International Journal for Innovative Engineering and Management Research
A Peer Revieved Open Access International Journal
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IJIEMR Transactions, online available on 21st November 2017. Link :
http://www.ijiemr.org/downloads.php?vol=Volume-6&issue=ISSUE-10

Title: An Experimental Investigation on Concrete by Replacement of Cement With Plaster of Paris

Volume 06, Issue 10, Page No: 371 – 395.

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AN EXPERIMENTAL INVESTIGATION ON CONCRETE BY REPLACEMENT OF CEMENT WITH PLASTER OF PARIS

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ABSTRACT:

Concrete is the most commonly used construction material in the world. It is basically composed of two components: paste and aggregate. The paste contains cement, water, sometimes other cementitious and chemical admixtures, where as the aggregate contains gravel or crushed stone. The paste binds the aggregates together. The aggregates are relatively inert filler materials which occupy 70% to 80%of the concrete and therefore be expected to have influence on its properties. The proportion of the subcomponents, the paste and the aggregate is controlled by strength, durability of the desired concrete, the workability of the fresh concrete and the cost of the concrete. Cement which is one of the components of concrete plays a great role but is the most expensive and environmentally unfriendly material. Therefore requirements for economical and more environmental-friendly cementing materials have extended interest in other cementing materials that can be used as partial partial replacement of the normal Portland cement Recently ,plaster of paris, a product of Gypsum has been tested in some parts of the world for its pozzolanic property and has been found to improve some of the properties of the paste,mortar and concrete like compressive strength and water tightness in certain replacements.

INTRODUCTION

1.1 General Theory

Concrete is the most commonly used construction material in the world. It is basically composed of two components: paste and aggregate. The paste contains cement, water, sometimes other cementitious and chemical admixtures, whereas the aggregate contains gravel or crushed stone. The paste binds the aggregates together. The aggregates are relatively inert filler materials which occupy 70% to 80% of the concrete and can therefore be expected to have influence on its properties. The proportion of these components, the paste and the aggregate is controlled by the strength, durability of the desired concrete, the workability of the fresh concrete and the cost of the concrete. Cement which is one of the components of concrete plays a great role but is the most expensive and environmentally unfriendly material. Therefore requirements for economical and more environmental-friendly cementing materials have extended interest in other cementing materials that can be used as partial replacement of the normal Portland cement. Ground granulated blast furnace slag, flyash, silicafume, etc have been used successfully for this purpose. Recently, Plaster of Paris, a product of Gypsum has been tested in some parts of the world for its pozzolanic property and has been found to improve some of the properties of the paste, mortar and concrete like compressive strength and water tightness in certain replacements. Therefore, this study attempts to make use of the Plaster of Paris as a pozzolanic material to replacement. An experimental investigation was carried out to examine the impact of adding Plaster of Paris to the mechanical and physical properties of pastes, mortars and concrete such as consistency, setting time, workability, compressive, tensile, flexural strength and durability.

1.2. Alternatives to Portland cement

1.2.1. Introduction

Cement or some form of cementing material is an essential ingredient in most forms of building construction. Cement is the vital binding agent in concretes, mortars, renders and is used for the production of walling blocks and roofing tiles.

Since it's invention in the first half of the 19th century, Portland cement has become the most widely available cementitious material. It's dominance over alternative cements has been in part, due to successful, aggressive marketing. This is despite it's clear technical disadvantages for certain applications. In addition Portland cement is relatively expensive to produce and is often in short supply in many developing countries. Typically, a rural African labourer may need to work for up to two weeks to earn enough money to buy one bag of cement. In comparison alternative cements can be produced locally on a small scale and at much lower cost.

The most common of these so-called 'alternative' binders is lime, to which other materials, known as pozzolanas, can be added to enhance strength and water resistance. Other binders such as gypsum, sulphur, bitumen, mud and animal dung have also been used.

1.2.2. Binding systems from history

The simplest, and possibly the earliest, binding material used was wet mud, and there are records of its use in ancient Egypt. Another example of a binder from the distant past is the use of naturally occurring bitumen by the Babylonians and Assyrians in their brick and alabaster (gypsum plaster) constructions.

mixed this already hydraulic lime with an equal proportion of imported Italian pozzolana (so adding extra 'hydraulicity' to the mortar).

1.2.3. Why continue to use alternative cements

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Major advantages of alternatives to Portland cement are that they are usually cheaper to produce, needing much lower or even negligible capital inputs to get started, and requiring far less imported technology and equipment. They can also be produced on a small scale to supply a local market resulting in greatly reduced transportation costs and a much greater degree of local accountability in the supply of building materials.

From an environmental angle lime-pozzolana cements can be produced with lower energy input than either lime by itself or Portland cement – giving a half to one third consumption in use compared with Portland cement and about one fifth compared with lime by itself. Low energy consumption is particularly prevalent with naturally occurring pozzolanas, or those from waste materials, which might need little additional processing other than drying. The use of clay as a binder, of course, results in negligible energy consumption in production.

Pozzolanic cements additionally have numerous other technical advantages to the user:

- ✓ Improved workability
- ✓ Improved water retention/reduced bleeding
- ✓ Improved Sulphate resistance
- ✓ Improved resistance to alkali – aggregate reaction
- ✓ Lower heat of hydration

1.2.4. Types of alternative cements

1.2.4.1. Lime

There are two forms of lime: quicklime and hydrated lime.

Quicklime is produced by heating rock or stone containing calcium carbonate (limestone, marble, chalk, shells, etc.) to a temperature of around 1000°C for several hours in a process known as ‘calcining’ or sometimes simply ‘burning’. It is an unstable and slightly hazardous product and therefore is normally ‘hydrated’ or ‘slaked’, by adding water, becoming not only more stable but also easier and safer to handle.

To produce dry powdered hydrated lime just sufficient water is added for the quicklime lumps to break down to a fine powder. This material would have a ‘shelf life’ of only a number of weeks, depending on storage conditions. ‘Old’ hydrated lime would have partially carbonated and become a less effective binder.

