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Effect of Admixture on the Compressive Strength of Composite Cement Mortar

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Abstract

The effect of superplasticizer on the development of composite cement based on flyash/limestone powder as per EN-197-2000 has been studied. Various mixes of fly ash and limestone up to 40% has been blended. The results have been compared with clinker of 43 grade ordinary portland cement used in the present study. 1 day strength of mixes with 5% and 10% limestone powder has been found to be is comparable to control. Further, it has been found that 28 days strength of mix with 15% lime stone powder and 25% fly ash gives more than 32.5 R required for composite cement. With the use of superplasticizer, strength has been found comparable or more in all the mixes at 1day to 43 grade OPC. X-ray diffraction (XRD) analysis of various mixes at different hydration times has also been evaluated.

Keywords: Authors are required to provide at least five keywords, separated by semicolons (;) to briefly describe the contents of the article for indexing purposes.

1. Introduction

The production of portland cement containing limestone, inter-ground or blended with clinker, has increased particularly in the past decade due to technical and economical/environmental reasons. The technical reasons are satisfactory physical and mechanical properties of hydrated cement paste, and the economic/environmental reasons include energy saving during the decreased clinker production without impairing the quality of the cement and concrete properties and consequently the reduction of environmental pollution by carbon dioxide [1-3]. The European standard EN 197-1 allow up to 35 wt % of limestone in cement [4]. During the hydration of Portland cement clinker minerals react with water yielding a complex microstructure consisting mainly of amorphous calcium silicate hydrate gel, ettringite, portlandite, carbonated phases and calcite. When limestone is present in portland cement, the rate and degree of hydration change, as does the composition of the hydrated cement paste. Some of the beneficial effects of limestone powder are attributed to its filler effect. It has been reported an acceleration of the C_3S and an incorporation of the calcium carbonate into the C–S–H [5,6].

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The literature findings on the effect of limestone on the composition of hydrated cement paste are not always in close agreement but the general conclusion is that limestone participates to a certain extent in chemical reactions during hydration, not being only inert filler [5-9]. The increase in the rate of hydration of the clinker has been attributed to the formation of mono-carboaluminates, and the modification of the microstructure. Further, addition of $CaCO_3$ accelerates the hydration of C_3S, especially at the early age. This is due to the modification of the hydrating C_3S surface and its nucleation effect. [10-12].

Composite cement is hydraulic cement composed of portland cement and one or more inorganic materials that take part in the hydration reaction. The mineral addition may be ground together with the cement clinker and gypsum, or mixed with portland cement is used. As per standard composite cement can have the highest cement to clinker ratio as high as 3.33, as the cement can be made from 30% clinker. It is estimated that on addition of limestone in OPC as filler from the existing level of 5% to 10% will result in green house gas reduction of 25.0 Kg CO_2/MT cement.

Composite cements are contained in class of moderate strength (EN 32.5R or 32.5), and are produced for special purpose in lower and are called as market-oriented cements i.e. cements suitable for making concrete or mortar of predetermined usage properties [13].

Currently there is no standard for producing composite cement in India.

The purpose of the present study is to study the effect of superplasticizer on the compressive strength of various blends of composite cement developed using various percentages of fly ash and limestone filler (upto 40%). Since effect of the superplasticizer is to compensate drop in compressive strength due to addition of lime stone and fly ash blend, it will help to see how far lime stone and fly ash can be blended to form composite cement having comparable compressive strength. This will help in reducing the clinker factor and thus reducing CO_2 emission and saving in energy.

2. Materials

2.1. Clinker

Clinker used in the present study was supplied by M/s Ambuja Cements Ltd.. The clinker was ground with gypsum in ball mill to prepare cement and then it was sieved through 75 micron sieve. The physical and chemical analysis of cement is given in Table 1.

2.2 Fly Ash

Fly ash used in composing cement was procured by a thermal plant in Indraprastha, New Delhi. The fly ash is used as per BIS: 3812 (part 1). The physical and chemical analysis of fly ash is given in Table 2.

2.3 Sand

The standard sand (Ennore) used in the present study conforms to BIS: 650-2005.

2.4 Limestone

Limestone was procured in raw form and was grounded in the ball mill followed by sieving through 75 micron sieve.

2.5 Superplasticizer (SP)

Super Plasticizer used in the present study was Sikament 170 conforming to BIS: 9103 – 2003. It is based on Sulphonated Naphthalene Formaldehyde Condensate (SNF). It is used 1% by weight of cement.

