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INVESTIGATION OF MECHANICAL PROPERTIES AND CHLORIDE IONS INGRESS IN CONCRETES CONTAINING CALCINED

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ABSTRACT: Portland cement production is known as an environmental pollutant and high energy-consuming industry. One way to reduce cement production and consumption is to use supplementary cementitious materials. Pozzolans are widely used as supplementary cementing materials (SCMs) nowadays. Due to the widespread use of Portland cement in the construction industry, partial replacement of PC with SCMs such as calcined clays can reduce the harmful environmental impacts of cement production and enhance the durability of concrete structures and increase service life. In this study, the mechanical properties and durability of OPC and concretes containing Calcined Clays (CCs) and Limestone powder (LS) have been compared. In this research, the effect of using calcined clays (CC) and limestone powder (LS) as SCMs on the mechanical properties and durability of concrete was investigated. Six concrete mixtures have been prepared by replacing 30% of PC by 3 different CCs and LS as binary and ternary blended mixtures (LC3 mixtures). Mechanical properties, permeability and durability of concrete mixtures containing different CCs have been investigated by means of compressive strength, water absorption, electrical resistivity and rapid chloride migration test (RCMT). According to the results, although using binary and ternary blended mixtures have reduced the compressive strength compared with the control mixture, but the permeability and durability of mixtures have been significantly improved.

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1- Introduction

Concrete is the most important material used in the construction to build bridges, tall buildings, residential and commercial buildings. Production of cement accounts for 5–8% of man-made CO_2 emissions. As the world's growing population and need for habitation drive concrete demand, the associated carbon emissions are consequently set to rise. Due to the huge amounts of concrete produced and used globally, being able to reduce the carbon emissions per ton of concrete produced would make a significant contribution to controlling global carbon emissions. An alternate solution that has yet to be fully maximized would be to make use of supplementary cementitious material (SCM) to partially substitute cement clinker in concrete [1-3].

In addition, the presence of calcined clay and limestone reacted with calcium hydroxide (from cement hydration) to form calcium monocarboaluminate and calcium hemicarbaluminate [4, 5].Ramezanianpour et al. indicated that partial cement replacement by calcined clay improves the mechanical properties, reduces permeability and improves durability against aggressive environmental conditions. This improvement in properties is due to the pozzolanic properties of calcined clay and the reduction of voids and capillary cavities [6].

The main goal of this research was to investigate the effect of cement replacement by calcined clays and limestone on mechanical properties and durability against chloride ions ingress in binary and ternary systems. Using these clays is economically viable and reduces life cycle costs and carbon dioxide emissions and also moves towards sustainable development.

2- Materials and Methods

Type II Portland cement produced by the Kordestan Cement factory was used in this study with a density of 3020 kg/m^3. Also, 3 types of kaolinitic clays were calcined at 800ºC for 1 hour. These clays were obtained from domestic sources. Utilized Limestone was also provided by Poodrsazan Company with a density of 2620 kg/m^3. Furthermore, concrete mix designs included crushed gravel and natural sand. Specific gravity and water absorption of these aggregates are shown in Table1 . The proportion of gravel and sand were 40% and 60% of the total weight, respectively. A polycarboxylate ether was consumed in these mix designs

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Table 1. Mixture Proportions

Properties	Gravel	Sand
Specific gravity (kg/m^3)	2550	2540
Water absorption (%)	2.19	3.2

Table 2. Mixture Proportions

	OPC	CC1	CC2	CC3	LS-CC1	LS-CC2	LS-CC3
Cement (kg/m^3)	400	280	280	280	280	280	280
Calcined Clay (kg/m^3)	-	120	120	120	80	80	80
Limestone (kg/m^3)	-	-	-	-	40	40	40
Gravel (kg/m^3)	703	695	695	695	695	695	695
Water (kg/m^3)	160	160	160	160	160	160	160
Superplasticizer (%)	0.21	0.3	0.37	0.33	0.35	0.38	0.31
Slump (mm)	140	100	110	125	105	120	130

and complied with ASTM C494 –Type F admixture.

The concrete mixtures were prepared based on the national method for concrete mix design [7] with a Water/Binder of 0.4 and the amount of cementitious materials was 400 kg/m3. The cement Replacement level of Portland cement by calcined clays and limestone was 30% in both binary and ternary systems. The composition of the seven mixing design is shown in Table 1.

Also, Slump, compressive strength, water absorption, electrical resistivity and Rapid Chloride Migration Test (RCMT) were performed as an experimental program.

3- Results and Discussion

Results of the Slump test for each mix composition are represented in Table2 . It shows that utilizing calcined clay and limestone leads to increment of SP dosage and also reduced concrete workability with respect to OPC mixture.

Results of compressive strengths are shown in Table3 . As it can be seen, using calcined clay and limestone in binary and ternary systems has a reverse effect on mechanical properties of concrete. It might be due to predominance of dilution effect over the filler effect and pozzolanic reactions.Table 3 shows the effect of calcined clay and limestone on water absorption. Utilizing SCMs resulted in better behavior with respect to OPC. Also, binary systems had better performance than ternary mixtures.

Table3 represents the results of electrical resistivity. It was observed that the replacement of cement with calcined clays and limestone had a significant effect on electrical resistivity. So, for concretes containing calcined clay, an increase in electrical resistivity is observed in some cases even more than 2.5 times compared to the control sample.

Table 3 indicates the proper chloride migration coefficient in the specimens with binary and ternary blended cements and it was observed that electrical resistivity and RCMT results had similar behavior in different blended mixtures. Better performance in binary and ternary mixtures compared to OPC is due to pozzolanic reactions that caused pore structure refinement and remarkable decrement in concrete porosity.

Furthermore, by aging concrete specimens, all results improved due to their cement hydration.

4- Conclusion

This research tried to investigate the effect of calcined clay and limestone on the mechanical and durability properties of concrete. The results of this study can be summarized as follows: The use of calcined clay and limestone causes a reduction in slump test and workability of concrete because of preventing aggregates and cement paste from moving freely. These supplementary cementitious materials had negative effects on the compressive strength of concrete in both binary and ternary mixtures.

Table 3. Results of the compressive strength tests, water absorption, electrical resistivity and RCMT.

	OPC	CC1	CC2	CC3	LS-CC1	LS-CC2	LS-CC3
7-day compressive strength (MPa)	43	33.8	34.1	31.8	29	32.5	27.8
28-day compressive strength (MPa)	49.3	47.3	44.9	44.6	38.4	43.9	39.2
90-day compressive strength (MPa)	55.5	49.3	45.6	46.9	43.3	46.2	40.8
28-day Water absorption (%)	3.31	3.08	3.1	3.13	3.15	3.27	3.31
90-day Water absorption (%)	3.2	3	2.84	3.09	3.12	3.11	3.28
28-day Electrical resistivity (kΩ.cm)	10.5	37	32	24.4	20.5	25.1	23.5
90-day Electrical resistivity (kΩ.cm)	14.9	51.6	42.8	34.2	28.1	34.1	29.5
28-day RCMT (*10^{-12} m^2/s)	18.3	6.8	7.4	12.3	13.1	10.8	15.3
90-day RCMT (*10^{-12} m^2/s)	11.5	4.7	6.7	7.9	10.5	7.3	8.2

According to water absorption, Electrical resistivity and RCMT test results, mixtures including calcined clays and limestone indicated lower permeability with respect to OPC.

Concrete mix designs containing CC1 calcined clay had the best performance in CC1 and LS-CC1 mixtures because of its more pozzolanic activity index.

There was an appropriate connection between the results of RCMT and electrical resistivity.

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