However, if quicklime is hydrated with a large excess of water and well agitated, it forms a milky suspension known as milk of lime. Allowing the solids to settle, and drawing off the excess water, forms a paste-like residue, termed lime putty, which is the form of lime which can be used in building applications to best effect. This will keep almost indefinitely and, in fact, improves with age. In most countries, though, lime is most widely available as a powder, due to its widespread utilization in process and treatment industries rather than in construction. Lime putty, which needs a stiff bag or container for transportation, is more rarely produced.

Plain lime-sand mortars are quite weak; any early adhesive strength results from drying out, and longer term hardening occurs through the action of the air's carbon dioxide on the lime.

Traditionally lime renders and plasters were often mixed with animal hair to improve cohesion. Today the addition of gypsum or Portland cement and/or pozzolanas to increase durability and give faster setting times is usual.

1.2.4.2. Pozzolanas

Pozzolanas are materials which, although not cementitious in themselves, will combine chemically with lime in the presence of water to form a strong cementing material. They include:

- ✓ Volcanic ash
- ✓ Power station fly ash (usually known as pfa)
- ✓ Burnt clays
- ✓ Ash from some burnt plant materials
- ✓ Siliceous earths (such as diatomite)

Materials not already in a fine powdered form must be ground, and some require calcining at around 600–750°C to optimize their pozzolanic properties.

Pozzolanas can be mixed with lime and/or Portland cement and can improve quality and reduce costs of concretes made from both materials.

1.2.4.3. Gypsum plaster

Gypsum is not an uncommon mineral, needs only a low temperature, of around 150°C, to convert it into a very useful binding material, known as hemi-hydrate or Plaster of Paris.

On its own, Plaster of Paris sets very rapidly when mixed with water. To give time for it to be applied, around 5% of lime and 0.8% of a retarding material (such as the keratin glue-like extracts from boiling fish bones or animal hoof and horn) are added to the plaster.

Retarded plaster of Paris can be used on its own or mixed with up to three parts of clean, sharp sand. Hydrated lime can be added to increase its strength and water resistance. Gypsum plasters can be reinforced with various fibrous materials from reeds to chopped glass fibers.

Gypsum plaster is not wholly resistant to moist conditions and so is normally used internally, except in the drier Mediterranean and Middle Eastern countries where it has traditionally been used as an external render.

1.2.4.4. Other alternative binders

Sulphur is used as an alternative binder in the Gulf region, where a million tonnes a year comes from natural gas plants in the United Arab Emirates. In some other locations, such as St Lucia, sulphur that accumulates around the vents of volcanic fumaroles is utilized.

A mixture of 15–25% molten sulphur, heated to around 130°C with 5% of organic additive, and 75–85% sand or other mineral aggregates which have previously been heated to 160–170°C, can be cast and de-moulded in only about five minutes. The additive is mainly used to impart durability. Sulphur concrete has applications which either exploit its quick curing and corrosion resistance or in situations where Portland cement concrete is expensive, unavailable or, for example in freezing conditions, impracticable.

A number of other alternative binders have been used in a number of applications, which generally relate to soil stabilization, waterproofing, or the application of a waterproofing or wear resistant coating to vulnerable earth based constructions. Such binders include tars and bitumen's (as by-products from petro-chemical industries), sodium silicate (produced from the heat activated reaction between silica and sodium hydroxide), casein (milk whey), oils and fats, molasses, and certain locally specific plant-based materials such as gum Arabic, other specific resins and the sap, latexes and juices from specific trees and other plants.

1.3 Justification for the thesis

The production of cement is one of the most environmental unfriendly processes due to the release of CO_2 gases to the atmosphere. It is believed that one ton of Portland cement clinker production creates about one ton of CO_2 and other greenhouse gases. This shows that the cement industry contributes to today's worldwide concern, which is global warming. This endangers the sustainability of the cement industry and that of concrete.

In addition to its negative environmental impact ,Cement is also one of the most expensive materials when compared to the other constituents of concrete. The raw materials for the cement production like lime are also being exploited in large amount which may result in running out of them, as it is predicted to happen in some places of the world.

Gypsum is a not an uncommon mineral and needs only a low temperature of around 150°C to convert it into a very useful binding material known as hemi-hydrate or plaster of Paris.

Thus this thesis deals with checking the feasibility of the Plaster of Paris which is produced on heating of gypsum for using it as cement replacement material.

1.4 Objectives of the research

1.4.1 General objectives

The general objective of this research work is to assess the availability of Plaster of Paris and to study the feasibility of using this material as a cement replacement material.

1.4.2 Specific objectives

The specific objectives of this research work can be stated briefly as follows:

A. Checking the availability of Plaster of Paris in the country.
B. Checking the chemical composition of the Plaster of Paris.
Evaluating the performance of paste, mortar and concrete made of Plaster of Paris as a replacement material by conducting some laboratory tests on the fresh and hardened state and determining the quantity of Plaster of Paris that can be used successfully.

C. Investigating the economical and environmental issues of using Plaster of Paris for cement replacement.

Finally after making such assessment on the performance of the Plaster of Paris some conclusions and recommendations will be forwarded on the performance and various aspects of the material as cement replacement.

1.5 Research methodology

The following methodology has been employed to achieve the objectives of the research:

1. Literature survey, which includes concrete, cement replacement materials, Plaster of Paris as cement replacing material, performance tests on the fresh and hardened concrete. The review includes text books, periodicals and academic journals, seminars, and research papers.
2. Sample preparation at 20% percentage of Plaster of Paris replacing cement.
3. Performing different tests on pastes, mortars and concretes at both fresh and hardened state, including determination of fineness for Plaster of Paris and cement and their blends, water absorption test, normal consistency and setting time, and compressive strength at 7, 28 and 90 days, for the concrete including tensile and flexural tests at 7, 28 and 90 days and acidic durability at 7, 28 and 90 days on the hardened concrete.
4. Analysis of the test results in which the results were presented in graphical form and interpretation and discussion were made on the research findings.
5. And finally formulation of conclusion and recommendations based on the results obtained.

1.6 Scope of present study:

The scope of present study includes the following aspects:

Laboratory tests on cement, coarse aggregate, fine aggregate.

