VISVESVARAYA TECHNOLOGICAL UNIVERSITY

"Jnana Sangama", Belgaum-590 014

A Dissertation Project Report on

"UTILIZATION OF COCONUT SHELLS AGGREGATE AS A PARTIAL REPLACEMENT FOR COARSE AGGREGATE IN PAVEMENT QUALITY CONCRETE"

Submitted in partial fulfilment for the award of the degree of

BACHELOR OF ENGINEERING IN

CIVIL ENGINEERING

BY

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C.M.R. INSTITUTE OF TECHNOLOGY
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Department of Civil Engineering

Certificate

This is to certify that the project work entitled "UTILIZATION OF COCONUT SHELLS AGGREGATE AS A PARTIAL REPLACEMENT FOR COARSE AGGREGATE IN PAVEMENT QUALITY CONCRETE ''has been successfully completed by Ms.Bhumika D (1CR16CV010) Ms.Deepika S V(1CR16CV015),Ms Prajna Ganesh Gunaga (1CR16CV043),bonafide students of C.M.R. Institute of technology in partial fulfilment of the requirement for the award of degree of Bachelor of Engineering in Civil Engineering of the "VISVESVARYA TECHNOLOGICAL UNIVERSITY", Belgaum during the academic year 2019-20. It is certified that all corrections indicated for internal assessment has been in corporated in the Report. The project report has been approved as it satisfies the academic requirements in respect of project work prescribed for the said Degree.

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2.		

C.M.R. INSTITUTE OF TECHNOLOGY
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Department of Civil Engineering

DECLARATION

We, Ms.Bhumika D, Ms.Deepika S V, Ms.Prajna Ganesh Gunaga. bonafide students of CMR Institute of Technology, Bangalore, hereby declare that dissertationen titled "UTILIZATION OF COCONUT SHELLS AGGREGATE AS A PARTIAL REPLACEMENT FOR COARSE AGGREGATE IN PAVEMENT QUALITY CONCRETE'' has been carried out by us under the guidance of Mr.Ravi Kant Talluri (Assistant Professor), Department of Civil Engineering, C.M.R.Institute of Technology, Bangalore, in partial fulfilment of the requirement for the award of degree of Bachelor of Engineering in Civil Engineering of the Visvesvaraya Technological University, Belgaum during the academic year 2019-2020.

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ABSTRACT

Concrete is the premier construction material around the world and is most widely used in all types of construction works, including infrastructure, low and high-rise buildings, and domestic developments. It is a man-made product, essentially consisting of a mixture of cement, aggregates, water and admixture(s). Inert granular materials such as sand, crushed stone or gravel form the major part of the aggregates. Traditionally aggregates have been readily available at economic prices and of qualities to suit all purposes. But, the continued extensive extraction use of aggregates from natural resources has been questioned because of the depletion of quality primary aggregates and greater awareness of environmental protection.

In light of this, the non-availability of natural resources to future generations has also been realized. Different alternative waste materials and industrial by products such as fly ash, recycled aggregates, foundry sand, china clay sand, crumb, glass were replaced with natural aggregate and investigated properties of the concretes. Apart from above mentioned waste materials and industrial by products, few studies identified that coconut shells, the agricultural by product can also be used as aggregate in concrete.

According to a report, coconut is grown in more than 86 countries worldwide, with a total production of 54 billion nuts per annum. India occupies the premier position in the world with an annual production of 13 billion nuts, followed by Indonesia and the Philippines. Limited research has been conducted on mechanical properties of concrete with coconut shells as aggregate replacement. However, further research is needed for better understanding of the behavior of coconut shells as aggregate in concrete.

Thus, the aim of this work is to provide more data on the strengths of coconut shell concretes at different coconut shells (CS) replacements and study the transport properties of concrete with coconut shells as coarse aggregate replacement. Coconut shell may offer itself as a coarse aggregate as well as a potential construction material in the field of construction industries and this would solve the environmental problem of reducing the generation of solid wastes simultaneously. The coconut shell cement composite is compatible and no pre-treatment is required. coconut shell concrete has better workability because of the smooth surface on one side of the shells. Moisture retaining and water absorbing capacity of coconut shell are more compared to conventional aggregate. The amount of cement content may be more when coconut shell are used as an aggregate in the production of concrete compared to conventional aggregate concrete. The presence of sugar in the coconut shells as long as it is not in a free sugar form, will not affect the setting and strength of concrete.

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CHAPTER 01

INTRODUCTION

A concrete material is a combination of cement, fine aggregate, coarse aggregate and water. This is very widely used construction material due to its good compressive strength and non-corrosivity as compared with steel. Due to the increase in population, the constructions are increasing accordingly so there is more demand for this construction material. Hence the demand for ingredients of concrete also increased. Now it is the need of the day to search for alternate ingredients for concrete. Coconut which is produced in around 93 countries can be a rich source for coarse aggregate.

The cost for making concrete is increasing day-by-day so we have to reduce that by using eco waste instead of using costly materials. The best waste material to mix with concrete is coconut shells, which makes concrete stronger. Due to its tough create tissue, coconut shell is not rotten easily and stay as solid for years. This agricultural waste can be used as coarse aggregate and hence helps in the reduction of solid waste in environment.

Coconut shell is assessed as light weight aggregate. The dried coconut shell contains polysaccharide, lignin, pentose and ash in various proportions. In Asia the development enterprise is to create use of the advantage of light weight concrete at intervals the production of excessive upward thrust structures.

The goal of our project is to discuss on the strength and durability of coconut shell of concrete at high demand for concrete within construction mistreatment traditional weight aggregates like granite and gravel extremely decreases the deposits of natural stone. There by inflicting ecological imbalance there is essential to range over and to seek out appropriate replacement material substitute the natural stone. Until now, industrial merchandise and domestic wastes area used in concrete.

Coconut shell is associate agricultural waste. At present, coconut shell has additionally has been burnt to supply charcoal and activated charcoal for food and effervescent drinks and filtering water.

However, the coconut shell remains underutilised. From the analysis works reviewed higher than, it will be perceiving that coconut shells will be successfully used as a substitute for coarse aggregates in concrete.

The study bestowed here is specializing looking for the optimum —— replacement of coarse combination with coconut shells supported its strength properties. The study put together aims to seek out the advantage of commercially made coconut shell concrete add terms of self-weight reduction. **Utilization of coconut shell aggregate as partial replacement for coarse aggregate in pavement quality concrete.**

CHAPTER 02

LITERATURE REVIEW

1. Ismail Saifulla, MD.Abdul Haleem, MD.Zahur-Uz-Zaman.

Using mix proportion of 1:1.5:3, results of experiments on the physical and mechanical properties of concrete, replaced coarse aggregates with coconut shells have been presented in this research. Based on the experimental results of this study the following conclusions can be drawn

- Coconut shells can be used as partial replacement for the conventional stone aggregates in concrete production.
- In terms of strength, 20% crushed stone chips can be replaced with coconut shells to produce structural lightweight concrete as per the requirements provided by American Concrete Institute.

2.Akshay S Shelke, KalyaniR.Ninghot, Pooja P.Kunjekar, Shraddha P. Gaikwad

To increase the speed of construction, enhance green construction environment we can use lightweight concrete. The possibility exists for the partial replacement of coarse aggregate with coconut shell to produce lightweight concrete.

- Coconut shell exhibits more resistance against crushing, impact and abrasion, compared to crushed granite aggregate.
- Coconut shell can be grouped under lightweight aggregate. There is no need to treat the coconut shell before use as an aggregate except for water absorption.
- Coconut shell is compatible with the cement. The 28-day air-dry density of coconut shell aggregate concrete are less than 2000 kg/m^3.
- Coconut shell aggregate concrete satisfies the requirements of ASTM C 330.

3. B.Damodhara Reddy, S.ArunaJyothy, Fawaz Shaik

In study, they replaced coarse aggregate with coconut shell, by volume. Specimens were cast by replacing 25%, 50%, 75% and 100% of coarse aggregate with coconut shells. Tests were conducted on the cast specimens after 28 days as mentioned in the IS code. Tests for workability, flexure, compression and split tensile strength were conducted and results were obtained. Coconut shell concrete has better workability because of the smooth surface on one side of the shells and the smaller size of coconut shells.

So we could possibly use coconut shell concrete in concretes where high workability is desirable. The flexural strength of CSC is approximately 5.36N/mm^2, 4.32N/mm^2, and 2.4N/mm^2 for specimens replacing

25%,50%,100%, of coarse aggregate respectively. But in case of 100% replacement of coarse aggregate flexural strength was not obtained as the specimen failed under its self weight. Its corresponding compressive strengths were obtained as 24N/mm^2, 22.62N/mm^2, 14.93N/mm^2 and 5.48N/mm^2. The splitting tensile strength of CSC was obtained as 2.48N/mm^2, 2.22N/mm^2, 1.27N/mm^2 and 0.495N/mm^2 respectively. From the above results we can see that in CSC where 25% of the coarse aggregate is replaced, shows properties similar to the nominal mix and 50% replaced CSC shows properties similar to light weight concrete which can be used as filler materials in framed structures, flooring tiles, thermal insulating concrete etc.

4. Anand Ramesh, Anandhu K J, AnlySaju, Jerin K Jain, VineethaThankachan

After the curing time specimens were tested for compressive strength, split tensile strength and flexural strength. Results showed a rise in compressive strength at 7 days curing time for 5%, 10% replacement of coarse aggregate with coconut shell. There was a rise in compressive strength at 28 days curing time for 5% but strength lowered for 15% replacement of coarse aggregate with coconut shell. Splitting tensile strength decreased for 5% replacement of coarse aggregate with coconut shell. Compare with 5% replacement 10% replacement has a slight increase but not much as for conventional mix. Flexural strength has a notable decrease with increase in replacement of coarse aggregate with coconut shell. Densities of coconut shell concrete showed decrease with increase in replacement.

From the test results, the coconut shell has a future as lightweight aggregate in concrete. It also reduces the total cost of concreting, because of the low cost and its ease of availability is profusion. Coconut Shell Concrete can be used in rural areas and places where coconut is inprofusion and the places where the regular aggregates are not economic. It is concluded that the Coconut Shells are more suitable as low strength-giving lightweight aggregate when used to replace common coarse aggregate in production concrete. Coconut shells have more power to resist crushing, and impact compared to traditional granite aggregate. There is no need to treat the coconut shell before use as an aggregate except for water absorption.

5. Yogesh Narayan Sonawane, Chetan JaiprakashChitte

Overall cost of construction isreduced. The maximum compressive strength in control mix is 21.28 N/mm^2 at 28 days, while the minimum strength at same days is 14.23 N/mm^2. Thus compressive strength decreased as percentage of coconut shell is increased. Therefore coconut shell can be used where light weight concrete is required. Proper bonding between coconut shell and cement is not possible because ofsmooth surface textureof coconut shell aggregate. In future, we can increase strength of coconut shell concrete by adding admixtures.

6. S.Andavan, N. Ravi Sreekar, P. Vivek

In this paper, the coconut shell accurate strength and it was investigated as limited replacement of coarse combine with coconut shell as various mix percentages. Experimental investigation is based on tests conducted for workability, compressive strengths, split tensile strengths, flexural strengths. Hence the subsequent conclusions are above literature review derived from study. Coconut shell is used as a limited replacement for the standard coarse aggregate within the construction of concrete

- For further studies out to be allotted to determine the chance of exploitation coconut shell mix as a structural material.
- The ability of concrete studies on coconut shell concrete out to be distributed to assess its behaviour in aggressive environments.
- It is completed that the coconut shells is a lot of appropriate as lower strength of giving particular light-weight concrete production.
- The density of concrete will be reduced as the replacement material increases.
- This paper helps to complete the construction within budget.

7. A.Santhiya, N.Sakthieswaran, G.ShinyBrintha, O.GaneshBabu

- Based on limited experimental investigation on the compressive strength of concrete, Flexural strength, Split tensile strength the following observations are made regarding the resistance of partially replaced coconut shell scrap.
- In comparison of coconut shell concrete itself, in between 35%,45%,55% the strength is achieved in 35%.
- To compare conventional concretewith the coconut shell concrete the strength of the coconut shell concrete didn’t attained target strength.
- The application of coconut shell concrete to flooring concrete and surface coatings. etc.
- This project suggests reduction in amount of coarse aggregate.
- On one hand the waste disposal problem is solved and on other hand the coconut shell is gainfully utilized.
- In our location the coconut shell concrete is not use for structural elements but we used for non-structural elements.

8. Apeksha Kanojia1, S.K. Jain

- This review focuses on production of concrete using agricultural waste as point of this ingredients replacing fast depleting conventional aggregate sources construction material and there by finding the solution for social and environmental issues. At present, the rising cost of building construction materials is the factor of great concern. The challenge in making a lightweight concrete is decreasing the density while maintaining strength and without adversely affecting cost.

- Introducing new light weight aggregates into the mix design is a common way to lower a concrete's density. Coconut shell can be grouped under lightweight aggregate because 28-day air-dry densities of coconut shell aggregate concrete are less than 2000 kg/m^3. Actual Density of coconut shell is in the range of 550 - 650kg/m^3.
- From the experimental results and discussions of above researches on coconut shell, the coconut shell has potential as lightweight aggregate in concrete. Also, using the coconut shell as aggregate in concrete can reduce the material cost in construction because of the low cost and its availability is abundance.
- Coconut Shell Concrete can be used in rural areas and places where coconut is abundant and may also be used where the conventional aggregates are costly. It is concluded that the Coconut Shells are more suitable as low strength-giving lightweight aggregate when used to replace common coarse aggregate in concrete production.
- Coconut shell exhibits more resistance against crushing, impact and abrasion, compared to crushed granite aggregate. There is no need to treat the coconut shell before use as an aggregate except for water absorption.
- These studies also paved the way to the recognition of using coconut shells and fibre as substitute for aggregates in developing concrete hollow blocks.
- From the above researches it also found that the addition of CS decreases workability and addition of fly ash either as cement replacement or aggregate replacement increases workability of CS concrete. We can also use fly ash to improve workability of CS concrete.
- The amount of cement content may be more when coconut shell are used as an aggregate in the production of concrete compared to conventional aggregate concrete.

9.Miss. Anjali S. Kattire, Miss. Priyanka A. Bujughade, Mr. Shashiraj S. Chougule

- Increase in percentage replacement by coconut shell reduces compressive strength and split tensile strength of concrete.
- The reduction in compression strength is less in comparison with the split tensile strength with the replacement of conventional material.
- Using the coconut shell as coarse aggregate in concrete can reduce the material cost in construction because of the low cost.

