Performance of Limestone Calcined Clay Cement (Lc^3)

Apsa, V Ranga Rao

Abstract: ***As world population is expected to reach 9million by 2050, infrastructural changes are done which require huge quantity of cement, as it produces 60 62to % of CO_2 during calcination, there is a need for alternative binders. As cement demand increases, CO_2 emissions increases, this might become a threat to atmosphere.***

LC^3 is a modern cement which is a blend of 50% clinker, 15% limestone, 30% calcined clay and 5% gypsum. Here, clinker is reduced by 50% there by CO_2 emission can be reduced by 30%. $LC^3$is a low carbon, sustainable, cost effective and double the efficiency of existing cement factory. The increase in demand of cement in coming decades might not be reached with existing alternative binders of Fly ash and GGBS, so limestone and clay are the best supplementary Cementious material that are naturally available. As LC^3 has less workability, super plasticizers need to be used.

In this paper, physical properties of LC^3 were studied by varying clinker and clay content i.e. 40% clinker, 40% clay;50% clinker,30% clay and 60%clinker,20%clay which were calcined at 600°c in muffle furnace by fixing the proportions of limestone 15% and gypsum 5% by adding super plasticizer(pc20) and the results were compared with that of OPC concrete. Durability was also studied by exposing LC^3 cubes to Acid attack and sulphate attack and compared with that of OPC concrete

Index Terms: ***LC^3, Clinker, Limestone, Calcined clay, Compressive strength, Durability***

I. INTRODUCTION

Limestone calci ned clay cement (LC^3) is a blend of limestone, calcined clay, clinker and gypsum. This LC^3 can also be called as future cement, which could meet the upcoming challenges in future. The usage of supplementary cementious materials (scm) for partial replacement of clinker in cement is one of the best ways to reduce carbon dioxide emissions in cement industry. Population is going to increase in coming decades, which require huge changes in infrastructure; therefore cement demand is going to increase in coming years. Today, greater than 80% of scm are used to reduce clinker content by using GGBS, Fly ash and limestone etc. [1]. The amount of slag available worldwide is around 5 to 10% of cement produced show in figure 1[2]. the demand of steel is increasing, but due to environmental pressures more steel is being recycled so production of iron slag is relatively been reduced. therefore availability of slag is even more Limited. The availability of fly ash is somewhat higher around 30% compared to cement, but to decrease environmental emission, the burning of coal to produce electricity is being questioned in many countries, therefore in long run availability of fly ash is also in doubt. Limestone is abundantly available, the addition of greater than 10% limestone alone to cement tends to increase porus nature. The problem of lacking availability of conventional scm are seen in marginal. Extra contribution of this strategy to reduce carbon dioxide emissions is seen in the study for the cement sustainability initiative CSI of the world Business Council of sustainability development standards.

For the further, successful strategy of reducing clinker factor is essential to find new types and sources of scm. There are many sources of scms which are widely known to certain degree and well-studied. But their availability is not in range of production of massive cement. for example, agricultural wastes Ash like rice husk or sugar cane are also considered as pozzolanic but due to its scattered distribution compromises the economic viability of their use [2]. so, there is a need of new type scm that are easily available in nature. The only material that is available in quantities needed to meet increasing cement demand is clay. Clay containing kaolinte can be effective scm through calcinations. Such clays are vastly available in tropical belt of world [3] in countries like India where cement demand is going to increase in coming years. limestone is vastly available in earth's crust.

Calcined clay was already used as pozolonans, the innovation here in LC^3 is to make a coupled substitution of clinker with limestone and calcined clay. Blends with calcined clay allows higher level of substitution to clinker around 65 to 70%, further combination of calcined clay with limestone allow clinker reduction to around 50%[4].

