



# Strength and Economic Evaluation of Dry Lean Concrete with Fly Ash and Recycled Concrete Aggregates

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**Abstract:**-This study focuses on the performance optimization of Dry Lean Concrete (DLC) by incorporating fly ash and recycled concrete aggregates (RCA) for rigid pavement applications. The increasing demand for sustainable construction materials and the need to reduce environmental impact have encouraged the use of industrial waste materials such as fly ash and construction waste in concrete production. In this research, Ordinary Portland Cement (OPC) is partially replaced with fly ash and natural coarse aggregates are substituted with recycled concrete aggregates in different proportions. Various mixes are prepared to evaluate the influence of these materials on the compressive strength and overall performance of DLC. Standard cube specimens of size 150 mm × 150 mm × 150 mm are cast and tested at different curing periods. The results indicate that the inclusion of fly ash improves workability and reduces water demand, while the use of RCA contributes to sustainable resource utilization. An optimum combination of fly ash and RCA shows improved compressive strength compared to conventional DLC. Additionally, the

economic analysis reveals that the use of these waste materials can significantly reduce construction cost.

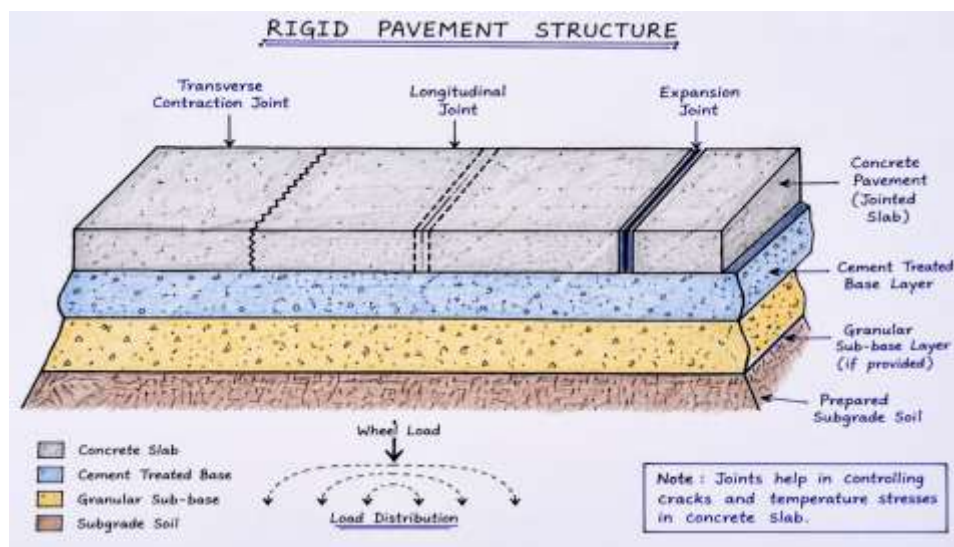
**Keywords:** Dry Lean Concrete, Fly Ash, Recycled Concrete Aggregate, Compressive Strength, Sustainable Construction and Rigid Pavement.



## 1. Introduction

### 1.1 General

Pavement is an essential component of transportation infrastructure, designed to safely transfer vehicular loads to the underlying soil. Rigid pavements, constructed using cement concrete, are widely preferred due to their high strength, durability, and long service life. A typical rigid pavement system consists of different layers such as sub-grade, sub-base, and base layer, where Dry Lean Concrete (DLC) is commonly used as a sub-base material. Dry Lean Concrete is a low cement content concrete with a high proportion of aggregates. It provides a uniform and stable base for the pavement slab and improves load distribution. Due to its low cost and good performance characteristics, DLC is extensively used in highway construction.



*Figure 1.1 Rigid Pavement*

### 1.2 Dry Lean Concrete

Rigid pavements, commonly known as Portland Cement Concrete (PCC) roads, are increasingly being adopted in recent infrastructure projects due to their longer service life, superior riding quality and minimal maintenance requirements. In India, the construction of cement concrete roads is being actively promoted by the Government at national, state and local levels, including rural and municipal sectors. In modern rigid pavement construction practices, a layer of Dry Lean Concrete (DLC) is provided as a base course over the prepared sub-base. This layer acts as a stable and uniform support for the overlying Pavement Quality Concrete (PQC) slab, ensuring effective load distribution and improved performance of the pavement system. Dry Lean Concrete is a low cement content concrete with a high proportion of aggregates, designed primarily for strength and durability rather than workability. As per standard guidelines, the mix proportion of DLC is controlled by limiting the aggregate-to-cement ratio. The maximum aggregate to cement ratio is generally kept as 14:1 when Ordinary Portland Cement (OPC) is used and 12:1 when blended cements such as Portland Pozzolana Cement (PPC) or Portland Slag Cement (PSC) are used. Additionally, the minimum cementitious material content in DLC should not be less than 140 kg/m<sup>3</sup> of concrete, to ensure adequate strength and binding properties. Proper mix design, compaction and curing of DLC are essential for achieving the desired



structural performance in rigid pavements.

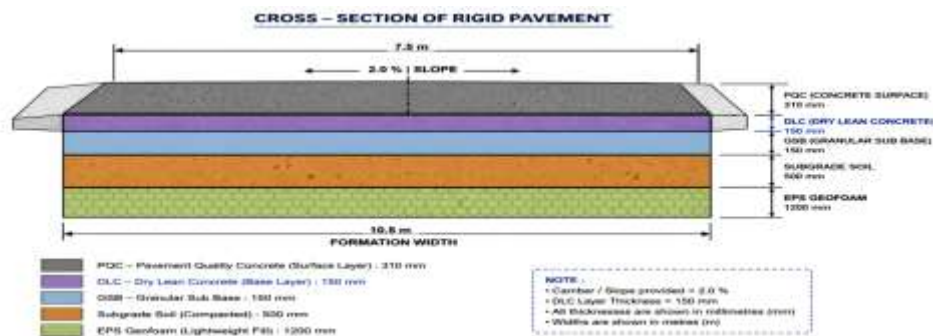


Figure 1.2 DLC Thickness Layer Section

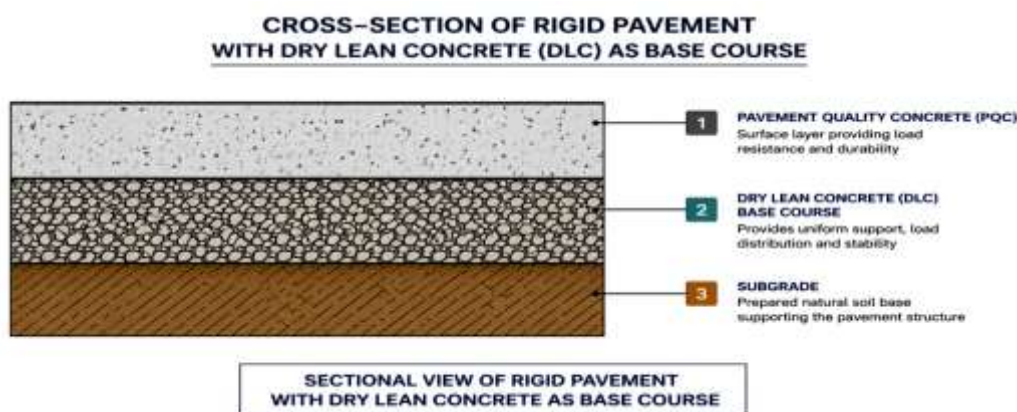


Figure 1.3 DLC Cross Section Layer

### 1.3 Need of Study

The construction industry is facing challenges related to environmental sustainability and resource depletion. The production of cement releases a large amount of carbon dioxide, while the disposal of industrial and construction waste such as fly ash and demolished concrete creates environmental concerns. Therefore, there is a need to develop alternative construction materials that are both economical and eco-friendly. The use of fly ash as a partial replacement of cement and recycled concrete aggregate as a substitute for natural aggregates can help in reducing environmental impact. These materials not only utilize waste effectively but also improve certain properties of concrete.

### 1.4 Objective of Study

The main objective of this study is to evaluate the performance of Dry Lean Concrete by incorporating fly ash and recycled concrete aggregates. The study aims to analyze compressive strength, optimize mix proportions, and assess economic feasibility for rigid pavement applications.