10.KalyanapuVenkateswara Rao, A.H.L.Swaroop ,Dr.P.Kodanda Rama Rao, Ch.NagaBharath

Results of experiments on compressive strength, split tensile strength, water sorption for different coconut shells replaced concretes have been presented with those of control concrete. However, performance of coconut shells aggregate concrete having a marginal variation than normal aggregate concrete. The main points of this study are:

- Addition of coconut shells decreases workability and addition of fly ash as cement replacement increases workability of coconut shells concrete. Increase in coconut shells percentage decreased densities of the concretes.
- By replacement of coconut shells in place of aggregates, 10% & 20% replacement will have been decreased marginally the strength properties of concrete compared to the normal concrete.
- But the replacement of coconut shells in place of aggregates and replacement of fly ash in place of cement will increase the strength properties of concrete compared to the normal concrete.
- The replacement of the 10%coconut shells as coarse aggregate will decreases the marginal value of 2.88% in compression and 2.7% in split tensile strength.
- The replacement of the 20%coconut shells as coarse aggregate will decreases the marginal value of 8.39% in compression and 10.25% in split tensile strength.
- The replacement of the 10%coconut shells as coarse aggregate and 10%fly ash as cement will decreases the marginal value of 0.525% in compression and increase of 4.05% in split tensile strength.
- The replacement of the 10%coconut shells as coarse aggregate and 10%fly ash as cement will decreases the marginal value of 0.205% in compression and increase of 2.7% in split tensile strength.
- The compressive strength of concrete will decrease with increase of coconut shell percentage.
- Replacement of coconut shell as coarse aggregate and Fly ash as cement will increase the compressive strength of concrete.

11. Sangeetha G, Nirmala P, Pugazhselvi D, Ramya K, K. Jegan Mohan

In this study the density and strength characteristics of concrete produced by volume replacement of 10%, 20% and 30% replacement of crushed granite with crushed coconut shells and cement with clay were investigated. It is concluded that:

- Increase in percentage replacements by coconut shells reduced the strength and density of concrete.
- Durability studies on coconut shell and clay in concrete should be carried out to assess its behaviour in aggressive environments.
- The challenge in making a lightweight concrete is decreasing the density while maintaining strength and without adversely affecting cost.

- The coconut shell as aggregate and clay as cement in concrete can reduce the material cost in construction because of the low cost and its availability is abundance.
- From the above researches it also found that the addition of coconut shell decreases workability and addition of clay either as cement replacement or aggregate replacement increases workability of coconut shell in concrete.
- Coconut Shells are more suitable as low strength giving lightweight aggregate and clay as plastic behaviour when wet, so used to replace in concrete production.
- Increase in percentage replacement by coconut shell and clay reduces compressive strength and split tensile strength of concrete. Using the coconut shell as coarse aggregate and clay as cement in concrete can reduce the material cost in construction because of economic in cost.
- In this less compression strength of concrete can be used in making of garden lawn, less load on footpath.

12. Dr. B. Rajeevan, Shamjith K M

India is the largest producer of coconut in the world accounting for 20% of the world's production. Hence, the disposal of coconut shell creates environmental issues since it is not easily degradable. The test results obtained from this study provides significant understanding on basic properties of coconut shell aggregate concrete. The properties of coconut shell and coconut shell aggregate concrete were determined and the use of coconut shell aggregate as coarse aggregate in concrete was examined. Based on the limited number of experimental investigation carried out to determine the mechanical properties of concrete namely, compressive strength, split tensile strength and flexural strength of concrete, an optimum replacement of coarse aggregate with coconut shell aggregate, corresponding to the mix ratio 1: 1.63: 3.13, was determined as 15%. Cement content for 15% replacement was kept at 387 kg/m^3. The observed value of 28 day compressive strength, split tensile strength and flexural strength were 24.6 N/mm^2, 2.57 N/mm^2 and 2.89 N/mm^2 respectively. This indicates that concrete made with coconut shell aggregate has strength comparable with that of conventional concrete. The possibility of recycling and reuse of coconut shells which are discarded as waste led to the present study on its possible use as coarse aggregate in the development of lightweight concrete. The study established that coconut shell aggregate can replace conventional coarse aggregate in the production of lightweight concrete structures effectively without compromising on strength aspects.

13. Amarnath Yerramalaa, Ramachandrudu C

- Addition of CS decreases workability and addition of fly ash either as cement replacement or aggregate replacement increases workability of

CS concrete. Increase in CS percentage decreased densities of the concretes.

- With CS percentage increase the 7 day strength gain also increased with corresponding 28 day curing strength. However, the overall strength decreased with CS replacement when compared to control concrete. Furthermore, fly ash as cement replacement had negative influence when compared to corresponding CS concrete and fly ash as aggregate replacement had similar performance as that of corresponding CS replaced concrete.
- Similar to compressive strength, the split tensile strength also decreased with increase in CS replacement. Furthermore, for 28 days of curing addition of fly ash as cement replacement reduced overall split tensile strength of CS concrete and fly ash addition as aggregate replacement showed no major difference with corresponding CS replaced concrete (M4).
- The results demonstrated that, irrespective of CS percentage replacement there was good relationship between compressive strength and split tensile strength. The equation proposed by Raphael, 1984 for normal concrete was over predicting at lower strengths for CS concretes.
- Increase in CS replacement permeable voids also increased. With 10% CS replacement the permeable voids were 30 percent higher than control concrete. Similarly, the permeable voids were 88 percent higher than control concrete for 20% CS replacement. Addition of fly ash as cement replacement increased permeable voids with corresponding CS concrete (M4). However, addition of fly ash as aggregate replacement reduced permeable voids.
- The absorption characteristics show that the initial 30 min absorption values for all the concretes were lower than limits commonly associated with good quality concrete. The maximum absorption was 2.3% for the concrete having 20% CS and 25% fly ash as cement replacement. Fly ash as cement replacement increased water absorption and fly ash as aggregate replacement did not show any marked difference with corresponding CS replaced concrete.
- Sorptivity of the concretes was higher than control concrete for all CS concretes. The maximum sorption was 0.18mm/s, 0.5 for the concrete having 20% CS and 25% fly ash as cement replacement. Similar to absorption, fly ash as cement replacement increased sorption and fly ash as aggregate replacement did not show any marked difference with corresponding CS replaced concrete.

14. Ajay Lone, AniketDeshmukh, PanditJadhav, Rahul Patil, Pritee Mistry

Broad exploration was completed on control concrete with ordinary total and CS incomplete percentile supplanting on total for cement with 25 - half coarse total supplanting were set up with consistent water – folio proportion of 0.45. For all blends, workability, thickness, water assimilation, compressive quality flexural quality and rigidity were resolved at 7, 14 and 28 days. The accompanying conclusions can be gotten from the present examination: The outcomes demonstrated a relentless decrease in the workability. The 0.45, water bond proportion which was kept consistent all through the blend made the workability lower. The workability really diminishes as there is an expansion in the measure of CS added to the blend. Because of the nonappearance of super plasticizers the workability of the solid was on the lower side. The water ingestion tests demonstrated that the rate water retention increments with expansion in the rate supplanting level of coarse total with CS. half of CS substitution demonstrates the most noteworthy water retention took after by 25% and in conclusion half of CS. The compressive qualities of CS 1concrete were observed to be lower than ordinary cement by 5–55% following 7 days, 9-half following 14 days and by 12–52% following 28 days, contingent upon the curing environment. Their qualities were inside the typical extent for auxiliary lightweight cement. Flexural quality of solid examples diminishes with expansion in the rate supplanting's of coarse total with CS for all curing days. 25% CS level was distinguished as the ideal substitution rate since its shows the most noteworthy flexural quality by supplanting a coconut shell by 25% as coarse total are helpful and all test outcome are effective.

15. Parag S. Kambli, Sandhya R. Mathapati

From the experimental results and discussion, the coconut shell has potential as lightweight aggregate in concrete. Also, using the coconut shell as aggregate in concrete can reduce the material cost in construction because of the low cost and abundant agricultural waste. Coconut Shell Concrete can be used in rural areas and places where coconut is abundant and may also be used where the conventional aggregates are costly. Coconut shell concrete is also classified as structural lightweight concrete. It is concluded that the Coconut Shells are more suitable as low strength-giving lightweight aggregate when used to replace common coarse aggregate in concrete production.

16.Dewanshu Ahlawat, L.G Kalurkar

It is concluded that Increase in percentage replacement by coconut shell reduces compressive strength of concrete. Increase in percentage replacement by coconut shell increases workability of concrete. Coconut Shell can be used as partial replacement of coarse aggregate in R.C.C concrete. Effect of different admixtures can be studied on Coconut Shell Concrete(C.S.C) Evaluating Bond Strength of Coconut Shell Concrete(C.S.C) Coconut Shell- Cement compatibility

17. Ajay Tharwani Ashish, Sablani Gaurav Batra, Sakshi Tiwari, Divya Reel, Manish N. Gandhi

- Up to 15% of aggregate replaced by coconut shell is good according to strength and cost wise.
- Increase in percentage replacements by coconut shells reduced the strength and density of concrete.
- It helps in reducing up to15% pollution in environment.
- It is concluded that the Coconut Shells are more suitable as low strength-giving lightweight aggregate when used to replace common coarse aggregate in concrete production.
- Trying to replace aggregate by coconut shell partially to make concrete structure more economic along with good strength criteria.
- From one cube calculation bulk amount of shell replacement can be evaluated & reduces over all construction cost.
- This can be useful for construction of low cost housing society
- Solves problems of disposal of coconut shell.
- Slump of concrete increases as percentage of coconut shell increases.
- It leads to sustainable development.
- Continuous extraction of aggregate from rocks will lead to its depletion.

CHAPTER 03

METHODOLOGY

The freshly discarded shells were collected from oil mill. The coconut shells were crushed using concrete hammers to a size such that it passes through a 20mm sieve and retained on 4.75 sieves.

Crushed shells were washed to remove fibres, mud, etc. from them. The washed shells were dried in sunlight for 2 days. The crushed edges were rough and spiky. The surface texture of the shell was fairly smooth on concave and rough on convex faces. Coconut shell aggregates used were in saturated surface dry (SSD) condition.

Portland Pozzolana Cement (PPC) 43 Grade was used as a binder (Malabar Cements). M sand (Manufactured sand passing through 4.75mm sieve) was used throughout the study as the fine aggregate. Crushed stone (passing through 20 mm sieve and retained on 4.75 mm sieve) was used as coarse aggregate along with coconut shells. Potable water was used for mixing and curing. A nominal mix of 1:2:4 with a water-cement ratio of 0.5 was used throughout.

Four different mixes were made with 0%, 25%, 50%, 100% replacement of coarse aggregate with coconut shells.

Specimens were cast in such a way as to produce full compaction of the concrete with neither segregation nor excessive laitance. Compaction was achieved through use of a table vibrator. Here in this experiment we replaced coarse aggregate with coconut shell, by volume.

Specimens were cast by replacing 25%, 50%, 75%, and 100% of coarse aggregate with Coconut shells. Tests were conducted on the cast specimens after 28 days as mentioned in the IS code. Tests for workability, flexure, compression and split tensile strength were conducted and results were obtained.

CHAPTER 04

TESTS ON MATERIAL

I. TEST ON COARSE AGGREGATE

1.CRUSHING TEST

One of the model in which pavement material can fail is by crushing under compressive stress. A test is standardized by **IS: 2386 part-IV** and used to determine the crushing strength of aggregates. The aggregate crushing value provides a relative measure of resistance to crushing under gradually applied crushing load.

The test consists of subjecting the specimen of aggregate in standard mould to a compression test under standard load conditions. Dry aggregates passing through 12.5 mm sieves and retained 10 mm sieves are filled in a cylindrical measure of 11.5 mm diameter and 18 cm height in three layers. Each layer is tamped 25 times with at standard tamping rod. The test sample is weighed and placed in the test cylinder in three layers each layer being tamped again. The specimen is subjected to a compressive load of 40 tonnes gradually applied at the rate of 4 tonnes per minute. Then crushed aggregates are then sieved through 2.36 mm sieve and weight of passing material (**W2**) is expressed as percentage of the weight of the total sample (**W1**) which is the aggregate crushing value.

Aggregate crushing value = (W1/W2)*10

A value **less than 10** signifies an exceptionally **strong aggregate** while **above 35** would normally be regarded as **weak aggregates**

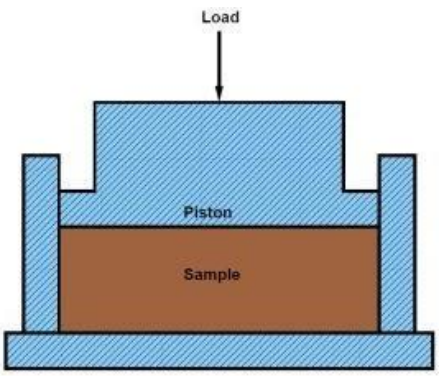
Equipment and apparatus

- Steel Cylinder
- Sieves (12.5mm,10mm)
- Cylindrical metal measure
- Tamping Rod
- Balance (0-10kg)
- Oven (300^0c)
- Compression testing Machine (2000KN)

Procedure

- The cylindrical steel cup is filled with 3 equal layers of aggregate and each layer is tamped 25 strokes by the rounded end of tamping rod and the surplus aggregate struck off, using the tamping rod as a straight edge.

- The net weight of aggregate in the cylindrical steel cup is determined to the nearest gram (WA) and this weight of aggregate is used for the duplicate test on the same material.
- The cup is fixed firmly in position on the base of the machine and the whole of the test sample is added in thirds, each third being subjected to 25stokes from tamping rod.
- The surface is leveled and the plunger is inserted so that it rests horizontally on the surface. The whole assembly is then placed between the platens of testing machine and loaded at a uniform rate so as to reach a load of 40 tons in 10 minutes.
- The load is then released and all aggregate is removed from the cup and sieved on 2.36 mm. IS sieve until no further significant amount passes in one minute.
- The fraction passing the sieve is weighed to an accuracy of 0.1 g (WB)



Calculation

The ratio of the weight of fines formed to the total sample weight in each test is to be expressed as a percentage, to the first decimal place

Aggregate crushing Value =(W_B/W_A) × 100

- **W_B**weight in g of fraction passing through appropriate sieve.
- **W_A** weight in g of saturated surface - dry sample,
- Aggregate Crushing Value 100

Conclusion / Result:

The aggregate crushing value of given sample of coarse aggregate is .... %

The aggregate crushing value should not be more than 45 per cent for aggregate used for concrete other than for wearing surfaces, and 30 per cent for concrete used for wearing surfaces such a runways, roads and air field pavements

2. ABRASION TEST

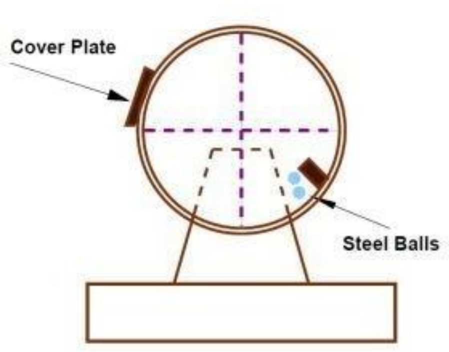
Abrasion test is carried out to test the hardness property of aggregates and to decide whether they are suitable for different pavement construction works. Los Angeles abrasion test is a preferred one for carrying out the hardness property and has been standardized in India (**IS: 2386 part-IV**).

The principle of Los Angeles abrasion test is to find the percentage wear due to relative rubbing action between the aggregate and steel balls used as abrasive charge.

Los Angeles machine consists of circular drum of internal diameter 700 mm and length 520 mm mounted on horizontal axis enabling it to be rotated (see Fig-2). An abrasive charge consisting of cast iron spherical balls of 48 mm diameters and weight 340-445 g is placed in the cylinder along with the aggregates. The number of the abrasive spheres varies according to the grading of the sample. The quantity of aggregates to be used depends upon the gradation and usually ranges from 5-10 kg. The cylinder is then locked and rotated at the speed of 30-33 rpm for a total of 500 -1000 revolutions depending upon the gradation of aggregates.

