CHARACTERIZATION OF DRY LEAN CONCRETE IN ROAD PAVEMENT WITH PARTIAL REPLACEMENT OF CEMENT BY RICE HUSK ASH AND LIME

A Thesis submitted to Faculty of Engineering and Technology, Jadavpur University in partial fulfillment of the requirement for the degree of

Masters of Construction Engineering

With specialization in

"Structural Repair and Retrofit Engineering"

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Certificate of Recommendation

To Whom It May Concern

This is to certify that the thesis entitled **"CHARACTERIZATION OF DRY LEAN CONCRETE IN ROAD PAVEMENT WITH PARTIAL REPLACEMENT OF CEMENT BY RICE HUSK ASH AND LIME"** submitted by **Amalendu Maji** is absolutely based upon his own work under our supervision and neither his thesis nor any part of the thesis has been submitted for any degree/ diploma or any other academic award any where before.

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This foregoing thesis is here by approved as a credible study of an engineering subject carried out and presented in a manner satisfactory to warrant its acceptance as a prerequisite to the degree for which it has been submitted. It is understood that by this approval the undersigned do not endorse or approve any statement made, opinion expressed or conclusion drawn the rein but approve the thesis only for the purpose for which it has been submitted.

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It is hereby declared that the thesis entitled **“CHARACTERIZATION OF DRY LEAN CONCRETE IN ROAD PAVEMENT WITH PARTIAL REPLACEMENT OF CEMENT BY RICE HUSK ASH AND LIME”** contains literature survey and original research work done by the undersigned candidate, and have been submitted for the partial fulfillment of the continuous assessment of the course of **Master of Construction Engineering** with specialization in **“Structural Repair and Retrofit Engineering”** of **Jadavpur University.**

All information in this document have been obtained and presented in accordance with academic rules and ethical conduct.

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Acknowledgement

Before submitting the Thesis on Title **" CHARACTERIZATION OF DRY LEAN CONCRETE IN ROAD PAVEMENT WITH PARTIAL REPLACEMENT OF CEMENT BY RICE HUSK ASH AND LIME",** I would like to convey my whole hearted gratitude and respect to **Dr**. **Partha Pratim Biswas** and **Mr. Manoj Kumar Sahis,** Professors of Construction Engineering Department who have given me their best guidance to carry out the postgraduate research work which acted as the most effective factor behind the completion of the Master Degree Thesis paper.

I feel extremely glad to say that I have got the best knowledge on the matter related to my thesis work which is submitting in partial fulfillment of the requirement for the Master Degree in Construction Engineering with specialization in **"Structural Repair and Retrofit Engineering"** at Department of Construction Engineering, Jadavpur University.

I would like to express my sincere gratitude to all my respected teachers of the department for extending all the facilities and constant support to carry out the present study.

I would like to take this opportunity to thank all my friends, seniors and also juniors who encourage me continuously for higher studies and research.

I would like to express my hearty gratitude to my Mother, Father, brother & all my family members for their encouragement to join Master of Engineering after completion of undergraduation parallel with my office duties.

This thesis paper is dedicated to my parents.

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ABSTRACT

Present study deals with characterization of Dry Lean Concrete (DLC) by replacing cement with locally available Rice Husk Ash (RHA) and hydrated lime. In this work, performance of RHA and lime in DLC has been studied in laboratory using Dry lean concrete design approach specified in IRC:SP:49-2014. In the design of DLC mix , RHA and lime act as substitute of cementitious material. Characterization of RHA and lime mixed with different proportion in DLC have been made by laboratory trials to ascertain suitability of DLC mix in pavement base and subbase . In this work, three different types of cement namely, OPC,PSC and PPC have been used to find out suitable mix proportions from 3 days and 7 days strength criteria. In order to determine the optimum moisture content in DLC, the relevant IRC specifications was followed whereas optimum moisture content in lime was determined using the principle of standard proctor test. For experimental investigation the RHA content in different mix was varied from 0-25%, whereas the lime content was varied between 0-15% . It has been found that the DLC made from PSC and PPC with replacement of cementitious materials by Rice husk Ash and lime , may be used in pavement base and subbase. However, the OPC can be replaced only by appropriate quantity of RHA to make it effective in use in pavement base and sub base without any addition of lime. It has also been found that the increase in strength of PPC based DLC mix with RHA and lime was higher in comparison to the DLC mix prepared with PSC. It is relevant to mention that the reason behind increase in strength of the DLC mix in presence of lime and RHA may be the reaction of lime $Ca(OH)_2$ with Silicon oxide (Sio_2) present in RHA by formation of Calcium Silicate Hydrate (C-S-H) gel.

Keywords: Dry Lean Concrete , Pavement Base, , Rice Husk Ash, Lime Powder, Optimum Moisture Content ,Compressive Strength.

Abbreviations:

- **DLC - Dry Lean Concrete**
- **RH - Rice Husk**
- **RHA - Rice Husk Ash**
- **LP - Lime Powder**
- **OPC - Ordinary Portland Cement**
- **PPC - Portland Pozzolana Cement**
- **PSC - Portland Slag Cement**
- **IRC - Indian Road Congress**
- **C-S-H - Calcium Silicate Hydrate**
- **OMC- Optimum Moisture Content**
- **ASTM – American Society For Testing And Materials,**
- **CA – Course Aggregate'**
- **FA – Fine Aggregate.**
- **GPa – Gigapascal,**
- **MPa – Megapascal,**
- **MoRTH – Ministry Of Road Transport And Highway**
- **STP – Standard Proctor Test**
- **f_{cr} – characteristic Flexural strength of concrete**
- **f_{ck} – characteristic compressive strength of concrete.**
- **CRRI – Central Road Research Institute**

- **Thesis Organisation**

The report consists of eight chapters as they are described below:

- The first chapter introduces an overview of the research area and, justification of the present study.
- In the second chapter described on scope and objectives of the present investigation.
- The third chapter includes discussion about review of literature on characteristics of rice husk ash with cement and lime.
- The fourth chapter discussed about methodology of experimental investigation with material characterisation, preparation of test specimens.
- In the fifth chapter discuss the relevant tests used in laboratory of present experimental investigation.
- The sixth chapter includes the results obtained from various tests in laboratory and discussion on results.
- The seventh chapter explore the conclusion on overall work of this investigation. Moreover, future scope of study has also been included in this chapter.
- References are given at the end of this report.

INTRODUCTION

CHAPTER -1

1.1 Overview

In the area of highway construction, good quality and economical materials are often in short supply. Highway construction industry uses materials in large quantities. Cost of conventional materials continues to increase due to reasons such as depletion of natural resources, rising cost of mining and high transportation cost. If the incorporation of waste materials in road construction activities can be justified, the resulting high volume use of waste material will increase the demand and help create a stable market. Again, incorporation of agricultural waste materials in road construction activities will not only reduce the current disposal problem, but also alleviate the shortage of conventional materials. Therefore, it is apparent that both the rising costs of virgin materials and solid waste disposal problem make recycling a viable waste disposal alternative. It is imperative that the highway industry continues to find innovative uses for waste materials in highway construction. The agricultural waste can be defined as crop residue which comes from final processing of crop and they are not use as food such as Rice husk ash comes after processing of rice from paddy. And this rice husk holds some compounds like silica oxide which can be utilised for cementation as well it can be used as filler material to produce concrete. Silica can be obtained from rice husk by burning under controlled temperature and burning of rice husk produce Rice Husk Ash (RHA). First, the material must meet specifications. Once its technical feasibility is established, it has to meet the economic and environmental suitability criteria. It has to be able to compete with conventional materials in the marketplace, and should not pose human health risks. Finally, its long-term feasibility should be proven through construction of test projects and monitoring their performance. Therefore, the acceptance of a waste material for long-term use in highway construction takes time and the criteria mentioned above should all be met. The use of waste material is not a new concept. In fact, highway construction industry has a long history of using various recycled materials in highway construction. One of the first recorded instances in modem history of recycled material use is when in the 1930s, Virginia used coal boiler slag and mining waste as aggregate in asphalt concrete pavements. Later, in the 1950s and 1960s, a number of other recycled materials were used including blast furnace slags and coal fly ash (FHWA, 1993). Asphalt cement, which is synonymous with highway construction today, was a waste product from oil refining.

The application of RHA is mostly currently in low quality/strength concrete, for example, pavement base and sub-base rather than used in structural concrete. The most common application of RHA is the use in concrete for sub-base in road construction, bank protection, noise barriers and embankments, many types of general bulk fills and fill materials for drainage structures.

1.2 Pavement components

Road section consist of different components known as pavement layer which are vertically oriented at different position .The four major components from the bottom to the top of road section are soil subgrade, Sub- Base layer/Sub-base coarse (cemented/ non-cemented), Base layer/Base coarse (cemented/non-cemented), Surface layer or Wearing Course. And their Characteristics and functions are described below.

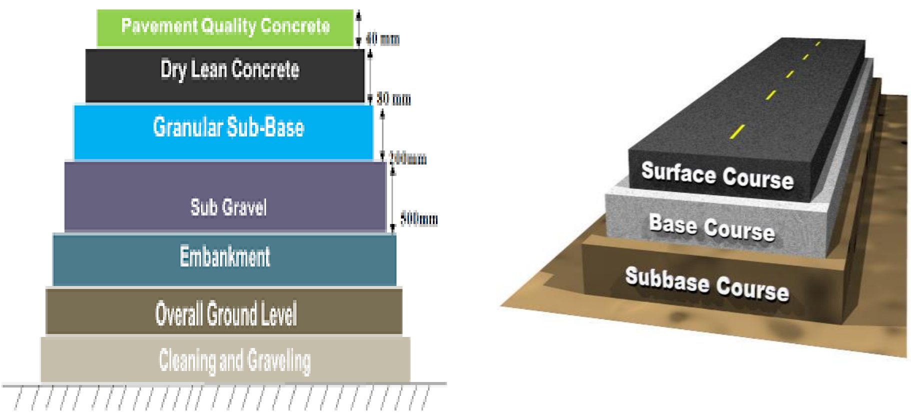

Fig. 1.1: Components of typical road cross-section.

1.2.1 Soil Subgrade

Subgrade is the top 500 mm of the embankment just below the bottom of the pavement. It is a layer of natural or imported soil prepared to support the total pavement materials placed over it. The stress due to wheel loads is ultimately transferred by the soil subgrade for dispersion to the natural soil deposit. The subgrade should be rammed and well compacted withstand the vertical stress commuting on it.

1.2.2 Sub-base course

After the Earth Work the Sub-Base of the road is constructed with Granular material. A layer between the subgrade and the granular base course, made from materials superior to that of subgrade likes gravel, moorum, broken stone. In case of a good quality of subgrade, the subbase course is omitted. Hence Granular base materials typically contain a crushed stone content in excess of 50 percent of the coarse aggregate particles. Granular sub-base is also dense graded, but tends to be somewhat more coarse than granular base.

1.2.2.1 Cement-treated Sub-base

Cement-treated sub-base is an intimate mixture of aggregate material and/or granular soils combined with measured amounts of cement and water that hardens after compaction and curing to form a durable paving material.

1.2.3 Base course

This layer is act as a main structural component of a road pavement. The function of base course is to transmit the wheel load to the subgrade through the granular sub base course. It reduce the stress intensity to the subsequent Sub-base layer by distributing the load to a wide area. The granular base is typically dense graded, with the amount of fines limited to promote drainage.

1.2.3.1 Cement treated Base

Cement-treated base (CTB) is an intimate mixture of aggregate material and/or granular soils combined with measured amounts of cement and water that hardens after compaction and curing to form a durable paving material.

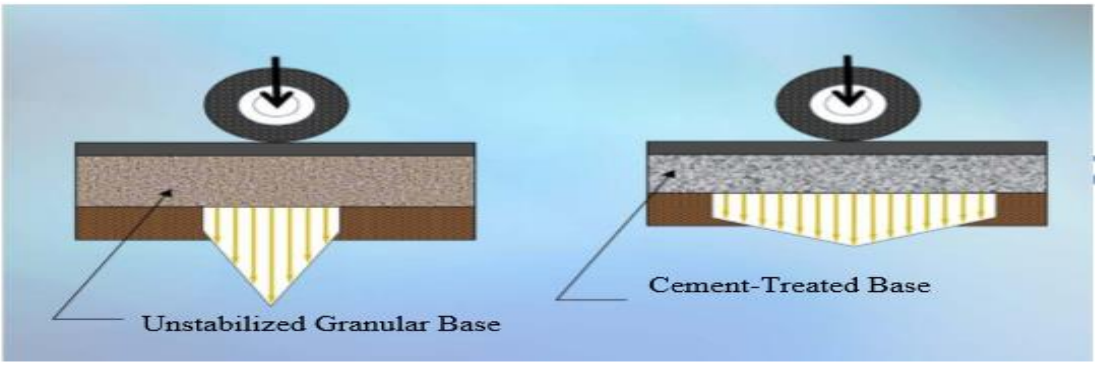

Fig.1.2: Stress transfer from wheel to subsequent bottom layer for non cement-treated base and cement-treated base.

1.2.4 Wearing course

It is the top most layer of the pavement. Wearing course should be the most durable and strong to resist abrasive forces due to wheel load movement directly on it. The wearing course is made by a mixture of course aggregates (CA), fine aggregates (FA), filler, stabilizing additive and bound together with asphalt cement or other bituminous binders.