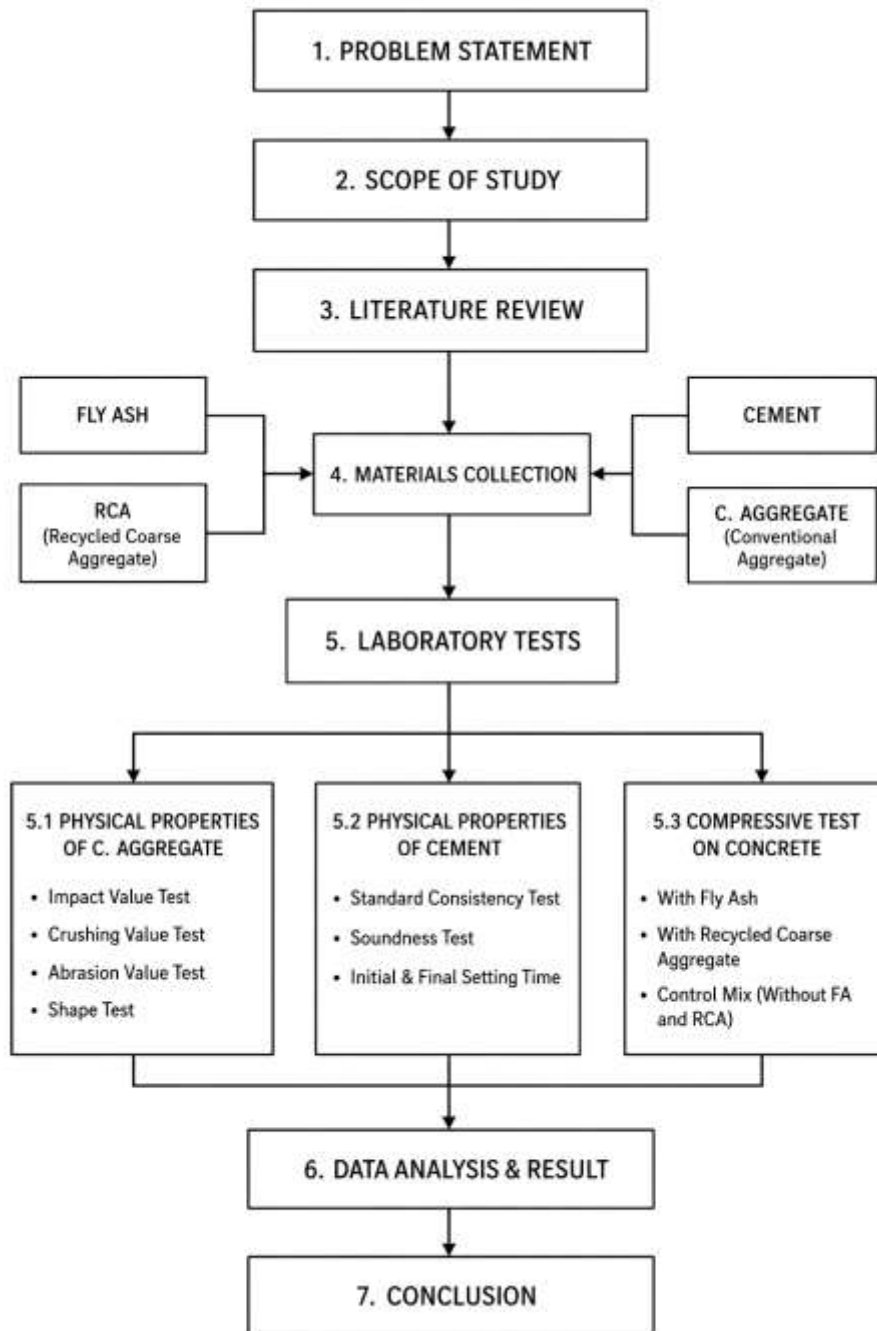
### 1.5 Scope of Study

This study focuses on the preparation and testing of Dry Lean Concrete using different proportions of fly ash and recycled aggregates. The compressive strength is evaluated at different curing periods. The study also includes comparison with conventional DLC and analysis of cost effectiveness.



### 3. Materials and Methodology

#### 3.1 Methodology Chart



*Figure 3.1 Methodology Chart*



### 3.2 Materials

Cement: (OPC 53grade)

Aggregate: Ca (20 mm & 10 Mm)

Fly ash:

Recycle Concrete Aggregate

#### 3.2.1 Cement

In the present study, Ordinary Portland Cement (OPC) of 53 grade conforming to IS: 12269 was used. The cement was procured from Shree Balaji Cement Store, an authorized dealer of UltraTech Cement. All physical and chemical properties of cement were tested as per relevant Indian Standards, and the results were found to be within permissible limits.

#### 3.2.2 Aggregate

Aggregates used in this study were collected from Pavan Construction Pvt. Ltd., a local construction material supplier.

- ❖ Coarse aggregates of 20 mm and 10 mm size and natural sand were used.
- ❖ Maximum size of aggregate: 26.5 mm
- ❖ Minimum size: 4.75 mm retained sieve
- ❖ Tests conducted as per IS: 2386

The aggregate satisfied IS: 383 requirements and were suitable for use in Dry Lean Concrete.

#### 3.2.3 Fly Ash

Fly ash used in this study was obtained from Bhanu RMC Plant, which sources fly ash from nearby thermal power plants such as NTPC Sipat.

Fly ash is a by-product of coal combustion and is widely used as a supplementary cementitious material. In this study, it was used as a partial replacement of cement to improve sustainability and workability.

#### 3.2.4 Recycle Concrete Aggregate

Recycled Concrete Aggregate (RCA) was collected from demolition waste at local construction sites in Raipur, particularly near Ring Road No. 1 Construction Demolition Zone. The collected concrete debris was crushed, cleaned, and sieved to obtain usable coarse aggregate.

- ❖ RCA used as partial replacement of coarse aggregate
- ❖ Fine aggregate used: 100% natural sand
- ❖ Helps in reducing environmental impact and conserving natural resources

The material properties were tested and found suitable for use in Dry Lean Concrete.

### 3.3 Laboratory Test on Aggregate

- ❖ Shape Test (IS: 2386-Part1)
- ❖ Flakiness Index
- ❖ Elongation Index
- ❖ Specific Gravity Test (IS: 2386-Part 3)



- ❖ Impact Value Test (IS: 2386-Part 4)
- ❖ Crushing Value Test (IS: 2386-Part 4)
- ❖ Abrasion Value Test (IS: 2386-Part 4)

### 3.4 Laboratory Test on Cement

- ❖ Soundness Test (IS4031-Part-III)
- ❖ Standard Consistency Test (IS4031-Part-IV)
- ❖ Initial Setting Time & Final Setting Time Test (IS 4031-Part-V)

### 3.5 Compressive Strength Test

#### 3.5.1 General

The procedure for casting of specimens for compressive strength test is discussed in this section. Cube specimens of dry lean concrete were cast for each percentage of moisture content 6.5% with various combinations of RCA i.e. 10%, 20%, 30% and Fly Ash 15%. Five number of cube specimens were cast for each combination of RCA with each percentage of moisture content. Six cube specimens of size 150×150×150 mm were cast for static compressive test. The quantity of cement, coarse aggregate, fine aggregate, Fly ash, RCA and water for each mix was weighed separately. Cement is mixed into the blend in dry form. The coarse aggregates were mixed to get the same throughout the batch. The compaction of concrete in molds was carried out by using Vibrating needle.

#### 3.5.2 Procedure

##### Method of Casting

Concrete's strength mostly depends on the mix design. But it's affected by several other factors. Such as mixing of concrete, placing of concrete, curing of concrete, as well as quality of concrete ingredients. So we can't be assumed that if we produced that if we produce concrete as per mix design we will get desired strength.

##### Procedure of making concrete Specimen

Making Concrete specimen such as cube for compressive strength, cylinder for splitting tensile strength and beam for flexural strength are simple and it's done in three simple steps.

- ❖ Cleaning & fixing mould.
- ❖ Placing, compacting & Finishing Concrete.
- ❖ Curing.

##### Cleaning & Fixing Mould

Clean the mould properly and apply oil on inner surface of mould. But no oil should be visible on surface. Fix the mould with base plate tightly. No gap should be left in joints so that cement slurry doesn't penetrate. Place the mould level surface.

##### Placing, Compacting & finishing Concrete

Preparation of concrete analogous to the traditional concrete. Drum Mixture have been accustomed prepare



concrete. Mix of all the materials are exhausted the laboratory at temperature machine have been turned 3 to 5 min. Place the concrete into mould in layer. Compact. Left the mould completely undisturbed period, put down identification mark and casting date on the top of concrete specimen.

### **Curing**

Remove the cube specimen from mould after 24 hours of casting. For removing Specimen from mould, first loosen all nut- bolts and carefully remove specimen because concrete is still lean weak and can be broken. Immediately after removing, put the specimen into a tank of clean water for curing. Make sure specimen is fully submerged in water. After 3, 7 and 28 days of curing take out specimen from water tank and send to laboratory for testing and the arrangement for compressive strength test. At the age of test, the specimens were taken out of the curing tank and kept outside at room temperature for 10-15 minutes so it becomes surface dry.