TABLE 1. PHYSICAL AND CHEMICAL ANALYSIS OF ORDINARY PORTLAND CEMENT

Sl No.	Parameters	Result (%)
1.	Loss of ignition	0.32
2.	SO_3	0.73
3.	Insoluble Residue	0.17
4.	SiO_2	22.41
5.	Fe_2O_3	3.56
6.	Al_2O_3	4.72
7.	CaO	64.93
8.	MgO	1.49
9.	Na_2O	0.05
10.	K_2O	1.0
11.	Setting time* (mins.)	
	Initial	105
	Final	180
12.	Compressive strength (MPa)	
	1 day	6.58
	3day	30.12
	7day	39.16
	28day	51.0

** As per BIS:4031(part-5) initial setting time must not be less than 30 min and for final setting time must not be more than 600 min*

TABLE 2. CHEMICAL ANALYSIS OF FLY ASH

Sl No	Property	Result (%)
1.	LOI	0.75
2.	SiO_2	16.8
3.	R_2O_3	28.20
4.	CaO	3.0
5.	R_2O ($MgO+CaO+SiO_2$)	75
6.	SO_3	1.25
7.	Surface area	3400cm^2/g
8.	Specific gravity	2.24

3. Preparation of Sample Mixes

The mixtures of cement, limestone and fly ash in different proportions were prepared and its composition is given in the Table 3. The mixtures are mixed thoroughly in powder mixer for half an hour.

TABLE 3. DIFFERENT COMPOSITIONS MIXTURES

System	Cement	Limestone	Fly Ash
Control	100	-	-
Mixture-1	60%	5%	35%
Mixture-2	60%	10%	30%
Mixture-3	60%	15%	25%
Mixture-4	60%	20%	20%

3.1 Preparation of mortar cubes

The mortar cubes were cast in constant temperature room maintained at 27±2˚C. A mixture of 200g cement was mixed with 600g standard sand on a dry non porous table with 80cc of water (which is fixed for all the cement mixtures) for 2 min till uniform mix was obtained. Then the mortar was filled in the iron moulds of 70.6mm as per BIS: 4031-Part 6(Determination of compressive strength of hydraulic cement other than masonry cement) through a hopper and prodded with rod to ensure elimination of air and vibrated for 2 min. The cubes were covered by wet gunny bag for 24 hours in the constant temperature room. After 24 hours the cubes were demoulded and cured for 28 days in curing chamber maintained at temperature 27±2˚C and humidity 90±5%.

3.2 Compressive Strength

The compressive strength of the cubes was determined at 1, 3, 7, 28 and 56 days. Minimum three cubes were tested for each set. The results are given in Table 4.

3.3 X-ray Analysis

X-ray graphs of control mixes & hydrated samples are shown in fig.1-5 & fig 6-8.