Mix design for normal concrete for M_{25} grade as per IS 10262:2009 was done by mixing and curing with potable water. Conducting trail mixes as per designed workability and target mean compressive strength of concrete. And the same mix made with different percentage replacement with Plaster of Paris. Specimens were tested at the age of 7 days, 28 days and 90 days to find compressive, tensile and flexural strength properties of the mix in normal environment. Specimens were tested after curing in H_2SO_4 acid in different concentrations 3% and 5% at the age of 7 days, 28 days and 90 days to find compressive strength property in aggressive environment. Fresh properties of concrete specimens were tested by slump cone test and compaction factor test. For hardened properties of concrete specimens were tested at the age of 7 days, 14 days and 28 days of curing in potable water and also with acidic water.

Casting cubes of size 150mmx150mmx150mm for the determination of Compressive strength of concrete.

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Casting cylinders of size 150mm diameter and 300mm length for the determination of Split tensile strength of concrete

Casting beams of size 100mmx100mmx500mm for the determination of Flexural strength of concrete.

LITERATURE REVIEW

2.1 Introduction

Cement and Concrete Technology has shown various advancements during the past years. One of the best advancements is the use of by-product materials as a cement replacement to alleviate environmental and economical impact of cement production. These cement replacing materials were reported to improve different properties of the mortar and the concrete.

Plaster of Paris is one of these by-product materials found from gypsum. Recently it has been studied for its feasibility as a cement replacing material in some parts of the world and has been found to improve some of the properties of mortar and concrete. The performance of mortar and concrete is assessed by different tests on both the fresh and hardened concrete. These include workability, strength and durability.

This chapter is, therefore, dedicated in discussing about cement, different performance criteria of concrete, pozzolanas and Plaster of Paris.

2.2 Cement

Cement is a fine grey powder which when reacted with water hardens to form a rigid chemical mineral structure which holds the aggregates together acting as glue and gives concrete its strength. The credit for its discovery is given to the Romans, who mixed lime ($CaCO_3$) with volcanic ash, producing a cement mortar which was used during construction of such impressive structures as the colosseum.

2.2.1 Types of cement

There are different types of cement depending on their composition, method of manufacturing (grinding, burning, etc.) and also the relative proportion of the different compounds. One of these types and the most commonly used one is Portland cement, which in turn is divided into many types. The other common type of cement is Portland pozzolana cement which contains some amount of pozzolanic materials.

2.2.1.1 Portland cement

Portland cement is one of the most widely used cement and is the most important hydraulic cement. It can also be used for mortar and plaster production. It is used in all types of structural concrete like walls, floors, bridges, tunnels, etc. It is further used in all types of masonry works like foundations, footings, dams, retaining walls, and pavements. When Portland cement is mixed with sand and lime, it serves as mortar for laying brick and stone; and when it is mixed with coarse aggregate and fine aggregate (sand) together with enough water, to ensure a good consistency, we get concrete.

The origin of the name “Portland cement" is usually attributed to Joseph Aspdin, a brick

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mason in England who in 1824 took out a patent for making a powder made from mixed and ground hard limestone and finely divided clay. This forms into slurry and then is calcined in a furnace till the $CO_2$was expelled. He called the resulting material Portland cement because when the mortar made with it hardened it produced a material resembling the stone which was quarried near Portland, England. The method of making cement has been improved upon since that time but the basic process has remained the same.

Modern Portland cement is made from materials which must contain the proper proportions of lime (CaO), silica (SiO_2), alumina (Al_2O_3), iron (Fe_2O_3) with minor amounts of magnesia and sulphur trioxide.

A typical composition of general purpose Ordinary Portland cement Of these compounds, C_3S and C_3A are mainly responsible for early strength of concrete. High percentages of C_3S (low C_2S) results in high early strength but also high heat generation as the concrete sets. The reverse combination, that is, low C_3S and high C_2S develops strength more slowly and generates less heat. C_3A causes undesirable heat and rapid reacting properties, which can be prevented by adding $CaSO_4$ to the final product.

2.2.1.2 Portland Pozzolana cement

Portland pozzolana cement (PPC) is manufactured by the inter grinding of OPC clinker with 15 to 35 % of pozzolanic materials. Pozzolanic materials are siliceous or aluminous materials which by themselves possess little or no cementitious properties. But in the presence of water they react with calcium hydroxide which is liberated from the hydration of cement to form a compound possessing cementitious property.

The reaction of the pozzolanic materials with calcium hydroxide results in many advantages of PPC over OPC. If these pozzolanic materials were not reacted with the calcium hydroxide, free calcium hydroxide would have been present in the concrete resulting in higher permeability of the concrete and susceptibility to other attacks. The pozzolanic reaction reduces the porosity of the concrete by producing cementitious compound. It also reduces the heat of hydration since its reaction is slower than that of OPC, which implies that it has slower rate of strength than OPC, making it suitable for mass concrete construction.

In addition to these cement types; there are also other types of cement which are produced by either adding other materials to the clinker or by forming other compounds during burning. They are collectively called modified Portland cements. Expansive cement, calcium sulphoaluminate cement, masonry cement, oil well cement, white cement etc. can be an example for this. There are also non-Portland inorganic cements which are used to some extent.

2.2.2 Hydration of cement

When water and Portland cement are mixed, the constituent compounds of the cement and the water undergo a chemical reaction resulting in hardening of the concrete. This chemical reaction of the cement and the water is called hydration and it results in new compounds called hydration products. Both C_3S and C_2S react with water to produce an amorphous calcium silicate hydrate known as C–S–H gel which is the main "glue" which binds the sand and coarse aggregate particles together in concrete.

Each of the compounds found in the cement react with water, but the rate at which they react is different. C_3S and C_3A are the most reactive compounds, whereas C_2S reacts much more slowly. Approximately half of the C_3S present in typical cement will be hydrated by 3 days and 80% by 28 days, in contrast, the hydration of C_2S does not normally proceed to a significant extent until approximately 14 days. **Gypsum** is added to lower the rate of hydration C_3A.

