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Ferrocement Technology used for Gutter Construction

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Abstract: ***Nowadays there is increase in use of ferrocement for small or large work in the shape ferrocement is mostly used. It is very difficult to give any shape to concrete by making formwork, but in ferrocement we can give any shape circular or any curved shape. Because of the advantage over the conventional concrete ferrocement is used for more purpose. It is mostly used for architectural purposes, circular water tanks small arch dam, retaining wall roof covering, cavity wall, etc. The term "ferrocement" was given to this product by its inventor in France. At the time, (1850's) he wanted to create urns, planters, and cisterns without the expense of kiln firing. In 1875 he created the first steel and concrete bridge. The outer layer was sculpted in its wet state to mimic rustic logs, thereby also introducing concrete into practice.***
Keywords: ferrocement, mix design, gutter section, tests etc.

I. INTRODUCTION

Ferrocement is a composite material comprising rich cement which is highly reinforced with continuous and small diameter steel rods and wires. It may be defined as sophistically designed well proportioned cement based compound in which optimum quantity of suitably sized steel sections are evenly dispersed for achieving remarkable homogeneity, ideal monolithic properties, excellent strength and absolute impermeability. Its engineering properties, not only in compression but also in tension, bending and fatigue are far superior.Unlike RCC, its panels are quite thin. Its thickness is generally between 10mm to 40mm. It is light in weight and can be constructed to any shape of cross section. Hence, widely suited for precast products.The term **f**errocement is most commonly applied to a mixture of Portland cement and sand applied over layers of woven or expanded steel mesh and closely spaced small-diameter steel rods rebar. It can be used to form relatively thin, compound curved sheets to make hulls for boats, shell roofs, water tanks, etc. It has been used in a wide range of other applications including sculpture and prefabricated building components. The term has been applied by extension to other composite materials including some containing no cement and no ferrous material. These are better referred to by terms describing their actual contents.The term "ferrocement" was given to this product by its inventor in France, Joseph Monier. At the time, (1850's) he wanted to create urns, planters, and cisterns without the expense of kiln firing. In 1875 he created the first steel and concrete bridge. The outer layer was sculpted in its wet state to mimic rustic logs, thereby also introducing Faux Bois concrete into practice. Ferro-cement materials technology A working definition of ferrocement is "a thin shell of highly reinforced Portland cement mortar." Generally ferrocement shells range from 1/2 inch to 2 inches in thickness. And the reinforcement consists of layers of steel mesh. Usually with steel reinforcing bars sandwiched midway between. The resulting shell or panel of mesh is impregnated with a very rich (high ratio of cement to sand) Portland cement mortar. (Other hydraulic cements may also be used.) Specifications of ferrocement technology range widely according to use-from oceangoing vessels in which human lives are totally dependent t on the material. To small expendable household items. Although this chapter deals with ferrocement materials science in general. In practice the quality of the ferrocement. Used must be matched with the end use of the product.

II. OBJECTIVES & METHODOLOGY

This paper is explained with the help of following points

A. To check suitability of ferrocement used for gutter construction.
B. To study the design considerations of ferrocement gutter as a retaining wall.
C. To check deflection for lateral load coming due to vehicles.
D. To check for permeability, abrasion, silting etc.

III. CONSTRUCTION OF FERROCEMENT

Ferrocement construction is a high precision work. As the structure is normally around 25mm thick, there lies no scope for error in workmanship. The construction process can be divided into 4 distinct phases

A. Designing the Structure

The basic steel structure has to be properly designed. Precision of design may make or mar the final outcome.

B. Fixing the Steel Frame

The correct quantity of steel has to be arrived at based on the use of the structure. Steel structure has to be properly fixed and then wrapped with adequate layers of chicken wire.

C. Mortar Application

Cement - Sand mortar of correct ratio has to be applied on both sides of the structure. This is a very meticulous job. The application has to be good enough so that the finishing is smooth.

D. Curing

Recommended Curing is for 14 days

IV. MIX DESIGN FOR GUTTER SECTION

A. Design Stipulation

Characteristic compressive strength (28 day) : 15Mpa
Degree of workability: 0.92 compacting factor

Table No.3.1 Workability, Slump and Compacting factor

Degree of workability	Slump (mm)	Compacting factor(small apparatus)	Compacting factor (large apparatus)	Use for which concrete is suitable
Medium	50-100	0.92	0.935	For flat slab and other conventional concreting works.