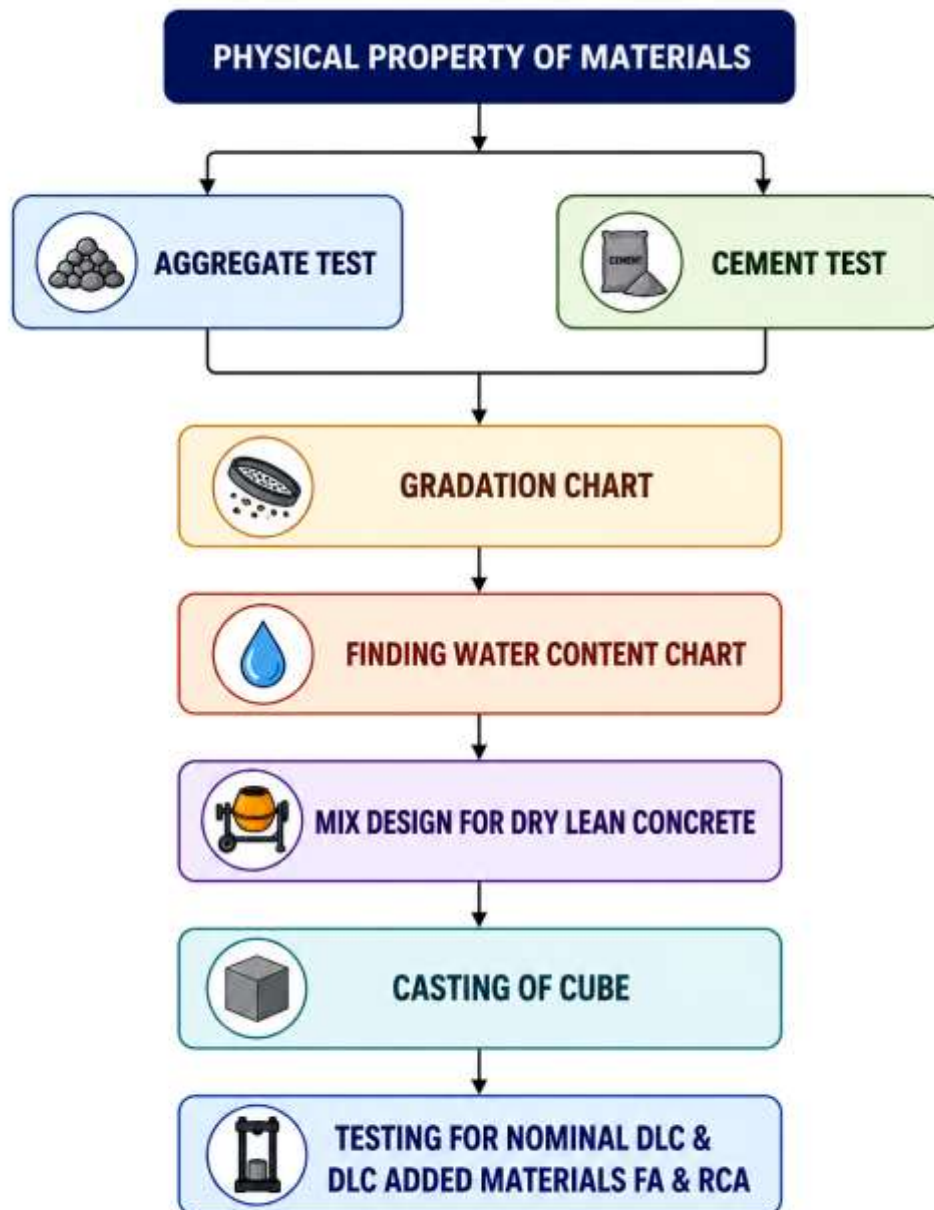


*Figure 3.11 Compression Testing Machine*



## 4. Experimental Work and Results

### 4.1 Experimental Chart





## 4.2 Result of Cement and Aggregate

### 4.2.1 Cement

Cement is used to work according to IS: 12269 -2013 – Ordinary Portland cement 53 Grade-Specification.

*Table 4.1 Physical Properties of Cement*

S. No.	Property	Result	Specification
1	Standard Consistency	26%	-
2	Soundness	6 mm	10 mm
3	IST	78 Minutes	Not less than 30 min
4	FST	235 Minutes	Not greater than 60 min

### 4.2.2 Coarse Aggregate

Coarse aggregate is used to work according to I.S. 383- Specifications for coarse aggregate and fine aggregate from natural sources for concrete which fraction is from 20mm to 4.75 mm.

*Table 4.2 Physical Properties of Aggregate*

S. No.	Property	Result	Specification
1	Impact Value Test	19.63%	Max 30%
2	Crushing Value Test	22.54%	Max 35%
3	Shape Test (Combined)	30.38%	Max 35%
4	Water Absorption	1.91%	Max 2%
5	Specific Gravity	2.63	-

## 4.3 Determination of Water Content

### Calculation for Density

Wet density = Weight of Cube/Volume of Cube

Dry density = Wet Density/ (1 + w/100)

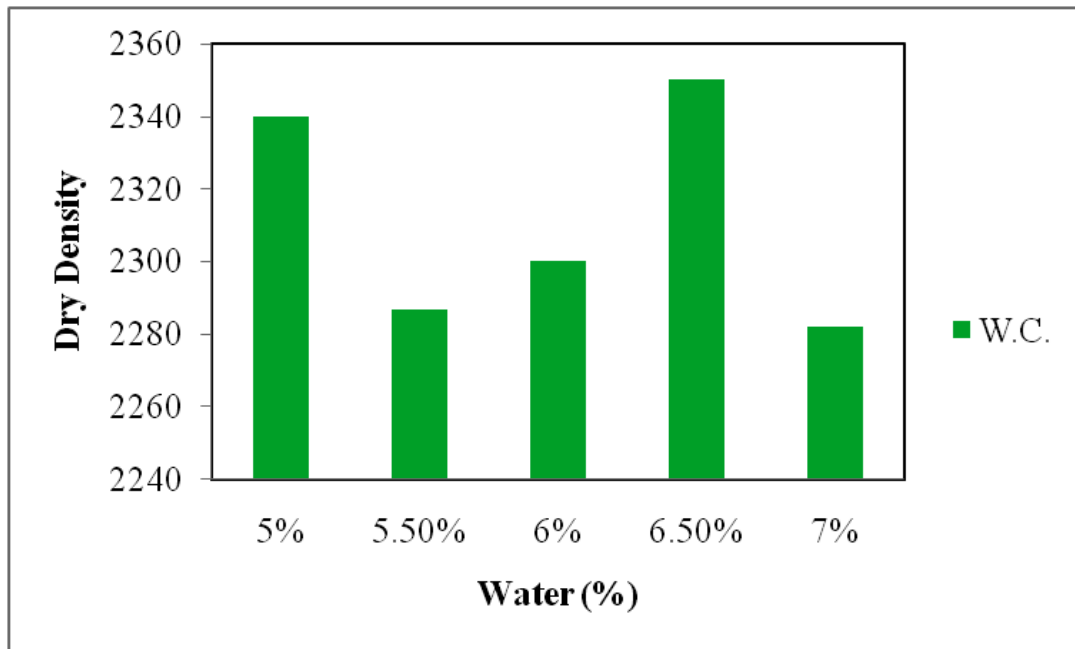


**Table 4.3 Water Content Chart**

w . c .	C u b e N o.	V o l u m e o f C u b e	W e i g h t o f E m p t y M o u l d	W e i g h t o f E m p t y M o u l d + C o n c r e t e	C o n c r e t e	W e t D e n s i t y	D r y D e n s i t y
5	5	337	7.2	12.9	7.3	24	23
		5	2	3		64	40
5 . 5	5	337	7.2	12.9	7.17	24	22
		5	2	5		20	87
6	5	337	7.2	12.9	7.25	24	23
		5	2	7		47	00
6 . 5	5	337	7.2	12.9	7.45	25	23
		5	2	9		14	50
7	5	337	7.2	12.9	7.34	24	22
		5	2	4		77	82

**Maximum W.C IS 6.5% Calculation**

- ❖ Volume of Cube:  $(0.78 \times d^2 \times \text{height}) = 3375 \text{cm}^3$
- ❖ Wet density = weight of cube/Volume of cube=  $12.99/3375=2514 \text{gm/cc}$
- ❖ Dry density=Wet density/  $((1+(w/100))=2514/((1+(6.5/100))=2350 \text{gm/cc}$



#### 4.4 Combined Gradation Chart

IS recommended for combined fine and coarse aggregate in case of DLC. This grading is applicable both of natural sand and crushed aggregate.

Table 4.4 Combined Gradations

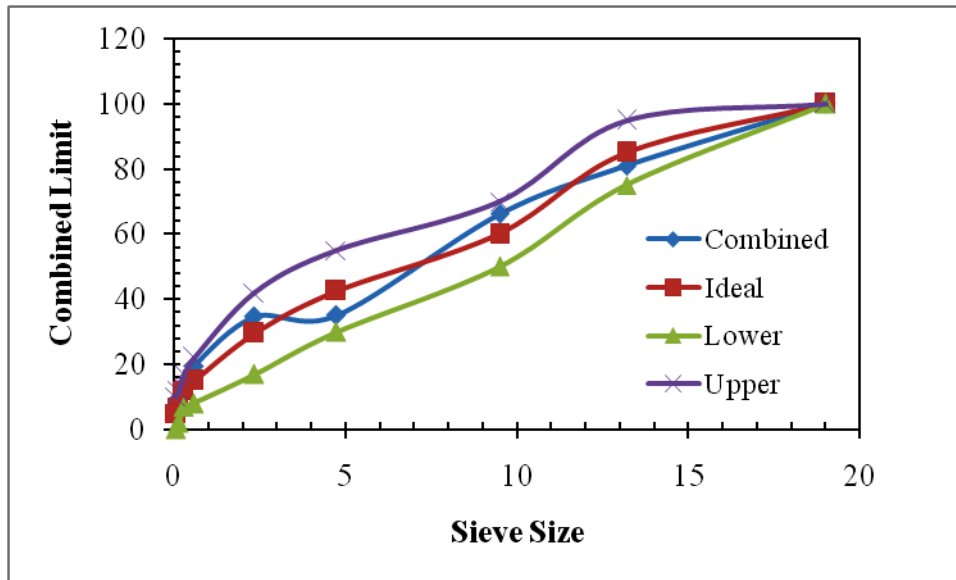
IS S i e v e ( m m )	Individual Gradation			Combined Gradation			All Aggregate		Limit (IRC 49)	
	200mm	100mm	Sand	20mm	10mm	Sand	Combined	Ideal	Lower	Upper
19	100	100	100	33	33	34	100	100	100	100
1	4	1	1	1	3	3	8	8	7	9



