Performance of OPC Mortars Partially Replaced by Kadapa Slab, Marble and Baritespowder against Chemical Impact

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Abstract. Construction industry uses Cement vividly to meet the demand towards infrastructure development. The type of cement paste formed during reaction of cement with water to produce durable products is very important to sustain in chemical environments. Several industrial by-products produced can be conveniently replaced in concrete to meet such needs of the contruction industry. Stone dust or powder is available in Kadapa slab, marble and barite industries. To improve the serviceability and sustainability against chemical environment, cement is partially replaced by various fractions of powders, barites(15%), marble(15%) and Kadapa slab(10%). Investigations have been made on the performance of cement mortar submerged in, sulfuric acid (H_2SO_4), hydrochloric acid(HCL), Potassium Hydroxide(KOH) and Sodium Hydroxide(NaOH) solutions. All the cement mixes were cured in these solutions for 56 days and determined their compressive strength and density along with conventional cement mortar for comparison. The cement mortar made with 15% replacement by barites powder in cement attained better compressive strength and density in comparison with other cement replacement materials. Also cement mortar offers high resistance against hydrochloric acid (HCL) impact in comparison with the impact of other chemicals.

Keywords- Cement Mortar(CM), Chemical Resistance(CR), Compressive strength(CS), Barites powder(BP), marble powder(MP) and Kadapa slab powder(KSP)

INTRODUCTION

Though the cement is proved to be considerable and leading construction materials, since concrete is strong in exhibiting mechanical as well as the durability properties. Day by day the raw materials for cement manufacturing were becoming absolete, so now its time to think about sustainable construction materials. Though wide research is carried out on different materials like flyash, GGBS and different slags etc,. In the current research, since the author belongs to Southern India-Kadapa district of Andhra Pradesh State where locally available materials such as Barites powder, Marble powder and Kadapa Slab powder i.e., residues during crushing and polishing of these stones are considered in the research without compromising in its size less than 90microns. Though much research is focused even on durability and mechanical properties of these materials. But comparative chemical resistance is not observed yet, hence the current research is concentrated on this comparative CR on CM is carried out. Initially, conventional CM cubes were casted and kept as origin for all the other proportions. Then from the literature review it is observed that at 15% replacement of these mentioned materials in cement has attained optimum strength. Therrefore 15% replacement of materials, MP and BP and 10% replacement of KSP in cement is maintained in CM. The CM with these materials were casted into moulds and cured in potable water for 28 days and the other 28 days in chemical solution with PH values of 2 for acids (HCL & H_2SO_4) and 12 for bases(NaOH & KOH). Then the CR is observed in terms of compressive strength and density after 56 days.

LITERATURE

Singh[1] et al(2017) referred that 15 percent of marble powder shows increased compressive strength as well as bond strength. **Sandeep[2] et al (2022)** outlined that marble powder can be used as replacement for both cement and lime aggregate over which appreciable compressive strength and tensile strength were achived. Wheras **FA Memon[3] et al (2017)** presented that replacement of marble dust with cement by 15% has optimum strength and increase in marble dust leads to reduction in workability. **Meenakshi[4] (2017)** revealed that 15% replacement of barite has appreciable increase in strength characteristics of concrete. At the same time, replacement of cement b y partial replacement of barites and lime powder is not appreciable. **Harinath[5] et al (2016)** outlined that barites density leads to production of high density concrete which protects hazardous radiations. But the barites are replaced partially as coarse aggregate up to 50% and observed excellent radiation protection than barium, wheresas compressive strength remains equal to conventional concrete. **Abdullah[6] et al (2014)** presented that marble powder can be replaced in cement as a sustainable material, but 15% replacement of marble powder gives good compressive strength than nominal mix. **P Mehta[7] (1985)** suggested that 1% H_2SO_4 , HCl, Lactic acid and 5% of acetic acid, sodium sulphate and ammonium sulphate were used for testing the chemical resistance of concrete. The criteria for failure is taken as reduction in weight by 25%. **Ankur[8] et al (2018)** inferred that acid and sulphate attack, chloride penetration, were some of the test on concrete to check chemical resistance. **Oumaima[9] et al (2022)** inferred that 15% of marble powder replacement in cement is the optimum percentage to attain appreciable concrete mechanical properties with conventional concrete as refrence.