Degree of quality control: good
Type of exposure: Mild

B. Test Data for Materials

Specific gravity of cement: 3.16

Compressive strength of cement at 7 days=23.35 N/mm^2

Compressive strength of cement at 3 days=17.74 N/mm^2

Satisfy the I.S Requirement
Specific gravity of fine aggregate:2.23
Water absorption of fine aggregate=3%
Free surface moisture of fine aggregate=2%
Target mean strength
Fck = fck + ks
=15 + 1.65 X 3.5
=20.775
K = 1.65 from table 11.3 (assuming 5% of result expected)

S = Standard deviation

C. Selection of Water Cement Ratio

From fig 11.10 the water cement ratio required for the target mean strength
20.775 MPA IS 0.57 (From fig 11.10 for 43 grade, page no 491, Concrete Technology by M.S.Shetty)
This greater than 0.55 prescribed for mild exposure

D. Selection of Water & Sand Content

Table No.3.2

I.S. sieve	% passing	Grading limit
4.75 mm	99.75	90-100
2.36mm	84.4	60-95
1.18mm	55.1	30-70
600µ	20.6	15-34
300µ	3.4	5-20
150µ	1.5	0-10
75µ	0.6	-

Hence sand satisfy grading Zone,Compaction Factor =0.92
Slump: 50-100mm (form table no 6.1 for manually compacted flat slab pg no 225, Concrete Technology by M.S.Shetty)
Water content: 200kg,Sand percentage40%for w/c ratio 0.6 workability C.F=0.8 slump 0.30 assume 200mm)
Adjustment of value of w/c content and sand

Table No.3.3

Change in condition for stipulated for table	Adjustment required in water content	Adjustment required in % sand in total aggregate
For sand confirming to grading zone 1,lll or lV of table 4 is 383-1979	O	+ 1.5% for zone l - 1.5% for zone lll - 3% for zone lV
Increase or Decrease in value of compacting factor by 0.1	±3%	0
Each 0.05 increase or decrease in water content ratio for rounded aggregate	0 =15kg	±1% -7%

Requirement of sand content =39.5%

Water content 200 - $\frac{3.6}{100}$ X 200=192.8 kg/m^3

E. Determination of Cement Content

Water and cement content =0.5

Water = 192.8 kg/m^3

Cement =385.6 kg/m^3

This cement content is adequate for mild exposure condition from (table no 9.18 Concrete Technology by M.S.Shetty)

minimum cement content =220 kg/m^3 for M15 and w/c ratio 0.6

F. Determination of Fine Aggregate Content

$$V = [\, w + \frac{c}{S_c} + \frac{1}{P} + \frac{Fa}{sfa}\,] \times \frac{1}{1000}$$

$$0.99 = [\, 192.8 + \frac{385.6}{3.16} + \frac{1}{P} + \frac{Fa}{0.5 \times 2.23}\,] \times \frac{1}{1000}$$

Fa = 753.35 kg/m^3

G. The Mix Proportion

Table No.3.4

water	Cement	Fine aggregate
192.8	385.6	753.35
0.5	1	1.95

The actual quantities for mix per bag of cement the mix is 0.5:1:1.95

1) Cement =50kg
2) Sand=97.5 kg
3) Water=w/c ratio is 0.5 quantities =25 lit of water

Extra water to be deducted for moisture present in sand 2% by mass=15.067 kg/m^3
Extra quantity of water for absorption in fa 3%
=22.60 kg/m^3
Actual quantity of water =
= 192.8+22.60-15.7=199.7 lit/kg
Actual quantity of sand
=753.35+15.7-22.60 =746.45 kg/m^3
Actual quantity of different constituent required

Table No.3.5

Water	cement	f.a
199.7	385.6	746.45
0.52	1	1.94

V. DESIGN OF GUTTER SECTION

Consider population =50,000
D.W.F.:-
Quantity of water supply= $\frac{50,000X270}{24X60X60}$
=156.25lit/sec
Assuming the maximum discharge is 1.5 times the average flow
Q1=1.5X156.25
=234.375 l/sec
=0.234 m^3 /sec
W.W.F
Storm water flow;
Assuming time of cone .of storm =20 min
Time of entry=5min
i=$\frac{760}{25+10}$ [for storm duration 10-20 min]
f= Duration of storm water in min
=$\frac{760}{25+10}$ =21.71 mm/hr
2.17cm/hr
Discharge due to rain water
Q= $\frac{c.i.A}{360}$ Rational formula

C= coeff. Of runoff = 0.45 for rural area
A= Drainage area in hectares
Assuming area to be served = 150 hectares

$$Q=\frac{0.45X2.17X150}{360}$$

$=0.4068\ m^3$/sec
Combined discharge=0.4068+0.234
$=0.641 m^3$/sec

Maximum permissible velocity for conc. gutter 0.5 m^3/sec
2.4 to 3 m/sec
We know that
Q=A.V
0.641=A X 3
=0.2134 sq.m.

