.08	
	3	361.8		48.9		19.56	
WPACP10	1	360.3	362.3	57.4	53.53	22.96	21.41
	2	362.8		52.7		21.08	
	3	363.8		50.5		20.20	
WPACP15	1	363.85	363.8	58.6	57.57	23.44	23.03
	2	366.1		58.9		23.56	
	3	361.35		55.2		22.08	
WPACP20	1	350	352.7	45.9	39.37	18.36	15.75
	2	353.5		36.7		14.68	
	3	354.45		35.5		14.20	
	2	346.3		34.5		13.80	
	3	352.9		35.1		14.04	
	2	332.1		33.1		13.24	
	3	336		37.3		14.92	

Table 8. 28 Days of Compressive Strength Curing in Sulfate Solution

Mix Code	Sample No.	Mass (gm)	Average Mass (gm)	Load (KN)	Average Load (KN)	Compressive Strength (Mpa)	Average Compressive Strength (Mpa)
WPACP0	1	353.35	355.72	63.4	63.40	25.36	25.36
	2	357.3		62.5		25	
	3	356.5		64.3		25.72	
WPACP5	1	358.3	360.17	68.6	66.63	27.44	26.65
	2	356.7		67.5		27	
	3	365.5		63.8		25.52	
WPACP10	1	362.8	363.13	73.4	74.53	29.36	29.81
	2	366.1		75.7		30.28	
	3	360.5		74.5		29.8	
WPACP15	1	365.8	365.97	86.9	83.50	34.76	33.40
	2	366.8		82.3		32.92	
	3	365.3		81.3		32.52	
WPACP20	1	357.5	353.73	60.5	58.13	24.2	23.25
	2	355		57.7		23.08	
	3	348.7		56.2		22.48	
	2	349.85		53.7		21.48	
	3	348		52.5		21	
	2	324.8		50.5		20.2	
	3	319.5		52.6		21.04	

Table 9. 56 Days of Compressive Strength curing in Sulfate Solution

Mix Code	Sample No.	Mass (gm)	Average Mass (gm)	Load (KN)	Average Load (KN)	Compressive Strength (Mpa)	Average Compressive Strength (Mpa)
WPACP0	1	351	354.0	76.1	77.33	30.44	30.93
	2	357		78.4		31.36	
	3	353.9		77.5		31.00	
WPACP5	1	360.5	359.6	81.4	80.17	32.56	32.07
	2	357.5		78.6		31.44	
	3	360.8		80.5		32.20	
WPACP10	1	366.5	362.8	84.5	82.10	33.80	32.84
	2	360		79.6		31.84	
	3	362		82.2		32.88	
WPACP15	1	363.5	363.5	95.8	93.63	38.32	37.45
	2	368.5		93.5		37.40	
	3	358.6		91.6		36.64	
WPACP20	1	357.5	355.9	71.6	69.70	28.64	27.88
	2	356		67.7		27.08	
	3	354.1		69.8		27.92	
	2	346.5		63.5		25.40	
	3	345		65.1		26.04	
	2	335		60.3		24.12	
	3	333.5		57.5		23.00	

Table 10. 91 Days of Compressive Strength Curing in Sulfate Solution

Mix Code	Sample No.	Mass (gm)	Average Mass (gm)	Load (KN)	Average Load (KN)	Compressive Strength (Mpa)	Average Compressive Strength (Mpa)
WPACP0	1	353	356.0	77.7	78.77	31.08	31.51
	2	359		80.1		32.04	
	3	355.9		78.5		31.40	
WPACP5	1	362.5	361.7	83.5	81.90	33.40	32.76
	2	360.7		80.4		32.16	
	3	361.8		81.8		32.72	
WPACP10	1	364.5	363.5	84.1	82.27	33.64	32.91
	2	362.5		80.5		32.20	
	3	363.6		82.2		32.88	
WPACP15	1	373.5	368.2	96	95.17	38.40	38.07
	2	368		94.2		37.68	
	3	363		95.3		38.12	
WPACP20	1	366.5	366.9	70.5	70.00	28.20	28.00
	2	363		67.1		26.84	
	3	371.1		72.4		28.96	
	2	343.1		66.5		26.60	
	3	353.4		65.7		26.28	
	2	341.2		61.2		24.48	
	3	340.7		59.6		23.84	

