Comparative Study of Mechanical Properties of Limestone Calcined Clay Cement, Ordinary Portland Cement, and Pozzolana Portland Cement

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Carbon emissions from cement manufacturing are reduced by partially replacing cement clinkers with supplementary cementitious materials (SCM). In this study, Limestone calcined clay cement (LC^3) was prepared by blending 50% of OPC-43 grade with 50% Limestone calcined clay- LC^2 (63.3 % of calcined clay, 31.7% of lime, and 5% of gypsum), Fly ash-based Pozzolana Portland Cement (PPC) and Ordinary Portland Cement (OPC) was used to compare the mechanical properties at the age of 7 & 28 days of curing for M-25 and M-50 grades of concrete. The specimens for the compressive strength test, flexure strength test, Modulus of elasticity test, and Bond test of concrete with reinforcement of 25mm diameter bars were prepared as per Indian standard codes. The results of the study showed that the LC^3 had higher compressive strength values at the age of 7 days, which is substantiated by flexure strength, modulus of elasticity, and pull-out strength values, whereas at the age of 28 days, LC^3, OPC, and PPC had similar strengths.

Keywords: *Limestone calcined clay cement, Fly ash-based pozzolana Portland Cement, Modulus of elasticity test, Bond test with reinforcement, Pull out strength*

Introduction

OPC is the 2nd most consumed resource after water, and OPC is Manufactured by the process of calcination, where the heating of limestone and clay is done, which leads to the release of carbon dioxide into the atmosphere. The cement industry contributes 8% of worldwide artificial emissions of CO_2 gas, from which 50% is from the chemical process, 40% is from burning fuel, and 5-10% is emissions from electricity for plant machinery and transportation of raw materials (Rao AB, Rubin ES (2002)). With growing environmental demand for low-carbon emitting materials globally, the development of green construction materials is becoming significant in addressing the challenges of climate change. Limestone calcined clay cement (LC^3) is one such cement that has less environmental impact and excellent properties with regard to strength and durability (Scrivener K.et al 2018, Sharma M. 2021, F. Avet et al. 2019)

LC^3 is made by substituting cement clinker with limestone and calcined clay. It is expected to reduce the carbon emission of cement production by 30-40% (Berriel et al. 2016). In this experimental work, the mechanical performance of LC^3 concrete is evaluated and compared with the conventional OPC and PPC concrete.

Materials and methods

This study designed the concrete of standard grade M-25 and M-50 according to IS 10262-2019. The details of mix proportions for M-25 and M-50 are given in table 4 The amount of chemical admixture was varied in order to maintain slump at 80-100 mm for different grades and types of cement.

Materials

The three types of cement used were OPC- grade 43, PPC- Fly-ash based, LC^3- Prepared by blending 50% of OPC 43 grade with 50% LC^2 containing 63.3 % of calcined clay, 31.7% of lime, and 5% of

gypsum. The aggregates used were crushed angular quartz stones of 20 mm and 10 mm nominal sizes whereas the fine aggregate used was river sand.

The specific gravity of cement was determined using Le Chatelier's flask as per IS 4031 Part-11, and the specific gravity of coarse and fine aggregates was determined as per IS 2386.

Table 1 Specific gravity of Materials

Material	OPC	PPC	LC^3	Coarse (20mm)	Coarse (10mm)	Sand
Sp. gravity	3.17	2.81	3.00	2.81	2.68	2.62

Coarse aggregates used were well graded and fine aggregates conformed to zone-II of IS 383. Malvern Mastersizer 3000E was used for determining the particle size of cement. Isopropyl alcohol was used as a dispersion medium. The particle size is mentioned in Table 2.

Table 2 Particle Sizes of different types of cement

D_x	**OPC**	**PPC**	**LC^3**
D_{10} (μm)	5.76	4.53	2.96
D_{50} (μm)	21.0	19.6	14.8
D_{90} (μm)	62.5	58.5	51.9

X-ray Fluorescence of different types of cement was done to determine the oxide composition of the cement.

Table 3 X-ray Fluorescence of different types of cement

Oxides Component	**OPC (%)**	**PPC (%)**	**LC^3 (%)**
SiO_2	20.69	35.22	29.70
Fe_2O_3	5.26	5.54	3.86
Al_2O_3	4.03	12.92	19.10
CaO	59.90	34.51	32.21
MgO	0.98	1.20	1.36
SO_3	2.53	2.86	2.74
Na_2O	0.09	0.42	0.48
K_2O	0.57	0.82	0.46
TiO_2	0.40	1.09	1.39
LOI	4.30	4.10	7.90

The materials were dry mixed for two minutes after that.water was mixed along with chemical admixtures to obtain a homogenous mixture. The specimens for compression, split tensile and flexural strength were demoulded after 24 hours of the casting and then these specimens were cured in a water tank until the age of testing.