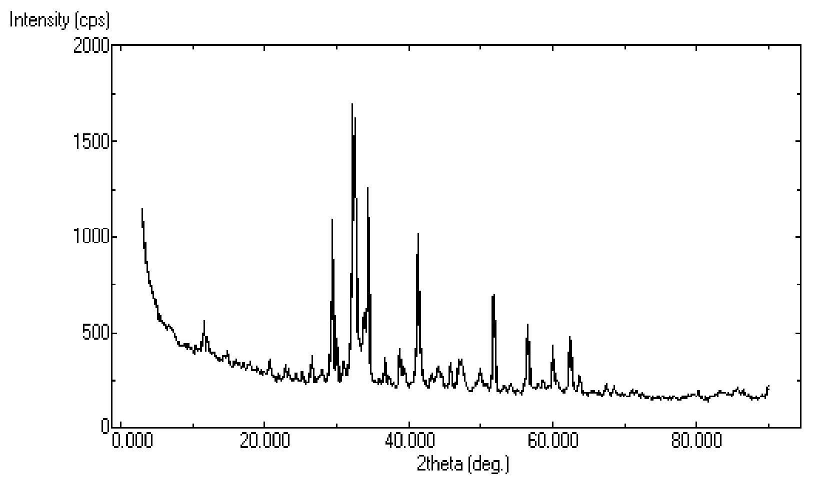


Fig.-1 XRD Profile of Clinker

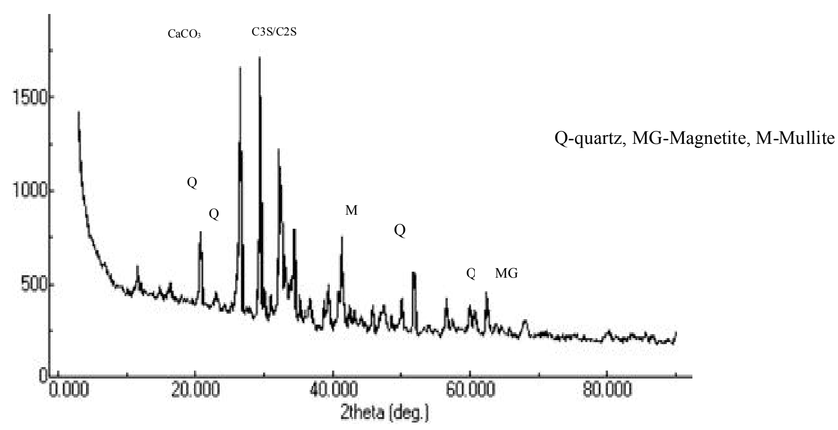


Fig.-2 XRD Profile of (M-1)

4. Results and Discussion

X-ray analysis of control samples of cement and mixes (M-1-M-4) are shown in figure Nos. 1-5. It is clear from the figure that the intensity of calcite peak increases from mix-1 to mix-4 since the limestone content increases from 5% to 20%. The quartz peak also increases from M-1 to M-4 mix. X-ray of hydrated mixtures at 1, 3, 7 and 28 days are shown in figure Nos. 6-8.

The XRD patterns of M-1 to M-4 after 1 day of hydration portlandite can be observed. Further in case of M-1 hydrated mix the intensity of CH is less at 28 days compare to 7 days, since the mix contains 35% fly ash and is well known that fly ash starts reacting after 7days which accounts for less CH content. Further, this intensity is less compared to control, suggesting lime liberated from cement is reacting silica of fly ash. Same is true for C_3S/C_2S peaks. Also intensity of $CaCO_3$ peaks reduces as the hydration progresses due to the formation of calcium carbo- aluminate hydrate.

In case of M-2-M4, increase in CH content indicates that $CaCO_3$ increases the rate of reaction [5].

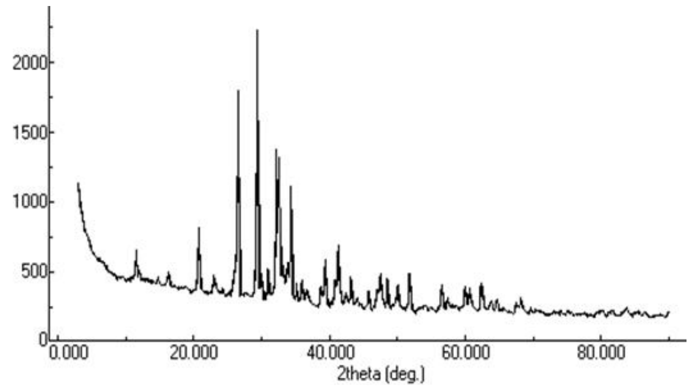


Fig.-3 XRD Profile of (M-2)

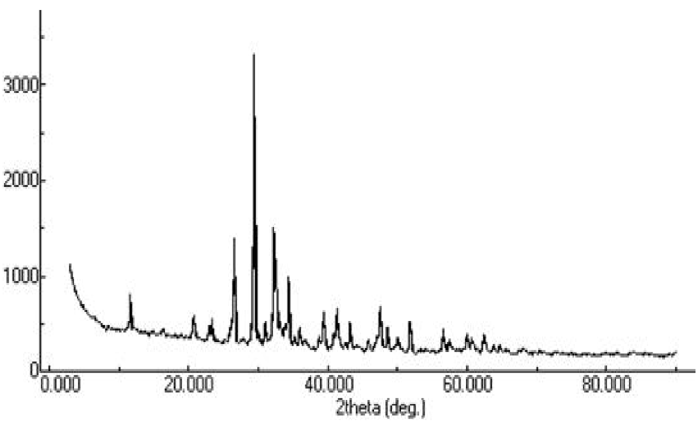


Fig.-4 XRD Profile of (M-3)