The main function of wearing course is-

- To provide a smooth riding surface.
- To resist the damage from attrition and suction.
- To make the pavement air-tight and water-tight.
- To make the surface dust free.

1.3 Pavement Type

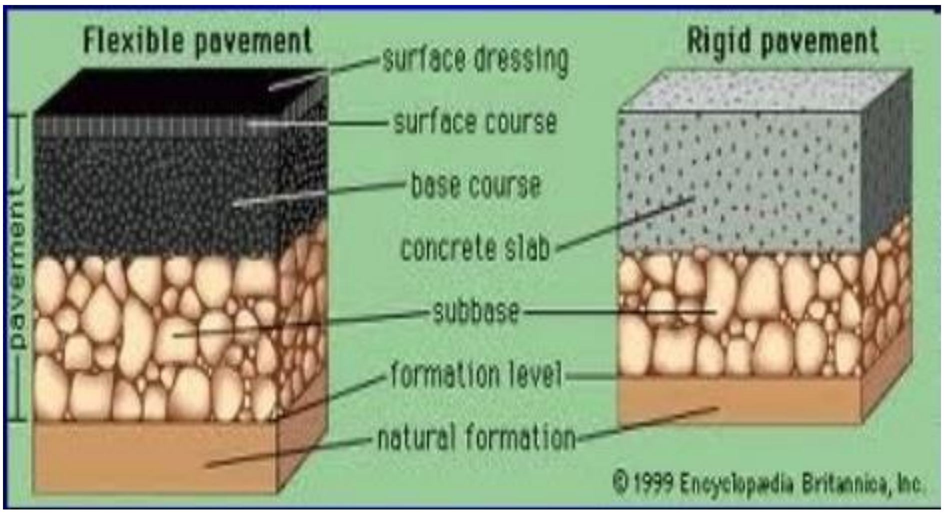

Fig. 1.3: Typical cross section of flexible and rigid pavement.

1.3.1 Rigid Pavement

Rigid pavements are typically constructed using a portland cement bound surface layer over one or more support layers over a prepared natural earth subgrade Figure 1.3 . The base layer is typically provided to support construction traffic and to provide uniformity of support to the PCC surface. The base layer may consist of unbound aggregate, bitumen-, or cement-bound aggregate. The bound layers may be conventional dense-graded asphalt, lean concrete, or cement-treated; or open-graded asphalt or concrete designed to promote lateral drainage within the pavement structure. The subbase layer is typically used to protect the pavement from the effects of frost heave and/or used to improve the constructability of the pavement layers above the subbase.

As shown in Figure-1.4 , wheel load applied to a PCC-surfaced rigid pavement are spread over a large area of subgrade, compared to loads applied to an asphalt concrete-surfaced flexible pavement. This permits the use of thinner bases for rigid pavements than for flexible pavements.

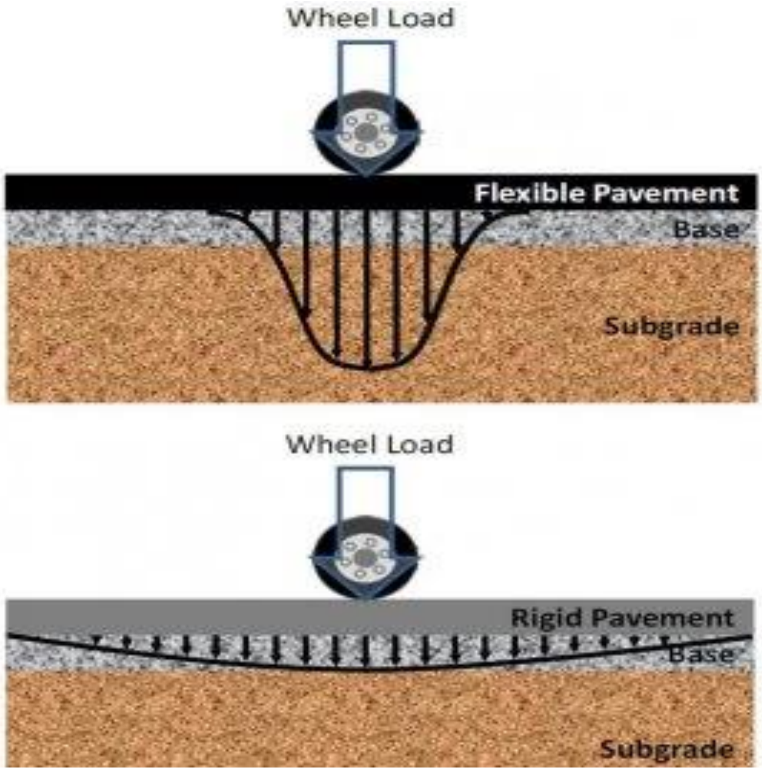

Fig. 1.4: Wheel load transformation to the subsequent bottom layer for Flexible and Rigid pavement.

1.3.2 Flexible pavement

Flexible pavement can be defined as the one consisting of asphaltic or bituminous material and aggregates placed on a bed of compacted granular material of appropriate quality in layers over the base. This type of pavement have less rigidity which unable to sprayed the wheel load over a relatively large area like rigid pavement. In such cases load ,at a certain depth below the wheel is very high as shown in figure 1.4.

1.4 Rice husk Ash

Rice husk is the outer cover of paddy and accounts for 20-25 % of its weight. It is removed during rice milling and is used mainly as fuel for heating in Indian homes and industries. The annual generation of rice husk in India is 18-22 million tons. Rice husk ash is produced by burning the outer shell of the paddy that comes out as a waste product during milling of rice. rice husk can be effectively converted through controlled burning. At around 500ºC a valuable siliceous product that can enhance the durability of concrete in the chemical composition of rice husk ash is obtained. Variations in the burning temperature much above or below will drastically alter the silica content of the ash.

1.5 Lime

Lime is a calcium-containing inorganic mineral composed primarily of oxides, and hydroxide, usually calcium oxide and/ or calcium hydroxide. It is also the name for calcium oxide which occurs as a product of coal seam fires and in altered limestone xenoliths in volcanic ejecta. These materials are still used in large quantities as building and engineering materials (including limestone products, cement, concrete, and mortar), as chemical feedstocks.

The rocks and minerals from which these materials are derived, typically limestone are composed primarily of calcium carbonate. They may be cut, crushed, or pulverized and chemically altered. Burning (calcination) of these minerals in a lime kiln converts them into the highly caustic material burnt lime, unslaked lime or quicklime (calcium oxide, CaO) and, through subsequent addition of water, into the less caustic (but still strongly alkaline) slaked lime or hydrated lime (calcium hydroxide, Ca(OH)2), the process of which is called slaking of lime. Laboratory tests are conducted with hydrated lime or calcium hydroxide [$Ca(OH)_2$].

1.6 Dry Lean Concrete (DLC)

It is a plain concrete with a large ratio of aggregate to cement than conventional concrete whose slump value is very low or no slump and generally used as a base/sub base of rigid pavement.

IRC:SP:49 "Guidelines for the Use of Dry Lean Concrete as Sub-base for Rigid Pavement" was published in 1998. The Rigid Pavement (H-3) Committee decided to revise the IRC:SP:49-2014[23] with lower 7-day compressive strength as per latest trend in other Countries e.g. Australia & other countries. The revised draft was also to include mineral admixtures i.e. fly ash & GBFS. The draft was prepared based on tests carried out at CRRI on DLC using OPC, PPC and PSC, for the desired 7-day compressive strength of concrete.

Fig. 1.5: Dry Lean Concrete Base for Rigid Pavement

Fig. 1.6: Construction of base for road pavement by Dry Lean Concrete.

1.6.1 Requirement of DLC

IRC:SP:49-2014[23] recommends some important specification as tabulated below-

Particulars	Recommended value
Maximum Aggregate cement ratio	1:14
Minimum cementitious material content	140 kg/cum
Minimum UCS in 7 days	7 MPa
Minimum Modulus of rupture in 7 days	1.4 MPa
Slump value	No slump
Minimum Curing period	7 days
Compaction at field	Minimum 97% of trial value
Minimum thickness	150mm for major road & 100mm for others
Max. time allowed from batching to finishing the work	90 minutes (at temp. 25-30 ^{0}C) 120 minutes (at temp. >30 ^{0}C)

Table 1.1: General requirement parameters of Dry Lean Concrete.

1.6.2 Strength parameter of DLC

To satisfy various criteria such as performance, durability, safety etc. the minimum unconfined compressive strength as well flexural strength requirement is given in different code. This criteria is given below.

IRC:SP:49:2014[23] recommend The average compressive strength of each consecutive group of 5 concrete cubes shall not be less than 7 MPa at 7 days. In addition, the compressive strength of any individual concrete cube shall not be less than 5.5 MPa in 7 days.

As per IRC:37-2012[24] ,Cemented base layers may consist of aggregates or soils or both stabilized with chemical stabilizers such as cement, lime, lime-fly ash or other stabilizers which are required to give a minimum strength of 4.5 in 7 days and 7 MPa in 28 days. the initial modulus of the cementitious bases may be in the range 10000 to 15000 MPa. Flexural strength is required for carrying out the fatigue analysis as per fatigue equation. The following values of modulus of rupture are recommended for cementitious bases.

Cementitious stabilized aggregates – 1.40 MPa
Lime—fly ash-soil – 1.05 MPa
Similarly IRC:SP:58-2015[22] recommend for stabilized or cemented base used in highway, the minimum 7 days UCS of concrete cube is7 MPa.

1.6.3 Compaction

In laboratory investigation compaction of concrete cube, IRC-SP-49 recommend a flat footed vibratory hammer. Compaction of the mix shall be done in three layers with vibratory hammer fitted with a square or rectangular foot. But during in this laboratory test initially tamped in three layer by standard tamping rod with twenty five blows for each layer and table vibrator was used for compaction of concrete. The densities achieved at the edges i.e. 0.5 m from the edge shall not be less than 95 percent of that achieved during the trial construction as per para 7.9. Rolling shall commence on the lower edge of camber/one side slope and proceed towards Centre/outer edge.

1.6.4 Placing at site

At site, DLC should be placed at proper sequence and with a maximum thickness of layer is 150 mm for any major highway Project and minimum of 100 mm thickness in case of others .At site DLC compacted at least at a compaction level of 97% of laboratory compaction level as given in IRC:SP49-2014[23] para 7.6.1. Lean concrete shall be laid by a hydrostatic paver. The equipment shall be capable of laying the material in one layer in an even manner without segregation, so that, after compaction the total thickness achieved is as specified. The laying of the two-lane road sub-base shall be done in full width. For a pavement more than two-lanes, the operation may be carried out by two pavers in echelon separated by appropriate distance (15-20 m). Transverse and longitudinal construction joints shall be staggered by 500-1000 mm and 200-400 mm respectively from the corresponding joints in the overlaying joints in the overlaying concrete slabs.

1.6.5 Opening to Traffic

As directed by IRC:SP:49-2014[23] ,no heavy commercial vehicles like trucks and buses shall be permitted on the lean concrete sub-base after its construction. Light vehicles if unavoidable may, however, be allowed after 7 days of its construction with prior approval of the Engineer.

SCOPE AND OBJECTIVE

CHAPTER -2

2.1 Objective

The primary objective of this research is to evaluate the effectiveness of RHA obtained from agricultural waste as cementitious and filler material by partial replacement of ordinary Portland cement(OPC), Portland Pozzolana Cement(PPC) and Portland Slag Cement(PSC) for application in Dry Lean Concrete (DLC) in pavement base course and sub-base course in highway construction. Moreover, present study is intended to determine the optimum proportion of lime when mixed with RHA in preparing DLC made with different types of cement for its use in pavement base and subbase.

2.2 Scope of work

Characterization of DLC with RHA has been made in this work by experimental investigation of compressive strength of different samples prepared with OPC, PPC and PSC . Present study includes characterization of RHA used in present experimental work. The compressive strength of the mix prepared in required proportion were determined on 3 days and 7 days after casting. Study on variation of strength of such mix has been made to find out optimum RHA content in different types of mix prepared with different types of cement. Moreover, considering the reactivity of lime with silica present in RHA mix, attempts are made in this work to study the effect on variation of strength of DLC prepared with suitable proportion of mix with lime powder and RHA. Study on variation of strength of the mix prepared with required proportion of lime, RHA, cement has been made to determine the optimum lime content in a DLC mix, prepared by substitution of cement by RHA. Outcome of present work is expected to give a better understanding on the properties of DLC with RHA as an alternative material in structural concrete with a cost effective solution in highway construction.

LITERATURE REVIEW

CHAPTER -3

3.0 Literature review

3.1 R. Bhushan[14] (2017) studied on *"Partial Replacement Of Cement By Rice Husk Ash"*. This paper summarizes the feasibility of using partial rice husk ash on the cement in order to mitigate the availability, affordability, quality and pollution issues. Solid masonry blocks size 150 X 150 X 150 mm of M20 grade were casted by replacement of cement to RHA by weight at 0%, 5%, 10%, 15%, 20%, 25%. Cubes were made ready for testing after 7, and 28 days curing in water served as the control. Testing was included for the strength (compressive, flexure and split tensile), workability (water binding ratio and setting time), costing analysis. The test results revealed that the workability and strength are slightly better than the standard concrete by satisfying the limits initiated endorsed by standard. The reduction on cost by 3.08% relative to the initial values.