3 . 2	2 . 5	0 0	0 0	4 . 0 3	3	4	1 . 0 3	5	5	5
9 . 5	1 8 . 6 3	7 8 . 8 8	1 0 0	6 . 1 5	2 6 . 0 3	3 4	6 6 . 1 8	6 0	5 0	7 0
4 . 7 5	2 . 5	0 . 6 8	1 0 0	0 . 8 3	0 . 2 2	3 4	3 5 . 0 5	4 2 . 5	3 0	5 5
2 . 3 6	2 . 1	0	1 0 0	0 . 6 9	0 . 0 0	3 4	3 4 . 6 9	2 9 . 5	1 7	4 2
0 . 6	0	0	5 7 . 6 5	0 . 0 0	0 . 0 0	1 9 . 6 0	1 9 . 6 0	1 5	8	2 2
0 . 3	0	0	3 9 . 2 5	0 . 0 0	0 . 0 0	1 3 . 3 5	1 3 . 3 5	1 2	7	1 7
0 . 1 5	0	0	2 6 . 7 9	0 . 0 0	0 . 0 0	9 . 1 1	9 . 1 1	7	2	1 2
0 .	0	0	1 9	0 . 0 0	0 . .	6 .	6 .	5	0	1 0



0			.		0	5	5			
7			3		0	8	8			
5			5							



#### 4.5 Mix Design of Dry Lean Concrete (DLC)

##### 4.5.1 General Mix Design Parameter

1. Types of concrete : Dry Lean Concrete
2. Minimum cement content : 150 kg/cum
3. Max. size of aggregate : 20 mm
4. Aggregate cement ratio : 1:12
5. Gradation : as per table 600.1 of MoRTH
6. Strength required at 7 days : 7 N/mm<sup>2</sup>

**Table 4.5 Mix Design of DLC**

Cement: Aggregate	1:12
Cement, Kg	150
Water,%	6.5
Aggregate, Kg	1800
Sand (34%)	612
Coarse Aggregate	1188
20 mm (33%)	594
10 mm (33%)	594
Total wt. of Concrete	1950



L	0.15
B	0.15
H	0.15
No. of Cube	5
Volume of Cube	0.016875
Quantity of Cube 5	32.9
Cement	2.15
Sand	10.33
20mm	9.018
10mm	9.018
Water	2.14

**Table 4.6 Mix Properties of Materials**

Materials Mixed	C.A. (20 mm)	C.A.(10 mm)	F.A
Percentage Mixed	33%	33%	34%

**Table 4.7 Mix Design of 15 % Fly Ash Added in DLC**

Cement: Aggregate	1:12	
Cement, Kg	150	
Water,%	6.5	
Aggregate, Kg	1800	
Sand (34%)	612	
Coarse Aggregate	1188	
20 mm (33%)	594	
10 mm (33%)	594	
Total wt. of Concrete	1950	
L	0.15	
B	0.15	
H	0.15	
No. of Cube	5	
Volume of Cube	0.016875	
Quantity of Cube 5	32.9	



Cement	2.15	FA = 0.38
Sand	10.33	
20 mm	10.02	
10 mm	10.02	
Water	2.14	
Dry Density	2350	

**Table 4.8 Mix Properties of Materials**

Materials Mixed	C.A. (20 mm)	C.A. (10 mm)	F.A
Percentage Mixed	33%	33%	34%

**Table 4.9 Mix Design of 15% Fly Ash & 10% RCA Added in DLC**

Cement: Aggregate	1:12	
Cement, Kg	150	
Water, %	6.5	
Aggregate, Kg	1800	
Sand (34%)	612	
Coarse Aggregate	1188	
20 mm (33%)	594	
10 mm (33%)	594	
Total wt. of Concrete	1950	
L	0.15	
B	0.15	
H	0.15	
No. of Cube	5	
Volume of Cube	0.016875	
Quantity of Cube 5	32.9	
Cement	2.15	FA=0.38
Sand	10.33	
20mm	9.018	RCA=2.00
10mm	9.018	
Water	2.14	
Dry Density	2350	

**Table 4.10 Mix Properties of Materials**

Materials Mixed	C.A. (20 mm)	C.A. (10 mm)	F.A	RCA
Percentage Mixed	33%	33%	34%	10%

**Table 4.11 Mix Design of 15% Fly Ash & 20% RCA Added in DLC**

Cement: Aggregate	1:12	
Cement, Kg	150	
Water,%	6.5	
Aggregate, Kg	1800	
Sand (34%)	612	
Coarse Aggregate	1188	
20 mm (33%)	594	
10 mm (33%)	594	
Total wt. of Concrete	1950	
L	0.15	
B	0.15	
H	0.15	
No. of Cube	5	
Volume of Cube	0.016875	
Quantity of Cube 5	32.9	
Cement	2.15	FA=0.38
Sand	10.33	
20mm	8.016	RCA=4.00
10mm	8.016	
Water	2.14	
Dry Density	2350	

**Table 4.12 Mix Properties of Materials**

Materials Mixed	C.A. (20 mm)	C.A. (10 mm)	F.A	RCA
Percentage Mixed	33%	33%	34%	20%

**Table 4.13 Mix Design of 15% Fly Ash & 30% RCA Added in DLC**

Cement: Aggregate	1:12	
Cement, Kg	150	
Water, %	6.5	
Aggregate, Kg	1800	
Sand (34%)	612	
Coarse Aggregate	1188	
20 mm (33%)	594	
10 mm (33%)	594	
Total wt. of Concrete	1950	
L	0.15	
B	0.15	
H	0.15	
No. of Cube	5	
Volume of Cube	0.016875	
Quantity of Cube 5	32.9	
Cement	2.15	FA = 0.38
Sand	10.33	
20mm	7.019	RCA = 6.00
10mm	7.019	
Water	2.14	
Dry Density	2350	



**Table 4.14 Mix Properties of Materials**

Materials	C.A. (20 mm)	C.A. (10 mm)	F.A	RCA
Mixed				
Percentage	33%	33%	34%	30%
Mixed				

#### 4.6 Casting Specimens

The procedure for casting of specimens for compressive Strength test is discussed in this section. Cube specimens of dry lean concrete were cast for each percentage of moisture content 6.5% with various combinations of RCA i.e. 10%, 20%, 30% and Fly Ash 15%. Five number of cube specimen cast for each combination of RCA with each percentage of moisture content. Six cube specimens of size 150×150×150mm were cast for static compressive test. The quantity of cement, coarse aggregate, fine aggregate, Fly ash, RCA and water for each mix was weighed separately. Cement is mixed into the blend in dry form. The coarse aggregates were mixed to get the same throughout the batch. The compaction of concrete in moulds was carried out by using Vibrating needle. After casting, the specimen kept for 24 hours. Next day the specimen was taking out from mould and the specimen are kept in curing tank. For each mix 6 cubes were cast i.e. three cubes for each 3 days, 7 days and 28 days compressive strength test.



**Figure 4.1 Dry Mixing Materials**



*Figure 4.2 Compaction Apparatus*



*Figure 4.3 Cube Casting With Mould*



## 4.7 Compressive Strength Test of DLC

### 4.7.1 DLC Cube Name & Contents

*Table 4.15 DLC Cube Name*

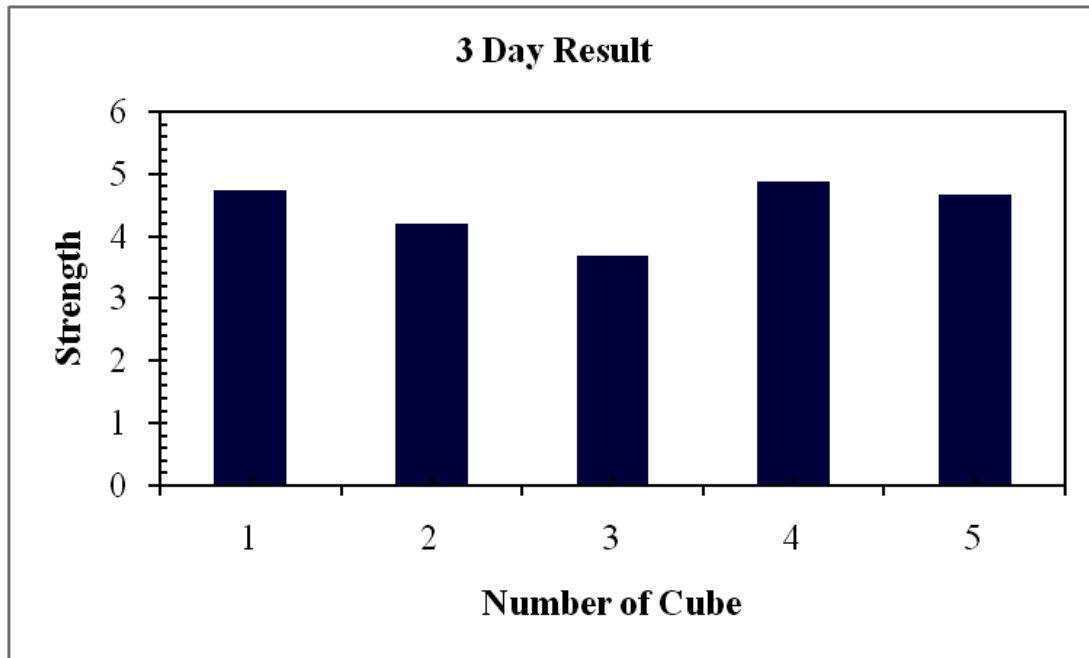
1	DLC
2	DLC+15%FA
3	DLC+ 15% FA+ 10% RCA
4	DLC+ 15% FA+ 20% RCA
5	DLC+ 15% FA+ 30% RCA