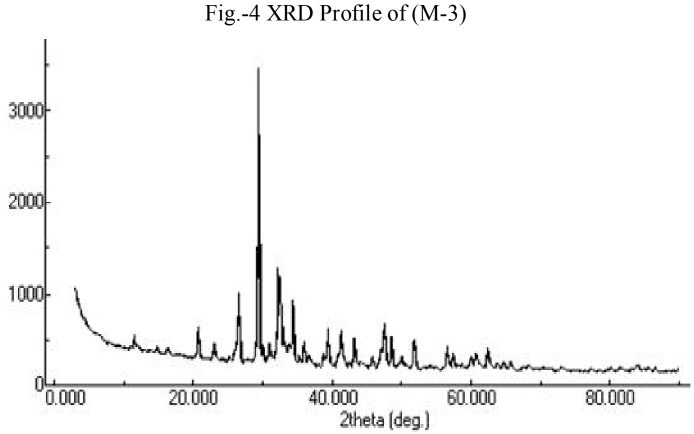


Fig.-5 XRD Profile of (M-4)

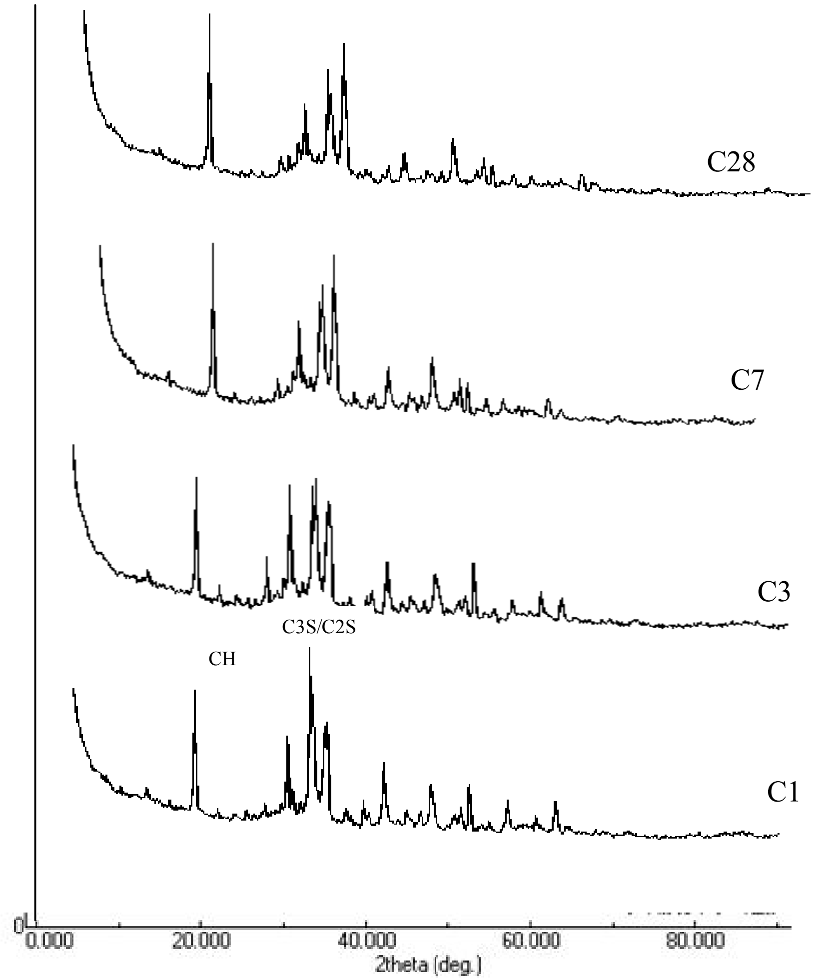


Fig 6. Hydration of cement at different time intervals

At 1-day age, the compressive strength of mix 1 and 2 with 5 and 10% lime stone powder is similar to control. With 15 and 20% lime stone powder, the strength is 15 and 20% lower than control cement. The additions of the limestone filler in cement cause significant decreases of the compressive strengths, in comparison with the reference, especially after 28 days of hardening. Initially (after 2 days), the negative effect of the addition of limestone is small, and the addition has even a positive influence on mechanical strengths, due to its filler effect and of a better dispersion in water of the cement particles, which favors the hydration processes. Further with the use of superplasticizer compressive strength is more in all the mixes. The effect of superplasticizer on cement hydration is mainly due to physical factors rather than chemical interaction. Thus better dispersion of individual cement grains leads to more efficient hydration and better early strength where no reduction in water content has been made. Since no specific standard specifying strength parameters for composite cement in India, strength data is being compared with ASTM C1157 type GU – hydraulic cement for general purpose construction. Even in this standard limit for 1day strength is not specified. However for 3, 7 and 28 days, limit is 13, 20 and 28MPa.