3.2 S. A. Zareeia[16] (2017) *"Rice husk ash as a partial replacement of cement in high strength concrete containing micro silica: Evaluating durability and mechanical properties"*. His preliminary and inevitable interest was the use of partial replacements or by–products as complementary pozzolanic materials was mostly induced by enforcement of air pollution control resulted from cement production industry. Rise husk is by-product taken from rice mill process, with approximately the ratio of 200 kg per one ton of rice, even in high temperature it reduces to 40 kg. This paper presents benefits resulted from various ratios of rice husk ash (RHA) on concrete indicators through 5 mixture plans with proportions of 5, 10, 15, 20 and 25% RHA by weight of cement in addition to1 0% micro-silica(MS) to be compared with a reference mixture with 100% Portland cement. Tests results indicated the positive relationship between 15% replacement of RHA with increase in compressive strengths by about 20%. The optimum level of strength and durability properties generally gain with addition up to 20%, beyond that is associated with slight decrease in strength parameters by about 4.5%. The same results obtained for water absorption ratios likely to be unfavorable. Chloride ions penetration increased with increase in cement replacement by about 25% relative to the initial values (about less than one fifth).

3.3 J. Hadipraman[4] (2016) under took a research work on **"***Pozzolanic Characterization Of Waste Rice Husk Ash (RHA) From Muar, Malaysia* ". In this work an Investigation of Rice Husk Ash (RHA) thoroughly under controlled burning is regular issue to obtain result to produce the amorphous silica that has high pozzolanic reactivity characteristic. This paper offered an observation about characteristic of ground and un-ground of un-controlled burning temperature RHA that were taken from rice millings in Muar, Johor Malaysia. Such tests as X-Ray Fluorescence (XRF), X-Ray Diffraction (XRD), Particle Size Analysis and Specific Area Surface, Fourier Transform Infrared Spectroscopy (FTIR), and Scanning Electron microscope (SEM) were conducted in this investigation to carry out the characteristic of RHA samples. The results show that the RHA was consist approximately 89.90% of silica and the RHA possessed the amorphous particle were dominant than its crystalline part. This proves that the RHA has a big potential as a pozzolanic material considering the silica content and porous structure. In addition, particle size analysis decides whether the pozzolanic reactivity can be increased by grinding process.

3.4 R. Kumar[13] (2016) studied on *"A comparative study on dry lean concrete manufactured with OPC vis-a-vis PPC to be used for the construction of concrete roads".* The experimental program included evaluation of the suitability of materials, development of trial mixes for DLC, preparation of DLC specimens, and finally testing of dry lean concrete specimens. A Jack Hammer was used for the preparation of the DLC specimens. The mixing of DLC mixes was done in a tilted drum mixture as per the standard procedures. After proper mixing the standard cube specimens of concrete were prepared. Optimum moisture was used near about that determined by Vee-bee test. Several specimens of 150 mm cube were cast for the determination of compressive strength on 3, 5, 7, and 28 days to study the strength development and to explore the possibility to reduce the curing period for the compressive strength required i.e. 10 MPa at early days for the same mix. Vibrating hammer was used to ensure proper compaction of cube specimens. the details investigation on DLC carried out by trial mix proportions manufactured with both OPC and PPC, respectively.

3.5 Obilade[9] (2014) studied on "*Use Of Rice Husk Ash As Partial Replacement For Cement In Concrete"* **.**He summarized the research work on the properties of Rice Husk Ash (RHA) when used as partial replacement for Ordinary Portland Cement (OPC) in concrete. OPC was replaced with RHA by weight at 0%, 5%, 10%, 15%, 20% and 25%. 0% replacement served as the control. Compacting factor test was carried out on fresh concrete while Compressive Strength test was carried out on hardened 150mm concrete cubes after 7, 14 and 28 days curing in water. The results revealed that the Compacting factor decreased as the percentage replacement of OPC with RHA increased. The compressive strength of the hardened concrete also decreased with increasing OPC replacement with RHA. It is recommended that further studies be carried out to gather more facts about the suitability of partial replacement of OPC with RHA in concrete.

3.6 S. M. Abbas[17] (2015) studied on *"Use of Rice Husk Ash in Concrete "*. He summarized the research work on the properties of Rice Husk Ash (RHA) when used as partial replacement for Ordinary Portland Cement (OPC) in concrete. OPC was replaced with RHA by weight at 5%, 10% and 15%. 0% replacement served as the control. Compressive Strength test was carried out on hardened 150mm concrete cubes after at1, 3, 7, 28, 45 & 56 days curing in water. The results revealed that the Compacting factor decreased as the percentage replacement of OPC with RHA increased. The compressive strength of the hardened concrete also decreased with increasing OPC replacement with RHA. It is recommended that further studies be carried out to gather more facts about the suitability of partial replacement of OPC with RHA in concrete.

3.7 S. Pavia[19] (2014) worked on *"Impact of the Properties and Reactivity of Rice Husk Ash on Lime Mortar properties"* . In this investigation various proportions of lime and rice husk ash were used to get an effective mortar and optimum dose of RHA.

3.8 P. Padma Rao[11] (2014) was carried out experiment on *" A Study on Use of Rice Husk Ash in Concrete"*. In this investigation, a feasibility study is made to use Rice Husk Ash as an admixture to an already replaced Cement with fly ash (Portland Pozzolana Cement) in Concrete, and an attempt has been made to investigate the strength parameters of concrete (Compressive and Flexural). For control concrete, IS method of mix design is adopted and considering this a basis, mix design for replacement method has been made. Five different replacement levels namely 5%, 7.5%, 10%, 12.5% and 15% are chosen for the study concern to replacement method. Large range of curing periods starting from 3days, 7days, 28days and 56days are considered in the present study.

3.9 M.S. Kulkarni[8] (2014) studied *"Effect of Rice Husk Ash on Properties of Concrete"*. In this investigation the optimized RHA, by controlled burn and/or grinding, has been used as a pozzolanic material in cement and concrete. Using it provides several advantages, such as improved strength and durability properties, and environmental benefits related to the disposal of waste materials and to reduced carbon dioxide emissions. The main objective of this work is to study the suitability of the rice husk ash as a pozzolanic material for cement replacement in concrete. However it is expected that the use of rice husk ash in concrete improve the strength properties of concrete. Also it is an attempt made to develop the concrete using rice husk ash as a source material for partial replacement of cement, which satisfies the various structural properties of concrete like compressive strength. From the entire experimental work & studies it is concluded that mix M2 (M0+20%RHA) is the best combination among all mixes, which gives max, tensile, flexure & compression strength over normal concrete.

3.10 D. K. Rao[2] (2012) performed on " A Laboratory Study on Affect of Rice Husk Ash & Lime on Properties of Marine Clay". In this investigation the main objective was to determine the properties of Marine Clay and Rice Husk Ash and to evaluate the performance of marine clay when stabilized with rice husk ash as an admixture and its suitability for pavement subgrade. In this laboratory investigation Optimum amount of rice husk ash and lime in the mix is determined at the suitable level for the pavement of road way.

3.11 S. D. Nagrale[18] (2012) carried out experiment on *"Utilization Of Rice Husk Ash"*. According to his investigation RHA can be used as a replacement of cement for concrete is 15 to 25%.The paper evaluates how different contents of Rice Husk Ash added to concrete may influence its physical and mechanical properties. Sample Cubes were tested with different percentage of RHA and different w/c ratio, replacing in mass the cement. Properties like Compressive strength, Water absorption and Slump retention were evaluated.

3.12 R.N. Krishna[15] (2012) investigated **"***Rice Husk Ash – An Ideal Admixture For Concrete In Aggressive Environments"*. In his work the use of durability enhancing mineral admixtures or supplementary cementing materials has gained considerable importance the last decade or so as a key to long service life of concrete structures. He stated that there are many mineral admixtures that are used in way throughout the world but rice husk ash stands out as an ecofriendly, sustainable and durable option for concrete. His paper attempts to bring out the effectiveness of rice husk ash as a versatile concrete admixture and discusses some versatile application of rice husk ash concrete.

3.13 Roads And Maritime Services, New South Wales Government[8] (2012) published *"Guide To QA Specification R82 Lean-Mix Concrete Subbase"* . This User Guide present a background to the requirements in R82 with examples and illustrations to complement specific clauses. It is intended as a guide only for the Principal's staff and has no contractual status. The Guide serves to assist the Principal's staff when examining the contractor's submitted mix design, process control and inspection and testing documentation at the start of a project and monitoring their implementation.

Whilst it contains much in common with the R83 User Guide (for concrete base), there are also many differences which reflect fundamental differences between the two layers (i.e. subbase and base).

The major emphasis of the specification is to achieve the required quality in the Works, and an assurance of consistency at that quality level.

3.14 Kartini. K[7] (2011) shows that the *"Rice Husk Ash – Pozzolanic Material For Sustainability"* . In this investigation a replacement for cement to assure sustainability is crucial as the raw materials (limestone, sand, shale, clay, iron ore) used in making cements which are naturally occurring are depleting. The raw materials are directly or indirectly mined each year for cement manufacturing and it is time to look into the use of agriculture waste by-products in replacing cement. Rice husk ash (RHA) which has the pozzolanic properties is a way forward. An intensive study on RHA was conducted to determine its suitability. From the various grade of concrete (Grade 30, 40, 50) studied, it shows that up to 30% replacement of OPC with RHA has the potential to be used as partial cement replacement (PCR), having good compressive strength performance and durability, thus have the potential of using RHA as PCR material and this can contribute to sustainable construction.

3.15 P.C. Kumar[10] (2010) investigated *"Benefits Of Use Of Rice Husk Ash In Concrete"*. In this investigation, a feasibility study is made to use Rice Husk Ash as an admixture to an already replaced Cement with fly ash (Portland Pozzolana Cement) in Concrete, and an attempt has been made to investigate the strength parameters of concrete (Compressive and Flexural). For normal concrete, Indian Standard (IS) method of mix design is adopted. Five different replacement levels namely 5%, 7.5%, 10%, 12.5% and 15% are chosen for the study concerned for replacement method. A range of curing periods starting from 3 days, 7 days, 28 days and 56 days are considered in the present study.

3.16 Transport and Main Roads Specifications, State of Queensland[21] (2010) published *"Transport and Main Roads Specifications MRTS39 Lean Mix Concrete Sub-base for Pavements*". This Specification also applies to the construction of concrete road pavements. This Technical Specification shall be read in conjunction with MRTS01 Introduction to Technical Specifications, MRTS50 Specific Quality System Requirements and other Technical Specifications as appropriate and forms part of the Transport and Main Roads Specifications Manual. In para 6.4 guideline of mix design of lean concrete used in sub-base were described. Also in para 9 of this specification is described on paving concrete used in sub-base.

3.17 J.N. Jha[5] (2006) studied on *"Effect of Rice husk Ash on Lime Stabilization of Soil"* and focused on the effectiveness of rice husk ash as a pozzolana to enhance the lime treatment of soil. The paper presents influence of different mix proportions of lime and RHA on Compaction, strength properties, CBR values and durability characteristic of soil. The results show that addition of RHA not only improves the strength development but also enhances the durability of lime.

3.18 A. Muntohar[1] (2000) investigated on *"Influence of rice husk ash lime on engineering properties of clayey subgrade"*. Objective of this experiment was to improve the Engineering Properties of those soil who need to improved to make them suitable construction and to reuse the waste materials such as rice husk ash. In this laboratory investigation a series of laboratory experiments have been implemented. Varieties of samples were made by blending both rice husk ash and lime together. These samples were 2%, 4%, 6%, 8%, 10% and 12% for lime and 7.5%, 10% and 12.5% for rice husk ash. The results from the LHRA (lime-rice husk ash) blend confirmed that the blend would diminish swell behavior of clayey soils. Their plasticity index would decrease from 41.25% to 0.96% when subjected to a Lime-HRA blend of 12-12.5%. Their swell potential would decrease from 19.23% to 0.019% when subjected to the same blending as well. Their CBR (California Bearing Ratio) value would increase from 3.03% to 16.3% at a Lime-HRA blend of 6-12.5%. Their internal friction angle concerning shear strength parameters would enhance from 5.36 to 23.85. Soil cohesion increased as well from 54.32 KN/m2 to 157.19 KN/m2. Increasing the shear parameter caused bearing capacity to be 4131 KN/m2 from

391.12 KN/m2. At Lime-HRA 6-10%, consolidation settlement was lowered from 0.03 to 0.006. All of these factors can be summarized to say that by blending lime-rice husk ash together, you may enhance the engineering properties of clayey soils. This is advantageous for work construction in the civil engineering field.

3.19 K.G. Jolly Kutty[12] (1990) studied on *"Kinetic study of the hydrothermal reaction between lime and rice-husk-ash silica"* .His paper describes a study of the reaction between lime and amorphous silica obtained from rice-husk (93–94% SiO2) under hydrothermal conditions, in the range 80–140°C. The progress of the reaction, conducted in stainless steel bombs was followed by analyzing unreacted lime. It was observed that the reaction follows two-stage progress pattern similar to the one reported earlier for lime-quartz hydrothermal reactions. X-ray diffractometry and DTA on the reaction products of both stage 1 and stage 2 indicated the formation of CSH (1), calcium-silicate-monohydrate in both the stages. An earlier model by Bezjak and coworkers developed for two-stage transformation observed in lime-quartz hydrothermal reaction was examined for a possible application to the data from the present work. Calculations were made following the general assumptions of the model, which could be applied satisfactorily to the first stage, but not the second stage, possibly because of the relatively more rapid reaction between lime and amorphous silica in the first-stage, creating sluggishness in the second stage.