Assume area of half circular section = $0.110 m^2$
A= $0.110 m^2$

Area of half circular section= $\frac{1}{2}$ X $\frac{\pi}{4}$ X d^2
d= 0.529 m ≈0.530
Provide 600 mm in dia half circular
Remaining area =0.2134-0.110
$=0.1036\ mm^2$
Providing rectangular section for remaining area
Thus diameter of section
bX d=0.1036 mm^2
0.53Xd=0.1036 mm^2
d= 0.195 ≈0.2m
Hence provide depth of rectangular section as 200mm
Hence the final dimension for gutter section is
Half circular section of 530 mm in diameter
Rectangular section of 530mmX200mm
Assuming free board of size 100mm
Hence final dimension of gutter is
Half circular section of 530 mm in diameter
Rectangular section of 530mmX300mm
i,e size of gutter is 530mmX300mm

Discharge through half circular section =0.33 m^3/sec

Discharge through rectangular section = 0.318 m^3/sec
Hence the external dimension for gutter section is 600X600 mm

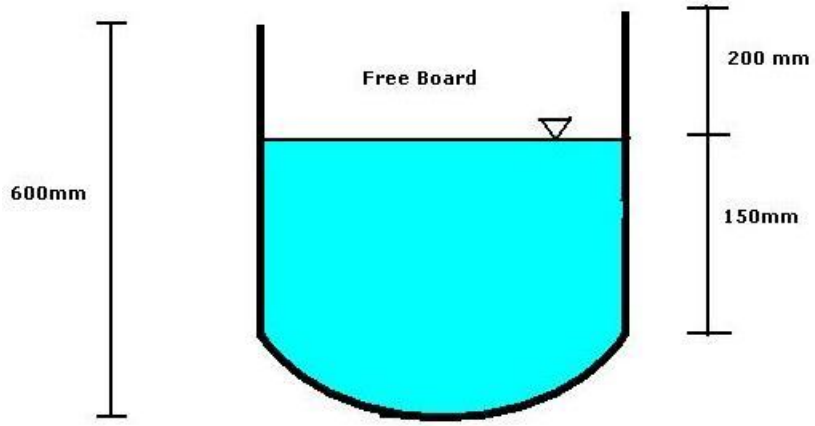


Fig.No. 3.1 – Cross section of gutter.

Hence the gutter section of width 0.530m and 0.570m depth are provided but the mould for casting of required size is not available, therefore slightly bigger size mould will be used for casting.

Calculation of weight of proposed gutter section

Mould dimension inner to inner is 600 mm Thickness will be deducted and size of inside to inside 540 mm and gutter thickness 30 mm

Height is 600-30=570mm

Density of ferrocement is 2500 kg/m^3

Avg dia of gutter section = $\frac{0.540+0.60}{2}$

=0.570m

Weight of half circular section W1

$= \frac{\pi D}{2}$ X thickness X density of ferrocement X length of section

$= \frac{\pi X 0.6}{2}$ X 0.03 X 2500 X 1.5

=106.026kg ≈ 110 kg

Weight of half circular section is 110 kg

Weight of rectangular section= depth X length X Density

=0.30 X 0.03 X2500

= 40 kg

Material required for gutter section

Reinforcement: For half circular section

Length of transverse stirrups $\frac{\pi X 0.6}{2}$ =1m +(0.3X25)=1.6m

Length of longitude section =1.5m

The spacing of ferroconcrete structure varies from 75mmto 500mmc/c

No of bars in longitudinal direction

$= \frac{Span - 2Xc/c}{spacing} + 1$

$= \frac{1600}{300} + 1 = 7$nos

Assuming spacing of bar 300mm c / c 25mm

That is 7 bar of 6mm in dia

No of bar in transverse direction

$= \frac{1500-2X25}{200} + 1$ +1=8.25nos that is 9 bars

Schedule of Reinforcement

S. R no	Description	shape	nos	ϕ (mm)	Length (m)	Total Length (m)	Weight (kg)	Total wt. (kg)
1	Longitudinal – bar	Straight	5	6	1.5	7.5	0.2827	4.12
2	Transverse steel	U shaped	9	6	1.6	14.4	0.2827	6.07

