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MECHANICAL PROPERTIES AND DESIGN OF RCC

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ABSTRACT

Roller compacted concrete is a special blend of concrete that has essentially the same ingredients as conventional concrete but in different ratios, and increasingly with partial substitution of fly ash for Portland cement. Roller compacted concrete is a mixture of cement / fly ash, water sand aggregate or common additives, but contains much less water. The produced mix is drier and essentially has no slump. Roller compacted concrete is placed in a manner similar to paving; the material is delivered by dump trucks or conveyors, spread by small bulldozers or specially modified asphalt pavers and then compacted by vibration rollers.

Roller compacted concrete is a recent development particularly in the field of dam construction. Roller compacted concrete is a lean no slump, almost dry concrete that is compacted by vibratory roller. A mixture of aggregates, cement & water are mixed in a conventional batch mixer or in other suitable mixers. Supplementary cementing material, such as fly ash can also be used. In some cases high volume fly ash to the extent of 60% by weight of cement has been used. The cement content ranges from 60 to 360 kg/cu-m.

Roller compacted concrete is placed in layers thin enough to allow complete compaction. The optimum layer thickness ranges from 20 to 30 cm. To ensure adequate bonding between the new & old layer are at cold joint, segregation must be prevented and a high plasticity bedding mix must be used at the start of the placement. A compressive strength of above 7 Mpa to 30 Mpa have been obtained.

INTRODUCTION

For effective consolidation, roller compacted concrete must be dry enough to support the mass of the vibrating equipment, but wet enough to allow the cement paste to be evenly distributed throughout the mass during mixing & consolidation process.

HISTORICAL DEVELOPMENT

In the World Rolled concrete been used to constructed many Dams, in the year

-1985-26% dams in RCC.

-2007-50% dams in RCC

World achievements over 400 dams constructed with Rolled concrete

- Asia- 46.6%
- South & Central America- 16.1%
- Europe - 10.7%

- Africa - 9.4%
- Indian subcontinent - 3.6%

The first Rolled concrete dam was taken up during 1978 and completed during 1980 in Japan. A no. of other dams quickly followed. By the end of 1985, seven RCC dams have been completed, and this method of construction technology has been accepted. In the next seven years(1992) the no. of dams constructed by this techniques rose to 96 in 17 different countries mainly in usa, Japan, Spain etc.

ENGINEERING PROPERTIES

The main engineering properties of the Rolled concrete are

- High flexural strength
- High compressive strength
- Modulus of elasticity
- High shear strength
- High density, low absorption
- Low water content
- Low water cement ratio
- Hard , durable, light coloured surface

MIX DESIGN

Work in designing the mix proportion for conventional and RC consists of a material testing and boundary gradation. The aggregate sizes are almost identical in both cases, except that for RC, the maximum size of the aggregate is generally smaller.

Aggregate sizes in the RC depend very much upon factors such as the lift's thickness, project requirements, and the cost involved. For conventional concrete mix design, having a specific W/C (water-cement ratio) and compressive strength for the 28-day age, along with the available mix-proportion charts and tables, would give a good estimate of the proportion in the designed mix. To achieve the required pavements for concrete, such as its compressive strength, the procedure may need some trial and error samples to be prepared in the laboratory for standardization.

MIX PROPORTIONING USING SOIL COMPACTION CONCEPT

Combine dry coarse and fine aggregate to produce a grading within the limits of following Table.

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Table A3.2—Recommended RCC pavement combined aggregate grading limits

Sieve size	Cumulative percent passing
25 mm (1 in.)	100
19 mm (3/4 in.)	82 to 100
12.5 mm (1/2 in.)	72 to 93
9.5 mm (3/8 in.)	66 to 85
4.75 mm (No. 4)	51 to 69
2.36 mm (No. 8)	38 to 56
1.18 mm (No. 16)	28 to 46
600 µm (No. 30)	18 to 36
300 µm (No. 50)	11 to 27
150 µm (No. 100)	6 to 18
75 µm (No. 200)	2 to 8

Approximately 9 kg of the combined aggregate are needed for each moisture- density test according to ACI-211.3R 18.

Determining of optimum moisture content

Determine the optimum moisture content by plotting the dry density of each specimen versus its respective moisture content and drawing a smooth curve through these plotted points (Fig. A3.3).
The moisture content and dry density corresponding to the peak of this curve is the optimum moisture.