METHODOLOGY

Initially from the available literature, it is concluded that 15% replacement of marble powder is optimum for attaining both mechanical and durability properties, whereas the literature review on Kadapa slab powder is limited. Hence by trial and error method the optimum proportion of replacement of both barites (15%) and Kadapa slab powder (10%) in cement is found. Later those optimum proportions of three materials i.e., barites, Kadapa slab and marble powder were considered for the study of chemical resistance of concrete by allowing the concrete specimen to cure for28 days in potable waterand 56 days in the following solutions. Hydrochloric acid-0.5%, Sulphuric acid-0.5%, sodium hydroxide-0.35% and potassium hydroxide -0.35%. Later compressive strength and density is monitored for all the proportions. The PH value of 2 for acidic solutions and 12 for alkaline solutions is maintained throughout the work.

MATERIALS AND PROPERTIES

Barites Powder

The mineral barite is made out of barium sulphate, Crushed and screened barite powder as shown in figure 1., is used in this research in partial replacement of cement. The barites powder is obtained from Mangampet-Barite mines, Annamaiah district, Andhra Pradesh. The properties of barites powder as mentioned in Table -1 and the powder is shown in figure 1.

TABLE-1: PROPERTIES OF BARITE POWDER

Sl.No	Property	Range/Nature
1	Name	Barite
2	Chemical Formula	$BaSO_4$
3	Color	It exhibits various colors like white, orange, grey and black etc.
4	Specific Gravity	4.3
5	Density	4.47g/cm^3
6	Fineness	5%
7	Streak	White

FIGURE 1: BARITES POWDER

Kadapa Slab Powder

Kadapa slab powder is the combination of limestone, silica and iron. Majority of Kadapa slabs are black in color. Due to its durability, compactness and impermeable nature with low maintenance this slabs are highly preferred by local people. The KSP is shown in figure 2, obtained at quary surrounding Kadapa as well as at stone polishing industries. The different properties are shown in Table-2 .

TABLE-2: PROPERTIES OF KADAPA SLAB POWDER

Sl.No	Property	Range/Nature
1	Name	Kadapa Slab
2	Bulk relative density Loose state Dense state	 1377kg/m^3 1497kg/m^3
3	Specific Gravity	2.49
4	Moisture Content (%)	1
5	Lime (CaO) Silica(SiO_2) Alumina(Al_2O_3)	38-42 20-25 2-4
6	Fineness	7%
7	Absorption (%)	1.23

FIGURE 2: KADAPA SLAB POWDER

Marble Powder

A mineral of metamorphic recrystallized carbonate composed of either calcite or dolomite materials. Crushed marble sludge obtained from the waste product of marble cutting industry, and was collected from local industries. The characterization of the amrble powder is shown in Table-3 and the powder is shown in figure-3.

TABLE-3: PROPERTIES OF MARBLE POWDER

Sl.No	Property	Range/Nature
1	Specific Gravity	2.7
2	Bulk Density	520kg/m^3
3	Color	Light Grey, White
4	Fineness	6

FIGURE 3: MARBLE POWDER

Cement

Ordinary Portland Cement of 53 grade is used, the various tests conducted on the cement are reported in Table-4.

TABLE-4: PROPERTIES OF CEMENT

Sl.No	Property	Range/Nature
1	Normal Consistency	30%
2	Initial Setting time	45 min
3	Final Setting time	560 min
4	Fineness (%)	4%
5	Specific Gravity	3.14

Fine Aggregate

Natural sand is used for this entire work, the fine aggregate is confirming to zone-II. Fine aggregate acts as a filler material for concrete. The properties of the fine aggregate are shown in table- 5 and powder is shown in figure 4.

