Durability Assurance of Production-Scale High-Performance Concrete using Surface Resistivity

Table 1 Details of the concrete mixes used in the study

Specimen ID	Grade	Binder OPC (kg/m³)	Binder GGBS (kg/m³)	Binder MS (kg/m³)	Coarse aggregate (kg/m³)	Fine aggregate (kg/m³)	Superplasticizer Dosage (kg/m³)	Superplasticizer Type	CIA* Dosage (kg/m³)	CIA* Type	Water Content (kg/m³)	w/b	Resistivity Face 1	Resistivity Face 2	Resistivity Face 3	Resistivity Face 4	Resistivity Face 5	Average 28-day resistivity (SSD), kΩ.cm	28 days compressive strength, MPa	Slump (mm)	Charge Passed at 28 days, Coulombs	Depth of Water Penetration at 28 days, mm
1	M30	370	-	-	1096	794	4	PCE	-	'	155	0.42	5.7	5.6	6.0	6.1	6.0	5.9	38	175±25	-	-
2													5.8	6.2	6.1	5.7	5.7	5.9	38			
3													6.0	5.8	6.1	6.3	5.7	6.0	35			
4	M35	240	160	-	1122	793	2	SNF	2	MM	150	0.38	38.3	28.5	32.4	33.1	34.7	33.4	52	175±25	-	8.0
5													35.5	27.6	28.0	31.9	35.0	31.6	52			
6													37.1	29.8	33.1	35.0	32.0	33.4	52			
7	M40	440	-	-	1090	721	4	PCE	-	'	152	0.35	11.4	11.5	10.2	11.5	13.5	11.6	58	175±25	-	9.3
8													11.5	12.1	10.6	11.5	12.6	11.7	57			
9													11.0	10.6	10.7	10.6	11.9	11.0	54			
10		278	208	34	1037	737	7	PCE	-	'	160	0.31	32.3	31.0	31.9	32.4	30.2	31.6	62	150±25	263	4.9
11													32.1	30.5	30.0	30.6	27.4	30.1	71			
12													32.3	30.3	28.3	31.4	29.8	30.4	66			
13		300	208	32	1024	729	7	PCE	3	MMO	159	0.29	33.2	32.9	32.9	33.2	32.8	33.0	68	150±25	356	5.8
14													29.1	32.3	31.0	28.8	33.0	30.8	68			
15													35.8	34.6	31.7	35.1	32.3	33.9	67			

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Specimen ID	Grade	Binder OPC (kg/m³)	GGBS (kg/m³)	MS (kg/m³)	Coarse aggregate (kg/m³)	Fine aggregate (kg/m³)	Superplasticizer Dosage (kg/m³)	Type	CIA * Dosage (kg/m³)	Type	Water Content (kg/m³)	w/b	Resistivity (kΩ.cm) Face 1	Face 2	Face 3	Face 4	Face 5	Average 28-day resistivity (SSD), kΩ.cm	28 days compressive strength, MPa	Slump (mm)	Charge Passed at 28 days, Coulombs	Depth of Water Penetration at 28 days, mm
16	M45	430	-	-	1157	819	3	PCE	3	M	130	0.30	14.6	14.3	14.1	15.4	14.3	14.5	63	150±25	417	6.6
17													12.9	12.3	13.1	13.5	13.1	13.0	62			
18													13.5	16.9	16.1	13.0	15.1	14.9	64			
19		215	350	25	1058	692	4	PCE	3	MMO	153	0.26	114.0	103.5	101.8	92.0	105.1	103.3	51	175±25	493	7.4
20													121.0	126.5	143.9	144.4	-	134.0	53			
21													114.6	99.0	110.0	92.0	-	103.9	52			
22	M50	440	-	25	1217	723	3	PCE	3	OM	132	0.28	8.0	9.2	9.7	8.5	8.1	8.7	67	150±25	1666	10.4
23													7.1	7.0	7.7	7.1	8.1	7.4	66			
24													6.5	6.6	7.1	7.1	7.6	7.0	66			
25		350	150	-	1149	692	3	PCE	2	MM	146	0.29	35.2	36.6	35.4	32.0	34.8	34.8	59	150±25	-	7.0
26													30.1	30.2	30.3	29.9	30.0	30.1	60			
27													30.1	28.1	29.1	30.3	27.9	29.1	65			
28		375	100	25	1190	698	2	PCE	3	MM	150	0.30	75.8	73.5	73.2	76.0	79.9	75.7	73	125±25	310	3.0
29													54.5	48.3	47.0	49.5	52.4	50.3	72			
30													55.4	58.8	58.1	56.5	57.9	57.3	77			
31		430	-	20	1136	766	4	PCE	-	-	155	0.34	8.4	8.8	9.5	9.3	10.4	9.3	63	175±25	-	9.0
32													13.2	13.6	14.2	13.2	14.2	13.7	57			
33													12.7	11.6	12.4	12.6	12.0	12.3	63			