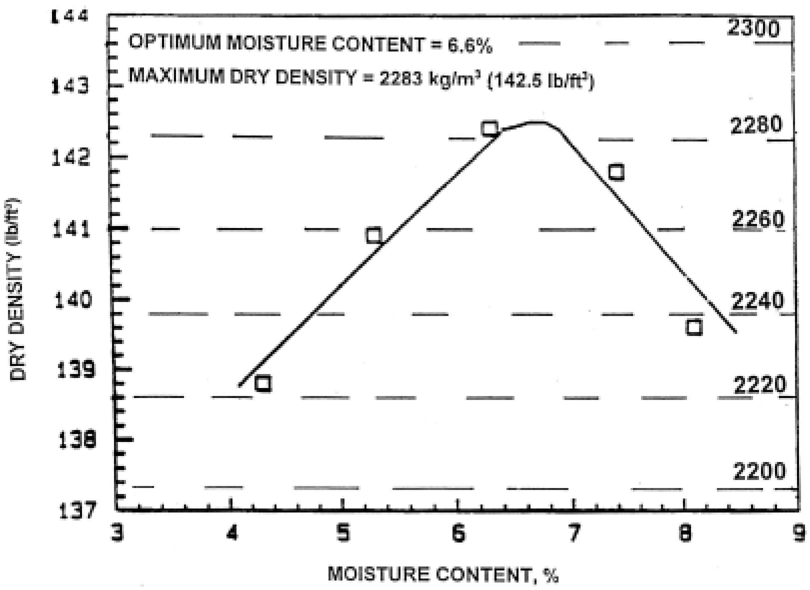


Fig. A3.3—Typical moisture-dry density relationship.

MIX PROPORTIONING CALUCULATIONS

Materials Used are

1. Cement: Ordinary Portland (53 grade) cement was used.
2. Fine Aggregate
3. Coarse Aggregate
4. Water

Sl. No.	Name of the Test	Req. as per IS: 12269-1987	Test Results
1.	Fineness of cement(Sieve Analysis)	Not more than 10 %	4%
2.	Standard Consistency (Water %)	----	30.00%
3.	Setting Times (minutes) • Initial Setting Time • Final Setting Time	Not less than 30 min. Not more than 600 min.	110 285
4.	Compressive strength (N/mm^2) • 3 day strength • 7 day strength • 28 day strength	Not less than 27.00 Not less than 37.00 Not less than 53.00	28.33 39.66 54.50
5.	Specific Gravity	---	3.15

MIX PROPORTIONS

INGREDIANT	PROPERTY	VALUE	UNIT WEIGHT (kg/m^3)
Cement	Specific Gravity	3.15	3150
Sand (FA)	Specific Gravity	2.65	2650
Coarse Aggregate	Specific Gravity	2.87	2870
Water	Specific Gravity	1.00	1000

CEMENT = 13%

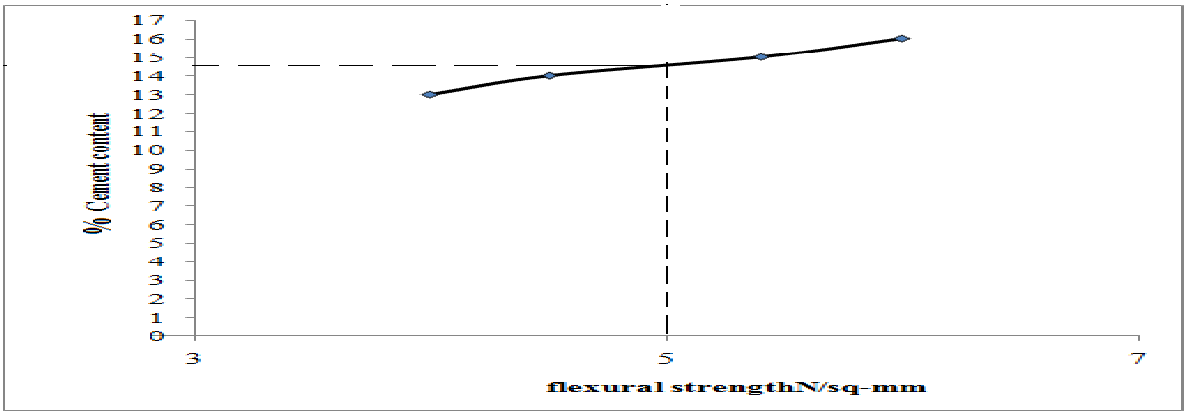
Calculation of Absolute volumes for 9 kg of aggregate

Ingredient	Sp. Gravity	Unit Weight (kg/m^3)	Volume in m^3
Cement	3.15	3150	$0.371x10^{-3}$
Sand (FA)	2.62	2620	$1.358x10^{-3}$
Coarse Aggregate	2.72	2720	$1.88x10^{-3}$
Water	1.00	1000	$0.54x10^{-3}$
Total Volume	$4.149x10^{-3}$		

For every % of cement we found the flexural Strength, split tensile & compressive strengths at 3,7,28 days.