3.20 J. James[6] (1985) worked on *"Reaction product of Lime and Silica from Rice Husk Ash"*. In this research work it is evaluated that physically rice husk ash has more than 95% silica of its total weight and chemical Characteristics has been reacts with Lime and Water. The setting process for a lime-excess and a lime deficient mixture has been investigated. The product of the reaction has been shown to be a calcium silicate hydrate, C-S-H(I) + by a combination of thermal analysis, XRD and electron microscopy. Formation of C-S-H(I) accounts for the strength of lime-rice husk ash cement. In this investigation two Proportion was made on HRA and Lime such 1:3 and 2:1 to get the effectiveness of reaction.

EXPERIMENTAL METHODOLOGY

CHAPTER -4

4.0 Methodology

An experimental study has been carried out in this work with partial replacement of OPC , PPC and PSC by RHA. Initially , the optimum water for each type of DLC made from different types of cement with RHA was determined following the provision of IRC:SP:49-2014[23]. The trial RHA content for replacement of cement in mix was varied from 5% to 25% at the increment of 5%. The compressive strength of the concrete cubes prepared with trial RHA content with respective type of cement was measured after 3days and 7 days in the laboratory. The variation of the strength of mix thus obtained has been studied to find out optimum RHA content for the respective mix category . The RHA content in the mix beyond which, the compressive strength falls below the required minimum strength recommended in the guidelines, has been considered as the optimum dose of RHA in the present work.

Moreover, to study the effect of addition of lime with RHA in DLC was another objective of present study. Keeping this in view, the optimum water content of lime was obtained from standard proctor test. The mix for preparation of DLC , lime powder was added in the mix as 5%, 10% and 15% of the weight of cementitious material in the mix, where RHA content of the mix was kept equal to that of lime content. The water content for the mix obtained experimentally without lime and with lime, which have further been analyzed mathematically to determine the required water in the mix when prepared with RHA and lime. The results obtained from 3 days and 7 days compressive strength have been analyzed to find out the maximum lime content in a DLC mix when prepared with RHA.

4.1 Methodology Flowchart

During present experimental work following steps have been adopted for successful completion of the investigation to fulfill the objective. The program are shown in a summarized form in the Methodology flowchart, given below whereas further discussion has been carried out later in the thesis for the entire programs.

4.2 Flowchart

Selection of materials

- ✓ Coarse Aggregates
- ✓ Fine aggregates
- ✓ Cement

↓

Characterization of materials

- ✓ Specific gravity of aggregates
- ✓ Water absorption of aggregate
- ✓ Specific gravity of cement
- ✓ Specific gravity of rice husk ash
- ✓ Specific gravity of lime

↓

Optimum moisture content

(corresponding to maximum density)

- ✓ Moisture content of RHA
- ✓ Moisture content of Lime
- ✓ Moisture content of dry mixed concrete

↓

Preparation of DLC

- ✓ Replacement of OPC by RHA
- ✓ Replacement of PPC by RHA
- ✓ Replacement of PPC by RHA and Lime
- ✓ Replacement of PSC by RHA
- ✓ Replacement of PSC by RHA and Lime

↓

Activities in preparation

- ✓ Proportioning
- ✓ Mixing
- ✓ Compacting
- ✓ curing

↓

Compressive Strength Test

- ✓ 3 days strength test
- ✓ 7 days strength test

↓

Flexural Strength

- ✓ 3 days strength test
- ✓ 7 days strength test

4.3 Materials

4.3.1 Course aggregates

Aggregates for dry lean concrete shall be natural aggregate complying with IS:383. The aggregates shall not be alkali-reactive. The deleterious materials content shall not exceed the limits as per IS:383. In case the aggregates are not free from dirt, the same may be washed and water drained out at least 72 hours before batching. Coarse aggregate (CA) shall consist of clean, hard, strong, dense and non-porous pieces of crushed stone or gravel and shall not consist of disintegrated stone, soft, flaky, elongated, very angular or splintery pieces. The maximum size of the coarse aggregate shall be 26.5 mm. The water absorption of the aggregates shall not exceed 3 percent.

Particular	value
Specific gravity	2.67
Water absorption (surface dry)	2 %
Water absorption (oven dry)	2.041%

Table 4.1 : Physical properties of coarse aggregate

Fig. 4.1: (a) Ungraded separated CA **(b)** Graded CA

4.3.2 Fine Aggregates

The fine aggregate shall consist of clean, natural sand or crushed stone sand or a combination of the two and shall conform to IS:383[27]. The fine aggregate shall be free from soft particles, clay, sea shell, loam, cemented particles, mica, organic and other foreign matter in accordance with IS:383. Aggregates which have water absorption of more than 3 percent, shall not be used. In this study zone-II and zone-III sand are used to maintain proper grading as per standards of code .

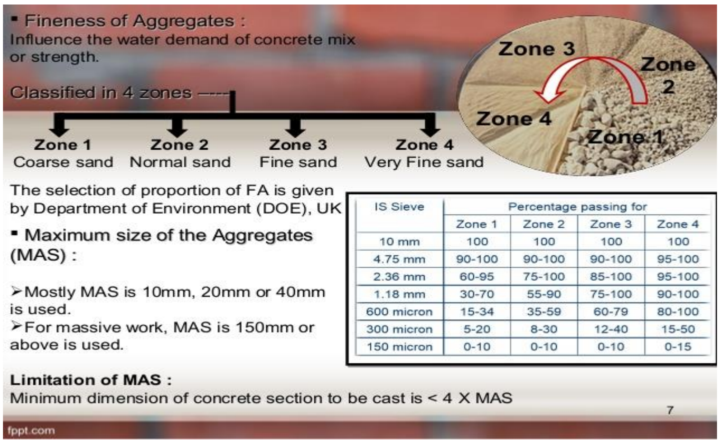

Fig. 4.2: (a) Fine agregate **(b)** Zoned fine aggregates.

4.3.3 Cementitious Materials

4.3.3.1 Cement

In the whole experimental study three types of cement are used to compare their effectiveness with rice husk ash . And they are confirmed by their respective Indian standard. Such as

i) Ordinary Portland Cement (OPC) IS:8112, IS:12269

ii) Portland Pozzolana Cement (PPC) IS:1489 (part 1), Fly ash based

iii) Portland Slag Cement (PSC) IS:455

The chemical composition of respective category of cement are given in table.

Compound	OPC, %	PPC, %	PSC, %
SiO_2	20–21	28–32	26–30
Al_2O_3	5·2–5·6	7·0–10·0	9·0–11·0
Fe_2O_3	4·4–4·8	4·9–6·0	2·5–3·0
CaO	62–63	41–43	44–46
MgO	0·5–0·7	1·0–2·0	3·5–4·0
SO_3	2·4–2·8	2·4–2·8	2·4–2·8
Loss on ignition	1·5–2·5	3·0–3·5	1·5–2·5

Table 4.2 : Chemical Properties of OPC,PPC and PSC as per IS code.

N.B: According to IRC-SP-49[1],If the subgrade soil contains soluble sulphates in a concentration more than 0.5 percent, the cement used shall be sulphate resisting Portland cement conforming to IS: 12330 or Portland slag cement with slag content up to 50 percent.

4.3.3.2 Rice husk ash

To investigate the effects on concrete properties of the variables described above. Fresh concrete properties evaluated included compressive strength. Additional tests were performed on the RHA including water absorption capacity, specific gravity. Also dose of water for concrete mix is fixed up by maximum density test.

Rice husk ash is characterized by low bulk density and high ash content (18-22% by weight). The large amount of ash generated during combustion has to be continuously removed for a smooth operation of the system. Silicon oxide forms the main component (90-97%) of the ash with trace amounts of CaO, MgO, K_2O) and Na_2O. The chemical and physical properties of RHA are given in table 4.3: (a) and 4.3: (b) respectively.

Composition	**% content**
Sio_2	88.32
AlO_3	0.46
Fe_2O_3	0.67
CaO	0.67
MgO	0.44
Na_2O_3	0.12
K_2O	2.91

Table 4.3 : (a) Chemical properties of rice husk ash,

properties	**value**
Loss of Ignition	5.81
Specific Gravity	2.1
Bulk Density	450 kg/cum
Void ratio	3.44
Porosity	0.774
Color	Blacky gray

Table 4.3 : (b) Physical properties of rice husk ash.

Fig. 4.3 Transformation of RHA from RH

4.3.3.3 Lime

The lime may contain lots of moisture content if it is exposed to various conditions and humidity. We all know that water cement ratio is an important factor for concrete. It is directly proportional to workability and the strength. Behind this reasons the optimum moisture content of lime was carried out in the laboratory by standard proctor test described in chapter five in this report and specific gravity of lime also found out. Properties of lime which have been obtained in laboratory investigation is given in table 5.1.

4.3.4 Water

Water used for mixing and curing of concrete taken from tap water which complies drinking water standard. It was clean and free from injurious amounts of oil, salt, acid, alkali, sugar, vegetable matter or other substances harmful to concrete. Water shall normally meet the requirements of IS:456-2000[29]. Potable water is generally considered satisfactory for mixing and curing. The pH value of water for mixing and curing up to 9 shall be permitted.

4.3.5 Filler

The additional RHA in a mix, which does not take part actively with lime may be characterized as filler material in the mix. Moreover, the mix which were prepared without lime powder, the role of RHA may in such mix may also be treated as filler material.

4.4 Grading of Aggregates

The grading of fine aggregate has been confirm to grading zones I, II, III or IV as given in IRC:15 or IS:383[27]. The grading of combined of both fine and coarse aggregate confirmed to the value specified in IRC:SP:49-2014[23] as given in table 5.6.

SIEVE SIZE	IRC recommendation % PASSING
26.5 mm	100
19 mm	75 - 90
9.50 mm	50 - 70
4.75 mm	30 - 55
2.36 mm	17 -42
600 micron	8 TO 22
300 micron	7 TO 17
150 micron	2 TO 12
75 micron	0 TO 10

Table 4.4: Recommended value of Gradation of aggregates as per IRC.

4.5 Optimum water content in concrete mix

Trial mixes of dry lean concrete was prepared with trial moisture contents of 5.5, 6.0, 6.5, 7.0 and 7.5 percent by weight of total concrete mix using required cement content based on aggregate-cement ratio as specified in para 4.2 of IRC:SP:49-2014[23].

Initially dry mix has been prepared with a aggregate cement ratio of 12:1 for OPC and 14:1 for PSC and PPC in a pan type concrete mixture. Thereafter water is added @ 5.5 %, 6%, 6.5%, 7%, and 7.5% of total weight of dry mix for each set of two cube mold having size 150 x 150 x 150 mm. The mix was placed in the mold in three layer and tamped with a 16 mm diameter and 600 mm long standard tamping rod by twenty five times for each layer. Then the mold filled with mixed concrete placed on table vibrator for 60 seconds to compact it. To ensure full compaction this 60 second was divided into two part by 30 seconds each , after first 30 second the displaced concrete at top of the cube were rearranged and then vibrate it for another 30 seconds.

After completion of compaction weight of mold with wet mixed concrete was taken to calculate the bulk density of the wet concrete mix. And calculated by following formula.

$$Bulk\ density,\ \rho = \frac{W2-W1}{V};$$

Where w_1 is the weight of mold and w_2 is weight of mold filled with concrete mix, and v is volume of mold (150mm x 150mm x 150mm).

Optimum water content is the moisture content at which the maximum density is obtained. Therefore, the optimum moisture content and density shall be determined by preparing cubes with varying moisture contents as stated above. In this work, OPC,PPC and PSC were used for preparation of DLC samples and determination of optimum moisture content for each type. A set of two 150 X 150 X 150 mm concrete cube were casted for each dose of water content to measure the bulk density of the mold and the average of these two has been considered to determine the optimum moisture content in DLC mix. The variation of bulk density with moisture content of different types of mix thus obtained has been presented in fig. 4.5 (a) to fig. 4.5 (c). It is evident fig. 4.5 (a) to fig. 4.5 (c) that the optimum water content for DLC mix made with OPC,PSC and PPC were found as 6.8%, 7% and 7.5% respectively.

Fig. 4.4: (a) Tamping rod diagram,

(b) Concrete mould diagram,

(c) Table vibrator diagram.