Table 4 The design mix used for the concretes

Materials' weight (kg) per m^3 of concrete	**OPC**		**PPC**		**LC^3**	
	M-25	M-50	M-25	M-50	M-25	M-50
Water Content	165.00	165.00	165.00	165.00	165.00	165.00
Cement Content	366.67	590.00	366.67	590.00	366.67	590.00
Fine Aggregate	638.45	523.87	623.19	501.49	627.41	507.67
Coarse Aggregate (10mm)	495.74	466.41	483.89	446.49	487.16	451.99
Coarse Aggregate (20mm)	743.60	699.62	725.84	669.73	730.74	677.99
Chemical Admixture	3.67	5.90	3.67	5.90	3.67	5.90

Results and Conclusions

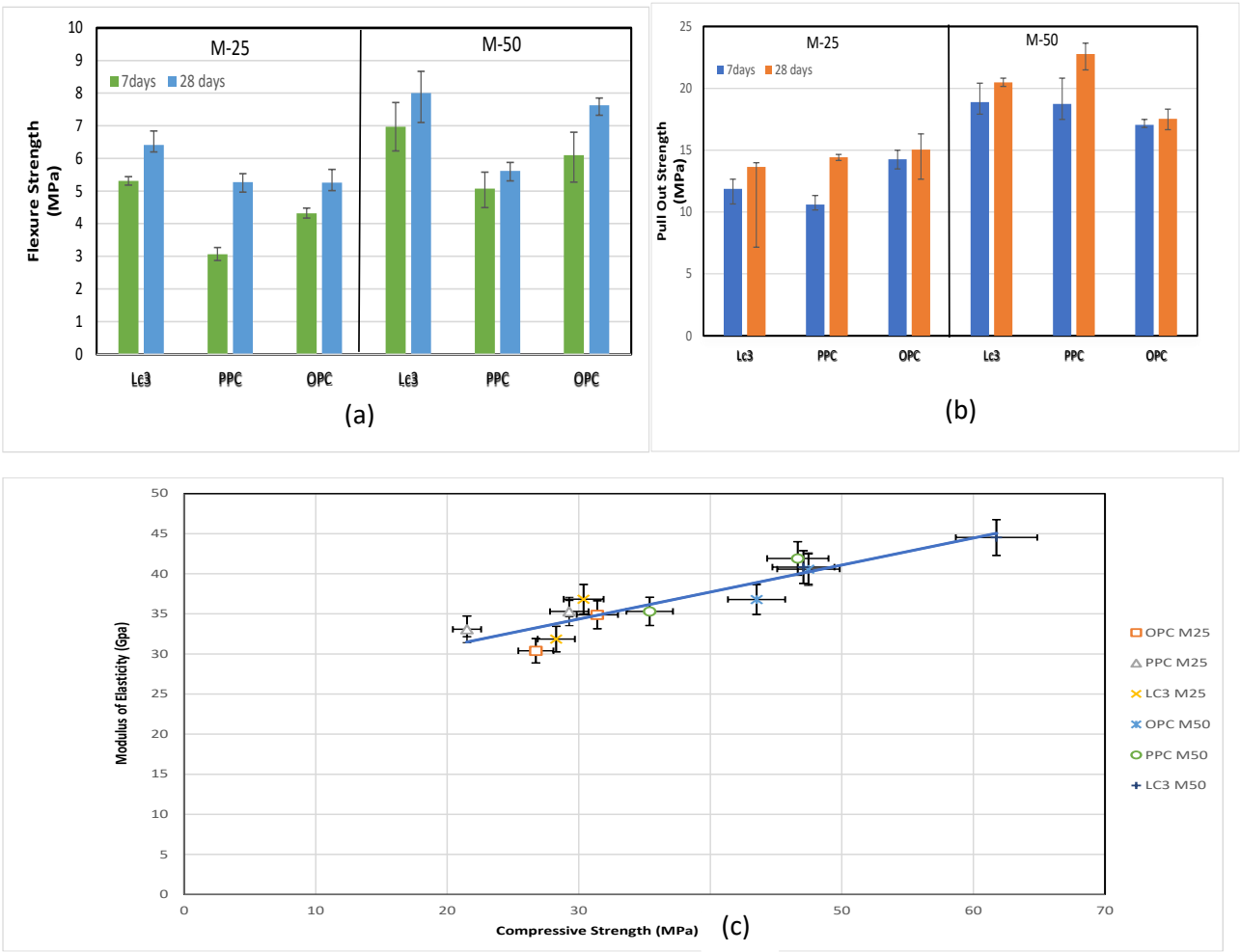

Figure 1 (a) Flexure Strength (b) Pull Out Strength (c) Modulus of Elasticity and Compressive Strength of the concrete samples at 7 and 28 days

Conclusions

From the results of the mechanical strengths of concrete specimens as shown in the graph it can be seen that LC^3 had similar strengths to OPC and PPC at 28 days, and the following conclusions were made from the study:

- The 7-day flexural and pull-out strength of the 25 mm steel bars and concrete were higher in LC^3 specimens for both grades of concrete than PPC and OPC, which signifies the high early strength of LC^3 this is because of the synergy reactions between the calcined clays, limestone and cement clinkers.
- The higher flexure, Modulus of elasticity, and compressive strength values of the LC^3 indicate that with similar mixture proportions, LC^3 binder has better strength evolution in concretes than OPC and PPC.
- LC^3 can be used as a potential alternative to the OPC and PPC.

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