% OF CEMENT	MIX PROPORTION	W/C RATIO
13	1:3.079:4.616	0.462
14	1:2.856:4.282	0.428
15	1:2.65:3.99	0.4
16	1:2.49:3.74	0.374

- Since flexure strength is main criteria for pavements, then the strength variation is shown fig
- By the curve a min of 5Mpa flexural strength is fixed for that 14.5% of cement content is obtained.
- Proportions for 14.5% cement are made & casted cubes, cylinders & beams



EXPERIMENTAL WORK

Experimental work on various combinations of materials

CODE	Combination of the Materials
FA-R	Partial Replacement of Cement with fly ash and River Sand as Fine Aggregate (20%, 40% and 60%)
GG-R	Partial Replacement of Cement with GGBS and River Sand as Fine Aggregate (10%, 20%, 30%, 40%, 50% and 60%)
SP-A	Addition of SP and River sand as Fine Aggregate (2.5 ml, 5 ml, 7.5 ml)

- Finally the cement is partially replaced by Admixtures and strength's were found. Graph is drawn between %replacements of cement to that of the respective strength. Hence the peak point in any Graph represents the optimum level of an Admixture that should be replaced in place of cement to get max strength.
- Using the obtained proportions we use to find the strength's like
- Flexural strength
- Compressive strength
- Split tensile strength

STRENGTH'S AND GRAPHS

4.1.1 FLEXURAL STRENGTH

FA-R Partial Replacement of Cement with Fly Ash in RCP with River Sand as Fine Aggregate

% of Fly Ash	Flexural Strength (N/mm^2)				
	@ 3 days	@7 days	@28 Days	@56 days	@90 days
20	3.2	4	5.4	5.75	5.98
40	4.4	4.4	7.1	7.32	7.60
60	0.4	1	4.2	4.7	5.38

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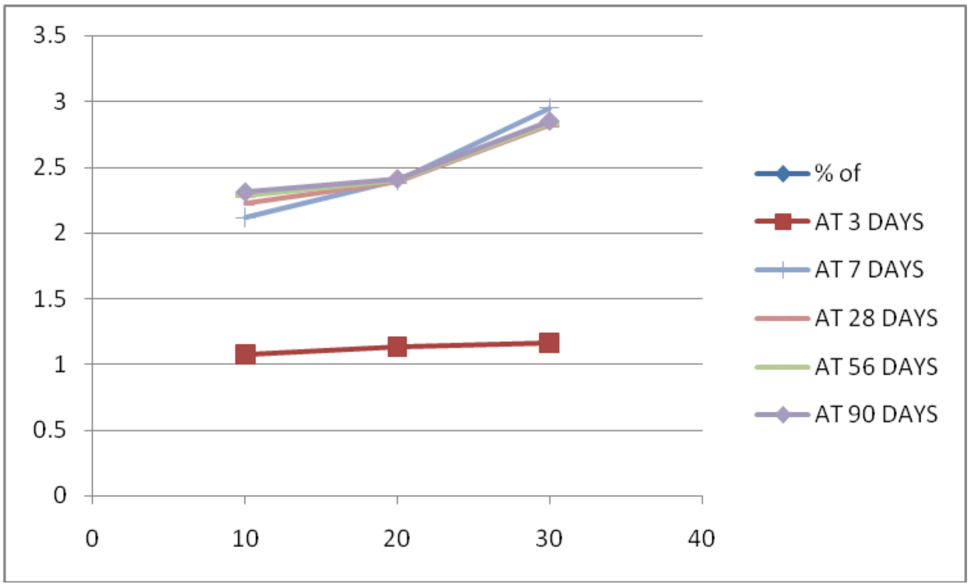
9.1.1(A) FLEXURAL STRENGTH GRAPH