The hydration of Portland cement as a whole is more complex than the individual compounds. This is because of different compounds have different products, reaction rate, and each of the compounds consume water.
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When cement is first mixed with water some of the added calcium sulphate, dissolve rapidly. The purpose of adding calcium sulphate is in order to retard the hydration of C_3A, which without calcium sulphate results in flash set due to its high rate of reaction with water. This is because C_3A is more reactive than any of the compounds in the cement and if allowed will take much of the water. The order of reaction is $C_3A > C_3S > C_4AF > C_2S$. But the rate of hydration of these compounds differs from cement to cement depending on the fineness, the rate of cooling of the clinker and other factors like presence of impurities and other cement compounds.

2.2.3 Physical properties of cement

Specifications for cement places limit on its physical properties. An understanding of the significance of some of the physical properties is helpful in interpreting results of cement tests. Tests of the physical properties of the cements should be used to evaluate the properties of the cement, rather than the concrete.

2.2.3.1 Fineness

The fineness of cement affects many of its properties. The heat released and the rates of hydration are the main properties which are affected by the fineness of cement. These properties of the cement in turn affect many other properties, like normal consistency, setting time, strength, etc.

Fineness of cement can be measured mainly by specific surface area method and particle size distribution. The specific surface area is the summation of the surface area of all of the particles in 1 gm. or 1 kg of cement. Most of the time, it is a general practice to describe fineness by a single parameter, specific surface area. Although it is possible to measure the particle size distribution of cement, there is still no agreement on what would contribute a best grading curve for cement. Due to this and other factors the specific surface area is preferred over the particle size distribution.

2.2.3.2 Consistency of cement paste

Many of the properties of concrete are affected by its water content. The physical

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requirements of cement paste like setting and soundness depends on the water content of the neat cement paste. Therefore it is necessary to define and study the water content to do these tests. This is defined in terms of the normal consistency of the paste which is measured according to IS: 4031-part 4-1988.

Standard consistency of a cement paste is defined as that consistency which will permit a vicat plunger having 10 mm diameter and 50 mm length to penetrate to a depth of 33-35 mm from top of the mould.

2.2.3.3 Setting time

Setting is a process in which cementitious mixtures of plastic consistency is converted into a set material which has lost its deformability and crumbles under the effect of sufficiently great external force. It is preceded by a stiffening of the paste in which the apparent viscosity of the material increases without losing its plastic character. There are two types of setting time i.e. initial and final setting times. The initial setting time indicates the time at which the paste begins to stiffen considerably and can no longer be moulded; while the final setting time indicates the time at which the paste has hardened to the point at which it can sustain some load. Like normal consistency, these tests are also used for quality control.

Indian Standard recommends that the initial setting time for cement not to be less than 30 minutes and the final setting time not to exceed 10 hours.

2.3 Concrete

Concrete is the most commonly used modern construction materials. It forms the basis of the modern construction system. Many of our activities directly or indirectly are affected by concrete structures; the buildings we live and work in, the roads we drive on, the dams from which we get water and energy, etc. can be an example. The ability of concrete to be cast into any desired shapes and configurations is the reason for its versatility.

The word concrete comes from a Latin word "concretus" which means to grow together, which implies that it is a composite of different materials. It is composed of coarse granular material called aggregate or filler which is embedded in a hard matrix of material (cement or binder with water) binding the aggregates together and filling the space formed between them. When the constituents are mixed with water the concrete solidifies and hardens due to a chemical reaction between the water and the cement called hydration, which finally forms a stone like material by binding the aggregates together.

2.3.1 Strength of concrete

Strength of concrete is commonly considered its most valuable property, although in many practical cases other characteristics, such as durability and permeability, may in fact be more important. Nevertheless, strength usually gives an overall picture of the quality of concrete because it is directly related to the structure of the hardened cement paste.

The strength of concrete is dependent on many things. The hydration reaction, water to cement ratio, aggregate type, amount and size, water

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content, cement content, curing condition, cement type, compaction method used will have an effect on the strength of concrete. Strength at any w/c ratio depends on the degree of hydration of the cement and its physical and chemical properties. The decrease in the water content of the concrete results in a higher strength of the concrete. The water required for the hydration reaction is less than that of the mixing water; the extra water provided is used to make the concrete more workable. The compaction of the fresh concrete reduces the amount of entrapped air and therefore increases the strength of the concrete. It is found that for each 1 % of air entrapped there will be a 5 to 6 % loss on strength. Curing temperature affects the hydration of cement and hence the duration of strength gained. Cubes kept at about $10^{o}C$ will have their 7-day strength reduced by 30% and their 28-day strength by 15%. Different pozzolanic materials have different effect on strength. But most of them including Plaster of Paris have been found to improve the strength of concrete especially at later days due to the secondary reaction.

2.3.2 Workability of concrete

Workability is the measure of how easy or difficult it is to place, consolidate and finish concrete. It contains different aspects like consistency, flow ability, mobility, compatibility, finish ability and harshness. It can also be defined in terms of the amount of mechanical work or energy required to produce full compaction of the concrete without segregation. This property of concrete is affected by a number of factors like: water content of the mix, mix proportions, aggregate properties, time, temperature, characteristics of the cement and admixtures.

The cement content and cement replacing materials also affect the workability. Higher cement content reduces workability. The effect of cement replacing materials depends on their nature. Finer materials result in reduction of workability while spherical materials increase it.

2.4 Plaster of Paris as cement replacing material

Title: Usage of waste plaster of Paris in concrete

Journal: International Journal of Innovative Research and Development

ISSN: 2278-0211

V.N.Kanthe.

Plaster is one of the oldest known synthetic building materials: it was used by the Egyptians at least 4000 years ago in the construction of the pyramids and the Greeks were producing decorative plaster work by 500 BC. The chemistry of the conversion of gypsum to plaster was also investigated early on by chemists such as Le Chatelier (1850 - 1936) and Vant Hoff (1852 - 1911). Plaster is made by heating gypsum ($CaSO4.2H2O$) powder, thus converting it to calcium sulphate hemi-hydrate ($CaSO4.H2O$). The hemi-hydrate is also known as stucco or Plaster of Paris .probably so named because of the very large deposit of pure gypsum found beneath Paris. When water is added to the stucco, the material rehydrates to give a solid mass of gypsum. This rehydration is accompanied by an increase in temperature and a slight expansion of the plaster, causing the gypsum to perfectly fill a mould. Plaster of Paris (POP) chemically is hemi-hydrate of calcium sulphate produced by calcinations / heat treatment of gypsum, a di-hydrate of calcium sulphate. It finds its application in various areas of construction, ceramic, chalk pieces, medical (dental and surgical), sculpting, etc. Physically POP is described in α-form, a referring to crystalline form and β-form referring to amorphous form. In India only α-form is produced and all further discussion refers to only this form.