After specified revolutions, the material is sieved through 1.7 mm sieve and passed fraction is expressed as percentage total weight of the sample. This value is called Los Angeles abrasion value.

A maximum value of **40 percent** is allowed for **WBM base course** in Indian conditions. For **bituminous concrete**, a maximum value of **35 percent** is specified



Equipment's and apparatus

- Los Angeles machines
- Sieves (1.70mm)
- Cylindrical metal measure
- Tamping Rod
- Balance (0-10kg)

Procedure

- The required weight of test sample(A) is selected conforming to one of the grading mentioned in Table II of IS: 2386 (Part IV) – 1963.
- The test sample and the abrasive charge are to be placed in the machine and rotated at a speed of 20 to 33 rev/min.
- For grading A, B, C & D [as per Table II of IS: 2386 (Part IV)- 1963] the machine is to be rotated for 1000 revolutions.
- At the completion of the test, the material is discharged from the machine and separation of the sample is made on 1.70 mm. IS sieve.
- The material coarser than 1.70 mm. IS sieve is washed, dried accurately weighed to the nearest gram (B).Oven (3000c)

Calculation

The difference between the original weight and the final weight of the test sample is expressed as a percentage of the original weight of the test sample.

$$Agg\,AbrasionValue = \frac{A-B}{A}\times 100$$

B weight in g of fraction passing through 1.70 mm ISSieves

A weight in g of saturated surface - dry sample,

Aggregate Abrasion Value 100

Conclusion / Result:

The aggregate Abrasion Value of given sample of coarse aggregate is ……….. %

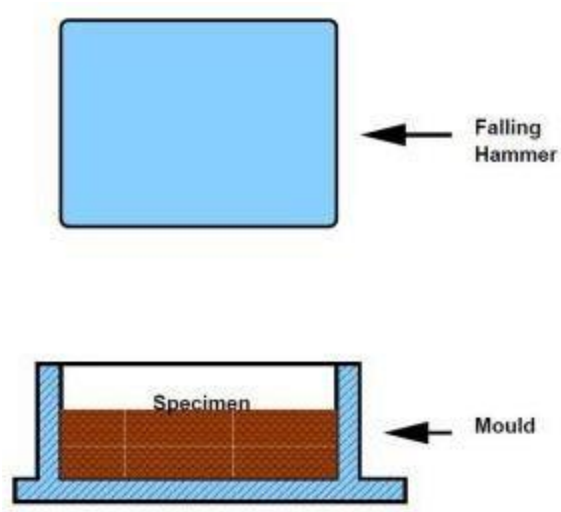
The percentage of wear should not be more than 16 per cent for concrete aggregates.

3.IMPACT TEST

The aggregate impact test is carried out to evaluate the resistance to impact of aggregates. Aggregates passing 12.5 mm sieve and retained on 10 mm sieve is filled in a cylindrical steel cup of internal dia 10.2 mm and depth 5 cm which is attached to a metal base of impact testing machine. The material is filled in 3 layers where each layer is tamped for 25 numbers of blows (see Fig-3). Metal hammer of weight 13.5 to 14 Kg is arranged to drop with a free fall of 38.0 cm by vertical guides and the test specimen is subjected to 15 numbers of blows. The crushed aggregate is allowed to pass through 2.36 mm IS sieve. And the impact value is measured as percentage of aggregates passing sieve (W2) to the total weight of the sample (W1).

Aggregate impact value = **(W1/W2)*100**

Aggregates to be used for wearing course, the impact value shouldn't exceed 30 percent. For bituminous macadam the maximum permissible value is 35 percent. For Water bound macadam base courses the maximum permissible value defined by IRC is 40 percent.



Equipments and apparatus

- Aggregate Impact Test Machine
- Sieves (12.5mm,10mm)
- Cylindrical metal measure
- Tamping Rod
- Balance (0-10kg)

Procedure

- Oven(3000c) The cylindrical steel cup is filled with 3 equal layers of aggregate and each layer is tamped 25 strokes by the rounded end of tamping rod and the surplus aggregate struck off, using the tamping rod as a straight edge.
- The net weight of aggregate in the cylindrical steel cup is determined to the nearest gram (W_A) and this weight of aggregate is used for the duplicate test on the same material.
- The cup is fixed firmly in position on the base of the machine and the whole of the test sample is placed in it and compacted by a single tamping of 25 strokes of tamping rod.

- The hammer is raised until its lower face is 380 mm. above the upper surface of the aggregate in the cup, and allowed to fall freely onto the aggregate 15 times, each being delivered at an interval of not less than one second.
- The crushed aggregate is removed from the cup and sieved on 2.36 mm. IS sieve until no further significant amount passes in one minute.
- The fraction passing the sieve is weighed to an accuracy of 0.1 g (W_B)

Calculations

The ratio of the weight of fines formed to the total sample weight in each test is to be expressed as a percentage, to the first decimal place.**Aggregate impact Value = (W_B / W_A) × 100**

- **W_B** weight in g of fraction passing through 2.36 mm ISSievs
- **W_A** weight in g of saturatedsurface - dry sample,
- Aggregate Impact Value 100

Conclusion / Result :

The aggregate Impact value of given sample of coarse aggregate is...............%

The aggregate impact value should not be more than 45 per cent for aggregate used for concrete other than for wearing surfaces, and 30 per cent for concrete used for wearing surfaces such a runways, roads and air field pavements

4.SPECIFIC GRAVITY AND WATER ABSORPTION

The specific gravity and water absorption of aggregates are important properties that are required for the design of concrete and bituminous mixes. The specific gravity of a solid is the ratio of its mass to that of an equal volume of distilled water at a specified temperature. Because the aggregates may contain water-permeable voids, so two measures of specific gravity of aggregates are used:

1. Apparent specific gravity and
2. Bulk specific gravity.

Apparent Specific Gravity, G_{app}, is computed on the basis of the net volume of aggregates i.e. the volume excluding water-permeable voids. Thus

$G_{app} = [(M_D/V_N)]/W$

Where,

- M_D is the dry mass of the aggregate,
- V_N is the net volume of the aggregates excluding the volume of the absorbed matter,
- W is the density of water.

Bulk Specific Gravity, G_{bulk}, is computed on the basis of the total volume of aggregates including water permeable voids. Thus

$G_{bulk} = [(M_D/V_B)]/W$

Where,

- V_B is the total volume of the aggregates including the volume of absorbed water.

Water Absorption: The difference between the apparent and bulk specific gravities is nothing but the water permeable voids of the aggregates. We can measure the volume of such voids by weighing the aggregates dry and in a saturated surface dry condition, with all permeable voids filled with water. The difference of the above two is M_W.

M_W is the weight of dry aggregates minus weight of aggregates saturated surface dry condition. Thus,

Water Absorption = $(M_W/M_D)*100$

The specific gravity of aggregates normally used in road construction ranges from about 2.5 to 2.9. Water absorption values ranges from 0.1 to about 2.0 percent for aggregates normally used in road surfacing.

Equipment and apparatus

- Wire basket
- Oven (3000c)
- Container for filling water and suspending the basket
- An air tight container
- Balance[0-10 kg]

Procedure

- Shallow tray & absorbent clothes. About 2kg of the aggregate sample is washed thoroughly to remove fines, drained and then placed in the wire basket and immersed in distilled water at a temperature between 22 to 32^{0}C with a cover of at least 50 mm of water above the top of the basket
- Immediately after the immersion the entrapped air is removed from the sample by lifting the basket containing it 25 mm above the base of the tank and allowing it to drop 25 times at the rate of about one drop per second.

The basket and the aggregate should remain completely immersed in water for a period of 24±0.5 hours afterwards.

- The basket and the sample are then weighed while suspended in water at a temperature of 22 to 32^{0}C. The weight is noted while suspended in water (W_1) g.
- The basket and the aggregate are then removed from water and allowed to drain for a few minutes, after which the aggregates are transferred to one of the dry absorbent clothes.
- The empty basket is then returned to the tank of water, jolted 25 times and weights in water (W_2) g.
- The aggregates placed in the dry absorbent clothes are surface dried till no further moisture could be removed by this clothe.
- Then the aggregate is transferred to the second dry cloth spread in a single layer, covered and allowed to dry for at least 10 minutes until the aggregates are completely surface dry. 10 to 60 minutes drying may be needed. The surface dried aggregate is then weighed W_3 g.
- The aggregate is placed in a shallow tray and kept in an oven maintained at a temperature of 110^{0}C for 24 hours. It is then removed from the oven, cooled in air tight container and weighed W_4 g.

CALCULATION

- Weight of saturated aggregate suspended in water with basket = W1 g
- Weight of basket suspended in water = W2 g
- Weight of saturated aggregate in water = (W1-W2)g = Ws g
- Weight of saturated surface dry aggregate in air = W4 g
- Weight of water equal to the volume of the aggregate = (W3-Ws) g
- Aggregate sp gravity 1
- Aggregate apparent sp gravity
- Aggregate water absorption 1

II. TEST ON CEMENT

1. Test on Consistency of Standard Cement Paste
2. Test on Setting Time of Standard Cement Paste
3. Test on Soundness of Cement by Le-Chatelier method
4. Test onFineness of Cement by dry sieving

1. Test on Consistency of Standard Cement Paste.

For finding out initial setting time, final setting time and soundness of cement, and strength a parameter known as standard consistency has to be used. The 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 the top of the mould.

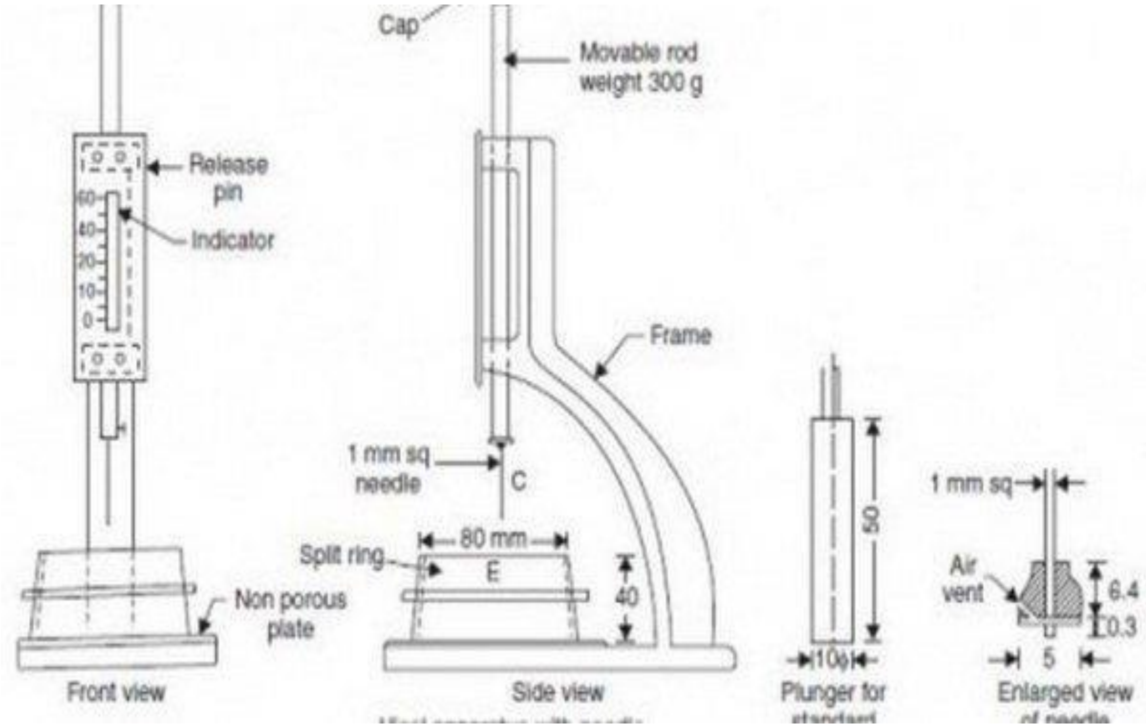
Apparatus:

- Vicat apparatus conforming to IS: 5513-1976.
- Balance.
- Gauging Trowel.
- Stop Watch, etc.

Procedure:

- The standard consistency of a cement paste is defined as that consistency which will permit the Vicate plunger to penetrate to a point 5 to 7 mm from the bottom of the Vicate mould.
- Initially a cement sample of about 300 g is taken in a tray and is mixed with a known percentage of water by weight of cement, say starting from 26% and then it is increased by every 2% until the normal consistency is achieved.
- Prepare a paste of 300 g of Cement with a weighed quantity of potable or distilled water, taking care that the time of gauging is not less than 3 minutes, or more than 5 min, and the gauging shall be completed before any sign of setting occurs. The gauging time shall be counted from the time of adding water to the dry cement until commencing to fill the mould.
- Fill the Vicat mould (E) with this paste, the mould resting upon a non-porous plate. After completely filling the mould, smoothen the surface of the paste, making it level with the top of the mould. The mould may be slightly shaken to expel the air.

- Place the test block in the mould, together with the non-porous resting plate, under the rod bearing the plunger; lower the plunger gently to touch the surface of the test block, and quickly release, allowing it to sink into the paste.
- This operation shall be carried out immediately after filling the mould.
- Prepare trial pastes with varying percentages of water and test as described above until the amount of Observation : Express the amount of water as a percentage by mass of the dry cement to the first place of decimal



Observation :

Sr. No.	Weight of cement (gms)	Percentage by water of dry Cement (%)	Amount of water added (ml)	Penetration (mm)
1.				
2.				
3.				

Conclusion / Result :

The normal consistency of a given sample of cement is ______%

2.Test On Setting Time of Standard Cement Paste.

For convenience, initial setting time is regarded as the time elapsed between the moments that the water is added to the cement, to the time that the paste starts losing its plasticity. The final setting time is the time elapsed between the moment the water is added to the cement, and the time when the paste has completely lost its plasticity and has attained sufficient firmness to resist certain definite pressure.