### 4.7.2 Compressive Strength Tests of DLC

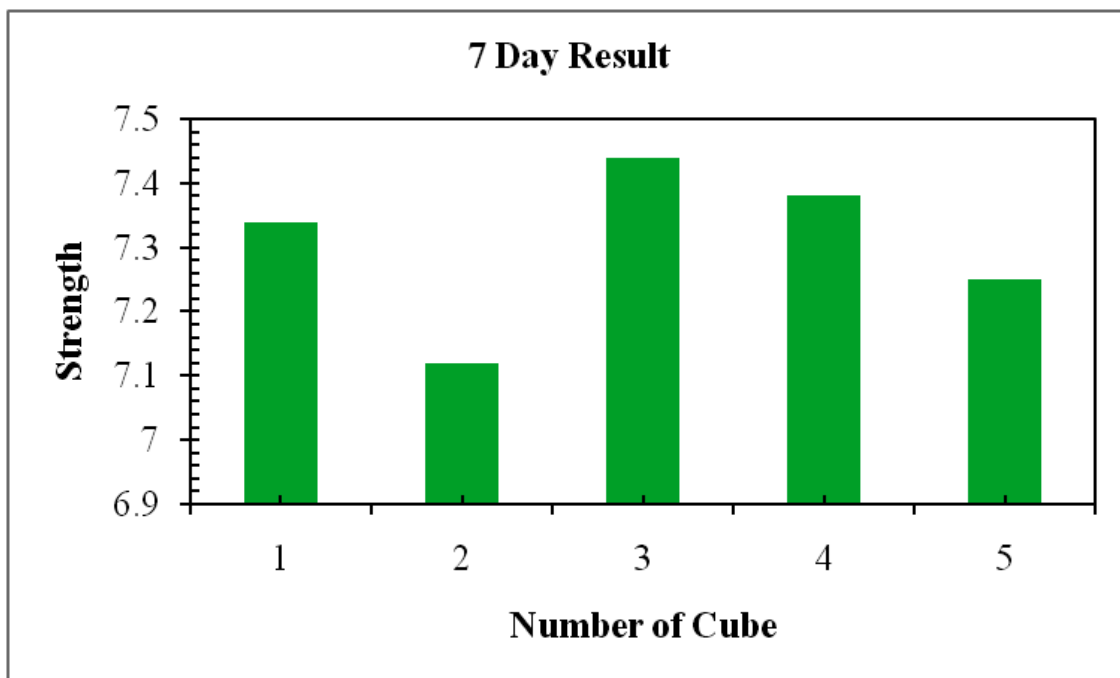
- ❖ The compressive strength at 3 days of DLC Grade of concrete average compressive strength 4.43MPA.
- ❖ The compressive strength at 7 days of DLC Grade of concrete average compressive strength 7.3MPA.
- ❖ The compressive strength at 28 days of DLC Grade of concrete average compressive strength 29.2MPA.

*Table 4.16 DLC*

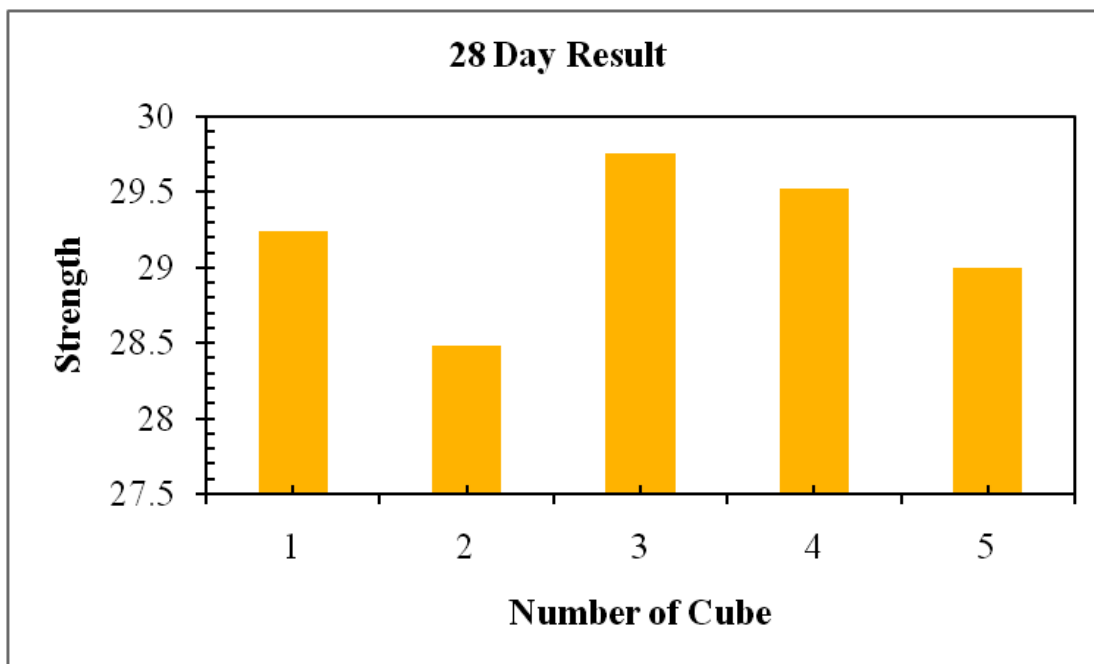
Cube No	3 Day	7 Day	28 Day
1	4.73	7.34	29.24
2	4.20	7.12	28.48
3	3.69	7.44	29.76
4	4.87	7.38	29.52
5	4.66	7.25	29.00