Methodology

Concrete Mix Design:

In present study M_{25} grade of concrete mix used. Ingredients of concrete are Cement, Fine aggregate, Coarse aggregate and waste POP.

Procurement of Ingredients:

For cement test result shown in Table No.2. And Fineness modulus of fine aggregate was found 4.6 and coarse aggregate were found that for 12mm size aggregate 9.6 and for 20mm size aggregate 6.79.

2.6 GENERAL

Extensive research works both at National and International level has been done on the use of various cement replacements in concrete.

- ✓ To combat the environmental hazards from the industrial wastes.
- ✓ To modify the properties of traditional concrete to the desired level suitable to the specific circumstances.
- ✓ To conserve the natural resources used in the production of construction materials.
- ✓ To bring down the increasing cost economics of cement, building blocks and high strength concrete.
- ✓ To combat the scarcity of traditional ordinary Portland cement and bricks.

In India, only government educational and research institutions and construction departments are responsible for research while in advanced countries, the most remarkable breakthrough have been achieved by the building material industries and their R & D laboratories. An accepted fact is that these encouraging results on the cement replacement concrete into the user community and the entire research work is getting flocked at their origination. With the result the very purpose of research work is questioned. The policy maker and consultants should take more interest in handling these issues directly keeping not only the techno economics in view but also national obligations.

2.7.1 Experimental study on partial replacement of cement by Neutralized red mud in concrete

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International journal of Engineering and advanced technology (IJEAT)

ISSN : 2249-8958, volume-2, issue-1, October 2012.

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They have discussed about disposal of large quantities of red mud; a solid waste generated at the Aluminum plants all over the world possess an increasing problem of storage, land cost & availability and pollution. Because of the complex physico-chemical properties of red mud it is very challenging task for the designers to find out the economical utilization and safe disposal of red mud. Due to industrialization, infrastructure development and soft housing policy of Government of India, the construction industry is in full boom due to which within short span of time there is a tremendous increase in the utilization of cement and concrete for various construction activities. It is expected that the same rate will continue in the next decade and this may invite the threat to the environment. Availability of raw material required for manufacturing of cement and production of concrete are limited in nature. This increased demand will lead to fast depletion of natural resources and will cause big threat to environment. So as to overcome this problem it is very much essential to utilize the industrial waste materials and by-products generated in manufacturing of cement and in concrete construction. In this paper the attempt is made to check the effectiveness of neutralized red mud as a partial replacement of Portland cement.

METHODOLOGY

3.1 Introduction

In this chapter, material properties and concrete mix design calculations for M25 grade concrete in detail was presented.

3.2 Materials and their Properties

Raw materials required for the concrete use in the present work are

- ✓ Cement
- ✓ Coarse Aggregates
- ✓ Fine Aggregates
- ✓ Water
- ✓ Plaster of Paris

3.2.1 Ordinary Portland cement

Ordinary Portland cement is used for general constructions. The raw materials required for manufacture of Portland cement are calcareous materials, such as limestone or chalk and argillaceous materials such as shale or clay. The manufacture of cement consists of grinding the raw materials, mixing them intimately in certain proportions depending upon their purity and composition and burning them in a kiln at a temperature of about 1300^0C to 1500^0C at which temperature, the material sinters and partially fuses to form nodular shaped clinker. The clinker is cooled and ground to a fine powder with addition of about 2 to 3% of gypsum. The product formed by using the procedure is a “Portland cement”.

3.2.1.1 Testing on Cement

The following tests as per IS: 4031-1988 is done to ascertain the physical properties of the cement. The results of the tests are compared to the specified values of IS: 4031-1988.

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3.2.1.2 Consistency

The standard consistency of cement paste is defined as consistency, which will permit the Vicat plunger to penetrate to a point 5-7 mm from the bottom of the mould, this test is done to determine the quantity of water required to produce cement paste of standard consistency. For determining the setting time, compressive strength and soundness, the percentage of water required to produce cement paste of normal consistency is used. Consistency depends upon the composition of cement, this test was conducted as per the procedure given in IS: 4031-1988. The consistency value obtained is shown in table 3.1.

3.2.1.3 Initial and Final Setting Time

Lower the needle gently and bring it in contact with the surface of the test block and quickly release. Allow it to penetrate into the test block. In the beginning, the needle will completely pierce through the test block. But after some time when the paste starts losing its plasticity, the needle may penetrate only to a depth of 33-35mm from the top. The period elapsing between the times when water is added to the cement at the time of which the needle penetrates the test block to a depth equal to 33-35mm from the top is taken as initial setting time.

Replace the needle of the Vicat apparatus by a circular attachment. The cement shall be considered as finally set when, lowering the attachment gently cover the surface of the test block, the centre needle makes an impression, while the circular edge of the attachment fails to do so. In other words the paste has attained such hardness that the centre needle does not pierce through the paste more than 0.5mm.

Table: Fehler! Kein Text mit angegebener Formatvorlage im Dokument.**.1Physical properties of cement**

S. No	Property	Test results
1	Normal consistency	28%
2	Specific gravity	3.13
3	Initial setting time	110 minutes
4	Final setting time	225 minutes

Ordinary Portland Cement (OPC) of 53 Grade (Jaypee cement) from a single lot was used throughout the course of the investigation. It was fresh and without any lumps.

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3.2.2 Aggregates

Aggregates are the important constituents in concrete. They give body to the concrete, reduce shrinkage and effect economy. Aggregates occupy 70 to 80 percent of volume of concrete. Aggregates are obtained either naturally or artificially. Aggregates can be classified on the basis of size as fine aggregate and coarse aggregate.

3.2.2.1 Fine Aggregate (sand)

The size of the fine aggregate is below 4.75mm.Fine aggregates can be natural or manufactured. The grade must be throughout the work. The moisture content or absorption characteristics must be closely monitored. The fine aggregate used is natural sand obtained from the river Godavari conforming to grading zone-II of table 3.3 of IS: 10262-2009. The results of various tests on fine aggregate are given in table 3.2.