Table 11. 3 and 7 Days UPV Results of Mortar Cubes

3 Day					7 Day			
Mix Code	Distance (m)	Time (us)	UPV (m/s)	Average UPV (Km/s)	Time (us)	UPV (m/s)	Average UPV (Km/s)	
WPACP0	0.05	21.1	2,369.67	2.55	18.8	2,659.57	2.73	
		18.1	2,762.43		18.5	2,702.70		
		19.8	2,525.25		17.7	2,824.86		
WPACP5	0.05	19	2,631.58	2.66	18.3	2,732.24	2.76	
		19.5	2,564.10		17.4	2,873.56		
		17.9	2,793.30		18.7	2,673.80		
WPACP10	0.05	17.3	2,890.17	2.72	17	2,941.18	2.95	
		18.6	2,688.17		16.4	3,048.78		
		19.3	2,590.67		17.5	2,857.14		
WPACP15	0.05	17.4	2,873.56	2.86	16.8	2,976.19	3.06	
		19	2,631.58		16.6	3,012.05		
		16.3	3,067.48		15.7	3,184.71		
WPACP20	0.05	23.2	2,155.17	2.26	17.5	2,857.14	2.68	
		20.9	2,392.34		20	2,500.00		
		22.5	2,222.22		18.7	2,673.80		
		22.5	2,222.22		19.3	2,590.67		
		21.8	2,293.58		20.2	2,475.25		
		20.7	2,415.46		18.7	2,673.80		
		20.7	2,415.46		19.5	2,564.10		

Table 12. 28 and 56 Days UPV Results of Mortar Cubes

28 Day						56 Day		
Mix Code	Sample No.	Distance (m)	Time (us)	UPV (m/s)	Average UPV (Km/s)	Time (us)	UPV (m/s)	Average UPV (Km/s)
WPACP0	1	0.05	15.6	3,205.13	3.31	14.3	3,496.50	3.42
	2		15	3,333.33		14.7	3,401.36	
	3		14.7	3,401.36		14.9	3,355.70	
WPACP5	1	0.05	14.1	3,546.10	3.35	14.5	3,448.28	3.52
	2		15	3,333.33		14.1	3,546.10	
	3		15.8	3,164.56		14	3,571.43	
WPACP10	1	0.05	13.8	3,623.19	3.41	15.7	3,184.71	3.44
	2		14.4	3,472.22		13	3,846.15	
	3		15.9	3,144.65		15.2	3,289.47	
WPACP15	1	0.05	13.3	3,759.40	3.63	13.6	3,676.47	3.64
	2		14	3,571.43		13	3,846.15	
	3		14.1	3,546.10		14.7	3,401.36	
WPACP20	1	0.05	15.7	3,184.71	2.97	17.2	2,906.98	2.96
	2		17.4	2,873.56		16.1	3,105.59	
	3		17.5	2,857.14		17.4	2,873.56	
	2		17.7	2,824.86		18.1	2,762.43	
	3		17.8	2,808.99		16.5	3,030.30	
	2		18.5	2,702.70		17.2	2,906.98	
	3		17.1	2,923.98		17.8	2,808.99	

Table 13. 91 Days UPV Results of Mortar Cubes

Mix Code	Sample No.	Distance (m)	Time (us)	UPV (m/s)	Average UPV (Km/s)
WPACP0	1	0.05	13	3,846.15	3.62
	2		14.2	3,521.13	
	3		14.3	3,496.50	
WPACP5	1	0.05	12.9	3,875.97	3.69
	2		14.2	3,521.13	
	3		13.6	3,676.47	
WPACP10	1	0.05	13.3	3,759.40	3.78
	2		14.1	3,546.10	
	3		12.4	4,032.26	
WPACP15	1	0.05	13.2	3,787.88	4.08
	2		12.1	4,132.23	
	3		11.6	4,310.34	
WPACP20	1	0.05	13.7	3,649.64	3.38
	2		13.9	3,597.12	
	3		17.2	2,906.98	
	2		15.2	3,289.47	
	3		15	3,333.33	
	2		16	3,125.00	
	3		17.7	2,824.86	