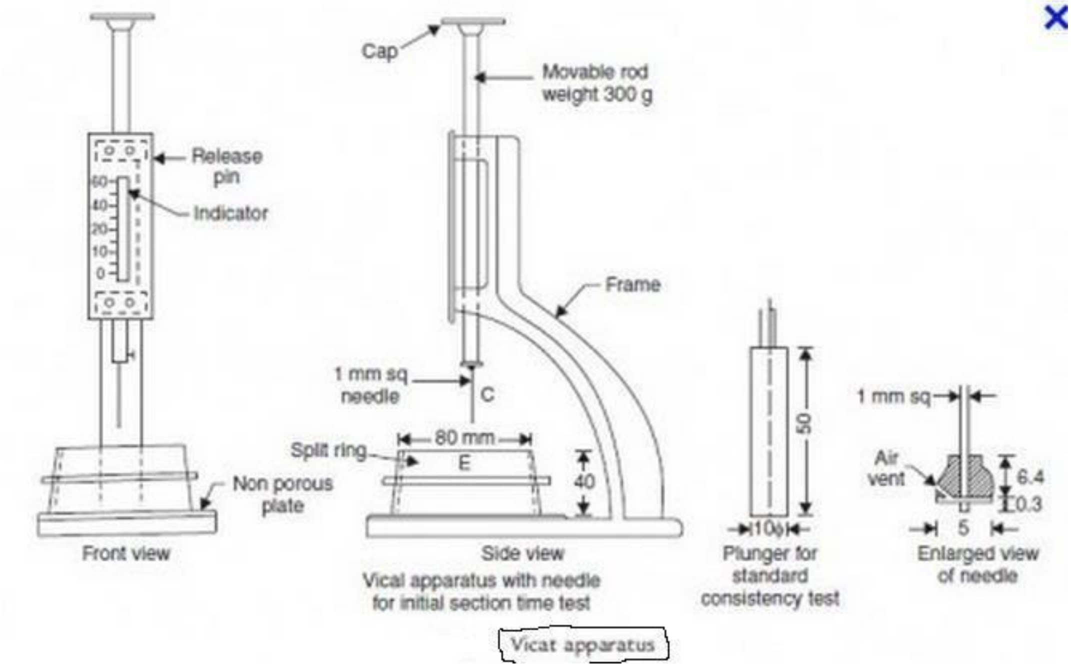
Apparatus :

- Vicat apparatus conforming to IS : 5513-1976.
- Balance.
- Gauging Trowel.
- Stop Watch, etc.

Procedure :

- Preparation of Test Block - Prepare a neat 300 gms cement paste by gauging the cement with 0.85 times the water required to give a paste of standard consistency. Potable or distilled water shall be used in preparing the paste.
- Start a stop-watch at the instant when water is added to the cement. Fill the Vicat mould with a cement paste gauged as above, the mould resting on a nonporous plate. Fill the mould completely and smooth off the surface of the paste making it level with the top of the mould.
- Immediately after moulding, place the test block in the moist closet or moist room and allow it to remain there except when determinations of time of setting are being made.
- **Determination of Initial Setting Time** - Place the test block confined in the mould and resting on the non-porous plate, under the rod bearing the needle (C); lower the needle gently until it comes in contact with the surface of the test block and quickly release, allowing it to penetrate into the test block
- Repeat this procedure until the needle, when brought in contact with the test block and released as described above, fails to pierce the block beyond 5.0 ± 0.5 mm measured from the bottom of the mould shall be the initial setting time.
- **Determination of Final Setting Time** - Replace the needle (C) of the Vicat apparatus by the needle with an annular attachment (F).
- The cement shall be considered as finally set when, upon applying the needle gently to the surface of the test block, the needle makes an impression thereon, while the attachment fails to do so.
- The period elapsing between the time when water is added to the cement and the time at which the needle makes an impression on the surface of

test block while the attachment fails to do so shall be the final setting time.



Observation :

1. Weight of given sample of cement is ______gms

2. The normal consistency of a given sample of cement is ______%

3. Volume of water addend (0.85 times the water required to give a paste of standard consistency) for preparation of test block _____ ml

Sr. No.	Setting Time (Sec)	Penetration (mm)	Remark
1.			
2.			
3.			

Conclusion / Result:

i) The initial setting time of the cement sample is found to be …..

ii) The final setting time of the cement sample is found to be …..

3.Test On Soundness of Cement by Le-Chatelier method

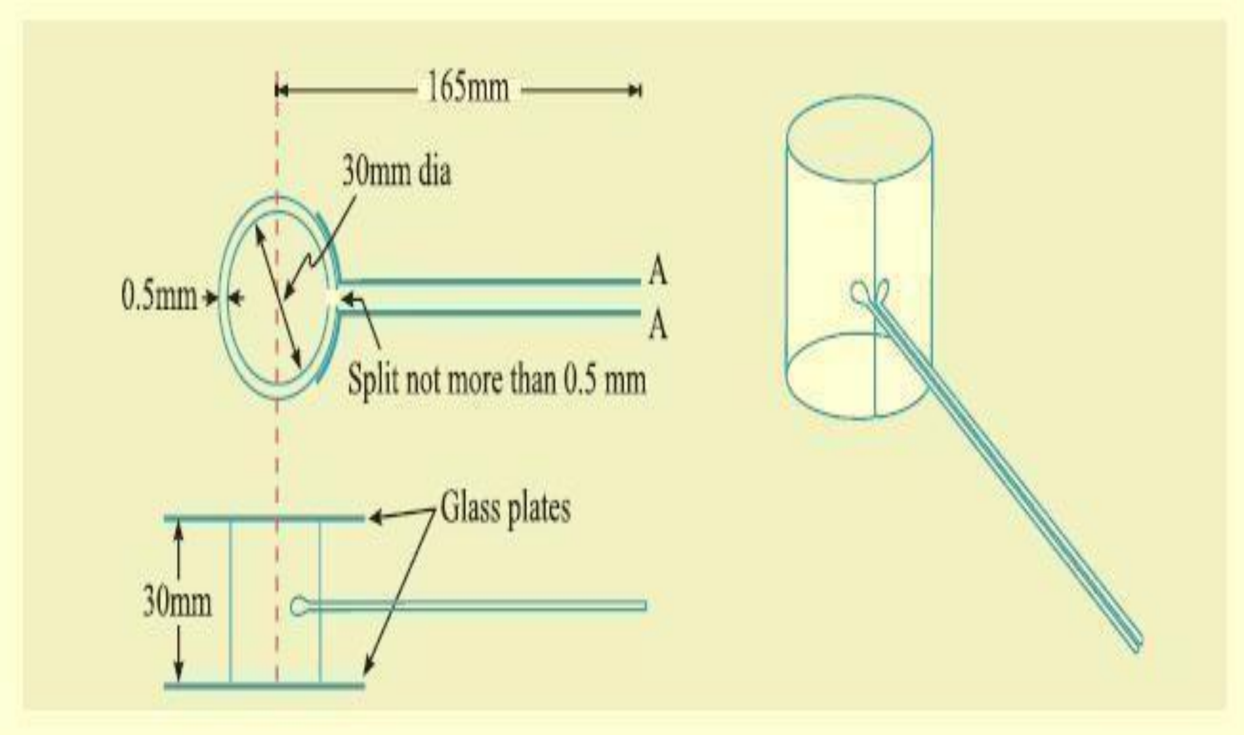
It is very important that the cement after setting shall not undergo any appreciable change of volume. Certain cements have been found to undergo a large expansion after setting causing disruption of the set and hardened mass. This will cause serious difficulties for the durability of structures when such cement is used. The unsoundness in cement is due to the presence of excess of lime than that could be combined with acidic oxide at the kiln. It is also likely that too high a proportion of magnesium content or calcium sulphate content may cause unsoundness in cement. Soundness of cement may be determined by two methods, namely Le-Chatelier method and autoclave method

Apparatus :

- Le- Chatelier test apparatus conform to IS : 5514-1969.
- Balance.
- Gauging Trowel.
- Water Bath etc.

Procedure:

- Place the lightly oiled mould on a lightly oiled glass sheet and fill it with cement paste formed by gauging cement with 0.78 times the water required to give a paste of standard consistency.
- The paste shall be gauged in the manner and under the conditions prescribed in experiment No.1, taking care to keep the edges of the mould gently together while this operation is being performed.
- Cover the mould with another piece of lightly oiled glass sheet, place a small weight on this covering glass sheet and immediately submerge the whole assembly in water at a temperature of 27 ± 2°C and keep there for 24 hours.
- Measure the distance separating the indicator points to the nearest 0.5 mm. Submerge the mould again in water at the temperature prescribed above.
- Bring the water to boiling, with the mould kept submerged, in 25 to 30 minutes, and keep it boiling for three hours. Remove the mould from the water, allow it to cool and measure the distance between the indicator points.
- The difference between these two measurements indicates the expansion of the cement. This must not exceed 10 mm for ordinary, rapid hardening and low heat Portland cements. If in case the expansion is more than 10 mm as tested above, the cement is said to be unsound.



Observation :

Express the amount of water as a percentage by mass of the dry cement to the first place of decimal.

Sr. No.	Distance separating the indicator submerge in normal temp water for 24 hours.	Distances separating the indicator submerge in boiling for three hours.	The difference between these two measurement	Remark
1.				
2.				
3.				

Conclusion / Result:

The given cement is said to be sound / unsound:………

4. Test on Fineness of Cement by dry sieving

The fineness of cement has an important bearing on the rate of hydration and hence on the rate of gain of strength and also on the rate of evolution of heat. Finer cement offers a greater surface area for hydration and hence faster the development of strength, (Fig. 3). The fineness of grinding has increased over the years.

But now it has got nearly stabilized. Different cements are ground to different fineness. The particle size fraction below 3 microns has been found to have the predominant effect on the strength at one day while 3-25 micron fraction has a major influence on the 28 days strength. Increase in fineness of cement is also found to increase the drying shrinkage of concrete.

Fineness of cement is tested in two ways:

(a) By sieving.

(b) By determination of specific surface (total surface area of all the particles in one gram of cement) byair-permeability apparatus. Generally Blaine Air permeability apparatus is used.Expressed as cm^2/gm or m^2/kg.

Apparatus :

- Test Sieve 90 microns.
- Balance.
- Gauging Trowel.
- Brush, etc.

Procedure :

- Fit the tray under the sieve, weigh approximately 10 g of cement to the nearest 0.01 g and place it on the sieve, being careful to avoid loss.
- Fit the lid over the sieve. Agitate the sieve by swirling, planetary and linear movement until no more fine material passes through it.
- Remove and weigh the residue. Express its mass as a percentage, R1, of the quantity first placed in the sieve to the nearest 0.1 percent. Gently brush all the fine material off the base of the sieve into the tray.
- Repeat the whole procedure using a fresh 10 g sample to obtain R2. Then calculate the residue of the cement R as the mean of R1, and R2, as a percentage, expressed to the nearest 0.1 percent.
- When the results differ by more than 1 percent absolute, carry out a third sieving and calculate the mean of the three values.

Conclusion / Result:

The fineness of a given sample of cement is _ _ _ _

III. TESTS ON FINE AGGREGATES

1.SURFACE MOISTURE CONTENT & ABSORPTION

Equipment for Specific Gravity Test of Soil

The major measuring equipment in this test is Pycnometer. This is a glass jar of 1 liter capacity that is fitted at its top by a conical cap made of brass. It has a screw type cover as shown in figure-1.

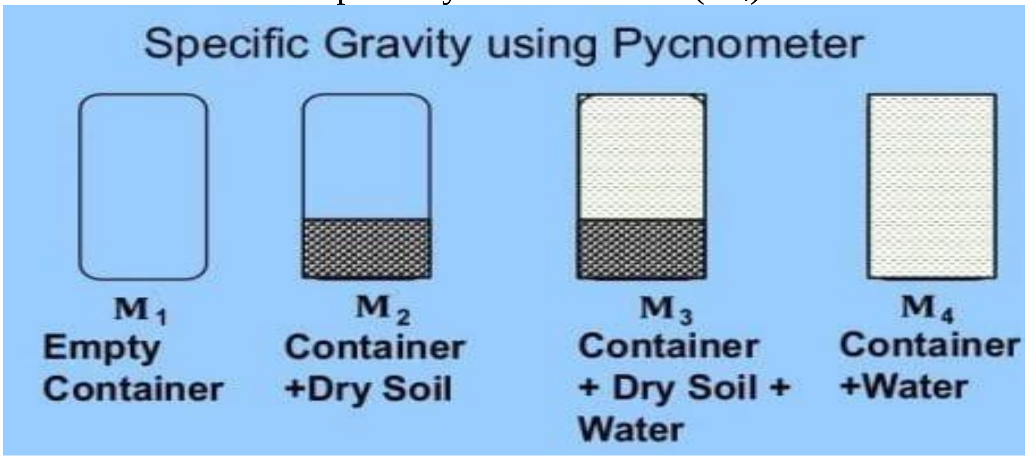
Mentioned below are the equipment and apparatus required to conduct the test for specific gravity of soil by pycnometer method.

1. Pycnometer of about 1 litre capacity
2. Weighing balance, with an accuracy of 1g.
3. Glass rod
4. Vacuum pump
5. Oven

Procedure for Specific Gravity of Soil by Pycnometer Method:

- Clean and dry the Pycnometer. Tightly screw its cap. Take its mass (M_1) to the nearest of 0.1 g.
- Mark the cap and Pycnometer with a vertical line parallel to the axis of the Pycnometer to ensure that the cap is screwed to the same mark each time.

- Unscrew the cap and place about 200 g of oven dried soil in the Pycnometer. Screw the cap. Determine the mass (M_2).
- Unscrew the cap and add sufficient amount of de-aired water to the Pycnometer so as to cover the soil. Screw on the cap.
- Shake well the contents. Connect the Pycnometer to a vacuum pump to remove the entrapped air, for about 20 minutes for fine-grained soils and about 10 minutes for coarse-grained soils.
- Disconnect the vacuum pump. Fill the Pycnometer with water, about three-fourths full. Reapply the vacuum for about 5min till air bubbles stop appearing on the surface of the water.
- Fill the Pycnometer with water completely upto the mark. Dry it from outside. Take its mass (M_3).
- Record the temperature of contents.
- Empty the Pycnometer. Clean it and wipe it dry.
- Fill the Pycnometer with water only. Screw on the cap upto the mark. Wipe it dry. Take its mass (M_4).



Observations and Calculations for Specific Gravity of Soil

The specific gravity of soil is determined using the relation:

$$G = \frac{M_2 - M_1}{(M_2 - M_1) - (M_3 - M_4)}$$

Where M_1=mass of empty Pycnometer,
M_2= mass of the Pycnometer with dry soil
M_3= mass of the Pycnometer and soil and water,
M_4 = mass of Pycnometer filled with water only.
G= Specific gravity of soils.

Observations and Calculations for Specific Gravity of Soil

Sl. No.	Observations an Calculations	Determination No.		
		1	2	3
Observation				
1	Pycnometer No.			
2	Room Temperature			
3	Mass of empty Pycnometer (M_1)			
4	Mass of Pycnometer and dry soil (M_2)			
5	Mass of Pycnometer, soil and water (M_3)			
6	Mass of Pycnometer and water (M_4)			
Calculations				
7	$M_2 – M_1$			
8	$M_3 – M_4$			
9	Calculate G using formula			

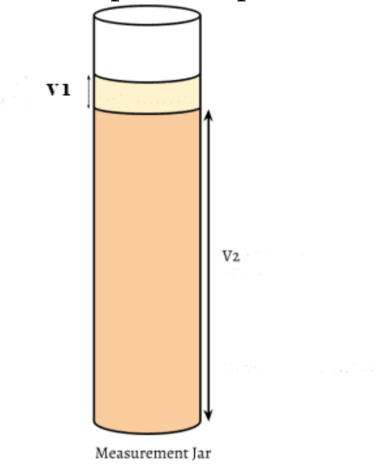
Results of Pycnometer Test
Specific gravity of soil at____^{0}C =______.

2.SILT CONTENT TEST FOR SAND

Apparatus
A measuring cylinder (250ml), Water, sand
Procedure for the Test

1. Firstly, a 50ml solution of 1% salt and water is prepared in the measuring cylinder. The addition of salt increases the settlement time of silt.