Specific gravity

Specific Gravity is defined as the ratio of mass of material to the mass of the same volume of water at the stated temperature. The experiment was conducted as per IS: 2386-1963 and the values are tabulated in table-3.2.

Sieve analysis (fineness modulus)

The process of dividing a sample of aggregates into fractions of same particle size is known as a sieve analysis and its purpose is to find fineness. According to size, the fine aggregate may be described as coarse, medium and fine sands. Depending upon the particle size distribution IS: 383-1970 has divided the fine aggregate into four grading zones (Grade I to IV). The grading zones become progressively finer from grading zone I to IV. The sieve analysis was carried out using locally available river sand and tabulated in table 3.3.

Bulk density

Bulk density is defined as mass of material to the volume of the container. The experiment was conducted and the values are tabulated in table-3.2.

Table: Fehler! Kein Text mit angegebener Formatvorlage im Dokument.**.2 Physical properties of fine aggregate**

S. No	Property	Value
1.	Specific gravity	2.6
2.	Fineness modulus	2.46
3.	Bulk density: Loose Compacted	 10.33kN/m^3 10.45kN/m^3
4.	Grading	Zone-II

Table: Fehler! Kein Text mit angegebener Formatvorlage im Dokument.**.3 Sieve analysis of fine aggregate**

S. No	Sieve	Retained	%	Cumulative	%

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	size in mm		Retained	% retained	Passed
1	10	-----	----	-----	100
2	4.75	-----	----	-----	100
3	2.36	42	4.2	4.2	95.8
4	1.18	183	18.3	22.5	77.5
5	600	316	31.6	54.1	45.9
6	300	354	35.4	89.5	10.5
7	150	102	10.2	99.7	0.3
8	Pan	3	0.3	100	0

3.2.2.2 Coarse aggregate

The material whose particles are of size are retained on IS sieve of size 4.75mm is termed as coarse aggregate and containing only so much finer material as is permitted for the various types described in IS: 383-1970 is considered as coarse aggregate.

Aggregates are the major ingredients of concrete. They constitute 70-80% of the total volume, provide a rigid skeleton structure for concrete, and act as economical space fillers. Because at least three-quarters of the volume of the concrete is occupied by aggregate, it is not surprising that its quality is of considerable importance. The properties of aggregate greatly affect the durability and structural performance of concrete. Aggregate was originally viewed as an inert material dispersed throughout the cement paste largely for economic reasons. It is possible, however, to take an opposite view and to look on aggregate as a building material connected in to a cohesive whole by means of the cement paste, in a manner similar to masonry construction. In fact, aggregate is not truly inert and its physical, thermal and sometimes also chemical properties influence the performance of concrete. Aggregate is cheaper than cement and it is, therefore, economical to put in to the mix as much of the former and as little of the later possible. But economy is not only the reason for using aggregate, it confers considerable technical advantages on concrete, which has a higher volume stability and better durability than hydrated cement paste alone.

Specific gravity

Specific Gravity is defined as the ratio of mass of material to the mass of the same volume of water at the stated temperature. The experiment was conducted as per IS 2386-1963 and the values are tabulated in table-3.4.

Sieve analysis (fineness modulus):

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The process of dividing a sample of aggregates into fractions of same particle size is known as a sieve analysis and its purpose is to find fineness. The sieve analysis was carried out using locally available river sand and tabulated in table 3.5.

Bulk density

Bulk density is defined as mass of material to the volume of the container. The experiment was conducted and the values are tabulated in table-3.4.

Table: Fehler! Kein Text mit angegebener Formatvorlage im Dokument.**.4 Physical properties of coarse aggregate**

S. No	Property	Value
1.	Specific gravity	2.79
2.	Fineness modulus	8.83
3.	Bulk density Loose Compacted	 14 kN/m^3 16 kN/m^3
4.	Nominal maximum size	20 mm

Table: Fehler! Kein Text mit angegebener Formatvorlage im Dokument.**.5 Sieve analysis of coarse aggregate**

S.No	Sieve size in mm	Retained	% Retained	Cumulative % retained
1	80	0	0	0
2	40	0	0	0
3	20	1.72	17.2	17.2
4	16	5.54	55.4	72.6
5	12.5	2.12	21.2	93.8
6	10.0	0.58	5.8	99.6
7	4.75	0.04	0.4	100
8	pan	0	0	
	Total			383.2+500 =883.2

Fineness Modulus = $\frac{\text{Cumulative \% reatained}}{100}$

=883.2÷100 = 8.832

3.2.3 Water

This is the least expensive but most important ingredient of concrete. The quantity and quality of water is required to be looked in to very carefully. In practice very often great control on the properties of all other ingredients is exercised, but the control on the quality of the water is often neglected. Since quality of the water effects strength, it is necessary for us to go in to the purity and quality of water. The water, which is used for making solution, should be clean and free from harmful impurities such as oil, alkali, acid, etc. in general, the distilled water should be used for making solution in laboratories. Water containing less than 2000 milligrams per litre of total dissolved solids can generally be used satisfactorily for making concrete. Although higher concentration is not always harmful they may affect certain cements adversely and should be avoided where possible. A good thumb rule to follow is that if water is pure enough for drinking it is suitable for mixing concrete.The physical properties of water are showed in the table 3.6Table: **Fehler! Kein Text mit angegebener Formatvorlage im Dokument.**.6 Physical properties of water

S. No	Property	Value
1.	Ph	7.1
2.	Taste	Agreeable
3.	Appearance	Clear
4.	Turbidity(NT units)	1.75

3.2.4 Plaster of Paris

Test conducted for Plaster of Paris is water absorption test. The values observed are 81% of water is absorbed by plaster of Paris by its weight. Some changes were made in mix design to obtain required workability.

3.3 CONCRETE MIX DESIGN

3.3.1 INTRODUCTION

The process of selecting suitable ingredients of concrete and determining their relative amounts with the objective of producing a concrete of the required, strength, durability, and workability as economically as possible, is termed the concrete mix design. The proportioning of ingredients of concrete is governed by the required performance of concrete in two states, namely the plastic and the hardened states. If the plastic concrete is not workable, it cannot be properly placed and compacted. The property of workability, therefore, becomes of vital importance.