*Figure 4.4-3 Day Result*



*Figure 4.5-7 Day Result*



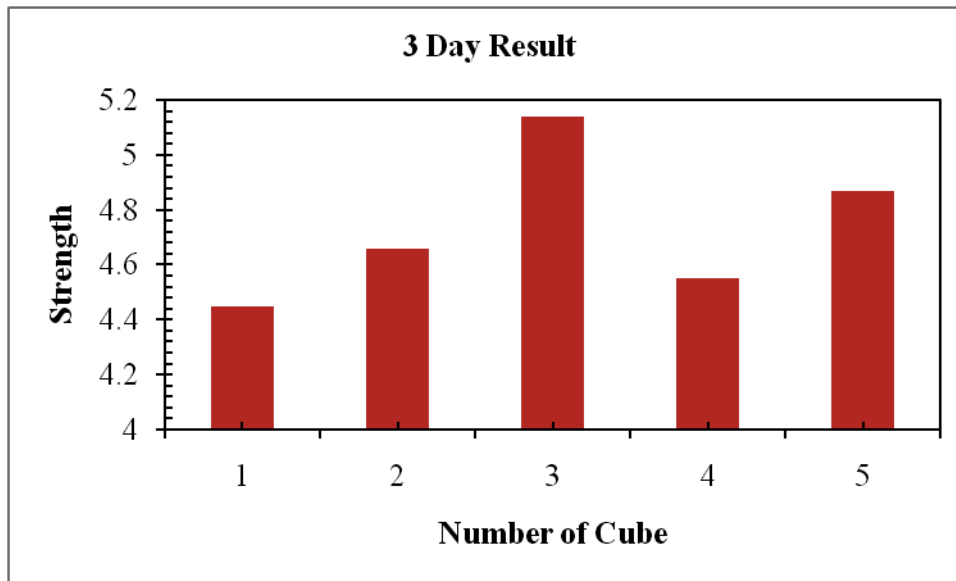
*Figure 4.6-28 Day Result*

#### 4.7.3 Compressive Strength Test of DLC+15% Fly Ash

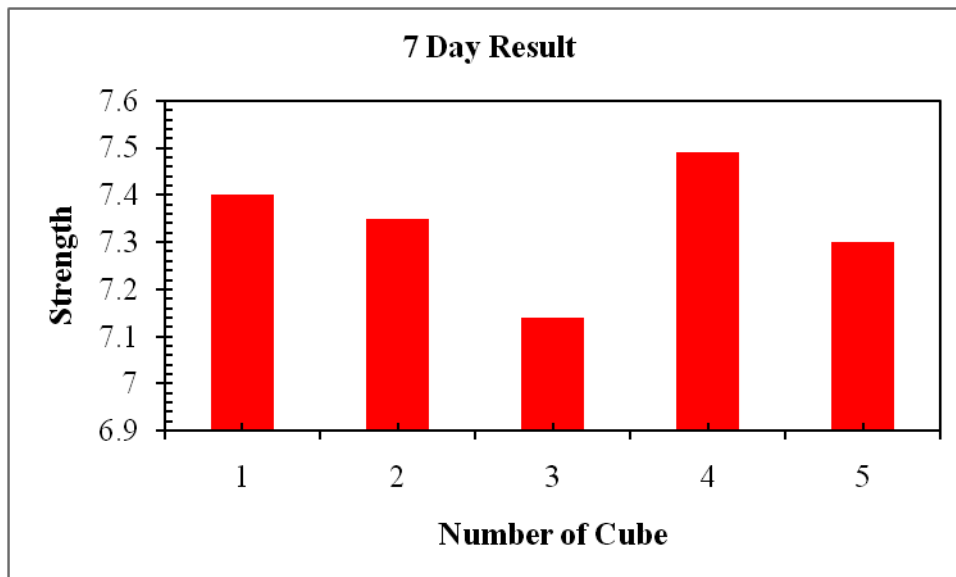
- ❖ The compressive strength at 3 days of DLC Grade of concrete average compressive strength 4.73MPa.
- ❖ The compressive strength at 7 days of DLC Grade of concrete average compressive strength 7.34MPa.
- ❖ The compressive strength at 28 days of DLC Grade of concrete average compressive strength 29.34MPa.

*Table 4.17 DLC+FA 15%*

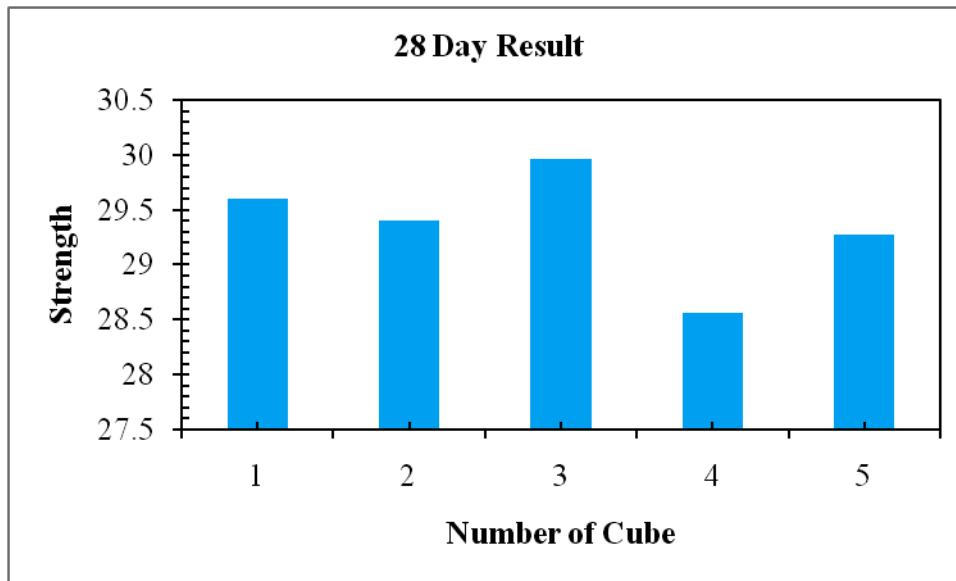
Cube No	3 Day	7 Day	28 Day
1	4.45	7.40	29.60
2	4.66	7.35	29.40
3	5.14	7.14	29.96
4	4.55	7.49	28.56
5	4.87	7.30	29.28



*Figure 4.7-3 Day Result*



*Figure 4.8-7 Day Result*



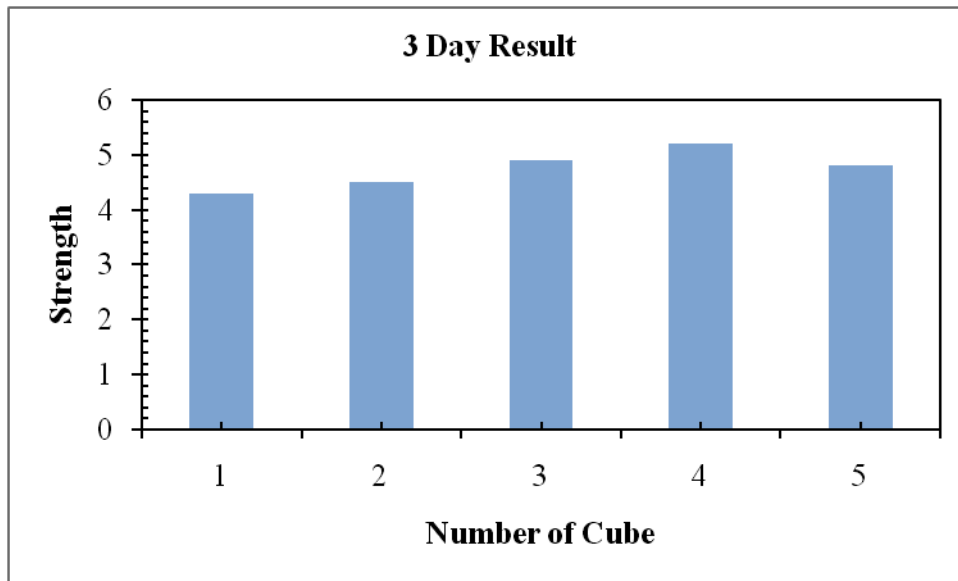
*Figure 4.9-28 Day Result*

#### 4.7.4 Compressive Strength Tests of DLC + 15% Fly Ash + 10% RCA

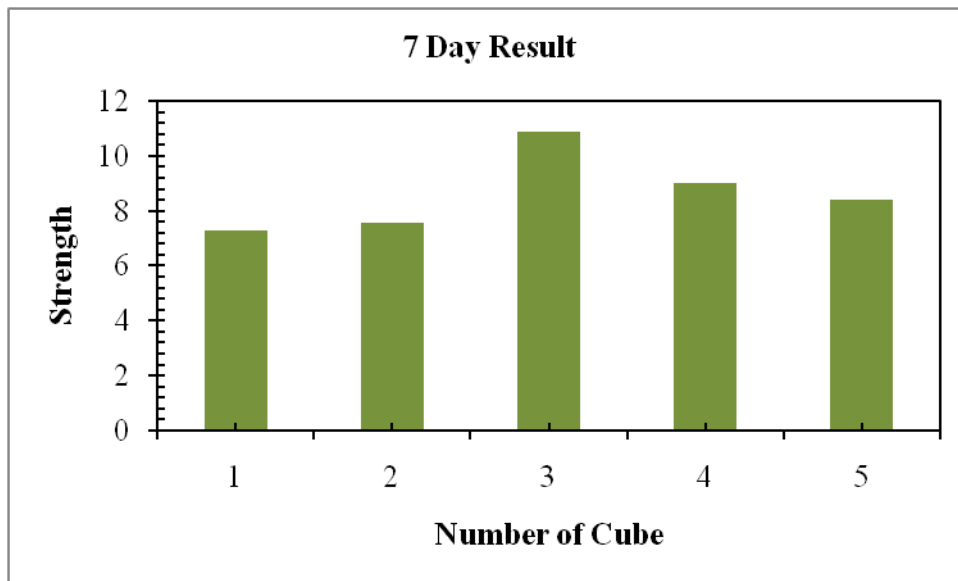
- ❖ The compressive strength at 3 days of DLC Grade of concrete average compressive strength 4.74MPa.
- ❖ The compressive strength at 7 days of DLC Grade of concrete average compressive strength 8.62MPa.
- ❖ The compressive strength at 28 days of DLC Grade of concrete average compressive strength 28.1MPa.