Wire mesh 13X13mm

Total Weight 10.2 kg

Add 5% for wastage =10.7kg

Material calculation

V= $\frac{\pi XDX0.03}{2} + 2X(bXd)X0.03$

V= $1.6X\frac{\pi X0.6X0.03}{2} + 2X(0.5X0.3)X0.03X1.5$

=0.0722m^3

Weight volume of concrete= 0.0722m^3

Dry volume of concrete=1.52X0.0722

=0.11m^3

Volume of Cement = 0.11/(1+2)

= 0.0367 m^3

No. of Cement Bags = $\frac{0.0367}{0.03472}$

= 1.1 bags

$\cong$ 2 bags

Volume of Sand = 0.0367$\times$2

= 0.0734 m^3

Thus the total material requirement

Cement = 1.5 bags (50 kg)

Sand =0.0734 m^3 = 0.21 brass

Reinforcement =7 kg (6mm Mild steel)

Binding Wire = 1 kg

Rate analysis for R.C.C.(1:3) for Gutter

Sr. no.	Particulars	Quantity	Rate	Per	Amount
1.	Material				
	a)Cement	2	310	Bag	620
	b) Sand	0.0734	1770	Cubic meter	130
	c)Steel	10.7	43	Kg	460
	d)Wire mesh	50	20	Sq. ft	1000
	e)Binding Wire	1	60	Kg	60
	F)Plywood	12	26	Sq.ft	312
2.	Labours				
	a)Mason	1	750	Day	750
	b)Male Mazdoor	2	300	Day	600
	c) Black Smith	1	750	Day	750
	d)Sundrise, T&P	L.S	L.S	L.S.	100
	e)Bhisti	1/2	200	Day	100

Total	4882

Add 10 % Contractor Profit = 600
GRAND TOTAL =5557/-
Rate analysis for R.C.C. (1:2:4) including Steel Reinforcement(6"thick)
Calculation of Materials

Wet Volume of R.C.C. = 1.035 m^3

Dry Volume of R.C.C. = 1.52×1.035

volume of Cement = $\frac{1.5732}{1+2+4}$

= 0.2247 m^3

No. of Bag of cement = $\frac{.2247}{0.03472}$

= 6.47 bags $\cong$ 6.5 bags

Volume of sand = 0.2247×2

= $0.45 m^3$

Volume of aggregate = 0.2247×4

= 0.9 m^3

Wt. of steel Reinforcement = $0.2 \times 1.5732 \times 7850$

= 24.69kg $\cong$ 25 kg

Binding Wire = 1 kg

Rate analysis for R.C.C.(1:2:4)6" thick

Sr. no.	Particulars	Quantity	Rate	Per	Amount
1.	Material				
	a) Cement	7	310	Bag	2170
	b) Sand	0.45	1770	Cubic meter	796.5
	c)Aggregate	.9	890	Cubic meter	800
	d)Steel	25	40	Kg	1000
	e)Binding Wire	1	60	Kg	60
2.	Labours				
	a)Mason	1	500	Day	500
	b)male Mazdoor	2	400	Day	800
	c)Female Mazdoor	2	300	Day	600
	d)Bhisti	1	200	Day	200
	e)blacksmith	2	500	day	1000
	f)sundries T&P	L.S	L.S	L.S	200
3.	Centering & Shuttering				
	a) 5% cost	Of Material	5% × 4826.5		241.325
	Carpenter	2	500		1000
	Mazdoor	2	400		800
	Nails	L.S	200		200
				TOTAL	1036.7825/-

Add $1\frac{1}{2}$ % for water charges = 155.517/-
Add 10 % Contractor profit = 1036.7825/-

Grand Total = 11560.124/-

Comparison between Ferrocement and Gutter Structure

Sr. no.	R.C.C.	Ferrocement
1)	Volume 0.3611 m^3	Volume 0.11 m^3
2)	Cement reqd. 3 bags	2 bags`
3)	Sand =0.078 m^3	0.0734m^3
4)	Aggregate = 0.156m^3	
5)	Wiremesh	100 sq.ft
6)	Labour req. Very high	Very less
7)	Formwork is required	Formless
8)	Weight = 866.64 kg	Weight = 200 kg
9)	Wt. Density = 2400 kg/m^3	Wt. Density=2500kg/m^3
10)	Steel req. = 86.35 kg	11kg
11)	Estimated cost = Rs 8858.86/-	Estimated cost = 5600/-
12)	Thickness= 150 mm	30mm
13)	Rigid in nature	Ductile in nature

Photo 3.7 - Reinforcement details.

VI. CASTING AND CURING

A. Casting of One Panel of Gutter Structure

Size of panel
Length = 1.5m
Thickness=30m
Inside diameter =600m
Material proportion
Cement: sand 1:2
Method of Casting

Casting in mould by application of mortar on one face .In this mathod, Timber planks on outer side of gutter fixed with the semicircular mould .The mortar is applied from inside of gutter.