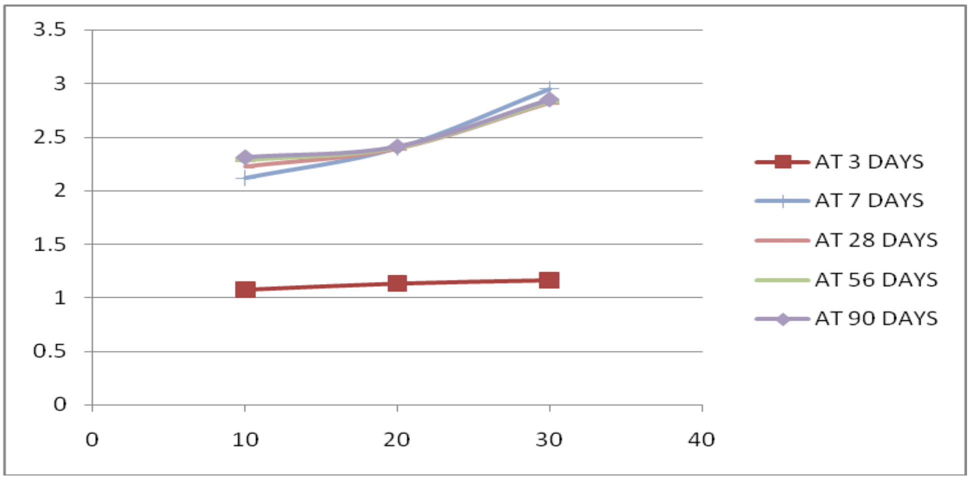


4.1.2 COMPRESSIVE STRENGTH

FA-R. Replacement of Cement with Fly Ash in RCP with River Sand as Fine Aggregate

% of Fly Ash	Compressive Strength (N/mm^2)				
	@ 3 days	@7 days	@28 days	@56 days	@90days
20	11.55	16.44	24.0	24.25	24.98
40	16.889	20.00	37.78	37.86	37.99
60	3.999	8.88	16.00	16.19	16.77

9.1.2(A) COMPRESSIVE STRENGTH GRAPH



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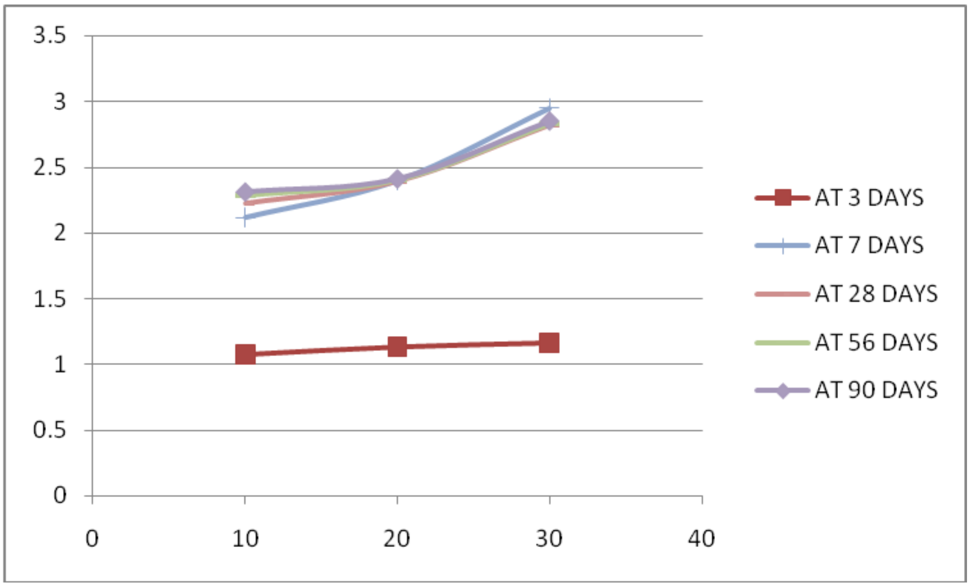
4.1.3 SPLIT TENSILE STRENGTH

FA -R. Replacement of Cement with FLY ASH in RCP with River Sand as Fine Aggregate

% of Fly Ash	Split tensile Strength (N/mm²)				
	@ 3 days	@7 days	@28 Days	@56 days	@90days
20	0.7412	1.5565	3.18	3.44	3.66
40	1.5565	1.98	5.30	5.64	5.71
60	0.1415	0.4245	1.6985	1.7123	1.7200

4.1.3(A) SPLIT TENSILE STRENGTH GRAPH



PAVEMENT DESIGN

DESIGN OF C.C PAVEMENT

DESIGN PARAMETERS

Location of pavement : HYDERABAD(A.P)

Design wheel load : 5100kg

Traffic intensity : 300vehicles/day

Tyre pressure : 7.2kg/cm²

Foundation strength (k) : 6kg/cm²

Flexural strength (fr) : 40kg/cm²

Young's modulus (E) : 3x10⁵ kg/cm²

Poisson's ratio (μ) : 0.15

Coefficient Of thermal expansion : $10x10^{-6}/^{0}c$

Joint spacing (L) : 4.5m

Lane width (W) : 3.5m

Assumed thickness : 25cm

From Table-2 of IRC-58,

For the location A.P and h= 25cm

The temperature differential (t) = 20.3˚c

$l= {}^{4}\sqrt{\{Eh^3/12k\,(1-\mu^2)\}}$

$=90.33cm$

l= radius of relative stiffness.