A. Availability of SCM million tons per year

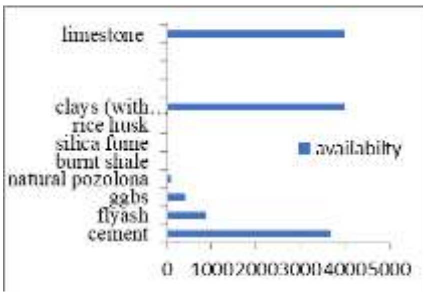

Fig.1: Availability of scm

LC^3 is a new type of cement with the blend of limestone and calcined clay where clinker is reduced to 50%. By reduction of clinker to 50% carbon dioxide emissions are reduced to 30% compared to conventional cement. low grade clay and limestone which are abundantly available could be used in LC^3. LC^3 is cost effective and doesn't require more capital modification to existing cement plant [5].

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B. UNIQUE FEATURES OF LC³

Low capital: LC³ can be produced through existing equipment; marginal increase in the investment might be needed only for calcination equipment [5].

low cost: Due to reduction in clinker content fuel consumption is reduced and calcination temperature is very low when compared to clinker. so, it contributes low cost of production [5].

Known Technology: limestone with clinker, calcined clay with clinker system were well established. LC³ is not about inventing a new technology but optimizing the Synergy between two already known chemical systems [5].

II. OBJECTIVE OF THE STUDY

The objective of this study is to find physical properties of LC³ with 40%, 50%, 60% clinker and 20%, 30%, 40% clay replacement at 600^0c. Durability of LC³ was also studied through acid attack and sulphate attack.

III. MATERIALS

Materials used in preparation of LC³ blend are.

A. clinker
B. calcined clay
C. limestone
D. Gypsum

A. Clinker

clinker is produced by heating Calcareous and Aluminous material at 1400^0c during this heating process, 60 to 62 % of carbon dioxide is liberated. The clinker produced after heating will be in forms of lumps shown in Fig. 2.

Fig.2: clinker in lumps form

Clinker in lumps form is taken in to Los Angeles abrasion machine. balls are added and revolution are done. this process converts lumps clinker to powder form. futher powdered clinker is kept in sieve shaker. powdered clinker was collected from passing 90-micron sieve.

Fig.3: Clinker powder

In LC³ clinker content is reduced to 50% thereby carbon dioxide emissions were reduced to 30% lower than OPC and 11% lower than PPC [4]. Here clinker content used in this study was 40%, 50% and 60%.

B. Calcined clay

Clay that is rich in kaolin mineral around greater than 40% is suitable for LC³[2]. clay can be calcined in conventional rotary kilns, flash calcination unit, roller hearth kilns, shuttle kilns and muffle furnace [4]. When clay containing Kaolin is calcined, metakaolin is formed which contains aluminosilicate. This reacts with calcium hydroxide as conventional pozzolana to give csh gel and Aluminum hydrate. In addition, the Alumina can react with limestone to produce carboalumination hydrates. All these products fill the space and improve strength and durability.

The reactivity of clay is mainly dependent on kaolinite content of clay with 40% or above gives strength comparable to plain Portland cement [2]. such clays are widely available. As Clay is one of the raw materials for cement production, it might be available in queries of existing cement plant.

clay is calcined at 600^0c in muffle furnace for 30 minutes. kaoline clay used here is of 81.9% kaoline content shown in Fig.4.

Fig.4: kaoline clay

After calcination kaoline becomes amorphorous and reactive. It changes its colour to dirty white as shown in Fig.5.

Fig.5: Calcined clay

clay is finely divided can easily react with clinker to higher degree than fly ash. fineness of clay has to be reduced if not water demand increases. The presence of limestone reduces water demand. Clay content used in this study was variable at 40%, 50% and 60%.

C. Limestone

LC³ can increase the life of mines by reducing wastage of raw material. low calcite limestone with impurities like dolomite and quartz can be used in LC³.limestone that is not suitable for clinker production can also be used in LC³.

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Limestone content in this study was constantly maintained at 15% in the blends. limestone used here is shown in Fig.6.

Fig.6: limestone

D. Gypsum

Gypsum as it plays major role in workability, it is also used in LC^3 for controlling rate of hardening of cement. gypsum content in this study was maintained constantly at 5% Gypsum used here is shown in Fig.7.