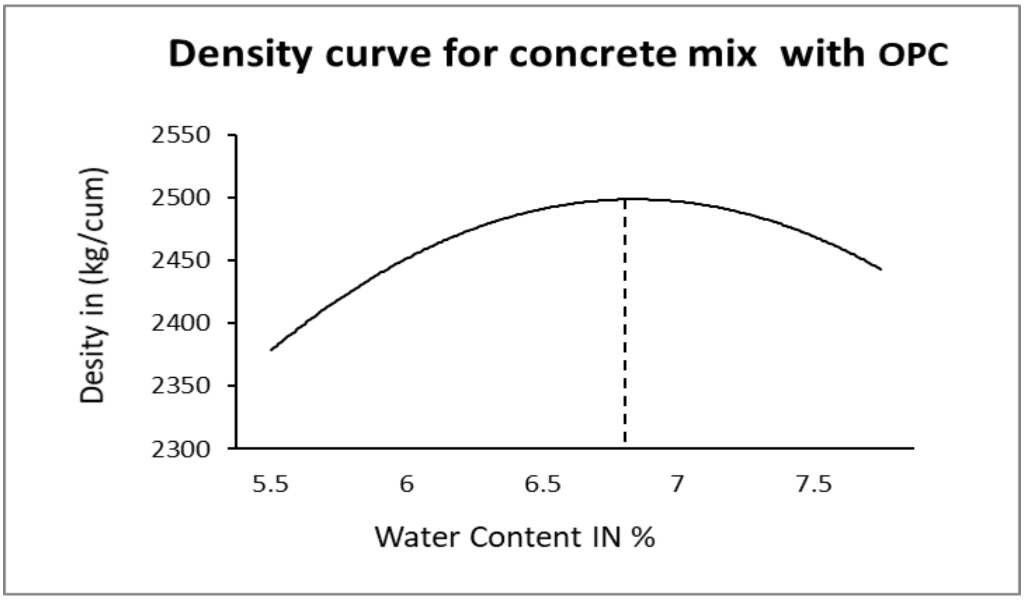

Fig. 4.5: (a) Moisture density variation for DLC Mix with OPC,

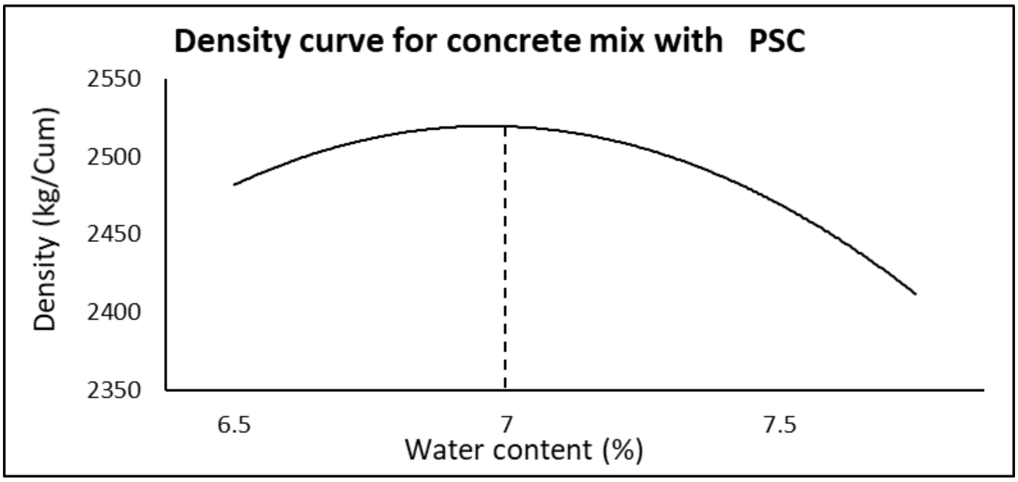

Fig. 4.5: (b) Moisture density variation for DLC Mix with PSC,

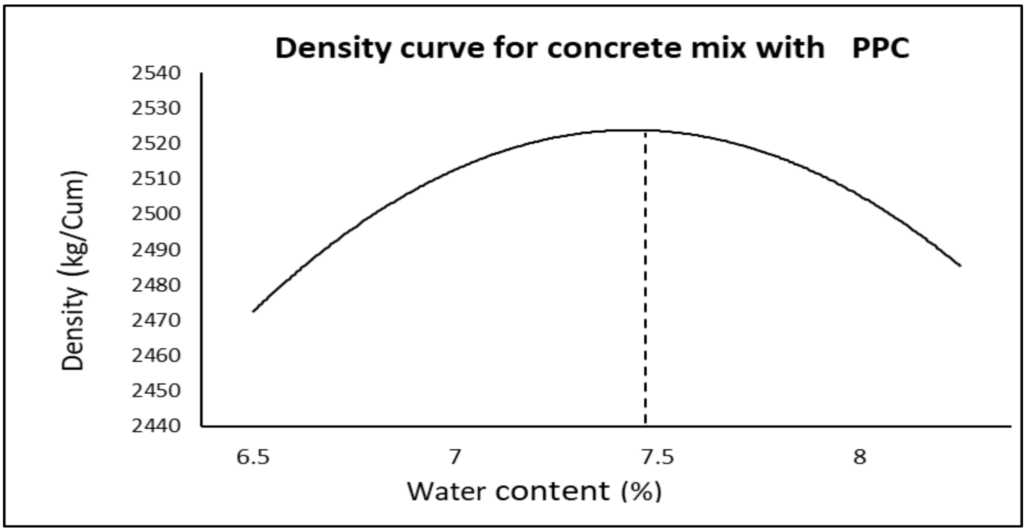

Fig. 4.5: (c) Moisture density variation for DLC Mix with PPC.

4.6 Proportioning

In this study the mix proportion for DLC is guided by IRC-SP-49. The concrete mix has been proportioned with a maximum aggregate cement ratio of 14:1 when OPC is used and the same was 12:1 when PPC or PSC is used. In the present work, the aggregate includes both coarse as well fine aggregate which satisfy overall gradation of aggregates. The minimum cementitious materials content in the mix shall not be less than 140 kg/cum of concrete. If this minimum cementitious materials content is not sufficient to produce the concrete of the specified strength, it shall be increased as necessary. It is relevant to mention that ,the fly ash or GBFS content shall be 15-30 percent or 25-50 percent by weight of cementitious materials respectively, as given in Clause 3.4 of IRC:SP:49-2014[23].Water content used in the DLC mix in present work, is same as the optimum water content which obtained corresponding to maximum density as stated in para 4.5.

4.7 Mixing

In the laboratory experiment the concrete mixing is done by Pan type concrete mixer. The batching and mixing has been carried out preferably in a forced action central batching and mixing plant having necessary automatic controls to ensure accurate proportioning and mixing.

Fig. 4.6: Pan type concrete mixer machine.

LABORATORY INVESTIGATION

CHAPTER -5

5.0 Laboratory Investigation

5.1 Determination of water absorption of coarse aggregate

Water absorption gives an idea on the internal structure of aggregate. Aggregates having more absorption are more porous in nature and are generally considered unsuitable, unless found to be acceptable based on strength, impact and hardness tests.

For the water absorption test, 1.5 kg specimens was dried in an oven for a 24 hours at a temperature 110 ^{0}C and then placed in a desiccator to cool. Immediately upon cooling the specimens has been weighed. The material is then emerged in water at room temperature nearly 27°C for 24 hours. Then Specimens were removed, patted dry with a lint free cloth, and weighed. In the laboratory study the water absorption of coarse aggregates has been found 2.041.

Water Absorption (%) = [(W1-W2)*100]/W2

Where W_1 is the weight of sample after 24 hours immersion in water.

W_2 is the weight of oven dried sample.

Fig. 5.1: Drying oven diagram.

5.2 Determination of specific gravity of RHA

This lab is performed to determine the specific gravity of RHA by using a pycnometer. Specific gravity is the ratio of the mass of unit volume of soil at a stated temperature to the mass of the same volume of gas-free distilled water at a stated temperature.

In laboratory 200 gm dry rice husk ash was taken as a sample for the test. Initially the dry and empty pycnometer with collar were weighted ,secondly the weight of pycnometer with collar and dry sample in it has been taken. There after distilled water poured in the pycnometer and fill it up to top hole of the collar and weighted it. In next step the water and RHA have been removed and washed out the pycnometer, thereafter the pycnometer was fully filled with a fresh distilled water and weighted it. Finally the specific gravity of RHA used in present study has been obtained as 2.03.

Specific gravity, $G = \frac{(M2-\mathrm{M}1)}{(M2-M1)-(M3-M4)}$

Where M_1 - mass of empty Pycnometer,

M_2 - mass of the Pycnometer with dry RHA

M_3 - mass of the Pycnometer and RHA and water,

M_4 - mass of Pycnometer filled with water only.

Fig. 5.2: Pycnometer diagram.

5.3 Determination of optimum water content of RHA

In the laboratory study the optimum moisture content was determined by standard proctor test. About 2 kg of RHA was taken as test sample for 1000 cc mold and a rammer of weight of 2.6 kg with free fall of 30 cm were used. Initially weight of empty mold were taken. Then water added to the sample at an amount of 10% of total weight of RHA and mixed thoroughly to make a homogeneous mix. Thereafter fill the mold with the mix in three layer subsequently and 25 number of blows of the rammer were applied with a freefall of 30 cm for each layer then weight the mold, filled with compacted sample. Thereafter remove the sample from the mold and more water were added to that sample at an increasing rate of 10% then repeat the procedure and weighted for different water content. This procedure were been repeated until the weight of mold ,filled with sample decreasing apart from a peak value. Finally optimum water content is considered at which the density of sample was maximum. Density was calculated by the formula given below.

$$Bulk\ density,\ \rho = \frac{W2-W1}{V};$$

Where W_1 is the weight of mold and W_2 is weight of mold filled with RHA - water mix, and, V is volume of proctor mold (1000 cc).

The variation of density with varying water content is shown in figure 5.4.

Fig. 5.3: Standard proctor mold and rammer diagram.

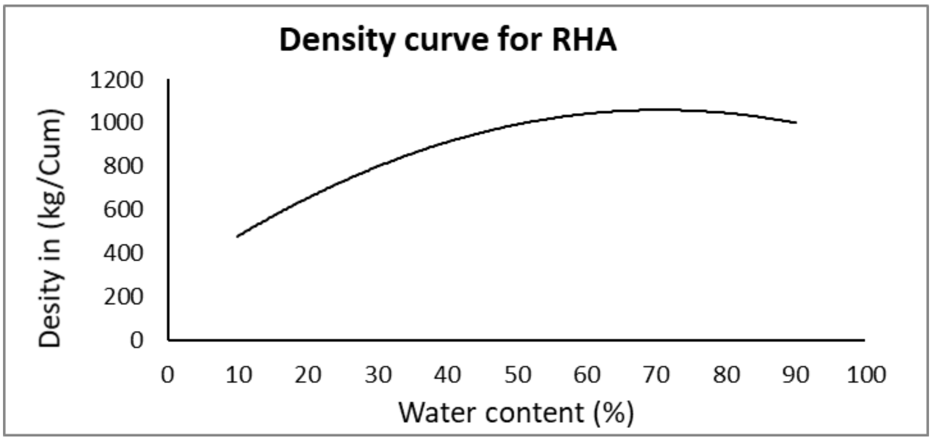

Fig. 5.4: Moisture density variation for RHA by SPT test.

5.4 Determination of specific gravity of lime

A 50 mL specific gravity bottle was used in the laboratory. The specific gravity bottle is another instrument (other than a pycnometer) used to measure specific gravity. The bottle is weighed empty, partially filled with lime whose specific gravity is to be found, partially filled with lime and rest portion filled with distilled water and finally the bottle completely filled with distilled water only ,then reweighed. Thereafter the specific gravity was calculated by the formula given below and it was found 2.73 in the laboratory test.

Specific gravity, $G = \frac{(M2-\mathrm{M}1)}{(M2-M1)-(M3-M4)}$

Where M_1=mass of empty Pycnometer,

M_2= mass of the Pycnometer with dry RHA

M_3= mass of the Pycnometer and RHA and water,

M_4 = mass of Pycnometer filled with water only.

Fig. 5.5: Specific gravity bottle diagram.

5.5 Determination of optimum water content of lime

In the laboratory study the optimum moisture content was determined by standard proctor test. About 2.5 kg of lime was taken as test sample for 1000 cc mould and a rammer of weight of 2.6 kg with free fall of 30 cm were used. Initially weight of empty mould were taken. Then water added to the sample at an amount of 10% of total weight of RHA and mixed thoroughly to make a homogeneous mix. Thereafter fill the mould with the mix in three layer subsequently and 25 number of blows of the rammer were applied with a freefall of 30 cm for each layer then weight the mould, filled with compacted sample. Thereafter remove the sample from the mould and more water were added to that sample at an increasing rate of 4% then repeat the procedure and weighted for different water content. This procedure were been repeated until the weight of mould ,filled with sample decreasing apart from a peak value. Finally optimum water content is considered at which the density of sample was maximum. Density was calculated by the formula given below.

$Bulk\ density,\ \rho = \frac{W2 - W1}{V}$;

Where W_1 is the weight of mould and W_2 is weight of mold filled with RHA -water mix, and, V is volume of proctor mould (1000 cc).

The variation of density with varying water content is shown in figure 5.6.

Particular	**Value**
Specific Gravity	2.73
Optimum moisture content at max. density	18% by weight
Color	white
Bulk Density	1.964 gm/cc

Table 5.1 : Physical properties of lime obtained in laboratory.

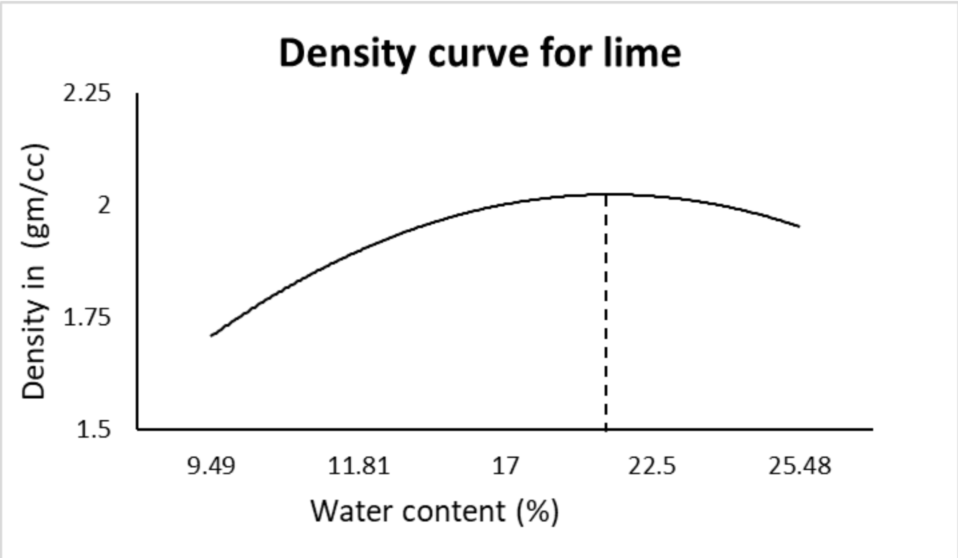

Fig. 5.6: Moisture density variation for lime by SPT test.