Table 16 Water absorption and porosity of mortar at 3 days

3 day			7 day		
Mix Code	Volume (m ³)	Mass (g)	Bulk Density (Kg/m ³)	Mass (g)	Density (Kg/m ³)
WPACP0	0.000125	345.7	2765.5	354.3	2834.1
WPACP5		349.5	2795.9	355.7	2845.3
WPACP10		356.2	2849.6	358.1	2864.8
WPACP15		358.6	2868.8	361.5	2892.0
WPACP20		340.5	2723.6	348.2	2785.9

Table 15. Density of mortar

28 day				56 day		91 day	
Mix Code	Volume (m ³)	Mass (g)	Bulk Density (Kg/m ³)	Mass (g)	Density (Kg/m ³)	Mass (g)	Density (Kg/m ³)
WPACP0	0.000125	358.10	2864.8	363.10	2904.8	365.1	2920.5
WPACP5		357.07	2856.5	362.07	2896.5	366.7	2933.3
WPACP10		359.07	2872.5	364.07	2912.5	370.2	2961.9
WPACP15		365.87	2926.9	370.87	2966.9	385.6	3084.8
WPACP20		351.57	2812.5	356.57	2852.5	363.0	2904.0

Table 16 Water absorption and porosity of mortar at 3 days

Mix Code	Sample No.	SSD Mass in air (gm)	Average Mass (gm)	Oven dry (gm)	Average Oven dry (gm)	SSD Mass in water (gm)	Average SSD Mass in water	Porosity (%)	Absorption (%)	Average Porosity	Average Absorption
WPACP0	1	341.0	339.17	308.3	308.1	130.1	131.27	15.5	10.6	14.9	10.1
	2	333.5		307.1		133.7		13.2	8.6		
	3	343.0		309		130		16.0	11.0		
WPACP5	1	340.5	343.17	312.5	313.6	131	131.80	13.4	9.0	14.0	9.4
	2	343.0		313.2		132		14.1	9.5		
	3	346.0		315.2		132.4		14.4	9.8		
WPACP10	1	354.0	354.63	327	327.0	133.1	133.77	12.2	8.3	12.5	8.5
	2	353.4		324		134		13.4	9.1		
	3	356.5		330		134.2		11.9	8.0		
WPACP15	1	346.0	347.90	320.4	322.9	132.1	133.33	12.0	8.0	11.7	7.8
	2	350.7		323.5		134.3		12.6	8.4		
	3	347.0		324.7		133.6		10.4	6.9		
	1	327.3		296		126.8		15.6	10.6		

Table 16 Water absorption and porosity of mortar at 3 days

WPACP20	2	324.1	328.67	290.5	298.2	125.7	126.83	16.9	11.6	15.1	10.3
	3	334.6		308		128		12.9	8.6		
	2	309.8		274.6		121.5		18.7	12.8		
	3	307.0		279.5		119.1		14.6	9.8		
	2	301.2		260.63		108.3		21.0	15.6		
	3	305.0		261.2		109.79		22.4	16.8		