Fig.7: Gypsum

Proportions of mix are shown in table

s.no	Mix	Clinker (%)	Calcined clay (%)	Lime Stone (%)	Gypsum (%)
1.	Mix1	40	40	15	5
2.	Mix 2	50	30	15	5
3.	Mix 3	60	20	15	5

Table -1: Proportions of mix

E. Properties of mix

Properties of mix are tested in laboratory using equipment for specific gravity-pynometer, Initial setting time, final setting time-vicat apparature, consistency-vicat apparature. Properties are shown in table 2

s.no	Mix	Specific gravity	Initial setting time	Final setting time	Consistency
1.	Opc	3.1	30	190	33
2.	Mix 1	2.4	95	152	41
3.	Mix 2	2.4	90	180	31.5
4.	Mix 3	2.4	93	165	29

Table-2: properties of lc3 blends.

IV. METHODOLOGY

Clickers with lump form is taken into Los Angeles aberration equipment shown in the fig.8.

Fig.8: Losangels aberration equipment

Steel balls are added balls are shown in figure9.

Revolution are made this make clinkers to powdered form. this powder is taken into seive Shaker. clinker powder is collected that passes to 90 Micron seive.

Fig.9: Clinker after an aberration test

clay is calcined in muffle furnace as shown in the figure at 600^0cfor 30 minutes.

Fig.10: Muffle furnance

After collecting clinker and calcined clay from 90 Micron sieve and muffle furnace respectively limestone and Gypsum powders are taken without altering. blends are prepared according to their proportions. Mix 1 preliminary test was performed.

A. Consistency test

Consistency test is performed by following IS: 4031 (part 4) -1988. Consistency for mix one was found to be **41**. motor cubes are casted by using code book IS :4031-6 (1988) Standard sand is prepared. mix 1 blend is mixed with standard sand and calculated water content according to consistency. Mortar cube is shown in Fig.11.

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Fig.11: Motar cubes.

motor cube shaker is used for vibration required depending on consistency is shown in fig12.

Fig.12: Equipment

after casting curing is done for 28 days compressive test is performed at 3 days 7 days and 28 days are shown in fig.13.

Fig.13: Motor cube testing CTM

same procedure is repeated for mix 2 and mix 3 and consistency found to be **31.5** and **29** water content is calculated. motor cubes are casted.

B. Specific gravity

By using code IS 2386-3(1963) mix 1 specific gravity is found. Specific gravity is done with pyncometer as shown in fig.14.

Fig.14: Pycnometer diagram

Mix 2 and Mix 3 specific gravity was tested.

C. Initial setting time and final setting time

By using code IS**:4031 (part 5)-1998** Mix1 initial setting time and final setting time were calculated by using vicat apparatus. same procedure is repeated for mix 2 and mix 3.

D. Concrete cubes casting

Mix design for M20 is done by following the code book IS456 -2000 and mix proportion are

cement - 300 kg/m^3
water 165
coarse aggregate 1094.9
fine aggregate 895.4
superplasticizer 0.5%

70% of coarse aggregate is of 20 mm and 30% is of 10 mm.

E. Coarse aggregates

The coarse aggregates used here is from klu university batching plant as per IS-383. The flakiness and elongation index are maintained.to arrest the voids casting is done with 10 mm and 20 mm of coarse aggregates are used. 30% of 10 mm and 70% of 20 mm size aggregates are used from the total weight of the aggregates.

F. Fine aggregates

According to the recommendation of IS- 383 code book the river sand particles are used as the fine aggregates. The fine aggregates are sieved and removed the deleterious materials which are present in it.

G. Admixtures

The super plasticizer is used in our laboratory with 0.5 % of the volume. According to the ASTM C-494 recommended. These are high water reducing agents which can reduces water about 20%. For the particles which are combined in this water requirement super plasticizer for good workability because calcined clay fineness requires water so, addition of the super plasticizer’s strength is a must in desired proportions.

H. Casting

first blend is prepared by the above proportions. then mixed with coarse aggregate, fine aggregate, water and plasticizer according to calculated content casted cubes are shown in fig15.