2. The sample of sand to be tested is then added to the cylinder until the level reaches 100ml.
3. 50ml of the solution of salt and water is again added to the measuring cylinder.
4. Close the open end of the measuring cylinder and shake it well.
5. After a period of 3-4 hours, you will notice a layer of silt settled over the sand.
6. Now note down the volume V1 of the silt layer settled over the sand.
7. Note down the volume V2 of the settled sand.
8. Repeat the procedure a couple more times to get the average.



Percentage of Silt Content = (V1/V2) x 100

V1–Volumeofsiltlayer
V2 – Volume of sand layer

Observation table

S.no	Description	Sample 1	Sample 2	Sample 3
1	Volume of sample Sand (V2)			
2	Volume of silt layer (V1)			
3	Percentage of silt			
	Average			

Result: The silt content in soil is______%

IV. TESTS ON HARDENED CONCRETE

1. Compressive Strength of Concrete

The compressive strength of the concrete cube test provides an idea about all the characteristics of concrete. By this single test one judge that whether Concreting has been done properly or not. Concrete compressive strength for general construction varies from 15 MPa (2200 psi) to 30 MPa (4400 psi) and higher in commercial and industrial structures.
Compressive strength of concrete depends on many factors such as water-cement ratio, cement strength, quality of concrete material, quality control during the production of concrete, etc.

Test for compressive strength is carried out either on a cube or cylinder. Various standard codes recommend a concrete cylinder or concrete cube as the standard specimen for the test.

Compressive Strength Definition
Compressive strength is the ability of material or structure to carry the loads on its surface without any crack or deflection. A material under compression tends to reduce the size, while in tension, size elongates.

Compressive Strength Formula
Compressive strength formula for any material is the load applied at the point of failure to the cross-section area of the face on which load was applied.

Compressive Strength = Load / Cross-sectional Area

Procedure: Compressive Strength Test of Concrete Cubes

For cube test two types of specimens either cubes of 15cm X 15cm X 15cm or 10cm X 10cm x 10cm depending upon the size of aggregate are used. For most of the works cubical molds of size 15cm x 15cm x 15cm are commonly used.

This concrete is poured in the mold and appropriately tempered so as not to have any voids. After 24 hours, molds are removed, and test specimens are put in water for curing. The top surface of this specimen should be made even and smooth. This is done by placing cement paste and spreading smoothly on the whole area of the specimen.

These specimens are tested by compression testing machine after seven days curing or 28 days curing. Load should be applied gradually at the rate of 140 kg/cm2 per minute till the Specimens fails. Load at the failure divided by area of specimen gives the compressive strength of concrete.

Following are the procedure for testing the Compressive strength of Concrete Cubes.

Apparatus for Concrete Cube Test:
Compression testing machine

Preparation of Concrete Cube Specimen:
The proportion and material for making these test specimens are from the same concrete used in the field.

Specimen:

9 cubes of 15 cm size Mix. M40

Mixing of Concrete for Cube Test:
Mix the concrete either by hand or in a laboratory batch mixer

Hand Mixing

- Mix the cement and fine aggregate on a watertight none-absorbent platform until the mixture is thoroughly blended and is of uniform color.
- Add the coarse aggregate and mix with cement and fine aggregate until the coarse aggregate is uniformly distributed throughout the batch.
- Add water and mix it until the concrete appears to be homogeneous and of the desired consistency.

Sampling of Cubes for Test

- Clean the mounds and apply oil.
- Fill the concrete in the molds in layers approximately 5 cm thick.
- Compact each layer with not less than 35 strokes per layer using a tamping rod (steel bar 16mm diameter and 60cm long, bullet-pointed at lower end).
- Level the top surface and smoothen it with a trowel

Curing of Cubes

The test specimens are stored in moist air for 24 hours and after this period the specimens are marked and removed from the molds and kept submerged in clear freshwater until taken out prior to the test.

Precautions for Tests

The water for curing should be tested every 7 days and the temperature of the water must be at 27+-2oC.

Procedure for Concrete Cube Test

- Remove the specimen from the water after specified curing time and wipe out excess water from the surface.
- Take the dimension of the specimen to the nearest 0.2m
- Clean the bearing surface of the testing machine
- Place the specimen in the machine in such a manner that the load shall be applied to the opposite sides of the cube cast.
- Align the specimen centrally on the base plate of the machine.
- Rotate the movable portion gently by hand so that it touches the top surface of the specimen.
- Apply the load gradually without shock and continuously at the rate of 140 kg/cm^2/minute till the specimen fails
- Record the maximum load and note any unusual features in the type of failure.

Note:

Minimum three specimens should be tested at each selected age. If the strength of any specimen varies by more than 15 percent of average strength, the results of such specimens should be rejected. The average of three specimens gives the crushing strength of concrete. The strength requirements of concrete.

Calculations of Compressive Strength

Size of the cube =15cmx15cmx15cm

Area of the specimen (calculated from the mean size of the specimen)=225 cm^2
Characteristic compressive strength(f ck)at 7 days =

Expected maximum load =fck x area x f.s

Range to be selected is …………………..

Similar calculation should be done for 28 day compressive strength

Maximum load applied =……….tones = ... N

Compressive strength = (Load in N/ Area in $mm^{2)}$=… .... N/mm^2

Reports of Cube Test

1. Identification mark
2. Date of test
3. Age of specimen
4. Curing conditions, including date of manufacture of specimen
5. Appearance of fractured faces of concrete and the type of fracture if they are unusual

Results of Concrete Cube Test
Average compressive strength of the concrete cube = ………….N/ mm^2 (at 7 days)
Average compressive strength of the concrete cube =………. N/mm^2 (at 28 days)

Compressive Strength of Concrete at Various Ages
The strength of concrete increases with age. The table shows the strength of concrete at different ages in comparison with the strength at 28 days after casting.

Age	**Strength percent**
1 day	16%
3 days	40%
7 days	65%

14 days	90%
28 days	99%

Compressive Strength of Different Grades of Concrete at 7 and 28 Days

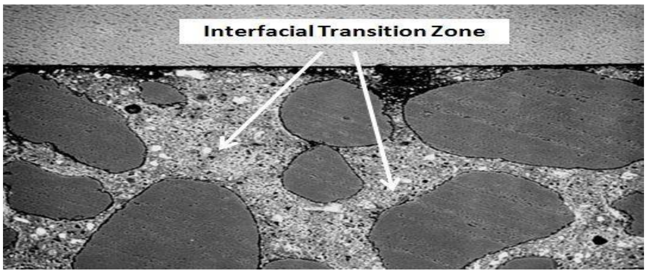
Grade of Concrete	Minimum compressive strength N/mm^2 at 7 days	Specified characteristic compressive strength (N/mm^2) at 28 days
M15	10	15
M20	13.5	20
M25	17	25
M30	20	30
M35	23.5	35
M40	27	40
M45	30	45

2.Split tensile strength of concrete

Tensile strength of concrete: The tensile strength of concrete is the ability of concrete to resist tensile force or stress applied to it.

The tensile strength of concrete is measured by the units of Force per Cross-Sectional area (N/Sq.mm. or Mpa).

Concrete is not a single solid material like steel which is strong in both tensions as well as compression. It is manufactured by mixing cementing materials, water and aggregate (and sometimes admixtures).



Interfacial Transition Zone

Interfacial Transition Zone:

The “interface transition zone” is the weakest link in the structure. When compressive stress or force applied on the zone, aggregate transfers the load from one to another. So, concrete in compression does not require much strength to resist compression stresses.

In the case of tensile stresses developed in concrete, the aggregates are trying to pull away from each other so this interfacial transition zone has to bear tensile stresses to holds the whole system together. Since the strength of this interface zone is weaker than the aggregates, so the failure starts at much lower stresses.

As per IS 456:2000 the tensile strength of concrete given by the equation.

$$f_{cr} = 0.7\sqrt{f_{ck}} \text{ in N/mm}^2$$

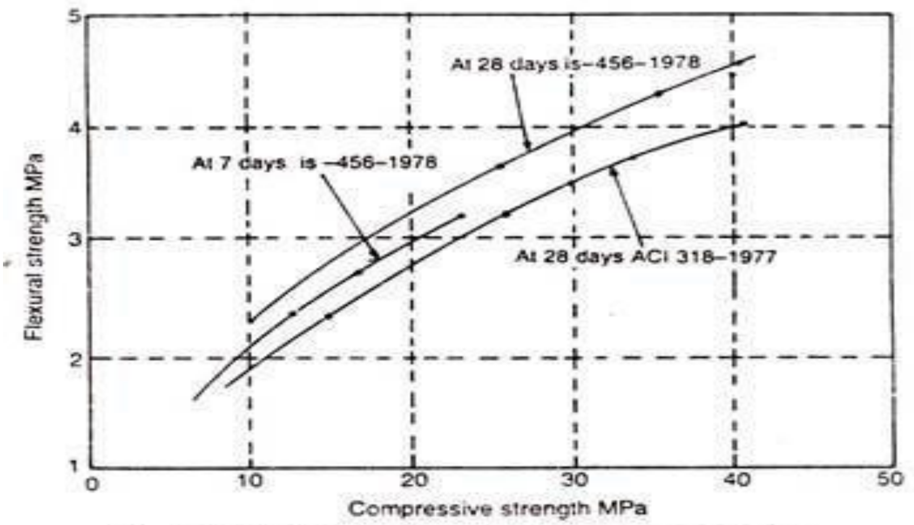


Fig. 13..5. Relation between flexural and compressive strength at various ages

The tensile strength of concrete under direct tension is roughly taken as one-tenth of the strength of concrete under compression.

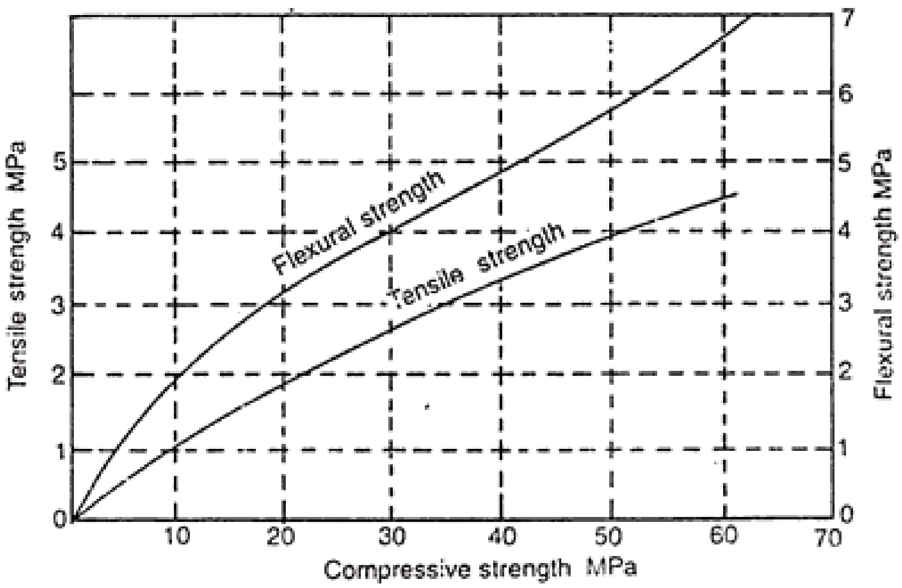


Fig. 13.6. Relation between flexural, compressive and tensile strength of concrete

Comparison of Strength gain

SPLITTING TENSILE STRENGTH OF CYLINDRICAL CONCRETE SPECIMENS

Age at Test – Tests shall be made at recognized ages of the test specimens, the most usual being 7 and 28 days. Where it may be necessary to obtain the early strengths, tests may be made at the ages of 24 hours ± ½ hour and 72 hours ± 2 hours. The ages shall be calculated from the time of the addition of water to the dry ingredients.

Number of Specimens – At least three specimens, preferably from different batches, shall be made for testing at each selected age.

Apparatus:

Testing Machine – The testing machine may be of any reliable type, of sufficient capacity for the tests and capable of applying the load at the rate specified in 5.5. The permissible error shall be not greater than ± 2 percent of the maximum load.

Cylinders –The cylindrical mould shall be of 150 mm diameter and 300 mm height conforming to IS: 10086-1982.

Weights and weighing device, Tools and containers for mi xing, Tamper (square in cross section) etc.

Procedure:

1.Sampling of materials

Samples of aggregates for each batch of concrete shall be of the desired grading and shall be in an air-dried condition. The cement samples, on arrival at the laboratory, shall be thoroughly mixed dry either by hand or in a suitable mixer in such a manner as to ensure the greatest possible blending and uniformity in the material.

2.Proportioning

The proportions of the materials, including water, in concrete mixes used for determining the suitability of the materials available, shall be similar in all respects to those to be employed in the work.

3.Weighing

The quantities of cement, each size of aggregate, and water for each batch shall be determined by weight, to an accuracy of 0.1 percent of the total weight of the batch.

4.Mixing Concrete

The concrete shall be mixed by hand, or preferably, in a laboratory batch mixer, in such a manner as to avoid loss of water or other materials. Each batch of concrete shall be of such a size as to leave about 10 percent excess after moulding the desired number of test specimens.

5.Mould

The cylindrical mould shall be of 150 mm diameter and 300 mm height conforming to IS: 10086-1982.

6.Compacting

The test specimens shall be made as soon as practicable after mixing, and in such a way as to produce full compaction of the concrete with neither segregation nor excessive laitance.

7.Curing

The test specimens shall be stored in a place, free from vibration, in moist air of at least 90 percent relative humidity and at a temperature of 27° ± 2°C for 24 hours ± ½ hour from the time of addition of water to the dry ingredients.

8.Placingthespecimeninthetesting machine

The bearing surfaces of the supporting and loading rollers shall be wiped clean, and any loose sand or other material removed from the surfaces of the specimen where they are to make contact with the rollers.

- Two bearings strips of nominal (1/8 in i.e 3.175 mm) thick plywood, free of imperfections, approximately (25 mm) wide, and of length equal to or slightly longer than that of the specimen should be provided for each specimen.
- The bearing strips are placed between the specimen and both upper and lower bearing blocks of the testing machine or between the specimen and the supplemental bars or plates.
- Draw diametric lines an each end of the specimen using a suitable device that will ensure that they are in the same axial plane. Centre one of the plywood strips along the centre of the lower bearing block.
- Place the specimen on the plywood strip and align so that the lines marked on the ends of the specimen are vertical and cantered over the plywood strip.
- Place a second plywood strip lengthwise on the cylinder, cantered on the lines marked on the ends of the cylinder. Apply the load continuously and without shock, at a constant rate within, the range of 689 to 1380 kPa/min splitting tensile stress until failure of the specimen
- Record the maximum applied load indicated by the testing machine at failure. Note the type of failure and appearance of fracture.