The compressive strength of hardened concrete which is generally considered to be an index of its other properties, depending upon many factors, e.g. w/c ratio quality and quantity of cement, water, aggregate, batching, placing, compaction and curing. The cost of concrete is made up of the cost of material, plant and labour. The variation in the cost of material arise from the fact that the cement is several times costly than the aggregates, thus the aim is to produce as lean a mix as possible.

The actual cost of concrete is related to the cost of materials required for producing a minimum mean strength called characteristic strength that is specified by the designer of the structure. This depends on the quality control measures, but there is no doubt that the quality control adds to the cost of concrete. The cost of labour depends on the workability of mix.

3.3.2 Requirements of Concrete Mix Design

The requirements which form the basis of selection and proportioning of mix ingredients are:

a) The minimum compressive strength required from structural consideration
b) The adequate workability necessary for full compaction with the compacting equipment available.
c) Maximum water-cement ratio to give adequate durability for the particular site conditions.
d) Maximum cement content to avoid shrinkage cracking due to temperature cycle in mass concrete.

Factors to be considered for mix design

- ✓ The grade designation, (the characteristic strength requirement of concrete).
- ✓ The type of cement influences the rate of development of compressive strength of concrete.
- ✓ Maximum nominal size of aggregates to be used in concrete may be as large as possible within the limits prescribed by IS: 456-2000
- ✓ The cement content is to be limited from shrinkage, cracking and creep.

The workability of concrete for satisfactory placing and compaction is related to the size, shape, quantity and spacing of reinforcement and technique used for transportation, placing and compaction.

3.3.3 Design of M25 Grade Concrete:

3.3.3.1 Stipulations for Proportioning:

a) Grade designation	M25
b) Type of cement confirming IS 12269-1987	OPC 53grade
c) Cement content	240 kg/m³
d) Maximum nominal size of aggregate	20 mm
e) Maximum water – cement ratio :	0.6
f) Workability :	30mm-75 mm (medium slump)
g) Exposure condition :	Moderate
h) Method of concrete	Hand

placing :	
i) Degree of supervision	Good
j) Type of aggregate	Crushed angular aggregate

3.3.4 Target Strength for Mix Proportioning:

$f'_{ck}=f_{ck}+1.65*s$

= 25+1.65x4 = 31.6 N/mm²

Where

f'_{ck} = target average compressive strength at 28 days

f'_{ck} = characteristic compressive strength at 28 days

s = standard deviation

From Table 1, standard deviation(s) =4N/mm²

Target strength = 31.6 N/mm²

3.3.5 Selection of Water-Cement Ratio:

From Table 5 of IS 456-2000, maximum water cement ratio= 0.45

Adopt w/c=0.44

3.3.6 Selection of Water Content:

From Table 2 maximum water = 186 litres (for 30 to 75 mm Slump range) for 20mm aggregate

Water content = 186 litres

3.3.7 Calculation of Cement Content:

Water-cement ratio = 0.484

Cement content = 186/0.484

= 384.29 kg/m³

From Table 5 of IS 456-2000 minimum cement content

For 'mild' exposure condition = 300 kg/m³

422 kg/m³ > 300 kg/m³,

Hence, O.K

3.3.8 Proportion of Volume of Coarse Aggregate and Fine Aggregate Content:

From Table 3 of IS: 10262-2009

Volume of CA corresponding to 20mm size aggregate &FA (Zone 2)

For water-cement ratio of 0.50=0.60

Volume of Coarse aggregate for the water - cement ratio 0.45 = 0.63

Volume of fine aggregate

= 1-0.63

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4.1 PROCESS OF MANUFACTURE OF CONCRETE

4.1.1 Aggregates

The coarse aggregate was kept completely immersed in clean water for 24 hours for water absorption. After 24 hours, the aggregate was gently surface dried with dry cloth. It was then spread out and exposed to the atmosphere until it appears to be completely surface dry. For fine aggregate, considering the huge time to be taken to become surface dry from wet condition, it was not immersed in water. Instead the water was sprinkled then it was spread out and exposed to the atmosphere until it appears to be completely surface dry.

4.1.2 Batching

The quantities of cement, Plaster of Paris, fine aggregate, coarse aggregate and water for each batch were measured by a weighing balance of an accuracy of 1 gm.

4.1.3 Mixing

The object of mixing is to coat the surface of all aggregate particles with cement paste and to blend all the ingredients of concrete in to a uniform mass. Thorough mixing of the materials is essential for the production of uniform concrete. The mixing should ensure that the mass becomes homogeneous, uniform in colour and consistency. Two methods are adopted for mixing concrete, Hand mixing and Machine mixing. In this study the process of mixing the materials has been done by machine mixing. The process of mixing is first add plaster of paris to cement in required proportion and then weigh the weigths. First put aggregates into mixer and after mixing for 1 minute add cement plaster to it and add water gentlyin according proportion.

4.1.4 Casting of Concrete Cubes

The test moulds are kept ready before preparing the mix. Moulds are cleaned and oiled on all contact surfaces. The concrete is filled into moulds in layers and then compacted with vibrator. The top surface of concrete is struck off level with a trowel. The date of casting are put on the top surface of the cubes.

4.2 WORKABILITY TESTS

4.2.1 Slump Cone Test

Slump test is the most commonly used method of measuring consistency of concrete which can be employed either in laboratory or at site of work.

The apparatus for conducting the slump test essentially consists of a metallic mould in the

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form of a cone having the internal dimensions as under:

Bottom diameter	:	20cm
Top diameter	:	10cm
Height	:	30cm

For tamping the concrete a steel tamping rod 16mm dia, 0.6meter along with bullet end is used. The internal surface of the mould is thoroughly cleaned and freed from superfluous moisture and adherence of any old set concrete before commencing the test. The mould is placed on a smooth, horizontal, rigid and non-absorbent surface.