Fig.15: Cube diagram

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casting is done by using Pan mixer, demolding is done after 24 hours. cubes are taken to curing and tested at 3 days 7 days and 28 days tested cubes are shown in fig.16.

Fig.16: Cube testing

same processor repeats for the mix 2 and mix 3 cubes are casted and tested.

I. Durability

Acid attack

Nacl solution of 2% is used for curing after 28 days test were performed

Sulphate attack Mgso$_4$ solution of 2% is used for curing 28 days test were performed

V. RESULTS

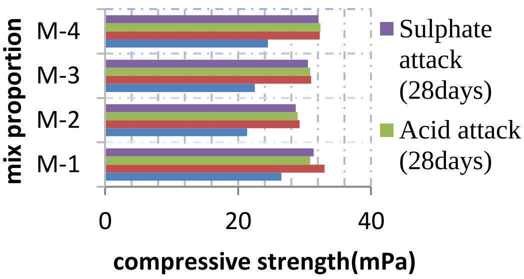

Fig.17: Compressive Strength.

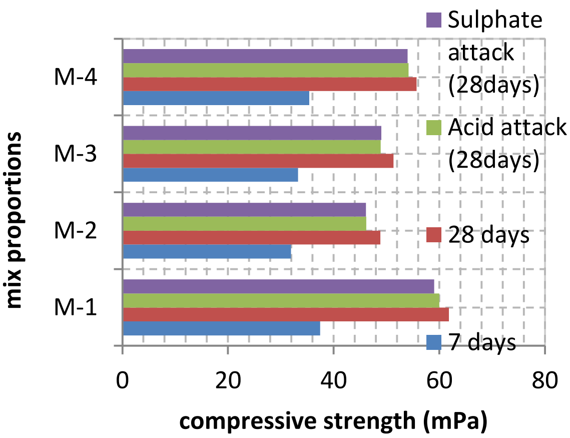

Fig.18: Compressive strength of mortar cubes

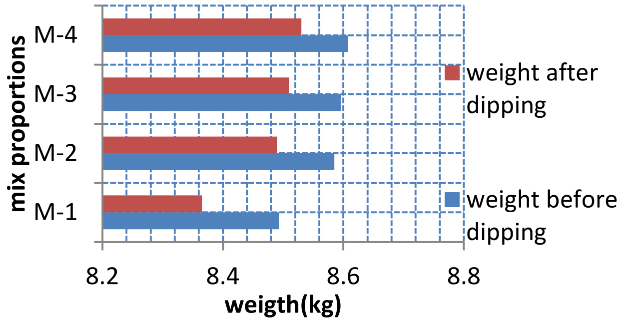

Fig.19: Acid attack on concrete

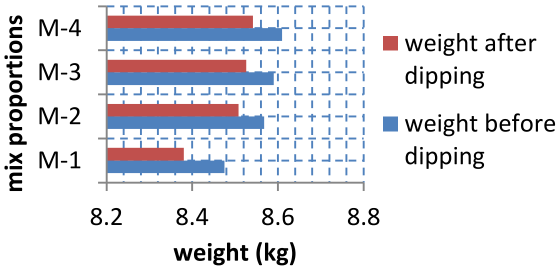

Fig.20: sulphate attack on concrete

CONCLUSION

Mix proportion (60%clinker, 20%calcined clay, 15%limestone, 5%gypsum) was shown approximately equal strength at 28 days when compared to OPC. Mix 4 was shown good compressive strength even after curing with sulphate and acid dilutions of 2%. Compressive strength of mortar cubes were best performed by mix 4. Acid attack and sulphate attack was well resisted by mix 1proportion (40%clinker, 40%calcinedclay, 15%limestone, 5%gypsum). As clinker content increased, strength was increased. As clay content increased, durability was increased. As clinker content was increased, strength was increased but durability was decreased in mix 4. As clay content increased, durability was increased but strength declains so, to overcome both strength and durability aspect optimistic mix was found as mix 3proportions (50%clinker, 30%clay, 15%limestone, 5%gypsum).

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