OBSERVATIONS:

Mix Proportion of Concrete	**For 1 m3 of concrete**	**For one batch of concrete**
Coarse aggregate (kg)		
Fine aggregate (kg)		
Cement (kg)		
Water (kg)		
S/A		
w/c ratio		
Admixture		

Sl NO	**Age of Specimen**	**Identification Mark**	**Dia of Specimen (mm)**	**Depth (mm)**	**Maximum Load (N)**	**Tensile Strength (MPa)**	**Avg Tensile Strength (Mpa)**
1							
2	**7 days**						
3							

4							
5	**28 days**						
6							

CALCULATION:

Calculate the splitting tensile strength of the specimen as follows:

T = 2P/πLD

Where

T = Splitting tensile strength

P = Maximum applied load

L = Length, m

D = Diameter

CONCLUSION:

1. i) The average 7 Days Tensile Strength of concrete sample is found to be…..…..
2. ii) The average 28 Days Tensile Strength of concrete sample is found to be…..…..

3.FLEXURAL STRENGTH OF CONCRETE

Flexural test evaluates the tensile strength of concrete indirectly. It tests the ability of unreinforced concrete beam or slab to withstand failure in bending.

The results of flexural test on concrete expressed as a modulus of rupture which denotes as (MR) in MPa or psi.
The flexural test on concrete can be conducted using either three point load test or center point load test. The configuration of each test is shown in Figure-2 and Figure-3, respectively. Test method described in this article is according to IS

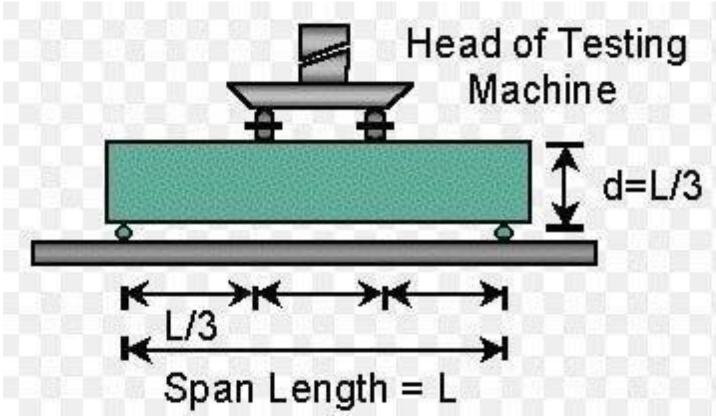


Fig.2: Three-Point Load Test

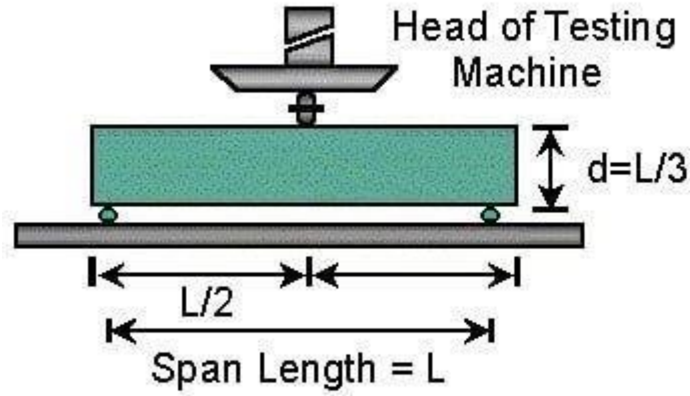


Fig.3: Center Point Load Test

It should be noticed that, the modulus of rupture value obtained by center point load test arrangement is smaller than three-point load test configuration by around 15 percent.

Moreover, it is observed that low modulus of rupture is achieved when larger size concrete specimen is considered.

Furthermore, modulus of rupture is about 10 to 15 percent of compressive strength of concrete. It is influenced by mixture proportions, size and coarse aggregate volume used for specimen construction.

Finally, the following equation can be used to compute modulus of rupture, but it must be determined through laboratory test if it is significant for the design:

$$f_r = 7.5\sqrt{f'_c} \rightarrow \text{Equation-1}$$

Where:
f_r: Modulus of rupture

f_c': concrete compressive strength

Fig.4: Flexural Test Machine and Concrete Specimen
Applications of Flexural Test on Concrete

Following are the applications of flexural test:

- Specifying compliance with standards
- It is an essential requirement for concrete mix design
- It is employed in testing concrete for slab and pavement construction

Factors Cause Variability in Flexural Test Results

- Concrete specimen preparation
- Specimen size
- Moisture condition of the concrete specimen
- Curing of the concrete specimen
- And whether the specimen is molded or sawed to the required size

Size of Concrete Specimen for Flexural Test

- According to IS the size of the specimen is 150mm width, 150mm depth and the length should not be at least three times the depth of the specimen.

- Indian standard determined the size of the concrete specimen as 150mm width, 150mm depth, and span of 700mm.
- It also states that a size of 100mm width, 100mm depth, and span of 500mm can be used if the maximum aggregate size used is not greater than 19mm.
- British standard specifies square specimen cross section with 100mm or 150mm dimension and the span ranges from four to five times specimen depth.
- However, it preferred 150mm width, 150mm depth, and span of 750mm for the specimen.

Apparatus for Flexural Test on Concrete

- Steel, iron cast, or other nonabsorbent material molds with size of (150mmX150mmX 750mm)
- Tamping rods: IS specify large rode (16mm diameter and 600mm long) and small rode (10mm diameter and 300mm long)
- Testing machine capable of applying loads at a uniform rate without interruption of shocks
- Scoop
- Trowel
- Balance with accuracy of 1g
- Power driven concrete mixer
- Table vibration in the case of using vibration to compact concrete in molds

Sample Preparation of Concrete

- Determine proportions of materials including cement, sand, aggregate and water.
- Mix the materials using either by hand or using suitable mixing machine in batches with size of 10 percent greater than molding test specimen.
- Measure the slump of each concrete batch after blending.
- Place molds on horizontal surface and lubricate inside surface with proper lubricant material and excessive lubrication should be prevented.
- Pour fresh concrete into the molds in three layers.
- Compact each layer with 16mm rode and apply 25 strokes for each layer or fill the mold completely and compact concrete using vibration table.

- Remove excess concrete from the top of the mold and smoothen it without imposing pressure on it.
- Cover top of specimens in the molds and store them in a temperature room for 24 hours.
- Remove the molds and moist cure specimens at 23+/-2 ^{o} C till the time of testing.
- The age of the test is 14 days and 28 days and three specimens for each test should be prepared (according to Indian Code, the specimen is stored in water at 24-30^{o}C for 48hours and then tested)

Procedure of Flexural Test on Concrete

- The test should be conducted on the specimen immediately after taken out of the curing condition so as to prevent surface drying which decline flexural strength.
- Place the specimen on the loading points. The hand finished surface of the specimen should not be in contact with loading points. This will ensure an acceptable contact between the specimen and loading points.
- Center the loading system in relation to the applied force.
- Bring the block applying force in contact with the specimen surface at the loading points.
- Applying loads between 2 to 6 percent of the computed ultimate load.
- Employing 0.10 mm and 0.38 mm leaf-type feeler gages, specify whether any space between the specimen and the load-applying or support blocks is greater or less than each of the gages over a length of 25 mm or more.
- Eliminate any gap greater than 0.10mm using leather shims (6.4mm thick and 25 to 50mm long) and it should extend the full width of the specimen.
- Capping or grinding should be considered to remove gaps in excess of 0.38mm.
- Load the specimen continuously without shock till the point of failure at a constant rate (Indian standard specified loading rate of 400 Kg/min for 150mm specimen and 180kg/min for 100mm specimen, stress increase rate 0.06+/-0.04N/mm^2.s according to British standard).
- The loading rate as per ASTM standard can be computed based on the following equation:

$$r = \frac{Sbd^2}{L} \quad \rightarrow \text{Equation-2}$$

Where:
r: loading rate
S: rate of increase of extreme fiber
b: average specimen width
d: average specimen depth
L: span length

- Finally, measure the cross section of the tested specimen at each end and at center to calculate average depth and height.

Computation of Modulus of Rupture
The following expression is used for estimation of modulus of rupture:

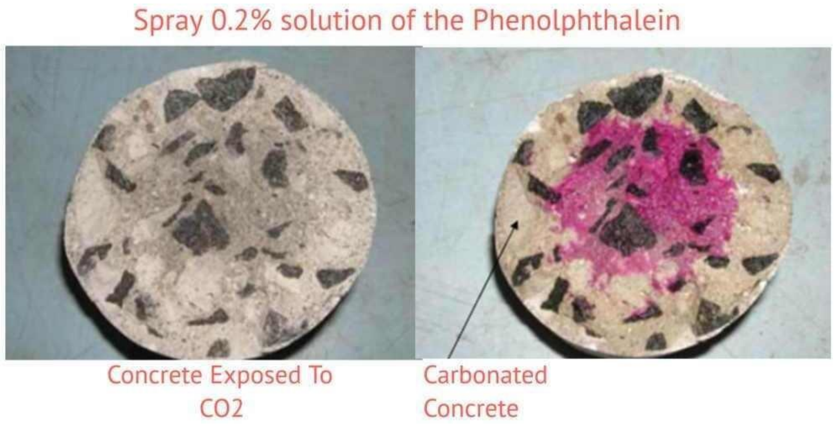
$$MR = \frac{3PL}{2bd^2} \rightarrow \text{Equation-3}$$

Where:
MR: modulus of rupture
P: ultimate applied load indicated by testing machine
L: span length
b: average width of the specimen at the fracture
d: average depth of the specimen at the fracture

3.DURABILITY TESTS ON HARDENED CONCRETE

Concrete Carbonation Test for Structure Analysis

Concrete chemistry is obviously tough to understand for a small house owner. Spending some amount towards concrete carbonation test is an excellent idea to know the effect of the atmospheric CO_2 on the RCC structure. The concrete carbonation test for in-situ concrete is associated with the corrosion of reinforcement steel. Due to the concrete carbonation, reinforcement corrosion often occurs on the building facades which are exposed to moisture, rainfall and shaded from sunlight. The steel corrosion in concrete also occurs due to the carbonation, when the concrete has a least cover over the steel reinforcementConcrete is basically alkaline in nature having pH more than 12.6. It is due to its alkalinity that the cover of concrete protects reinforcement from corrosion. Due to concrete carbonation, its alkalinity reduces and having a way for the corrosion. The corrosion leads to an expansion in volume of film over steel bar. This expansion in volume create cracks in concrete. This cracks further invite CO_2. Thus the vicious cycle continues and ultimately leading structure in a disaster state.



Concrete Carbonation occurs when the atmospheric carbon dioxide (CO_2) reacts with hydrated cement minerals ($CaOH_2$). CO_2 react in the presence of moisture with $CaOH_2$ and produce carbonates ($CaCO_3$). Carbonates slowly penetrate below the exposed surface of the concrete. Thus the carbonation affects the concrete cover over the reinforcing steel. Hence steel corrosion occurs due to the process of concrete carbonation. The concrete loses its durability, and finally, it cracks due to the expansion of film over the bar. At the same time, the rate of steel corrosion is at the highest level. The concrete carbonation process is also called Concrete depassivation.

Factor Affecting Concrete Carbonation Process:
The concrete carbonation is a slow process. The concrete carbonation highly depends on humidity, temperature and atmospheric carbon dioxide CO_2.

1. Relative Humidity:
The Carbonation of concrete occurs when the level of humidity in the atmosphere is ideally between 50 to 70%.

If humidity is below the normal level (<50%) then there is not enough water vapour present in the atmosphere. Hence CO_2 cannot dissolve.

Furthermore, if humidity is higher (>70%), more water vapour (atmospheric moisture) is present in the atmosphere. Hence pores of the concrete are filled with water and CO_2 cannot enter into the concrete. Ultimately no CO_2 diffusion takes place.

The most dangerous level of humidity for carbonation is 50 to 70% at which CO_2 react with calcium hydroxide ($CaOH_2$) and generate more carbonates. The generation of carbonates in concrete is called the process of carbonation. Ultimately, carbonation process reduces the level of the concrete pH from 13 to 9.

2. Temperature:
The carbonation is worse in hot environments.

3. Atmospheric CO_2:
The concentration of CO_2 gas in the atmosphere is about 0.04% (400 ppm) by volume of the atmosphere, but it is increasing annually due to motor vehicles and fossil fuel burning in cities. Which is also known as “Green House Effect”.

The Procedure of Concrete Carbonation Test:
When the steel is surrounded by concrete layer, Hydrated cement provides an alkaline environment at which concrete pH is around 12.6. It helps steel to form the passive film on the surface of the steel. The passive film protects the reinforcement steel from the corrosion. Thus concrete cover provides protection to the steel.

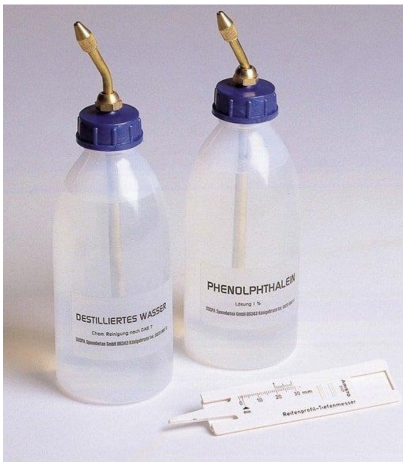
The attack of the atmospheric CO_2 reduces the alkalinity in the concrete. The concrete porosity allows the CO_2 to react with the alkalis like calcium, sodium and potassium hydroxides which are formed due to cement hydration in concrete. The reaction produces the carbonates which reduce the level of concrete pH. When carbonates ingress deeply in concrete, they also break the protective passive film of the steel. So the oxygen and moisture are easily available to steel, and it gets corroded. Hence we need to perform the carbonation test to determine the level or degree of carbonation to evaluate the rate of corrosion.

Two Method Measure the Level of Concrete Carbonation:

1. IR Spectrum Analysis for Concrete Carbonation:
IR spectrum method measures the concentration of CO_2 absorbed by the concrete specimen. This method of testing is not much attractive for chemical testing of concrete.

The IR spectrum method set up consists of a closed loop in which a mixture of air and carbon dioxide could be introduced at certain relative humidity. The pump circulates the mixture of air and CO_2. The concentration of CO_2 is reduced in gas mixture due to the carbonation reaction. The concentration of Co_2 in gas is measured by using IR absorption device. The relative humidity and temperature is also recorded.

2. pH Indicator Analysis for Concrete Carbonation:

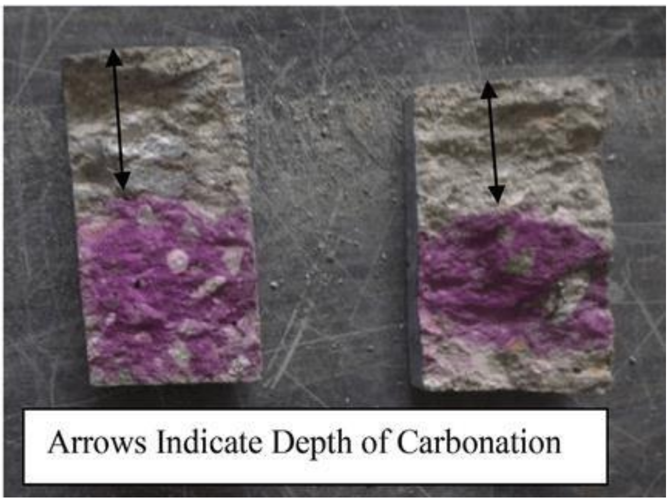


The pH indicator method is a very popular method for chemical testing of concrete. A spray of 0.2% solution of phenolphthalein chemical is done on the surface of the concrete to find the area affected by the carbonation. Phenolphthalein solution indicates the change of pH level in the concrete. If the concrete changes its grey colour to pink, it means that the concrete is in good condition. When there is no change in colour of concrete, it means that the area is affected by carbonation.