TABLE -5: PROPERTIES OF FINE AGGREGATE

Sl.No	Property	Value
1	Type	Natural
2	Specific Gravity	2.63
3	Grading Zone	Zone-II
4	Bulking(Optimum moisture content)	6%

FIGURE 4: FINE AGGREGATE

Design mix proportions

The cement mortar of 1:3 proportion is considered, with a water cement ratio of 0.44 by including the effect of bulking.

Experimental Tests and Results

The cement mortar cubes of 70.6x70.6x70.6mm are casted. The conventional cement mortar is considered as a reference. From the available literature review, the KSP (10%), MP (15%) and BP (15%) is replaced by cement for the study. The notations as shown in Table-6. The chemical resistance of cement mortar is observed by maintaining the P^H value of 2 for all the acidic solutions and P^H value of 12 for all the alkaline solutions. The various solutions used are hydrochloric acid (HCL), sulfuric acid (H_2SO_4), Sodium Hydroxide (NaoH) and Potassium Hydroxide (KOH).The cubes are cured conventionally for 28days, and in the above mentioned solutions for the remaining56 days. Totally CM is cured for 56 days and then Chemical resistance of the CM is observed individually.

TABLE-6: MIX PROPORTIONS AND NOTATIONS

Sl.No	Mix Proportion	Notation
1	Conventional cement mortar	G
2	85% Cement+15% Barites powder(Cement mortar)	G1
3	85% Cement+15% Marble powder (Cement mortar)	G2
4	85% Cement+15% Kadapa Slab powder (Cement mortar)	G3
5	85% Cement+15% Kadapa Slab powder (Cement mortar)	G3

TABLE-7: CHEMICAL RESISTANCE OF CONVENTIONAL CEMENT MORTAR

Solution	Weight of cube (gm)		Mean Weight (gm)		Compressive Strength (N/mm^2)		Mean strength (N/mm^2)	
	28 Days	**28+56 Days**	**28 Days**	**28+56 Days**	**28 Days**	**28+56 Days**	**28Days**	**28+56 Days**
HCL	774	710	795	726	33.7	30.9	32.8	30.0
	789	713			32.1	29.4		
	821	756			32.7	29.8		
H_2SO_4	783	715	770	699	31.2	28.5	30.7	27.7
	770	689			29.5	26.5		
	757	692			31.5	28		
NAOH	784	811	784	810	34.1	37.9	32.2	34.5
	787	812			32	34.3		
	780	806			30.5	31.4		
KOH	790	816	790	817	32.5	34.7	32.5	34.7
	796	821			31.6	33.6		
	783	812			33.5	35.8		

From Table-7, it is observed that for conventional cement mortar, the weight of CM is reduced by 8.67% in HCL, 9.2% in H_2SO_4 and increased by 3.2% in NAOH, 3.4% in KOH respectively. Where as the compressive strength is reduced by 8.5% in HCL, 9.7% in H_2SO_4 and increased by 7.2% in NAOH and 6.8% in KOH.

TABLE-8: CHEMICAL RESISTANCE OF CEMENT MORTAR WITH MARBLE POWDER

Solution	Weight of cube (gm)		Mean Weight (gm)		Compressive Strength (N/mm^2)		Mean strength (N/mm^2)	
	28 Days	**28+56 Days**	**28 Days**	**28+56 Days**	**28 Days**	**28+56 Days**	**28 Days**	**28+56 Days**
HCL	799	790	802	787	34.2	33.2	33.5	31.8
	787	777			33.3	31.0		
	820	793			32.9	31.2		
H_2SO_4	797	752	791	760	33.6	30.3	33.6	29.6
	800	782			34	29.8		
	775	745			33.2	28.6		
NAOH	802	832	799	820	32.8	34.3	33.5	35.2
	795	812			33.6	35.1		
	800	816			34.1	36.2		
KOH	805	823	786	799	35.3	37.3	34.3	35.7
	788	798			34.1	35.3		
	764	777			33.5	34.6		

From Table-8, it is observed that for cement mortor with 15% replacement of MP in cement, the weight of CM is reduced by 1.8% in HCL, 3.9% in H_2SO_4 and increased by 2.6% in NAOH, 1.6% in KOH respectively. Whereas the compressive strength is reduced by 11.9% in HCL, 11.9% in H_2SO_4 and increased by 4.1% in NAOH, 4.0% in KOH.