Table 17. Water absorption and porosity of mortar at 7 days

Mix Code	Sample No.	SSD Mass in air (gm)	Average Mass (gm)	Oven dry (gm)	Average Oven dry (gm)	SSD Mass in water (gm)	Average SSD Mass in water (gm)	Porosity	Absorption	Average Porosity	Average Absorption
WPACP0	1	344.2	344.03	316.4	316.7	133.6	133.63	13.2	8.8	13.0	8.6
	2	346.5		321.2		134.8		12.0	7.9		
	3	341.4		312.5		132.5		13.8	9.2		
WPACP5	1	346.5	347.33	322	322.1	134.51	134.81	11.6	7.6	11.9	7.8
	2	349.5		323.74		135.6		12.0	8.0		
	3	346.0		320.54		134.33		12.0	7.9		
WPACP10	1	353.2	357.90	329.8	332.5	136.67	138.38	10.8	7.1	11.6	7.6
	2	361.4		334.22		139.65		12.3	8.1		
	3	359.1		333.5		138.81		11.6	7.7		
WPACP15	1	353.5	351.67	329.8	328.0	136.68	136.01	10.9	7.2	11.0	7.2
	2	349.1		325.7		135.08		10.9	7.2		
	3	352.4		328.5		136.28		11.1	7.3		
WPACP20	1	333.4	334.67	303.62	304.7	118.95	119.37	13.9	9.8	13.9	9.8
	2	331.7		303.7		118.38		13.1	9.2		
	3	338.9		306.65		120.78		14.8	10.5		
	2	321.1		286.62		125.06		17.6	12.0		
	3	325.3		300.46		126.58		12.5	8.3		
	2	312.0		271.57		114.45		20.5	14.9		
	3	317.5		276.34		116.45		20.5	14.9		

Table 18. Water absorption and porosity of mortar at 28 days

Mix Code	Sample No.	SSD Mass in air (gm)	Average Mass (gm)	Oven dry (gm)	Average Oven dry (gm)	SSD Mass in water (gm)	Average SSD Mass in water (gm)	Porosity (%)	Absorption (%)	Average Porosity	Average Absorption
WPACP0	1	346.0	347.40	318.4	319.7	132.88	133.39	13.0	8.7	13.0	8.7
	2	349.3		321.38		134.08		13.0	8.7		
	3	346.9		319.2		133.21		13.0	8.7		
WPACP5	1	349.3	350.80	323.32	324.9	133.93	134.48	12.1	8.0	12.0	8.0
	2	350.5		324.72		134.39		11.9	7.9		
	3	352.6		326.62		135.13		11.9	8.0		
WPACP10	1	357.5	355.00	331.45	329.2	139.98	138.82	12.0	7.9	11.9	7.8
	2	352.5		327.5		137.44		11.6	7.6		
	3	355.0		328.75		139.04		12.2	8.0		
WPACP15	1	366.7	363.53	346.4	342.4	136.57	135.65	8.8	5.9	9.3	6.2
	2	359.7		338.5		134.72		9.4	6.3		
	3	364.2		342.3		135.67		9.6	6.4		
WPACP20	1	345.0	338.73	311.5	308.5	132.14	129.86	15.7	10.8	14.4	9.8
	2	331.0		306.4		127.05		12.1	8.0		
	3	340.2		307.7		130.39		15.5	10.6		
	2	322.9		295.75		124.11		13.6	9.2		
	3	323.7		294.25		124.41		14.8	10.0		
	2	314.5		272.2		114.4		21.1	15.5		
	3	320.7		285.3		116.51		17.3	12.4		

Table 19. Water absorption and porosity of mortar at 28 days

Mix Code	Sample No.	SSD Mass in air (gm)	Average Mass (gm)	Oven dry (gm)	Average Oven dry (gm)	SSD Mass in water (gm)	Average SSD Mass in water (gm)	Porosity (%)	Absorption (%)	Average Porosity	Average Absorption
WPACP0	1	349.4	351.73	323.4	325.7	136.24	137.02	12.2	8.0	12.1	8.0
	2	353.5		327.65		137.81		12.0	7.9		
	3	352.3		326.01		137		12.2	8.1		
WPACP5	1	355.0	355.63	331.8	331.7	138.39	138.58	10.7	7.0	11.0	7.2
	2	354.2		328.5		138.1		11.9	7.8		
	3	357.7		334.7		139.25		10.5	6.9		
WPACP10	1	368.5	367.47	344	344.6	143.33	143.20	10.9	7.1	10.2	6.6
	2	366.6		344		142.3		10.1	6.6		
	3	367.3		345.7		143.97		9.7	6.2		
WPACP15	1	359.8	357.17	338.87	337.5	140.9	140.03	9.6	6.2	9.1	5.8
	2	355.4		336.4		139.3		8.8	5.6		
	3	356.3		337.2		139.9		8.8	5.7		
WPACP20	1	347.1	342.23	318.5	313.1	136.5	134.33	13.6	9.0	14.0	9.3
	2	336.2		307.3		131.8		14.1	9.4		
	3	343.4		313.5		134.7		14.3	9.5		
	2	325.7		297.1		127.64		14.4	9.6		
	3	329.6		301.3		129.4		14.1	9.4		
	2	316.3		285.5		124.2		16.0	10.8		
	3	322.0		291.1		126.4		15.8	10.6		