The carbonation test is performed by extracting the cores of in-situ concrete. The carbonation test is also performed by drilling a hole on the concrete surface to the different depth up to concrete cover. Remove the dust by brush and Blow the air to clean the hole.

Spray 0.2% solution of the phenolphthalein with physician's injection syringe or needle on such freshly drilled/broken concrete and observe the change in colour. Measure the depth of uncoloured layer (carbonated layer) in millimetres from the external surface at 4 to 8 positions. Take the average of measurement.

The Depth of Concrete Carbonation:



The Depth of concrete carbonation is estimated by the change in colour profile, and the degree of carbonation that can be measured in millimetre. The depth of carbonation is proportional to the square root of time. I.e, if the depth of carbonation is 1 millimetre in one-year-old concrete, it will be 3mm after 9 years, 5mm after 25 years and 10mm after 100 years.

We can also determine the pH value by analyzing the sample of core powder collected by drilling from the site. It is determined by dissolving the powder sample in distilled water and thereafter titration in the laboratory.

The phenolphthalein method for concrete carbonation test is a simple and cheap method. It easily determines the depth of carbonation in concrete. It also helps to decide about the information on the risk of reinforcement corrosion. The only limitation is the minor amount of damage done to the concrete surface by drilling a core.

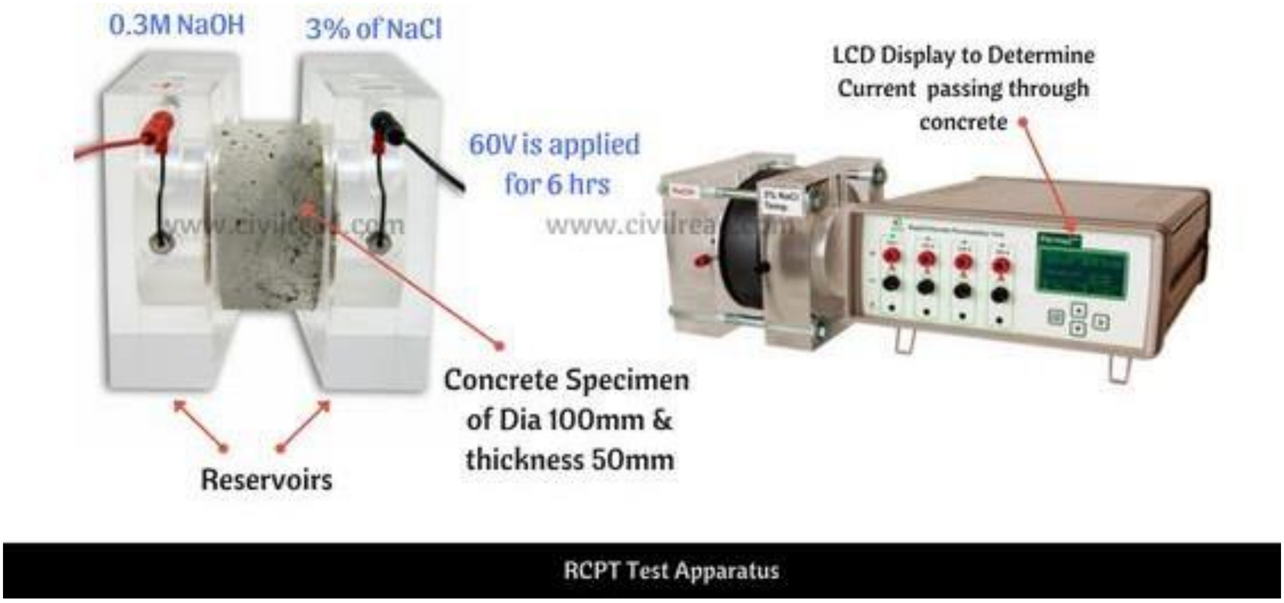
In concrete carbonation test, the depth of carbonation is also confirmed with microscopy either optical microscopy using the thin concrete section or scanning electron microscopy using polished concrete section. The carbonation test is very useful to make an initial assessment of reinforced concrete structures. Carbonation test is quick, easy and used in the current scenario for the carbonation affected in-situ concrete.

Rapid Chloride Permeability test

- For Specifications and the quality control purposes on site, we prefer a test that is simple to conduct and that can be performed in a short time. The rapid chloride permeability test [RCPT} meets these goals.
- Rapid Chloride Permeability test is covered by **AASHTO T 277 or ASTM C 1202** it is the test for chloride ions**.** As the name itself proves that, this test is performed to check the **Concrete's Ability to Resist Chloride Ion Penetration.**
- This test is an Electrical Indication of Concrete's Ability to Resist Chloride Ion Penetration. This test enables to predict the service life of concrete structures. It can also be used for durability-based quality control purposes.
- In this test, the constant voltage (V) is applied on a concrete specimen for 6 hours and the current (i) passing through the concrete is recorded to find the coulombs.

Apparatus:

- This test is made possible by an equipment which is known as Rapid Chloride Permeability test equipment, The test equipment consists of two reservoirs. One of them has 3.0% of NaCl solution and another reservoir has 0.3M NaOH Solution, Concrete having thickness 50mm and dia 90-100mm is used as a test specimen.



Chloride test procedure:

1. The concrete specimen having dia 100mm and thickness 50mm is cast and saturated.
2. The concrete sample is placed in between the two reservoirs (which is called as a single cell) having NaCl solution in one reservoir and NaOH solution in the other.
3. These reservoirs are connected to DC supply and the voltage of 60V is applied to the concrete specimen at both the ends for 6 hours.
4. Now measure the current passing through the concrete at different time intervals.
5. The current passing through the concrete is determined by an LCD which is connected to the cell.

Formula of RCPT Test

$$Q = 900\,[I_0 + 2I_{30} + 2I_{60} + 2I_{90} + 2I_{120} + \ldots\ldots + 2I_{330} + 2I_{360}$$

$Q \longrightarrow$ Current flowing through one cell (coulombs)

$I_0 \longrightarrow$ Initial Current reading in amperes immediately after voltage is applied

$I_t \longrightarrow$ Current reading in amperes at t minutes after the voltage is applied

For determining the accurate concrete permeability 2-3 samples are taken from same batch of concrete mix and measured as mentioned, the average value is taken as a final reading. Permeameter can have 2-3 cells with separate LCD digital meter to determine 2-3 samples at a time.

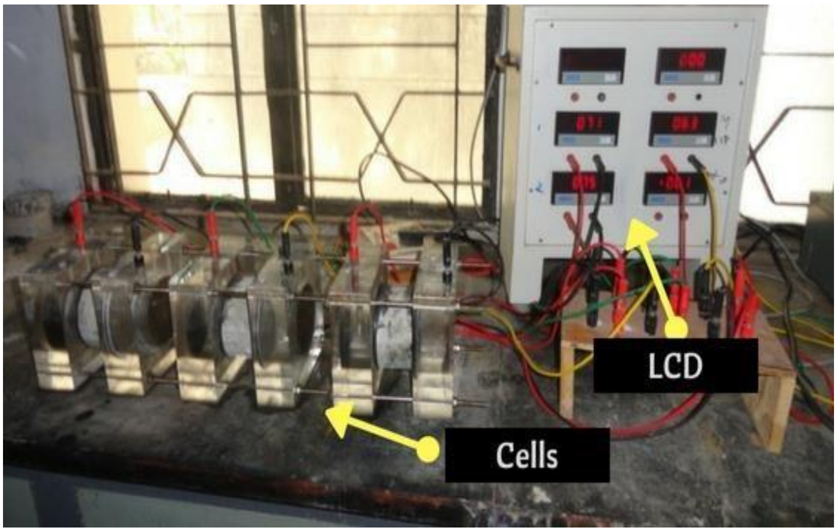


Table to interpret RCPT test Results:

The total charge passed is determined by the above mentioned formula and used to rate the concrete according to the below criteria.

Charge (Coulombs)	Chloride Permeability
>4000	High Permeable Concrete
2000 – 4000	Moderate
1000 – 2000	Low
100 – 1000	Very Low
<100	Negligible

CHAPTER 05

DESIGN OF RIGID PAVEMENTS AS PER IRC STANDARDS

Rigid pavement design. As the name implies, **rigid pavements** are **rigid** i.e, they do not flex much under loading like flexible **pavements**. They are constructed using cement concrete. In this case, the load carrying capacity is mainly due to the rigidity ad high modulus of elasticity of the slab (slab action).

H. M. Westergaard is considered the pioneer in providing the rational treatment of the rigid pavement analysis.

Design of **rigid pavements** is based on Westergaard's analysis, where modulus of subgrade reaction, radius of relative stiffness, radius of wheel load distribution are used. For critical **design**, a combination of load stress, frictional stress and warping stress is considered.

IRC: SP: 62-2004 Guidelines for the **Design** and Construction of Cement **concrete Pavements** for Rural Roads.

Modulus of sub-grade reaction

Westergaard considered the rigid pavement slab as a thin elastic plate resting on soil sub-grade, which is assumed as a dense liquid. The upward reaction is assumed to be proportional to the deflection. Base on this assumption, Westergaard defined a modulus of sub-grade reaction K in kg/cm3 given by K = p Δ where Δ is the displacement level taken as 0.125 cm and p is the pressure sustained by the rigid plate of 75 cm diameter at a deflection of 0.125 cm.

Relative stiffness of slab to sub-grade

A certain degree of resistance to slab deflection is offered by the sub-grade. The sub-grade deformation is same as the slab deflection. Hence the slab deflection is direct measurement of the magnitude of the sub-grade pressure. This pressure deformation characteristics of rigid pavement lead Westergaard to the define the term radius of relative stiffness l in cm is given by the equation .

l = 4 s Eh3 12K(1−μ2)

where ,E is the modulus of elasticity of cement concrete in kg/cm2 (3.0×105),

μ is the Poisson’s ratio of concrete (0.15),

h is the slab thickness in cm and

K is the modulus of sub-grade reaction.

Critical load positions

Since the pavement slab has finite length and width, either the character or the intensity of maximum stress induced by the application of a given traffic load is dependent on the location of the load on the pavement surface. There are three typical locations namely the interior, edge and corner, where differing conditions of slab continuity exist. These locations are termed as critical load positions.

Equivalent radius of resisting section

When the interior point is loaded, only a small area of the pavement is resisting the bending moment of the plate. Westergaard's gives a relation for equivalent radius of the resisting section in cm in the equation 29.2. $b = (\sqrt{1.6a^2 + h^2} - 0.675 h$ if $a < 1.724 h$ a otherwise .

Where, a is the radius of the wheel load distribution in cm and

h is the slab thickness in cm.

Wheel load stresses - Westergaard's stress equation

The cement concrete slab is assumed to be homogeneous and to have uniform elastic properties with vertical sub-grade reaction being proportional to the deflection. Westergaard developed relationships for the stress at interior, edge and corner regions, denoted as σ_i, σ_e, σ_c in kg/cm^2 respectively.

$$\sigma_i = 0.316\, P\, h^2\, [4 \log_{10}(l/b) + 1.069]$$

$$\sigma_e = 0.572\, P\, h^2\, [4 \log_{10}(l/b) + 0.359]$$

$$\sigma_c = 3\, P\, h^2\, [1 - a\sqrt{2}\, l\, !0.6]$$

where ,h is the slab thickness in cm,

P is the wheel load in kg,

a is the radius of the wheel load distribution in cm,

l the radius of the relative stiffness in cm and

b is the radius of the resisting section in cm

Temperature stresses

Temperature stresses are developed in cement concrete pavement due to variation in slab temperature. This is caused by (i) daily variation resulting in a temperature gradient across the thickness of the slab and (ii) seasonal variation resulting in overall change in the slab temperature. The former results in warping stresses and the later in frictional stresses.

Warping stress

The warping stress at the interior, edge and corner regions, denoted as σ_{ti}, σ_{te}, σ_{tc} in kg/cm^2 respectively and given by the equation.

$$\sigma_{ti} = E€t/2\, [C_x + \mu C_y / 1 - \mu^2]$$

$$\sigma_{te} = \text{Max}\, [C_x E€t/2\, ,\, C_y E€t/2]$$

$$\sigma_{tc} = E€t / 3(1-\mu)\, ra\, l$$

where E is the modulus of elasticity of concrete in kg/cm^2 (3×10^5),

€ is the thermal coefficient of concrete per °C (1×10^{-7}) t is the temperature difference between the top and bottom of the slab,

C_x and C_y are the coefficient based on L_x/l in the desired direction and L_y/l right angle to the desired direction,

μ is the Poisson's ration (0.15),

a is the radius of the contact area and l is the radius of the relative stiffness.

Frictional stresses

The frictional stress σf in kg/cm2 is given by the equation

σf =(WLf /2)×104

where W is the unit weight of concrete in kg/cm2 (2400),

f is the coefficient of sub grade friction (1.5) and

L is the length of the slab in meters.

Combination of stresses

The cumulative effect of the different stress give rise to the following thee critical cases

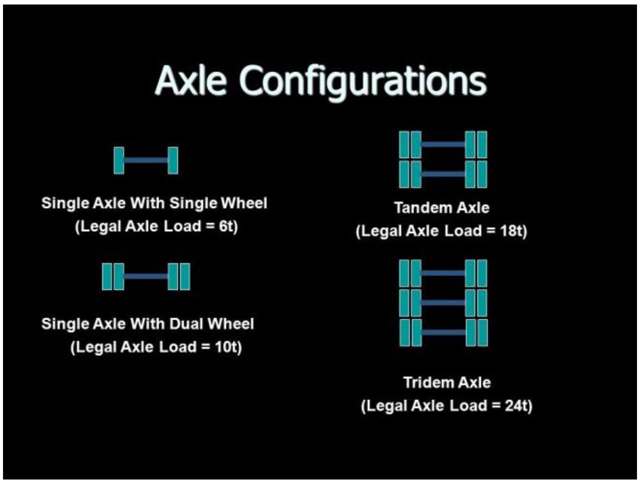
- Summer, mid-day: The critical stress is for edge region given by σcritical = σe + σte −σf
- Winter, mid-day: The critical combination of stress is for the edge region given by σcritical = σe +σte +σf
- Mid-nights: The critical combination of stress is for the corner region given by σcritical = σc + σtc.

Design of Rigid Pavement:

I. Design of CC pavement by IRC: 58-2002 for single axle and Tandem axle load.

ESAL is the acronym for equivalent **single axle load**. ESAL is a concept developed from data collected at the American Association of State Highway Officials (AASHO) Road Test to establish a damage relationship for comparing the effects of **axles** carrying different **loads**

"**Tandem axles**" **means** any two or more consecutive **axles** that have centers more than 40 inches but not more than 96 inches apart . Are individually attached to or articulated from, or both, a common attachment to the vehicle.