*Table 4.18 DLC+FA 15%+RCA 10%*

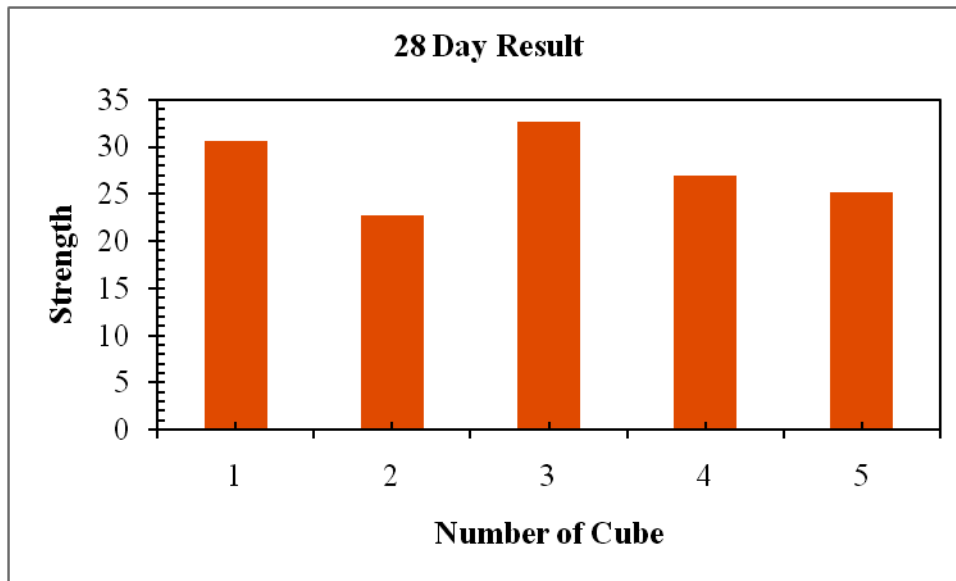
Cube No	3 Day	7 Day	28 Day
1	4.3	7.30	30.60
2	4.5	7.56	22.80
3	4.9	10.9	32.70
4	5.2	9.00	27.00
5	4.8	8.40	25.2



*Figure 4.10-3 Day Result*



*Figure 4.11-7 Day Result*



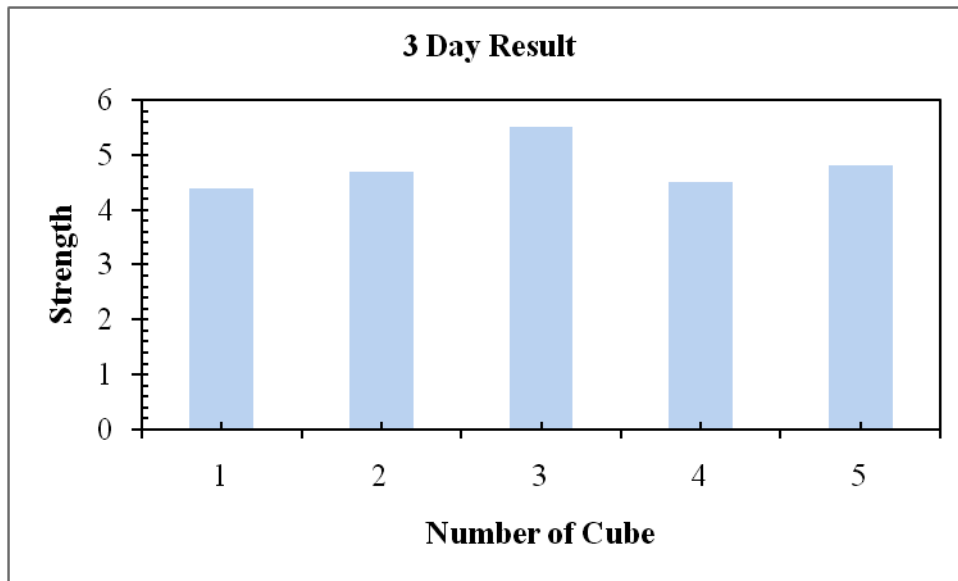
*Figure 4.12-28 Day Result*

#### 4.7.5 Compressive Strength Tests of DLC+15% Fly Ash+ 20% RCA

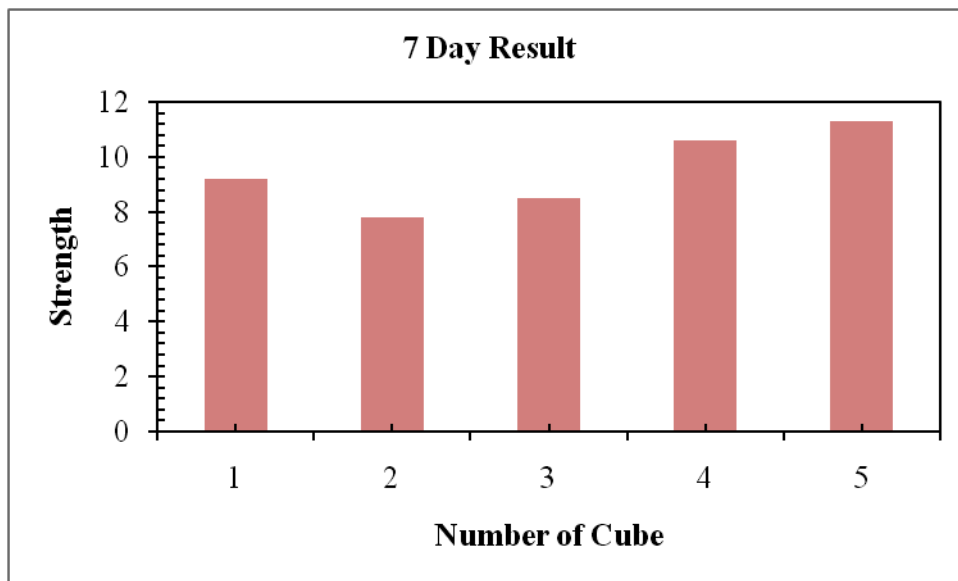
- ❖ The compressive strength at 3 days of DLC Grade of concrete average compressive strength 4.78MPA.
- ❖ The compressive strength at 7 days of DLC Grade of concrete average compressive strength 9.48MPA.
- ❖ The compressive strength at 28 days of DLC Grade of concrete average compressive strength 30.6MPA.

*Table 4.19 DLC +FA 15%+RCA 20%*

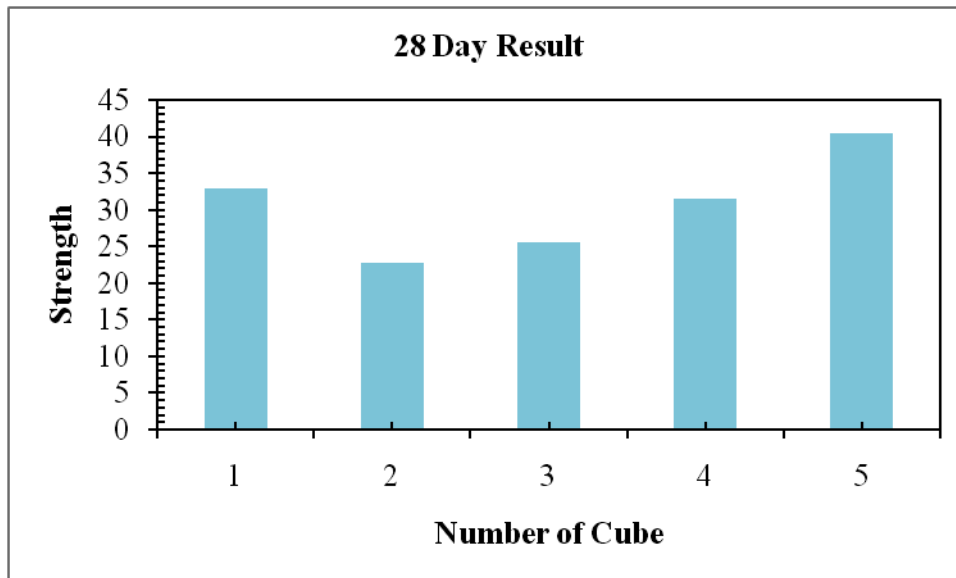
Cube No	3 Day	7 Day	28 Day
1	4.4	9.2	32.9
2	4.7	7.8	22.8
3	5.5	8.5	25.5
4	4.5	10.6	31.5
5	4.8	11.3	40.5