In the present study all mixes meet the ASTM C1157 requirement. Even Mix -4 which contain 20% (lime stone powder and fly ash), 28 day strength is 10% more than the specified limit.

It is clear from the table that strength decrease caused by the addition of lime stone at the 56 days seems to be smaller than at the age of 28 days.

TABLE 4. COMPRESSIVE STRENGTH (MPa) OF CEMENT WITH & WITHOUT SUPER-PLASTICIZER

System	1 Day	3 Day	7 Day	28 Day	56Day
Control	6.58	30.12	39.16	51.00	53.55
Mix-1	6.58	18.25	23.51	39.50	50.02
Mix-1(SP)	7.76	20.50	28.13	44.02	52.51
Mix-2	6.25	16.50	25.12	34.82	41.02
Mix-2(SP)	7.45	18.53	32.25	42.08	50.01
Mix-3	5.66	16.50	23.82	34.08	40.55
Mix-3(SP)	7.02	20.13	28.51	40.05	48.52
Mix-4	5.08	18.25	24.25	30.04	39.00
Mix-4(SP)	6.53	20.34	29.00	36.53	43.18

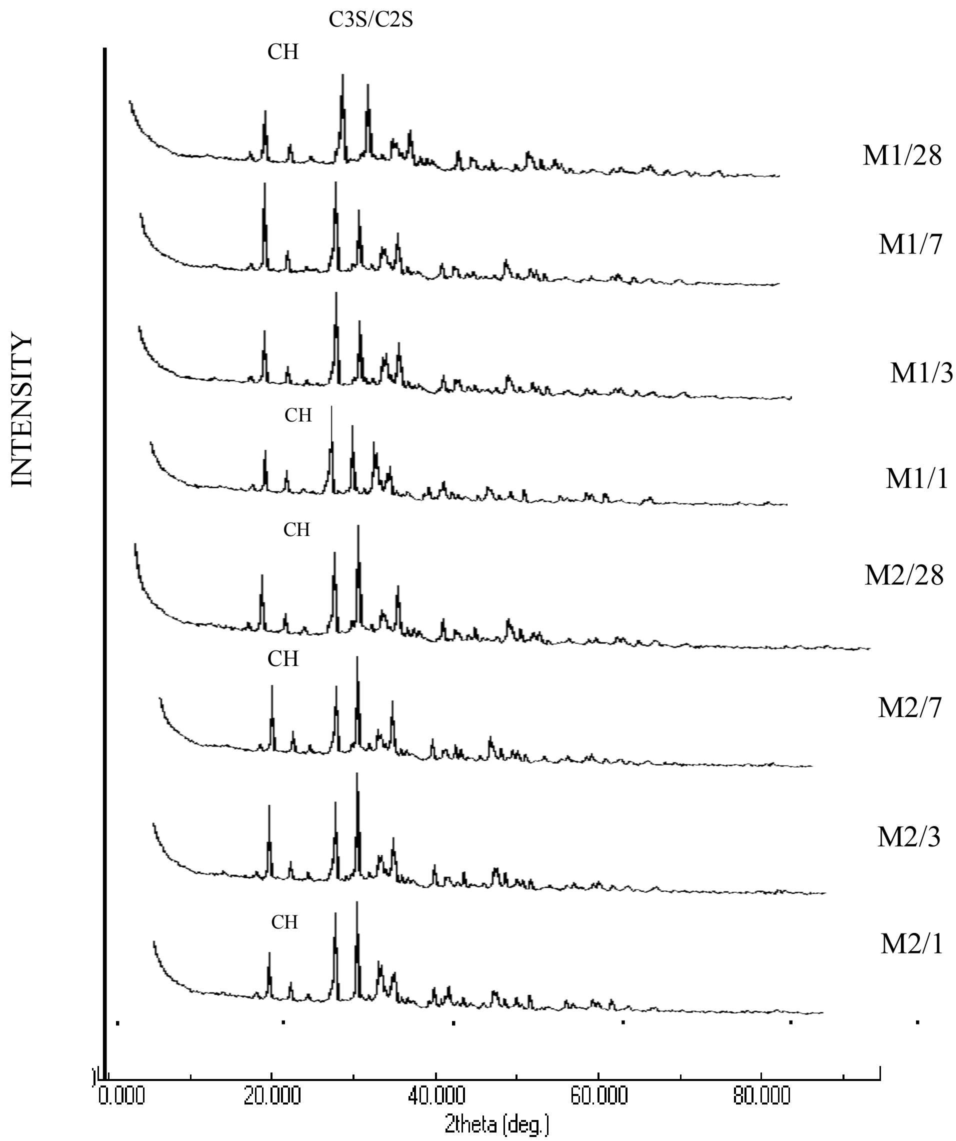
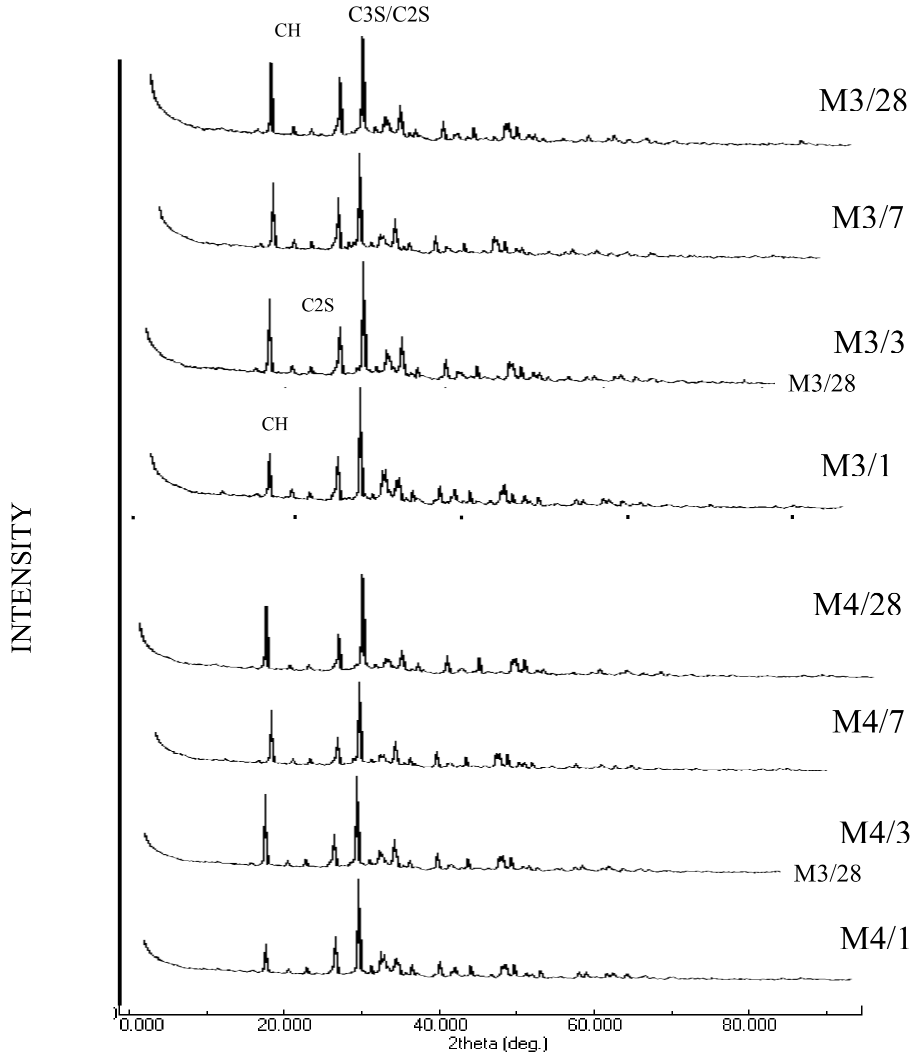


Fig 7. Hydration of mixes (M1 & M2) at different time intervals



5. Conclusion

Based on this study, the following conclusions can be made:

1. 1 day strength of mixes 1 & 2 is comparable to control, however with the use of 1 % SP the strength is more on the four mixes.
2. At 28 days, when SP is used there is a drop of 10 – 15% strength compare to control.
3. At 56 days, the drop in strength is only 5 – 10%.
4. From this study it can be concluded that, the strength properties of composite cement based on flyash and lime is more than EN 32.5R

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