Design procedure :

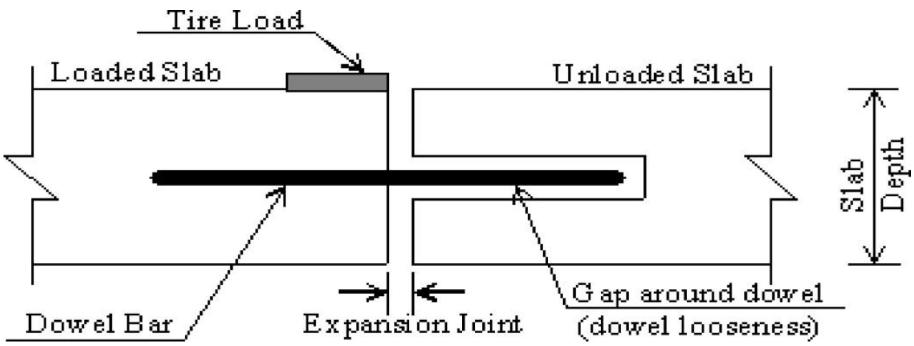
Step 1 : Stipulate design values for various parameters.
Step 2 : Decidetypes and spacing between joints.
Step 3 : Select a trial design thickness of pavement slabs.
Step 4 : Compote the repetitions of the axle loads of different magnitudes during design periods.
Step 5 : Calculate the stresses due to single and tandem axle loads and determine thecumulative fatigue damage (CFD)
Step 6 : If the CFD is more than 1.0,select a higher thicknessand repeat the steps 1 to 5.
Step 7 : Compute the temperature stress at the edge and if the sum of the temperature stress and the flexural stress due to the highest wheel load is greater than the modulus of rupture, select a higher thicknesss and repeat the steps 1 to 6.
Step 8 : Design the pavement thickness on the basis of corner stress if no dowel bars are provided and there is no load transfer ue to lack of aggregate inter-lock.

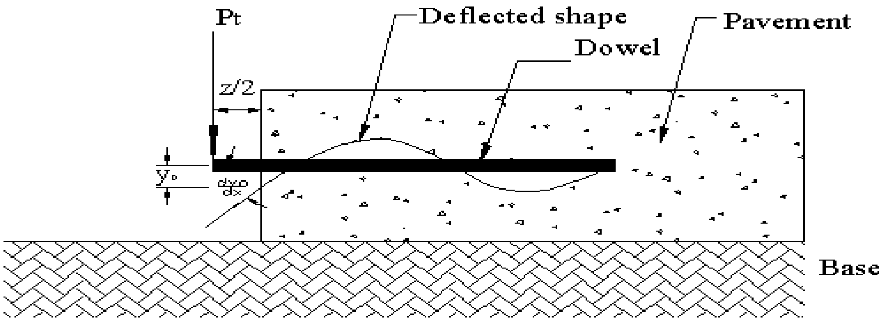
II. Design of Dowel bars.

Objectives and functioning of dowel bars

Joints are essential to relieve compressive stresses during expansion and also prevents the bucking of the slab near the joint.

Mainly made of steel bars Coated with zinc or lead based paint or epoxy coating Diameter - 25 to 32 mm Length – 500 mm Intervals – 250 to 300 mm About 50 mm less than half the length of the dowel bar are embedded in concrete along one slab whereas, the other half plus 50 mm is covered with a suitable plastic sheathing to prevent the development of bond between dowel bars and concrete.





Stresses in dowel bars

Bearing stress developed between dowel bar and concrete plays a crucial role Maximum bearing stress, , σmax

$\sigma max =$ ᅯ $k\ Pt\ (2 +\ )/4\beta 3EI$

$\beta = 4$ sqrt($kb\ 4EI$)

Where,

k – modulus of dowel-concrete interaction or dowel support, 41,500 kg/cm2

Pt – maximum load transferred by a dowel bar or load transferred by the first dowel bar from the edge, kg

b – diameter of dowel bar

z – joint width, cm

β – relative stiffness of dowel bar embedded in concrete, cm

E- modulus of elasticity of steel, 2×106 kg/cm2

I – moment of inertia of steel bar, cm4

Bearing stress developed between dowel bar and concrete plays a crucial role Maximum bearing stress, σmax

$\sigma max =$ ᅯ $k\ Pt\ (2 + \beta z\ 4\beta 3EI$

$\beta = 4$sqrt($kb\ /4EI$)

Allowable bearing stress, Fb

$Fb = (10.16 - b) \times fck\ /9.525$

Where,

k – modulus of dowel-concrete interaction or dowel support, 41,500 kg/cm2 Pt – maximum load transferred by a dowel bar or load transferred by the first dowel bar from the edge, kg

b – diameter of dowel bar

z – joint width, cm

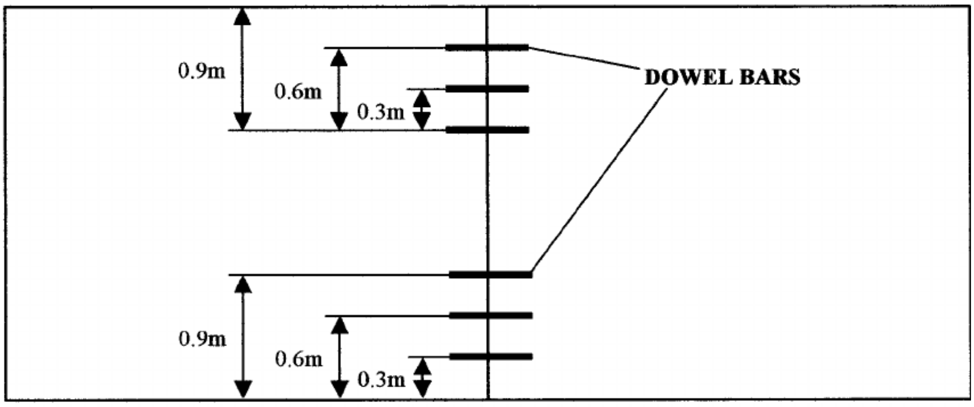
β – relative stiffness of dowel bar embedded in concrete, cm E- modulus of elasticity of steel, 2×106 kg/cm2

I – moment of inertia of steel bar, cm4

fck – ultimate compressive strength of concrete, kg/cm2, 400 kg/cm2

Design principle

Dowel bar system should transfer 40% of the design wheel load.Important factor governing its design is bearing stress First dowel bar is placed at 15 cm from edge Critical position is when the load is placed directly above the bar Bars next to dowel bar also will share the load, but carry lesser magnitudes of load Load transfer is in terms of linear variation Maximum distance upto which dowel group can carry part of load = 1.8l



Design of Dowel bars:

In order to design the length and diameter of the dowel bar we have to check its failure under the action of wheel load on the pavement slab. Failure may occur in three ways:

1. Failure of the dowel in shear
2. Failure of dowel bar in flexure
3. Failure of concrete in bearing.

Steps :

According to Indian roads congress(IRC) are used to find the load capacity of the dowel under shear, flexure and that of concrete in bearing.

For shear in the bar, $P' = 0.785\, d^2 F_s$

For bending in the bar, $P' = \dfrac{2 d^3 F_f}{L_d + 8.8\,\delta}$

For bearing on concrete, $P' = \dfrac{F_b L_d^2 . d}{12.5 (L_d + 1.5\,\delta)}$

where, P' = load transfer capacity of a single dowel bar, kg

d = diameter of dowel bar, cm

L_d = total length of embedment of dowel bar, cm

δ = joint width, cm

F_s = permissible shear stress in dowel bar, kg/cm^2

Generally the thickness of the expansion joint and diameter of the dowel bars are fixed. We first find out the length of the bar by equating the second formula with the third formula assuming that the load capacity of the concrete in bearing is equal to the flexure capacity of the dowel bar. The formula is given below in image, length has to be found by trial and error method.

$$L_d = 5d\left[\frac{F_f}{F_b} \times \frac{L_d + 1.5\delta}{L_d + 8.8\delta}\right]^{\frac{1}{2}}$$

Then use that length to find out the three load capacities corresponding the these three formulas.

The lesser of the three will be the capacity of the dowel bar because, failure at any case is the failure of the pavement system.

It is assumed that the wheel load is transferred to a distance of 1.8.l from the application of the load.

The capacity factor of the dowel system is defined as the ratio of the load capacity of the dowel system to the load capacity of the single dowel bar.

We must check the dowel system to be sufficient to provide the corresponding load factor and that will decide the spacing of the dowel bars and therefor the numbers of dowels required.

III. Design of tie bars

- Provided along the longitudinal joints .
- Purpose is mainly to hold the slabs in position.
- Prevent opening of joint.
- Act as hinges and relieve part of warping stresses in rigid pavements
- Do not transfer any load
- Designed to withstand tensile stresses, tensile force being equal to the force between the bottom of the slab and the base course.

Area of cross section of steel tie bars,

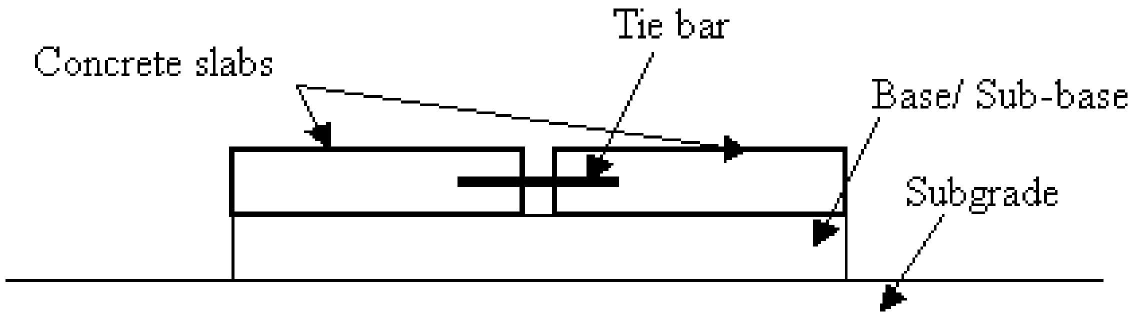
As Weight per m length of the slab = $\boldsymbol{b} \times \boldsymbol{h}\ \mathbf{100} \times \mathbf{1} \times \boldsymbol{W}$

Frictional force developed= $\boldsymbol{b} \times \boldsymbol{h}\ \mathbf{100} \times \boldsymbol{W} \times \boldsymbol{f} = \boldsymbol{As} \times \boldsymbol{Ss}$

or

As =$\boldsymbol{bhWf}\ /\mathbf{100}\boldsymbol{Ss}$

Allowable working stress in steel is taken as 1250 kg/cm2



Length of steel tie bars, As

Bond strength developed along the periphery of the slab should be equal to or more than the tensile force developed in the bar.

Let Lt be the length of the tie bar

Embedded peripheral area = $\pi d \times Lt/2$

Bond force developed = $Sb \times \pi d \times Lt/2$

Tensile force developed = $Ss \times \pi d2/4$

$Sb \times \pi d \times Lt/2 = Ss \times \pi d2/4$

$or\ Lt = Ss\ Sb \times d/2$

Recommended values:

Allowable tensile stress in plain tie bar, Ss = 1250 kg/cm2

Allowable tensile stress in deformed tie bar,Ss = 2000 kg/cm2

Allowable bond stress in plain bars = 17.5 kg/cm2

Allowable bond stress in deformed bars = 24.6 kg/cm2

Recommended values:

Dia – 12 to 16 mm

Minimum length = 64 to 80 cm

Spacing for 25 cm thick slab – 60 cm

Spacing for 30 cm thick slab – 100 cm

PROBLEM

1. **The design thickness of a cc pavement is 26 cm considering a design axle load (98th percentile load) is 12000 kg on single axle ad M40 concrete with characteristic compressive strength of 400 kg/cm2. The radius of relative stiffness is found to be 62.2 cm. If the elastic modulus of dowel bar steel is 2×106 kg/cm2 modulus of dowel-concrete interaction is 41500 kg/cm3 and joint width is 1.8 cm, design the dowel bar for 40% load transfer considering edge loading.**

Bearing stress developed between dowel bar and concrete plays a crucial role Maximum bearing stress, σmax

σmax =ሻ$k\ Pt$ (2 + βz 4β3EI

β =4√ (kb) /(4EI)

k = 41,500 kg/cm2
Pt = ? b – diameter of dowel bar
z = 1.8 cm
β – relative stiffness of dowel bar embedded in concrete, cm E = 2×106 kg/cm2
I – moment of inertia of steel bar, cm4
l = 62.2 cm
Design load = 12000 kg

Let b= 30 mm

I = $\boldsymbol{\pi b 4\ 64}$ = $\boldsymbol{\pi}$×$\boldsymbol{34\ 64}$
= 3.98 cm4

β =4√ (kb) /(4EI)
β =4 √(41500 × 3)/(4 × 2 × 106 × 3.98)
$\boldsymbol{\beta}$ **=0.25**

To get Pt 40% of design load = 0.4×6000 = 2400 kg

Let the spacing of dowel bar be 25 cm
[1 +{(62.2 – 25)/ 62.2}+{(62.2 − 25 × 2)/ 62.2}]= 2400
Pt (1+ 0.60+0.20)=2400
Pt = **1333.33 kg**

β = 0.25 cm wheel load =6000 kg
fck – ultimate compressive strength of concrete, kg/cm2, 400 kg/cm2

$\sigma max = k\ Pt\ (2 + \ )/4\beta 3EI$
σmax =41500 × 1333.3 (2 + 0.25 × 1.8)/(4 × 0.253 × 2 × 106 × 3.98)
σmax = 272.49 $kg/cm2$

Allowable bearing stress,
Fb = (10.16−b ×fck)/ 9.525
Fb =(10.16−3) ×400/ 9.525
= 300 kg/cm2

Since Allowable stress>max bearing stress developed, design is safe. **Use 3 cm dowel bar at 25 cm spacing.**

2. **A cement concrete pavement has a thickness of 26 cm and lane width of 3.5 m. Design the tie bars along the longitudinal joints using the data given below:**

Unit weight of CC = 2400 kg/m3
Maximum value of friction coefficient = 1.2
Allowable tensile stress in deformed bar, Ss = 2000 kg/cm2
Allowable bond stress in deformed bars = 24.6 kg/cm2

Given data : h = 26 cm
b = 3.5 m
W = 2400 kg/m3
f = 1.2
Ss = 2000 kg/cm2
Sb = 24.6 kg/cm2

As =($\boldsymbol{bhWf}$) /($\boldsymbol{100Ss}$)
As = ($\boldsymbol{3.5 \times 26 \times 2400 \times 1.2}$)/($\boldsymbol{100 \times 2000}$)
As = $\boldsymbol{1.31\ cm2}$

Use 12 mm dia
Area of 1 bar = 1.13 cm2

Number of bars = 1.31/1.13 = 1.16

Spacing of 12 mm dia bars = 100/1.16
= 86 cm

Length of tie bar $\boldsymbol{Lt}$ = ($\boldsymbol{2000/\ 24.6}$) × ($\boldsymbol{1.2/\ 2}$)
$\boldsymbol{Lt = 48.8\ cm}$

Hence provide 12 mm dia bar of length 50 cm at 86 cm c/c

CHAPTER 06

RESULTS AND CONCLUSIONS

- Fixing the percentage replacement of coconut shell aggregate(CSA).
- Life span of Rigid pavement with above percentage replacement of coconut shell aggregate(CSA).

CHAPTER 07

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