L/l =4.98 W/l = 3.87

From Table-8 of IRC-58

$C_l= 0.72$ $C_w= 0.59$C is the maximum of C_l and $C_w = 0.72$

5.1.2 TEMPERATURE STRESS FOR EDGE REGION

$\neg_{te} = (E\,\alpha\,t\,C)/2$

$= 21.024kg/cm^2$

$f_l = f_r - \neg_{te}$

$=18.97kg/cm^2$

5.1.3 EDGE LOAD STRESS

$\neg_{le}=18.33kg/cm^2$

$F.O.S = f_l / \neg_{le}$

$=1.03> 1$

HENCE OK

5.1.4 CORNER LOAD STRESS

$$\neg_{lc} = 3P/h^2 \left[1 - \left(\frac{a\sqrt{2}}{l}\right)^{1.2}\right]$$

$= 13.88$ kg/cm2

$\neg_{lc} < f_r$ ∴h = 25CM o.k.

DESIGN OF R.C PAVEMENT

5.2DESIGN PARAMETERS

Location of pavement : HYDERABAD(A.P)

Design wheel load : 5100kg

Traffic intensity : 300vehicles/day

Tyre pressure : $7.2kg/cm^2$

Foundation strength (k) : $6kg/cm^2$

Flexural strength (fr) : $66kg/cm^2$

Young's modulus (E) : $3x10^5\ kg/cm^2$

Poisson's ratio (μ) : 0.15

Coefficient Of thermal expansion : $10x10^{-6}/^{0}c$

Joint spacing (L) : 4.5m

Lane width (W) : 3.5m

Assumed thickness : 17.5cm

From Table-2 of IRC-58

for the location A.P and h=17.5cm

the temperature differential (t) = 18.15˚c

$l = {}^{4}\sqrt{\{Eh^3/12k(1-\mu^2)\}}$

=69cm

L/l =6.52 W/l = 5.07

From Table-8 of IRC-58

$C_l = 0.97$ $C_w = 0.73$

C is the maximum of C_l and C_w

= .97

TEMPERATURE STRESS FOR END REGON

⌐$_{te}$ = (E α t C)/2

= 26.41kg/cm^2

$f_l = f_r$ - ⌐$_{te}$

=39.59kg/cm^2

5.2.3 EDGE LOAD STREES

⌐$_{le}$=33.43kg/cm^2

F.O.S = f_l / ⌐$_{le}$

=1.18 > 1

HENCE OK

5.2.4 CORNER LOAD STRESS

⌐$_{lc}$ = $3P/h^2 \left[1 - \left(\frac{a\sqrt{2}}{l}\right)^{1.2}\right]$

= 21.66 kg/cm2

⌐$_{lc}$ < f_r

∴h = 17.5cm o.k.

CONCLUSIONS

- Rolled concrete has many times cost benefits over conventional concrete. The low cement content and use of fly ash causes less heat to be generated while curing than Conventional concrete.
- Initially Rolled concrete was used for back fill, sub-base and concrete pavement Construction, but increasingly it has been used to build concrete gravity dams. It can be used to any type of pavements that is subjected to heavy loads.

- The Rolled concrete can be used in parking areas, low speed broad ways and storage. Skid resistance to the vehicles can be easily achieved.
- The amount of labour required is significantly less than conventional p.c. c pavement of the same thickness this also results in low cost.
- Rolled concrete can be placed without form work, finishing or surface texturing. So that large quantities of concrete can be placed rapidly with minimum labour & equipment.
- As the water cement ratio is low the consumption of cement also decreases when compared to Conventional concrete. Hence it reduces the cost of construction.
- As Rolled concrete has zero slumps it is hard durable, offers resistance towards rutting & avoids the formation of pot holes.
- It will not deform under heavy & concentrated loads and will not deteriorate under weathering actions of climate. Roller compacted concrete pavements will not soften under high temperatures and its construction is fastest, easiest & most economical.