Specimen ID	Grade	Binder			Coarse aggregate (kg/m³)	Fine aggregate (kg/m³)	Superplasticizer		CIA *		Water Content (kg/m³)	w/b	Resistivity (kΩ.cm)					Average 28-day resistivity (SSD), kΩ.cm	28 days compressive strength, MPa	Slump (mm)	Charge Passed at 28 days, Coulombs	Depth of Water Penetration at 28 days, mm
		OPC (kg/m3)	GGBS (kg/m3)	MS (kg/m³)			Dosage (kg/m³)	Type	Dosage (kg/m³)	Type			Face 1	Face 2	Face 3	Face 4	Face 5					
34	M50	280	300	20	1002	772	8	PCE	3	MMO	138	0.23	124.0	134.0	132.0	118.0	119.4	125.5	78	175±25	604	9.0
35													102.5	119.5	115.5	127.2	112.0	115.3	80			
36													146.7	130.0	136.0	138.0	-	137.7	77			
37	M55	450	-	25	1215	721	3	PCE	3	OM	131	0.28	10.9	10.5	10.7	10.1	9.9	10.4	76	150±25	996	9.7
38													10.3	10.4	10.6	10.0	11.3	10.5	77			
39													9.4	9.6	9.8	11.3	9.4	9.9	73			
40		350	265	25	951	695	7	PCE	3	HO	160	0.25	140.0	152.0	149.0	140.0	132.4	142.7	69	175±25	669	4.7
41													151.2	133.3	150.0	150.0	-	146.1	70			
42													160.0	143.5	156.6	163.0	145.2	153.7	71			
43		450	-	23	1078	751	4	PCE	-	'	156	0.33	3.8	3.4	3.6	4.0	4.3	3.8	71	150±25	601	7.7
44													3.4	3.6	3.7	4.2	3.8	3.7	71			
45													3.9	3.4	3.6	3.6	4.1	3.7	71			
46		450	-	23	1078	751	4	PCE	-	'	156	0.33	4.2	4.9	4.6	4.6	4.8	4.6	71	150±25	601	7.7
47													4.1	3.3	3.7	3.7	3.2	3.6	71			
48													4.8	4.5	4.4	4.4	5.2	4.7	71			
49	M60	490	-	25	1205	621	4	PCE	-	'	134	0.26	59.7	-	77.0	66.4	90.2	73.3	69	50±25	614	9.3
50													86.1	107.0	-	60.2	61.8	78.8	66			
51													-	64.5	43.1	33.3	31.7	43.2	69			

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Specimen ID	Grade	Binder OPC (kg/m3)	GGBS (kg/m3)	MS (kg/m³)	Coarse aggregate (kg/m³)	Fine aggregate (kg/m³)	Superplasticizer Dosage (kg/m³)	Type	CIA * Dosage (kg/m³)	Type	Water Content (kg/m³)	w/b	Resistivity (kΩ.cm) Face 1	Face 2	Face 3	Face 4	Face 5	Average 28-day resistivity (SSD), kΩ.cm	28 days compressive strength, MPa	Slump (mm)	Charge Passed at 28 days, Coulombs	Depth of Water Penetration at 28 days, mm
52													123.0	144.0	126.8	132.0	115.2	128.2	75			
53		320	350	30	924	648	8	PCE	0	MMO	168	0.24	129.6	157.4	140.0	121.0	-	137.0	75	500 - 600	118	5.5
54													141.9	155.0	159.4	127.5	127.2	142.2	75			
55													87.3	89.5	76.3	75.6	86.3	83.0	78			
56	M60	424	151	40	1009	689	5	PCE	3	MMO	160	0.24	91.0	92.5	86.5	82.7	89.7	88.5	69	125±25	391	5.9
57													81.2	77.4	97.3	87.6	84.2	85.5	78			
58													65.9	69.2	65.0	67.4	68.0	67.1	75			
59		434	158	38	1018	668	7	PCE	3	MMO	158	0.25	71.0	73.4	74.7	75.4	68.4	72.6	77	125±25	260	4.7
60													69.2	65.0	62.4	66.6	65.1	65.7	71			

Notes:

1. OPC - Ordinary Portland Cement; GGBS - Ground Granulated Blast Furnace Slag; MS - Micro silica; CIA - Corrosion inhibiting admixture; PCE - Polycarboxylate ether-based superplasticiser; SNF - sulphonated naphthalene formaldehyde-based superplasticiser; w/b - water to binder ratio
2. *Refer Table 2 for CIA classification
3. Specimens 1-3 & 49 to 51 contain 0.04% of polyfiber

Table 2 Classification of CIA based on action and expect secondary effects on the resistivity

Type of CIA	Primary interaction	Expected effect on concrete resistivity
OM - Organic migrating	Adsorption on steel with partial pore lining	Slight increase/neutral
M - Migrating	Diffusion through pore solution	Neutral to slight decrease (Early age)
MM - Mixed mode	Electrochemical suppression without pore blocking	Largely neutral
MMO - Mixed Mode Organic	Adsorption and hydrophobic film formation	Moderate increase
HO - Hybrid organic	Electrochemical inhibition with partial pore blocking	Noticeable increase

Table 3 Indicative grouping of surface electrical resistivity results with corresponding mixes

Indicative resistivity range (kΩ·cm)*	Indicative durability interpretation	Mix ID	Typical mixture characteristics observed in this study
< 20	Low	1-3, 7-9, 16-18,22-24, 31-33, 37-39, 43-48	Predominantly OPC-based concretes; w/b typically ≥ 0.30
20-50	Intermediate	4-6, 10-15,25-27	Blended concretes incorporating GGBS; w/b typically < 0.30
> 50	High	19-21, 28- 30, 34-36, 40-42, 49-60	Concretes with significant GGBS replacement; w/b typically < 0.30

*Note: Resistivity ranges adapted from AASHTO T 358 and used solely for comparative interpretation; EN 12390-19:2023 does not prescribe durability classes or acceptance limits.