*Figure 4.13-3 Day Result*



*Figure 4.14-7 Day Result*



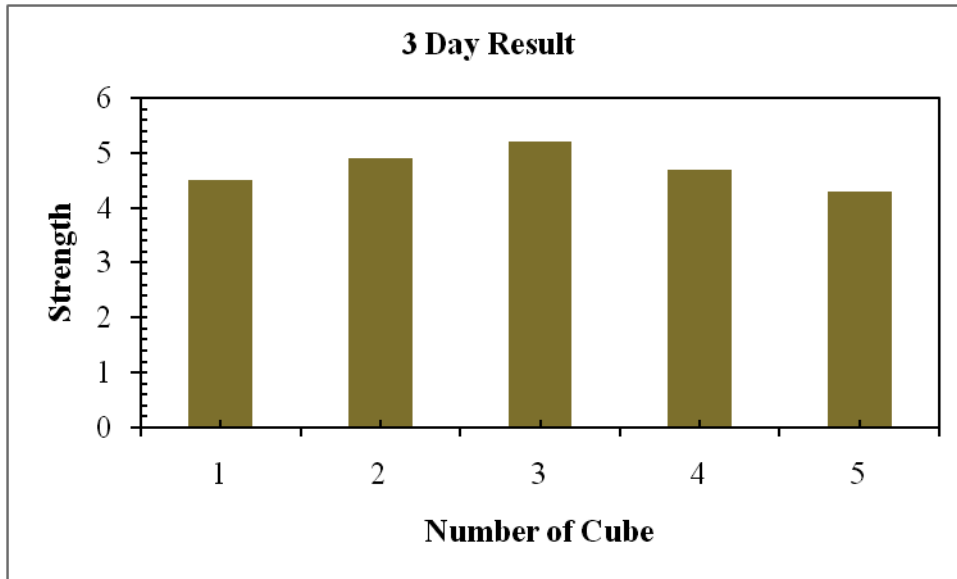
*Figure 4.15-28 Day Result*

#### 4.7.6 Compressive Strength Test of DLC+15% Fly Ash+ 30% RCA

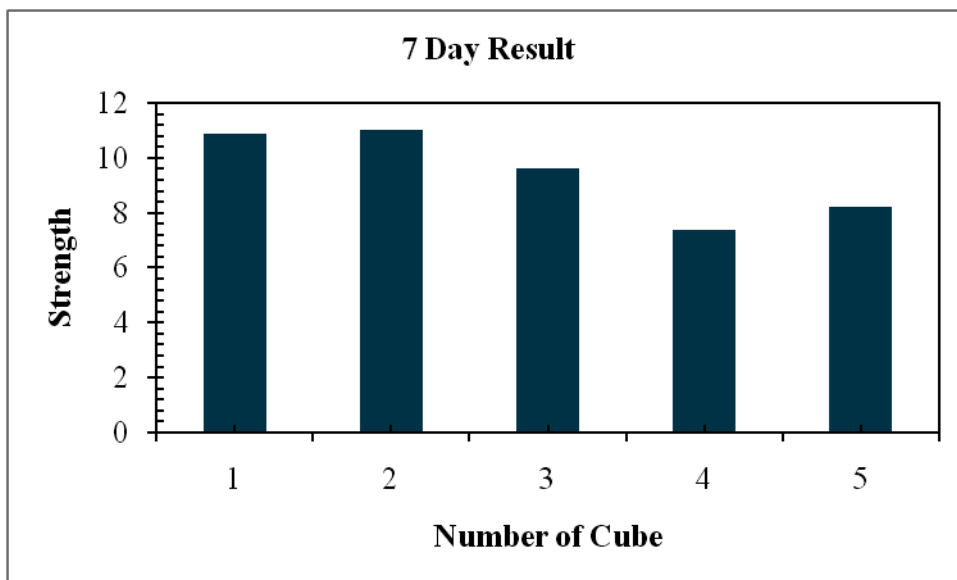
- ❖ The compressive strength at 3 days of DLC Grade of concrete average compressive strength 4.66MPA.
- ❖ The compressive strength at 7 days of DLC Grade of concrete average compressive strength 9.43MPA.
- ❖ The compressive strength at 28 days of DLC Grade of concrete average compressive strength 28.59MPA.

*Table 4.20 DLC +FA 15% + RCA 30%*

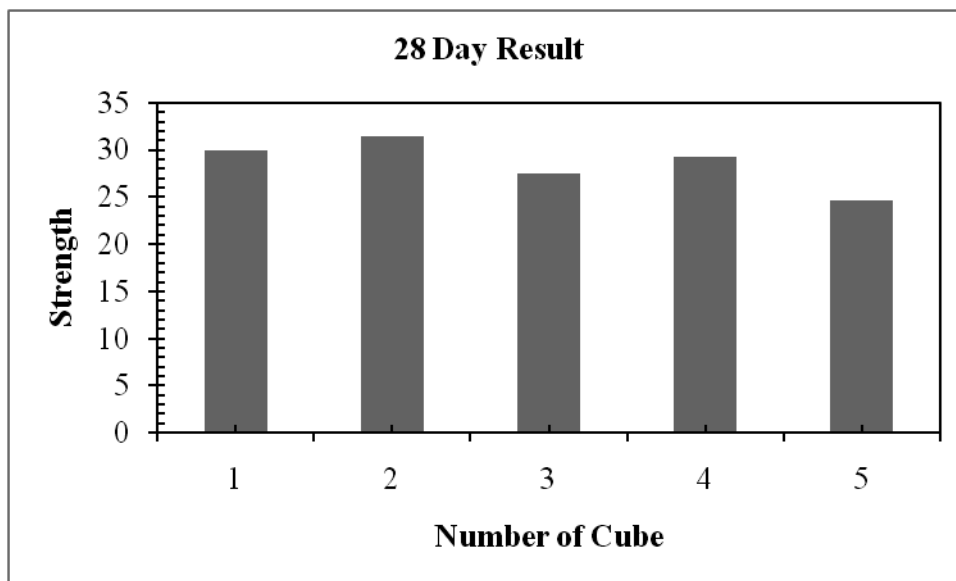
Cube No	3 Day	7 Day	28 Day
1	4.5	10.9	30
2	4.9	11	31.44
3	5.2	9.6	27.54
4	4.7	7.4	29.31
5	4.3	8.2	24.66



*Figure 4.16-3 Day Result*



*Figure 4.17-7 Day Result*



*Figure 4.18-28 Day Result*

#### 4.7.7 Summary of Result 3, 7 & 28 Days

*Table 4.21 Results Table*

Cube Name	Cube No	Results (MPA)		
		3 Day	7 Day	28 Day
DLC	01	4.73	7.34	29.24
	02	4.20	7.12	28.48
	03	3.69	7.44	29.77
	04	4.57	7.38	29.52
	05	4.66	7.25	29.00
DLC + FA 15%	01	4.45	7.40	29.60
	02	4.66	7.35	29.40
	03	5.14	10.9	29.96
	04	5.44	9.00	28.56
	05	4.87	8.40	29.28
DLC + FA 15% + RCA 10%	01	4.30	7.30	30.60
	02	4.50	7.56	22.80
	03	4.89	10.9	32.70
	04	5.23	9.99	27.00
	05	4.95	8.40	25.20
DLC+ FA 15% + RCA 20%	01	4.40	9.29	32.90
	02	4.77	7.80	22.80
	03	5.50	8.55	25.50
	04	4.55	10.69	31.50



	05	4.89	11.33	40.50
DLC + FA 15% + RCA 30%	01	4.49	10.90	30.00
	02	4.90	11.00	31.44
	03	5.10	9.60	27.54
	04	4.57	7.40	29.31
	05	4.33	8.20	24.66

## 5. Conclusion

### 5.1 Conclusion

The present study evaluates the performance of Dry Lean Concrete (DLC) incorporating Fly Ash (FA) and Recycled Coarse Aggregate (RCA). Based on the experimental investigations, the following conclusions are drawn:

1. The test results of the physical properties of aggregates confirm that they satisfy the requirements specified by IRC guidelines.
2. The physical properties of cement used in this study are also found to be in compliance with IRC specifications.
3. Various percentages of water content were analyzed during the mix design process. It was observed that the optimum water content is 6.5%, which corresponds to the maximum dry density of 2350 kg/m<sup>3</sup>.
4. The compressive strength of conventional DLC (control mix) at 7 days was found to be 7.30 MPa.
5. The inclusion of Fly Ash (15%) and Recycled Coarse Aggregate (10%) (by weight of cement and coarse aggregate, respectively) resulted in a slight increase in compressive strength to 7.34 MPa at 7 days.
6. A further increase in compressive strength was observed with variation in RCA content while keeping FA constant at 15%. The compressive strength values increased up to 8.62 MPa and reached a maximum of 9.48 MPa at 20% RCA replacement.
7. At 30% RCA replacement (with 15% FA), the compressive strength slightly decreased to 9.43 MPa, although it remained higher than that of the conventional DLC.
8. Comparative analysis indicates that DLC mixes incorporating FA and RCA exhibit improved strength characteristics over conventional DLC.
9. Based on performance and material utilization, the mix comprising DLC + 15% FA + 20% RCA is identified as the optimum mix.
10. From an economic and sustainability perspective, the use of Fly Ash and Recycled Coarse Aggregate in DLC is found to be a cost-effective and environmentally beneficial alternative to conventional mixes.



## 5.2 Recommendations and Future Scope

Based on the results and observations of the present study on Dry Lean Concrete (DLC) incorporating Fly Ash (FA) and Recycled Coarse Aggregate (RCA), the following recommendations and future research directions are suggested:

1. The use of Fly Ash (up to 15%) and Recycled Coarse Aggregate (up to 20%) is recommended for DLC, as it enhances compressive strength while maintaining economic and environmental benefits.
2. It is recommended to adopt DLC mixes with FA and RCA in pavement base and sub-base layers, particularly in low to medium traffic roads, as per IRC guidelines.
3. Proper quality control of Recycled Coarse Aggregate should be ensured, including removal of impurities and grading consistency, to achieve reliable performance.
4. Future studies should investigate the long-term performance of DLC mixes with FA and RCA, including durability aspects such as shrinkage, creep, permeability, and resistance to environmental conditions.
5. The effect of higher percentages of RCA (beyond 30%) and varying proportions of Fly Ash can be explored to determine the maximum feasible replacement levels.
6. Further research may be carried out on the use of additional admixtures or fibers to enhance the mechanical and durability properties of DLC.
7. Field trials are recommended to validate laboratory results and assess the practical feasibility of DLC with FA and RCA under actual site conditions.
8. A life-cycle cost analysis and environmental impact assessment should be conducted to quantify the sustainability benefits of using recycled materials in DLC.
9. The performance of DLC with FA and RCA under different curing conditions and climatic variations should also be studied.
10. Future work can include comparative studies with other supplementary cementitious materials such as GGBS, silica fume, or rice husk ash for further optimization.

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