% water	weight of wet sample	weight of dry sample	weight of water	water content w (%)	Bulk density (ρ)	dry density (ρ_d)
10	27.7	25.3	2.4	9.49	1.715	1.57
13	30.3	27.1	3.2	11.81	1.864	1.67
18	35.1	30	5.1	17	2.058	1.76
23	39.2	32	7.2	22.5	1.979	1.62
26	52.7	42	10.7	25.48	1.964	1.57

Table 5.2 : Determination of optimum moisture content by SPT test for Lime.

Fig. 5.7: OMC test of lime in laboratory.

5.6 Grading of aggregates

These properties along with the water/cementitious material ratio determine the strength, workability, and durability of concrete. The grading or size distribution of aggregate is an important characteristic because it determines the paste requirement for workable concrete. The more these voids are filled, the less workable the concrete becomes, therefore, a compromise between workability and economy is necessary.

In the laboratory study the aggregates gradation were carried out as per IRC:SP:49-2014[23]. Initially the test was conducted on 10 kg of mixed coarse aggregates i.e. with quarter size and 20 mm down coarse aggregates. And it does not match the specified value given in code. To maintain the proper gradation, fine aggregate has been added to that coarse aggregates. There are deferent amount of fine and coarse aggregate were carried out in the final graded aggregate and that amount in percentage of total aggregate are given below.

i) Fine aggregate (zone-lll) – 18%
ii) Fine aggregate (zone-ll) – 22%
iii) Coarse aggregate (6 mm nominal) – 12%
iv) Coarse aggregate (20 mm nominal) – 48%

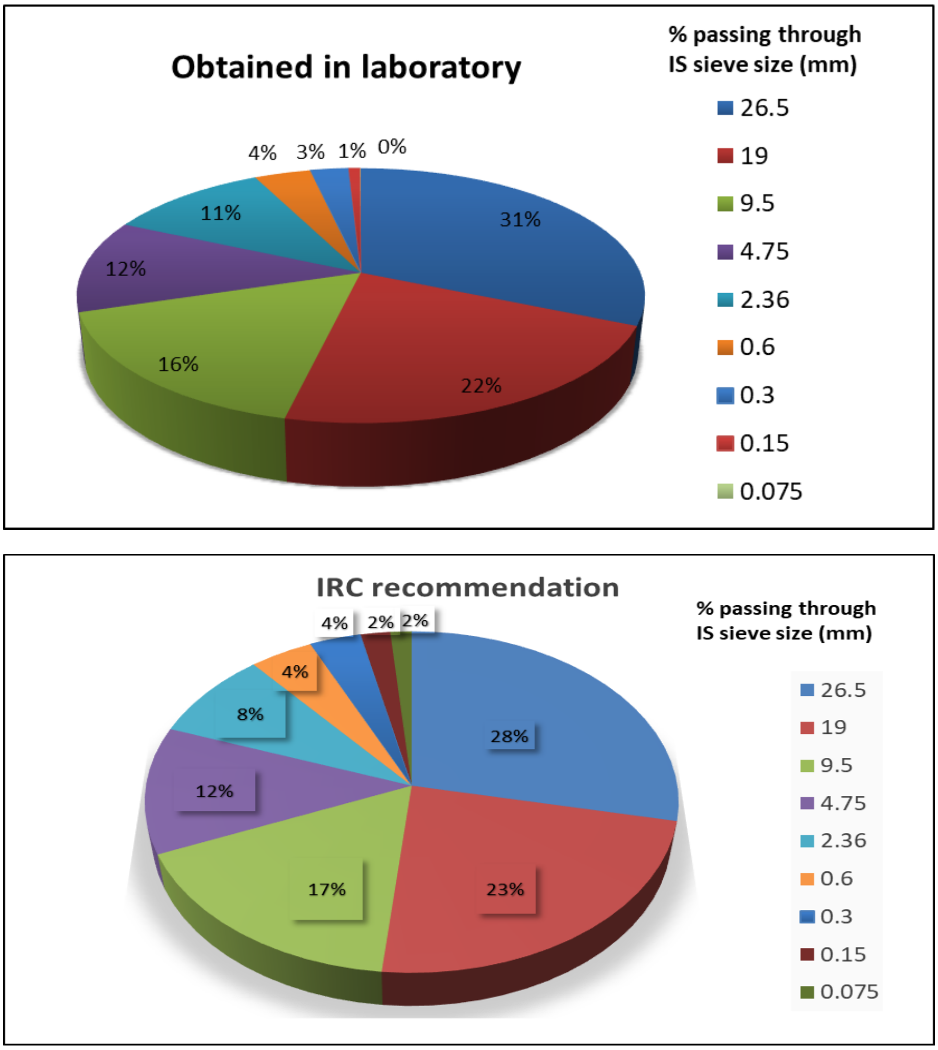

Fig. 5.8: Comparison on gradation of aggregates by pie chart.

Fig. 5.9: (a) IS sieves diagram, **(b)** Sieve shaker diagram.

5.7 Compressive strength testing

Compressive strength test was carried out at laboratory by compressive strength testing machine (CTM) of capacity 300 tons. The total number of 260 samples which were prepared in the laboratory with different types of cement has been illustrated in table 5.3.

SL. No.	Descriptions	Number of Cubes
1.	For maximum moisture content with OPC	10
2.	For maximum moisture content with PSC	10
3.	For maximum moisture content with PPC	10
4.	With OPC only	10
5.	With OPC and RHA	50
6.	With PSC only	10
7.	With PSC and RHA	20
8.	With PSC , RHA and Lime	50
9.	With PSC only	10
10.	With PSC and RHA	30
11.	With PSC , RHA and Lime	50

Table 5.3: Details of number of cube casted in the laboratory.

Unconfined compressive strength (UCS) result for present analysis was obtained by an average of five cube test data of each type of sample considered. Unconfined compressive strength Test was carried out on each set of cubes after 3 days and 7 days of casting by curing in water.

Fig. 5.10: Compressive strength test on concrete cube in laboratory.

RESULTS AND DISCUSSION

CHAPTER -6

6.0 Results and Discussion

The result obtained from the UCS test are discussed in details in this chapter. This chapter is divided into four sections. First section deals with determination of optimum dose of water in concrete mix prepared for DLC for different types of cement used. Second section deals with determination of optimum RHA content in DLC replacing OPC by RHA only. Third section deals with the determination of optimum RHA and lime content in DLC replacing PPC by RHA and lime. Fourth section deals with the determination of optimum RHA and lime content in DLC replacing PPC by RHA and lime. Also it is evident from the figure 6.3 (b), the optimum value of RHA and lime content have been obtained considering the minimum strength requirement criteria, discussed in para 2.2.2 of this report.

6.1 Optimum water content in DLC mix

Optimum water content required for preparation of DLC were found separately for each types of cements, described in para 4.5 of this report and it was found from figure-4.5,the optimum water content for OPC mixed concrete is 6.8 % by weight of total mix and for DLC prepared with PSC and PPC were 7% and 7.5% respectively.

6.2 Characterization of DLC with OPC

6.2.1 Variation of Strength of DLC replacing OPC by RHA

The variation of 3 days and 7 days strength of DLC by replacing OPC with different RHA content has been shown in figure-6.1 and the minimum strength requirement of DLC as per Indian specifications have been shown by a reference line named as Threshold Line. It is relevant to note that the RHA content above this line indicates accepted RHA contents in terms of the strength of mix as cement treated base. However, the RHA content below the line indicates the mix which is deficient in strength . Therefore the maximum RHA content up to which the strength of the mix complies the minimum strength requirement has been considered as optimum RHA content in present work, which is an indication of optimum quantity of replacement of cement by RHA.

It is relevant to the fig. 6.1(a) that the 7 days strength of DLC prepared with OPC and RHA mix reduces with increase of RHA content at a nearly constant rate. And it is evident from the figure that the optimum RHA content satisfying to the minimum strength of DLC is 13.7% by weight of total cementitious material. In the present work, the effect of lime on DLC mix prepared with OPC and RHA has not been attempted as no significant gain in strength of the mix was under initial trials.

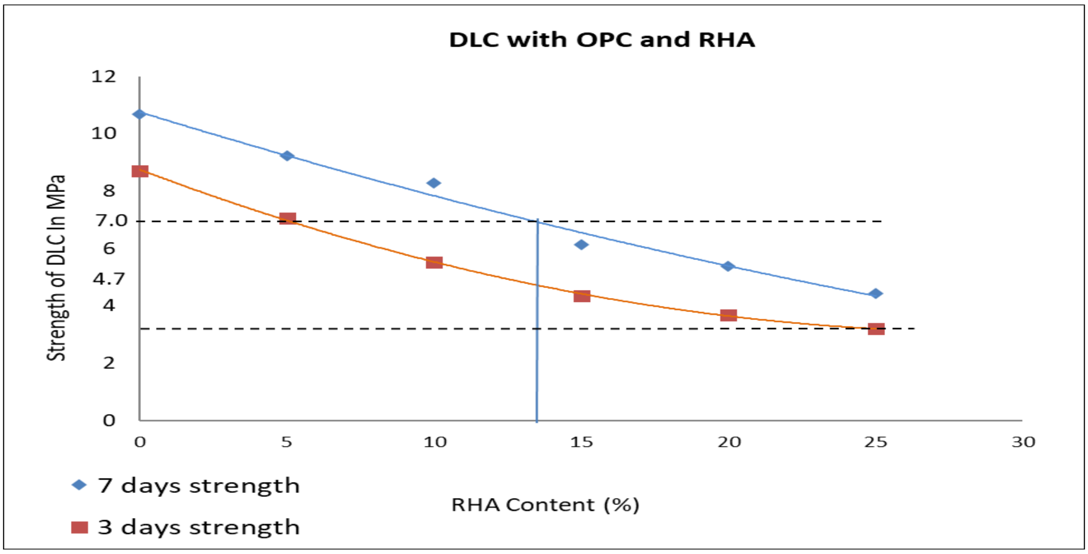

Fig 6.1: (a) Variation of strength of DLC by replacing OPC with RHA,

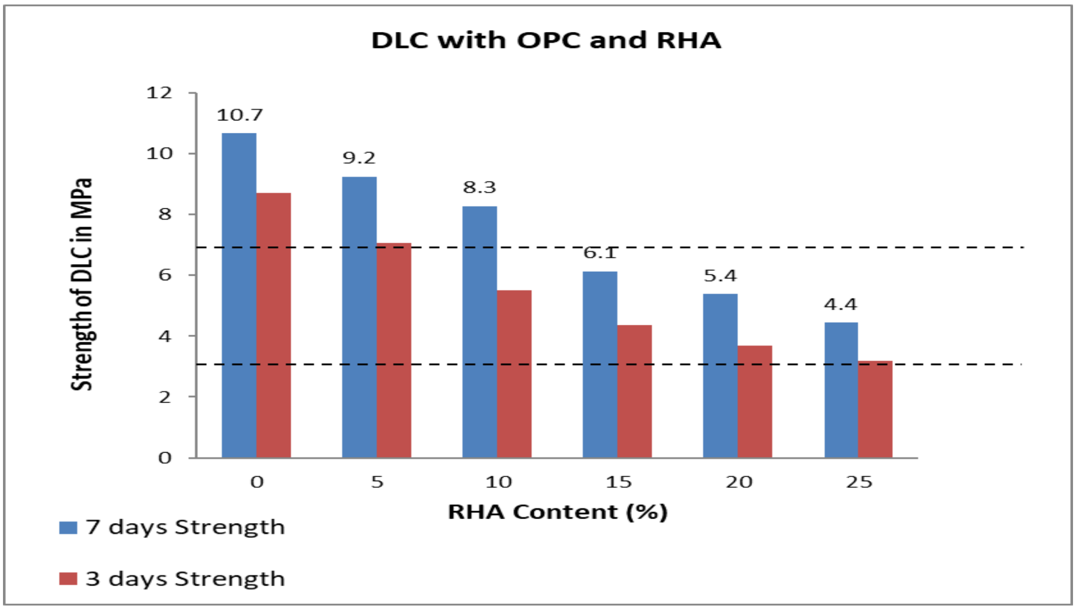

Fig 6.1: (b) Variation of strength of DLC by replacing OPC with RHA.