TABLE-9: CHEMICAL RESISTANCE OF CEMENT MORTAR WITH KADAPA SLAB DUST

Solution	Weight of cube (gm)		Mean Weight (gm)		Compressive Strength (N/mm^2)		Mean strength (N/mm^2)	
	28 Days	**28+56 Days**	**28 Days**	**28+56 Days**	**28 Days**	**28+56 Days**	**28 Days**	**28+56 Days**
HCL	792	753	799	763	33.4	31.9	32.8	30.1
	803	762			32.2	29.6		
	802	774			32.7	28.8		
H_2SO_4	794	767	785	755	31.6	28.7	30.9	27.7
	783	754			29.8	26.5		
	779	743			31.4	28		
NAOH	793	816	784	791	34.2	36.9	32.5	34.3
	796	812			32.5	34.4		
	761	776			30.7	31.5		
KOH	787	795	776	786	32.3	34.5	32.6	34.5
	779	792			31.7	33.4		
	761	771			33.9	35.7		

From Table-9, it is observed that for cement mortar with 15% replacement of KSP in cement, the weight of CM is reduced by 4.5% in HCL, 3.8% in H_2SO_4 and increased by 0.8% in NAOH, 1.3% in KOH respectively. Whereas the compressive strength is reduced by

8.2% in HCL, 10.3% in H_2SO_4 and increased by 5.5% in NAOH, 5.8% in KOH.

TABLE-10: CHEMICAL RESISTANCE OF CEMENT MORTAR WITH BARITES POWDER

Solution	Weight of cube(gm)		Mean Weight(gm)		Compressive Strength (N/mm^2)		Mean strength (N/mm^2)	
	28 Days	**28+56 Days**	**28 Days**	**28+56 Days**	**28 Days**	**28+56 Days**	**28 Days**	**28+56 Days**
HCL	811	803	829	824	32.4	31.9	32.9	32.1
	841	836			32.6	29.6		
	836	833			33.7	29.8		
H_2SO_4	833	827	814	804	31.6	29.7	32.6	31.7
	789	774			32.8	29.5		
	819	811			33.4	29.2		
NAOH	802	819	802	822	32.5	36.9	33.1	34.9
	818	827			34.2	34.4		
	792	821			32.7	33.3		
KOH	815	838	812	832	32.6	34.6	32.9	34.6
	807	832			33.7	33.4		
	813	825			32.6	35.8		

From Table-10, it is observed that for cement mortor with 15% replacement of BP in cement, the weight of CM is reduced by 0.6% in HCL, 1.2% in H_2SO_4 and increased by 2.5% in NAOH, 2.5% in KOH respectively. Whereas the compressive strength is reduced by 2.4% in HCL, 2.7% in H_2SO_4 and increased by 5.4% in NAOH, 5.1% in KOH

CONCLUSIONS

It is concluded that the compressive strength of the CM with BP has affered eminent resistance towards acids(HCL & H_2SO_4) around 7 & 14 % in comparison with coventionl CM.Where as CM with BP has offered considerable resistance towards alkalines(NAOH & KOH) around 2 & 2.8% in comparison with coventionl CM. Though the barites powder is dense material, which offered considerable CR in terms of weight in comparison with Convenional CM, KSP & MP.The weight of CM with BP is increased around 1.8% in KOH, 1.48% in NAOH, 13.4% in HCL and 15.02% in H_2SO_4 in comparison with conventional CM. Also it is concluded that, CM with BP offered prominent resistance towards acidic solutions in terms of strength and CM with MP offered great resistance towards alkaline solutions interms of strength. It is found that CM with BP has offered dominant resistence in comparison with KSPand MP towards chemicals in terms of weight.

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