Table 20. Water absorption and porosity of mortar at 28 days

Mix Code	Sample No.	SSD Mass in air (gm)	Average Mass (gm)	Oven dry (gm)	Average Oven dry (gm)	SSD Mass in water (gm)	Average SSD Mass in water (gm)	Porosity (%)	Absorption (%)	Average Porosity	Average Absorption
WPACP0	1	351.6	353.10	325.5	327.9	138.1	138.67	12.2	8.0	11.8	7.7
	2	354.0		329.8		139		11.3	7.3		
	3	353.7		328.4		138.9		11.8	7.7		
WPACP5	1	357.5	357.20	334.5	334.1	140.4	140.27	10.6	6.9	10.6	6.9
	2	355.4		330.4		139.6		11.6	7.6		
	3	358.7		337.5		140.8		9.7	6.3		
WPACP10	1	367.4	370.40	347.2	352.1	144.3	145.47	9.1	5.8	8.1	5.2
	2	368.5		353.5		144.7		6.7	4.2		
	3	375.3		355.6		147.4		8.6	5.5		
WPACP15	1	359.4	357.93	347.2	341.2	141.1	140.53	5.6	3.5	7.7	4.9
	2	356.8		341.8		140.1		6.9	4.4		
	3	357.6		334.5		140.4		10.6	6.9		
WPACP20	1	348.6	345.43	321.3	316.7	136.9	135.67	12.9	8.5	13.7	9.1
	2	341.2		310.2		134		15.0	10.0		
	3	346.5		318.6		136.1		13.3	8.8		
	2	325.4		300.4		127.8		12.7	8.3		
	3	333.2		302.4		130.8		15.2	10.2		
	2	317.5		287.5		124.7		15.6	10.4		
	3	325.3		297.7		127.7		14.0	9.3		

Table 21.Trial mix results

Mix Code	Trial Mixes	Waste Paper ash (%)	Ceramic Waste Powder (%)	Cement National (OPC) (%)	3 Days		7 Days	
					Average Load(KN)	Average Compressive Strength(MPa)	Average Load(KN)	Average Compressive Strength(MPa)
WPACP0	Trial mix 1 (control)	0	0	100	32.56	13.02	43.04	17.22
WPACP10	Trial mix 1 (1:1)	5	5	90	30.70	12.28	39.58	15.83
	Trial mix (1:2)	23.33	6.67	90	34.00	13.60	45	18.0
	Trial mix (2:1)	36.67	3.33	90	28.90	11.56	38.90	15.56
WPACP15	Trial mix 1 (1:1)	7.5	7.5	85	39.28	15.71	45.59	18.24
	Trial mix (1:2)	25	10	85	42.15	16.86	50.88	20.35

	Trial mix 3 (2:1)	10	5	85	35.19	14.08	43.11	17.24
WPACP20	Trial mix 1 (1:1)	10	10	80	27.20	10.88	37.14	14.86
	Trial mix 2 (1:2)	6.67	13.33	80	28.60	11.44	38.65	15.46
	Trial mix 3 (2:1)	13.33	6.67	80	25.12	10.05	33.21	13.28
	Trial mix 2 (1:2)	8.33	16.67	75	27.11	10.84	38.08	15.23
	Trial mix 3 (2:1)	16.67	8.33	75	25.72	10.29	31.15	12.46
	Trial mix 2 (1:2)	10	20	70	25.23	10.09	35.21	14.08
	Trial mix 3 (2:1)	20	10	70	23.66	9.46	29.81	11.92