SL NO.	% Cement (OPC)	% RHA	% LIME	3 days compressive strength (MPa)	7 days compressive strength (MPa)	MAX. IN 7DAYS	MIN. IN 7 DAYS	3 days flexural strength (Mpa)	7 days flexural strength (Mpa)
1	100	0	0	8.7	10.7	11.1	9.8	2.1	2.3
2	95	5	0	7.1	9.2	9.3	8.9	1.9	2.1
3	90	10	0	5.5	8.3	8.4	8.0	1.6	2.0
4	85	15	0	4.4	6.1	6.4	5.8	1.5	1.7
5	80	20	0	3.7	5.4	5.6	5.1	1.3	1.6
6	75	25	0	3.2	4.4	4.7	4.2	1.3	1.5

Table:6.1 Variation of strength of DLC with OPC mixed and RHA.

6.3 Characterization of DLC with PSC

6.3.1 Variation of Strength of DLC replacing PSC by RHA

The variation of 3 days and 7 days strength of DLC by replacing PSC with different RHA content has been shown in figure-6.2(a) and the minimum strength requirement of DLC as per Indian specifications have been shown by a reference line named as Threshold Line. It is interesting to note that the RHA content above this line indicates accepted RHA contents in terms of the strength of mix as cement treated base. However, the RHA content below the line indicates the mix which is deficient in strength. Therefore the maximum RHA content up to which the strength of the mix complies the minimum strength requirement has been considered as optimum RHA content in present work, which is an indication of optimum quantity of replacement of cement by RHA.

It is relevant to the fig. 6.2(a) that the 7 days strength of DLC prepared with PSC and RHA mix reduces with increase of RHA content at a nearly constant rate. And it is evident from the figure that the optimum RHA content satisfying to the minimum strength of DLC is 3.7% by weight of total cementitious material.

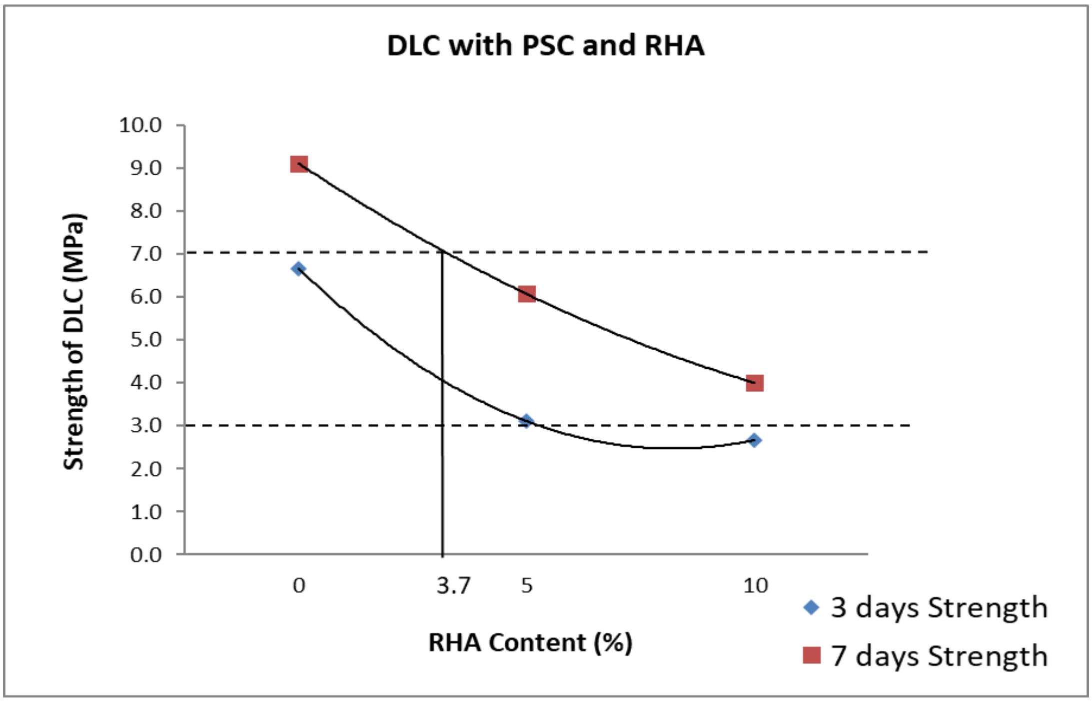

Fig 6.2: (a) Variation of strength of DLC by replacing PSC with RHA.

6.3.2 Variation of Strength of DLC replacing PSC by RHA and Lime

The variation of 3 days and 7 days strength of DLC by replacing PSC with different RHA content has been shown in figure-6.2(b) and the minimum strength requirement of DLC as per Indian specifications have been shown by a reference line named as Threshold Line. It is interesting to note that the RHA content above this line indicates accepted RHA and lime contents in terms of the strength of mix as cement treated base. However, the RHA and lime content below the line indicates the mix which is deficient in strength. Therefore the maximum RHA content up to which the strength of the mix complies the strength requirement has been considered as optimum RHA and lime content in present work, which is an indication of optimum quantity of replacement of cement by RHA and lime.

It is relevant to the fig. 6.2(b) that the 7 days strength of DLC prepared with PSC and RHA mix reduces with increase of RHA content at a nearly constant rate, where as replacement of PPC with both RHA and lime, the 7 days compressive strength of such mix was found to increase with the increase in lime content. It has to be noted that the reduction of strength of DLC mix with replacement of cement by RHA gets compensated when the lime content in the mix becomes equal to RHA content. In the present study it has been observed that 10% RHA with 10% lime yields a required strength of 7 MPa, thereby replacing total cement content to the extent of 20% in the mix. It is evident from the figure-6.2(b) that the RHA and lime content satisfying to the minimum strength of DLC is can be effective for both RHA and lime content in the DLC mix is 15 % for each by weight of total cementitious material. And it is evident from the figure that the optimum RHA content satisfying to the minimum strength of DLC is 20% by weight of total cementitious material. It is relevant to mention that the reason behind increase in strength of the DLC mix in presence of lime and RHA may be the reaction of lime $Ca(OH)_2$ with Silicon oxide (Sio_2) present in RHA by formation of Calcium Silicate Hydrate (C-S-H) gel.

SL NO.	% Cement (PSC)	% RHA	% LIME	3 days compressive strength (MPa)	7 days compressive strength (MPa)	MAX. IN 7DAYS	MIN. IN 7 DAYS	3 days flexural strength (Mpa)	7 days flexural strength (Mpa)
1	100	0	0	6.7	9.1	9.8	8.0	1.8	2.1
2	95	5	0	3.1	6.1	6.2	5.8	1.2	1.7
3	90	10	0	2.7	4.0	4.4	3.6	1.1	1.4
4	90	5	5	4.3	7.0	7.6	6.7	1.5	1.8
5	85	10	5	4.5	6.6	6.7	6.4	1.5	1.8
6	80	15	5	4.3	6.5	6.7	6.2	1.5	1.8
7	80	10	10	3.3	7.0	7.1	6.7	1.3	1.8
8	70	15	15	3.3	6.8	7.1	6.7	1.3	1.8

Table-6.2: Variation of strength of DLC with PSC and RHA & lime .

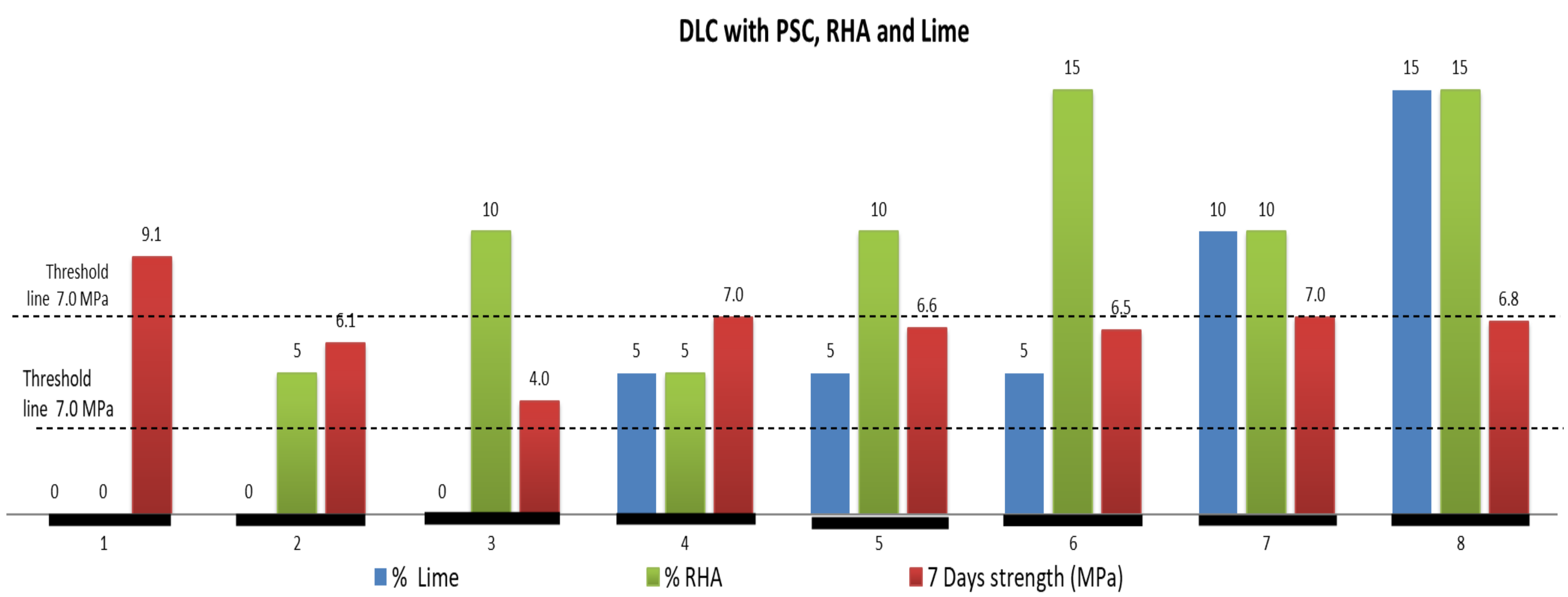

Fig. 6.2 (b): Variation of strength of DLC with PSC, replacing by RHA and lime

6.4 Characterization of DLC with PPC

6.4.1 Variation of Strength of DLC replacing PPC by RHA

The variation of 3 days and 7 days strength of DLC by replacing PPC with different RHA content has been shown in figure-6.3(a) and the minimum strength requirement of DLC as per Indian specifications have been shown by a reference line named as Threshold Line. It is interesting to note that the RHA content above this line indicates accepted RHA contents in terms of the strength of mix as cement treated base. However, the RHA content below the line indicates the mix which is deficient in strength. Therefore the maximum RHA content up to which the strength of the mix complies the strength requirement has been considered as optimum RHA content in present work, which is an indication of optimum quantity of replacement of cement by RHA.

It is relevant to the fig. 6.3(a) that the 7 days strength of DLC prepared with PPC and RHA mix reduces with increase of RHA content at a nearly constant rate. And it is evident from the figure that the optimum RHA content satisfying to the minimum strength of DLC is 2% by weight of total cementitious material.

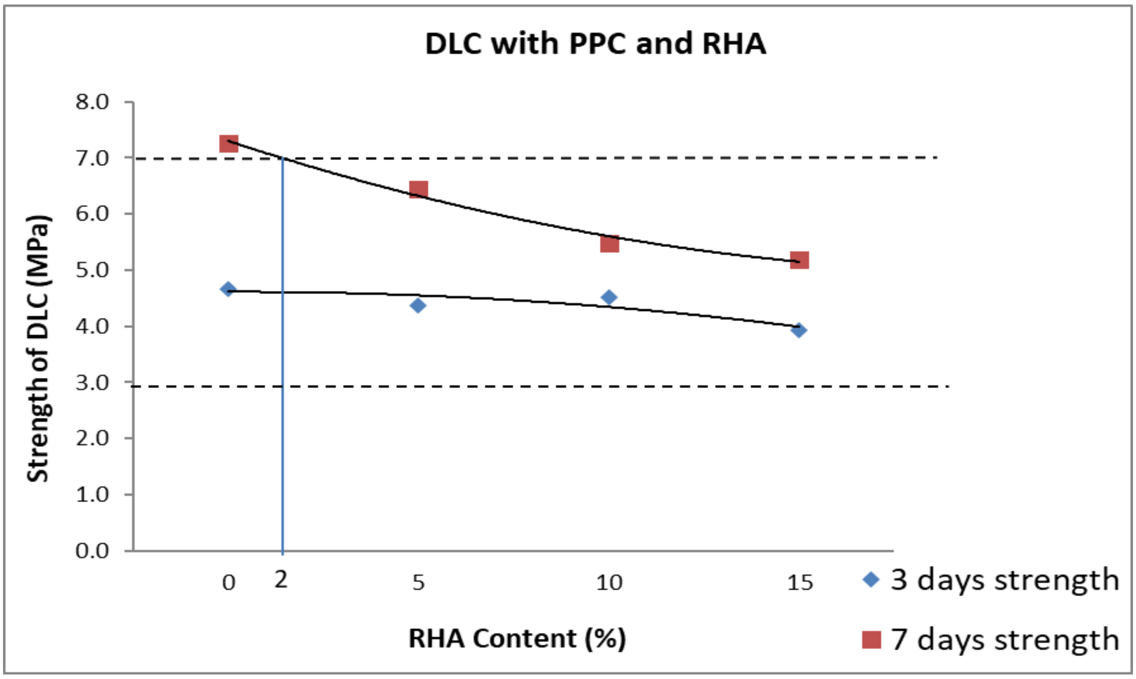

Fig 6.3: (a) Variation of strength of DLC by replacing PPC with RHA.