The mould is then filled in four layers, each approximately ¼ of the height of the mould. Each layer is tamped 25 times by the tamping rod taking care to distribute the strokes evenly over the cross section. After the top layer has been rodded, the concrete is struck off level with a trowel and tamping rod. The mould is removed from the concrete immediately by raising it slowly and carefully in vertical direction. This allows the concrete to subside. This subsidence is referred as SLUMP of concrete. The difference in level between the height of the mould and that of the highest point of the subsided concrete is measured. This difference in height in mm is taken as slump of concrete.

4.2.2 Compaction Factor Test

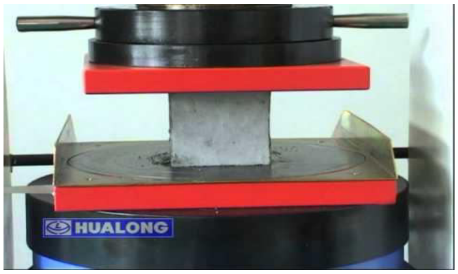
Compaction factor measures the workability in an indirect manner by determining the degree of compaction achieved by a standard amount of work done by allowing the concrete to fall through a standard height.

4.3 CURING

The test specimens were stored in a place free from vibration for 24 hours from the time of addition of water to the dry ingredients. After this period, specimens are removed from the moulds and immediately submerged in curing tank and kept there until taken out just period to rest. The water of curing tank was renewed or every seven days and maintained at a temperature of 27± 2 ^{0}C.

4.4 TESTS CONDUCTED

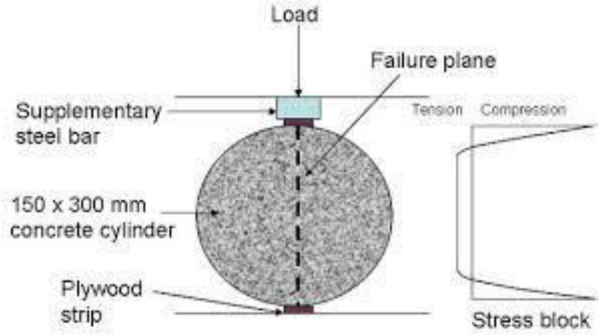
4.4.1Compression Strength Test:



Compression strength test was conducted on 150mm×150mm×150mm cubes. Concrete specimens were removed from curing tank and cleaned. In the testing machine, the cube is placed with the cast faces at right angles to that of compressive faces, then load is applied at a constant rate of 1.4 kg/cm^2/minute up to failure and the ultimate load is noted. The load is increased until the specimen fails and the maximum load is recorded. The compression tests were carried out at 7, 28, 56 and 90 days. For strength computation, the average load of three specimens is considered for each mix. The average of three specimens was reported as the cube compressive of strength.

$$\text{Cubecompressivestrength} = \frac{\text{Load}}{\text{Area of cross section}}$$

4.4.2 Split Tensile Strength Test:



The cylinder specimen is of the size 150 mm diameters and 300mm length. The test is carried out by placing a cylindrical specimen horizontally between the loading surfaces of compression testing machine and the load is applied until failure of cylinder, along its longitudinal direction. The cylinder specimens are tested at 7 days, 28 days, 56days and 90 days. The average of three specimens was reported as the split tensile strength.

Where

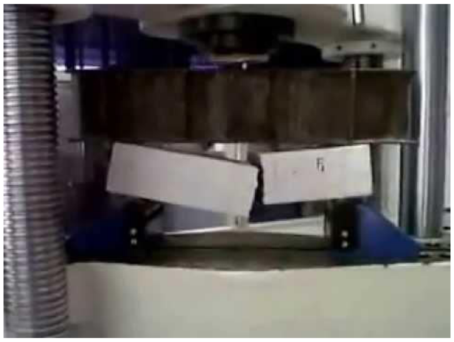
$$\text{Split tensile strength} = \frac{2\times P}{\pi\times D\times L}$$

P = compressive load on the cylinder.

L=length of the cylinder.

D=diameter of the cylinder.

4.4.3 Flexural Strength Test:



In the flexural strength test theoretical maximum tensile stress reached at the bottom fibres of the test beam is known as the modulus of rupture. When concrete is subjected to bending stress, compressive as well as tensile stresses are developed at top and bottom fibres respectively. The strength shown by the concrete against bending is known as flexural strength. The standard size of specimen is 100mm×100mm×500m with a span of 600mm.

The bed of testing machine should be provided with two rollers, 38mm in diameter, on which the specimen is to be supported and these two rollers should be mounted at one thawed points of the supporting span that is spaced at 13.3 cm centre to centre. The load is divided equally between the two loading rollers and the rollers are mounted in such a manner that the load is applied axially and without subjecting the specimen to any torsion stress or strains. The load is applied without shock and increasing continuously at a rate such that the extreme fibre stress increases at approximately 7kg/cm^2/minute i.e., at a rate of loading of 400kg/minute for the 15cm specimen. The load is increased until the specimen fails and the maximum load applied to the specimen during the test is recorded.

when 'a' is less than 20cm but greater than 17cm for 15cm specimen or less than13.30 But greater than 11.00cm for a 10cm specimen.

Where,

P = ultimate load in N

L = span of the beam in mm

b = width of the specimen in mm

d = depth of the specimen in m

The flexural beam specimens are tested at 7 days, 28 days, 56days and 90 days. The average of three specimens was reported as the flexural tensile strength.

CONCLUSION

The production of cement is one of the most environmental unfriendly processes due to the release of Carbon-di-oxide gases to the atmosphere. It is believed that one ton of Portland cement clinker production creates about one ton of Carbon-di-oxide and other greenhouse gases. This shows that the cement industry contributes to today's worldwide concern, which is global warming. This endangers the sustainability of the cement industry and that of concrete.

In addition to its negative environmental impact, cement is also one of the most expensive materials when compared to the other constituents of concrete. The raw materials for the cement production like lime are also being exploited in large amount which may result in running out of them, as it is predicted to happen in some places of the world.

Gypsum is a not an uncommon material and needs only a low temperature of around 150 degrees centigrade to convert it into a very useful binding material known as hemi-hydrate of plaster of paris.

Thus this thesis deals with checking the feasibility of the plaster of paris which is produced on heating of gypsum for using it as cement replacement material.

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