6.4.2 Variation of Strength of DLC replacing PPC by RHA and Lime

The variation of 3 days and 7 days strength of DLC by replacing PPC with different RHA content has been shown in figure-6.3(b) and the minimum strength requirement of DLC as per Indian specifications have been shown by a reference line named as Threshold Line. It is interesting to note that the RHA content above this line indicates accepted RHA and lime contents in terms of the strength of mix as cement treated base. However, the RHA and lime content below the line indicates the mix which is deficient in strength. Therefore the maximum RHA content up to which the strength of the mix complies the strength requirement has been considered as optimum RHA and lime content in present work, which is an indication of optimum quantity of replacement of cement by RHA and lime.

It is relevant to the fig. 6.3(b) that the 7 days strength of DLC prepared with PPC and RHA mix reduces with increase of RHA content at a nearly constant rate. where as replacement of PPC with both RHA and lime, the 7 days compressive strength of such mix was found to increase with the increase in lime content. It has to be noted that the reduction of strength of DLC mix with replacement of cement by RHA gets compensated when the lime content in the mix becomes equal to RHA content. In the present study it has been observed that 10% RHA with 10% lime yields a required strength of 7 MPa, thereby replacing total cement content to the extent of 30% in the mix. It is evident from the figure-6.3(b) that the minimum strength of DLC can be achieved when both ,RHA and lime content in the mix is 15 %. Therefore, a saving of 30% is possible in cement content in DLC by its replacement with RHA and Lime. It is to be noted that the reason behind increase in strength of the DLC mix in presence of lime and RHA may be the reaction of lime $Ca(OH)_2$ with Silicon oxide (Sio_2) present in RHA by formation of Calcium Silicate Hydrate (C-S-H) gel. It has also been found that the increase in strength of PPC based DLC mix was higher in comparison to the DLC mix prepared with PSC, which can be compared with table 6.2 and table 6.3.

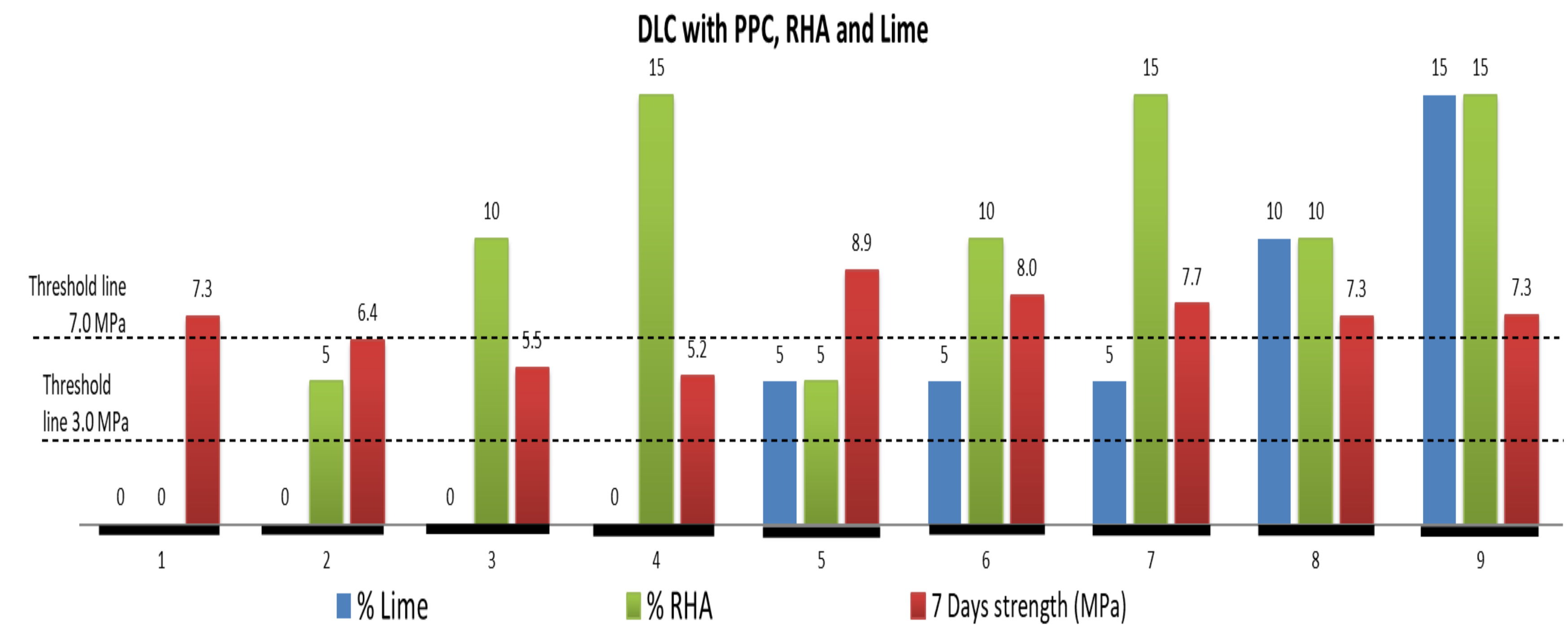

Fig. 6.3 (b): Variation of strength of DLC with PPC, replacing by RHA and lime

SL NO.	% Cement (PPC)	% RHA	% LIME	3 days compressive strength (MPa)	7 days compressive strength (MPa)	MAX. IN 7DAYS	MIN. IN 7 DAYS	3 days flexural strength (Mpa)	7 days flexural strength (Mpa)
1	100	0	0	4.7	7.3	7.6	7.1	1.5	1.9
2	95	5	0	4.4	6.4	6.7	6.2	1.5	1.8
3	90	10	0	4.5	5.5	5.8	5.3	1.5	1.6
4	85	15	0	3.9	5.2	5.3	4.9	1.4	1.6
5	90	5	5	5.8	8.9	9.8	8.4	1.7	2.1
6	85	10	5	6.1	8.0	8.4	7.6	1.7	2.0
7	80	15	5	4.4	7.7	8.0	7.6	1.5	1.9
8	80	10	10	4.6	7.3	7.6	7.1	1.5	1.9
9	70	15	15	4.2	7.3	7.6	7.1	1.4	1.9

Table-6.3: Variation of strength of DLC with PPC and RHA & lime .

6.5 Comparative study between OPC, PPC and PSC

A combination of mix proportion with RHA and lime was used for different types of cement such as ordinary Portland cement (OPC), Portland Slag Cement (PSC) and Portland Pozzolana Cement (PPC) respectively. The 3 days and 7 days UCS result was found higher when OPC is replaced by RHA than PSC and PPC. However the 3 days and 7 days compressive strength of DLC prepared with replacing PPC by RHA and lime developed more than the strength of DLC prepared with replacing PSC by RHA and lime .The cause of gaining more strength in case of PPC than PSC used in DLC is that the presence of chemical composition is different in between PPC and PSC. A comparison on strength among them were evaluated. This results are shown in figures 6.1 to figure 6.3 and table 6.1 to table 6.3.

6.6 Flexural Strength

Flexural strength of concrete also varies with the corresponding compressive strength of each sample as the flexural strength of concrete in present work has been estimated by the empirical formula given in IS:456-2000[29] (clause: 6.2.2) from compressive strength. Flexural strength of DLC cube are shown table 6.1 to 6.3.

Flexural strength, $f_{cr} = 0.7\text{x} \sqrt{fck}$ N/mm^2

Where f_{ck} is the characteristic cube compressive strength of concrete in N/mm^2.

It is relevant to the fig. 6.3(b) that the 7 days flexural strength of DLC prepared with PPC and RHA mix reduces with increase of RHA content at a nearly constant rate. where as replacement of PPC with both RHA and lime, the 7 days flexural strength of such mix was found to increase with the increase in lime content. It has to be noted that the reduction of flexural strength of DLC mix with replacement of cement by RHA gets compensated when the lime content in the mix becomes equal to RHA content. In the present study it has been observed that 10% RHA with 10% lime yields a required strength of 1.4 MPa as specified in IRC:37-2012[22], thereby replacing total cement content to the extent of 30% in the mix. It is evident from the figure-6.3(b) that the minimum strength of DLC can be achieved when both ,RHA and lime content in the mix is 15 %. Therefore, a saving of 30% is possible in cement content in DLC by its replacement with RHA and Lime. It has also been found that the increase in strength of PPC based DLC mix was higher in comparison to the DLC mix prepared with PSC, which can be compared with table 6.2 and table 6.3 and this results on flexural strength satisfying the minimum strength requirement.

6.7 Economy

In order to make comparative cost analysis, the cost estimate of different types of mix have been made on the basis of PWD schedule, Vol.-1,2017[32], Govt. of W.B. In this context, primarily the rate analysis has been made for DLC with OPC, PPC and PSC without any replacement of cement. The estimate thus prepared has been compared with the rate of DLC made by replacing cementitious material with maximum RHA and lime content for its use in pavement base and subbase.

The comparative analysis of DLC for different mix made with different cement, RHA and lime has been presented in table 6.4. It appears from the table 6.4 that the replacement of cementitious materials by RHA and lime in different DLC mix yields economy in the range of 3.22% to 9.43%.

Sl. No.	Description of DLC	Cost (Rs) / cum Without RHA and lime	Cost (Rs) / cum With RHA and lime	Cost saving (%)
1.	With OPC used in base	2790.00	2700.00	3.22
2.	With OPC used in sub-base	2790.00	2527.00	9.43
3.	With PSC used in base	2912.00	2746.00	5.70
4.	With PSC used in sub-base	2912.00	2663.00	8.55
5.	With PPC used in base	2912.00	2663.00	8.55
6.	With PPC used in sub-base	2912.00	2663.00	8.55

Table 6.4: Comparison of cost of DLC made with different cements with RHA and lime.

CONCLUSION

CHAPTER -7

7.1 Conclusion

Present study has been aimed to find out suitable mix proportion of DLC when made with cement replacement with RHA and lime in order to use it in pavement base and subbase layer. Conclusions are reached and recommendations provided for the use of RHA as a replacement of cement in new concrete pavements for different cases.

It has been found from the present investigation that the optimum RHA content in DLC when made from OPC and used in pavement base is 13.7% with a water content of 6.8% and cement content 136.8 kg/cum . However, when the mix needs to be used in pavement sub-base layer , the optimum RHA content may be considered as 25% with a water content 6.8%.

Moreover, it has been found from the present investigation that the optimum RHA content of DLC when made from PSC and used in pavement base is 3.7% With a water content of 7% and cement content 175.53 kg/cum . However, when the mix needs to be used in pavement sub-base layer , the optimum RHA content will be 10% with a water content 7.0%.

However, when DLC has been made from PSC by replacing RHA and lime together, the optimum content of RHA and lime were found as 10%. And 10% respectively for use in pavement base. But, in case of use of the mix in pavement sub-base , when DLC has been made from PSC by replacing RHA and lime together, the optimum content of RHA and lime were found as 15% and 15% respectively. In this work, the effect of lime on the strength of DLC was studied considering a highest RHA content as 15% with equal amount of lime in the mix. The results obtained from this study shows that the compressive strength of the mix with 15% RHA with 15% lime lies much above the required strength of such mix to be used in pavement subbase.

It has also been found from the present investigation that the optimum RHA content of DLC when made from PPC and used in pavement base is 2% With a water content of 7.5% and cement content 178.62 kg/cum . However, when the mix needs to be used in pavement sub-base layer , the optimum RHA content will be 15% with a water content 7.5%

Moreover, when DLC has been made from PPC by replacing RHA and lime together, the optimum content of RHA and lime were found as 15%. And 15% respectively for use in pavement base with a cement content 127.60 kg/cum. However, in case of use of the mix in pavement sub-base , when DLC has been made from PSC by replacing RHA and lime together, the optimum content of RHA and lime were found as 15% and 15% respectively. In this work, the effect of lime on the strength of DLC was studied considering a highest RHA content as 15% with equal amount of lime in the mix. The results obtained from this study shows that the compressive strength of the mix with 15% RHA with 15% lime lies much above the required strength of such mix to be used in pavement subbase. It has also been found that the increase in strength of PPC based DLC mix was higher in comparison to the DLC mix prepared with PSC.

7.2 Concluding Remarks

DLC made from PPC and PSC can be made with replacement of cementitious materials by Rice husk Ash and lime effectively, for only the application of the mix in pavement base and subbase. However, the OPC can be replaced by appropriate quantity of RHA to make it effective in use in pavement base and sub base.

7.3 Future scope of work

Future work in this area can be made with higher RHA and lime content in the mix to determine optimum dose of RHA and lime for its use in pavement subbase. In order to evaluate the behavior of the mix against fatigue, suitable laboratory investigation may be conducted for determination of optimum RHA and lime content in DLC mix. Present study is focused to evaluate the early strength of DLC mix with replacement of cementitious material by RHA and lime, but the long term behavior of the mix under repetitive load needs to be evaluated in future. Moreover, other industrial and agricultural waste which are locally available may be used in future study as has been done in present case with RHA. Use of locally available fibers in DLC could be another interesting topic of research in future to assess the change in flexural strength of the mix.

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CHAPTER -8

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31. *IS:8112-2013 - ORDINARY PORTLAND CEMENT, 43 GRADE — SPECIFICATION.*

32. *PWD SCHEDULE OF RATES , Volume- l, 2017- Building work ,Govt. of West Bengal.*