As reinforcement, we used stirrups of 6mm in diameter .These 6mmbars are shaped in semicircular shape as pair the shape of mould with vertical projection of bars with projection of 180 mm above upper edge of semicircular mould on both side also used the longitudinal 6mm bar at 300mm c/c spacing around its periphery.

Then the chicken mesh of size of 1mm gauge with hexagonal opening is tied inner side of mould with help of binding wire.

To avoid sticking of section with mould burned oil is applied on inside surface of mould.

The newspaper spread inside the mould to avoid sticking .Then prepared reinforcement mesh is placed in mould .then check the verticality of side wall planks by plumb bob.

As per concrete mix design mortar is prepared and applied from inside face mould on wire mesh by taking care of thickness is maintained all over the section.

B. Curing

PHOTO 3.8 - Curing

VII. TEST

A. Leakage Test

Photo 3.9 - Bund construction & Setup for leakage test.

This is very important test for any structure which conveying or storing water. Leakage test for structure which conveying water or waste water is necessary to depict the losses of water or waste water. If there was any voids are remain in the walls or pipes at time of construction. It must be leakage of water or waste water and it gives wrong result at other end.The objective of that test is no find out any leak/void remain in wall of gutter at time of construction. For that test purpose we have to store water in gutter for a long time for that first we construct the bund at both sides of gutter. The bund is constructed by bricks and mortar with inside plastering. At time of constructing bund, we take the care of no any spaces will be remain or gap will be remain in two bricks or brick and gutter wall. We done the plastering and all voids are fill up and stop water.The constructing bunds are kept for two days for hardening and at date of 12/03/2014 the gutter is full filled by water one bar is kept vertical in water at middle to measure depth by attaching measuring tape with vertical bar and after that check the depth at every 6 hours. And calculate water loss.We check the water level at 6 th hours interval not much difference is created small amount of water will be reduced it is by absorption and evaporation. There is no loss of water by any type of leakage.Hence this test concludes that the gutter structure which is constructed is leak proof. No any type of leakage will be found.

1st Day of leakage test

Measurement of depth at 1st day.

Actual depth at start 50cm

Depth of water reduced as bellow.

1) 2nd day after 24 hour=49.2cm

2) 3 rd day after 24 hour=48.1 cm

3) 4th day after 24 hour =47 cm

Photo-measurements of depth of leakage

B. Silting Test

Generally whenever the flow velocity in the channel reduces the silt or suspension particles carried by waste water in suspension gets deposited on the bed and sides of gutter. The silt so deposited reduces the effective gutter cross-section and the carrying capacity of gutter.In order to prevent too much of silt deposition gutter must be property designed so as to ensure a velocity which neither causes silting nor scouring in the gutter. As per our design, we have the minimum velocity 0.4 m/s and we have to check the silting of suspended particles in waste water at our designed minimum velocity.

Photo 3.15 – Silting test& Waste water.

To obtain this test, in fluid machines lab we make setup for this test.

1) First we fill the water in tank.
2) Then the water flow in gutter section.
3) We adjust the flow of water at designed velocity at 0.42 m/s.
4) Then soil mixed sand fully mix in the water in tank and the as water flow in gutter channel.

We kept that waste water flow in gutter for two hours. And in that two hours we check that how much sand or particles are deposited on gutter bed or not.After two hours when we stop the flow we found that very small amount of sand is deposited on gutter bed not more. It's weightier up to 163 gm.This conclude that our designed minimum velocity 0.4 m/s is safe against silting not much silt is there at that velocity but if there was reduce the velocity below the minimum velocity there was possibility of silting.

C. Scouring Test

PHOTO 3.18 – Scouring test & excavation

1) First we fill the water in tank.
2) Then the water allowed to flow in gutter section.
3) We adjust the flow of water in at designed velocity at 1.56 m/s. which is maximum velocity we obtained.

4) The test is conducted for 2 days to check scoring action. but at the end of test we see that there is no scouring at the velocity of 1.56m/s

D. Deflection Test

Last test which was conducted that is Deflection test on16 april2016 at 4.20pm

For this test we were dug the pit in our college campus with the help of concrete breaker as in photo. up to the depth of 750mm and 1.5 m in length…there was hard strata below 300 mm, so we dug nearby portion also to compact it after placing gutter to achieve better result

The pit was dug near road side so to achieve better result and it will be useable after test also.

So on 16 April we did the test by passing the vehicle near the gutter

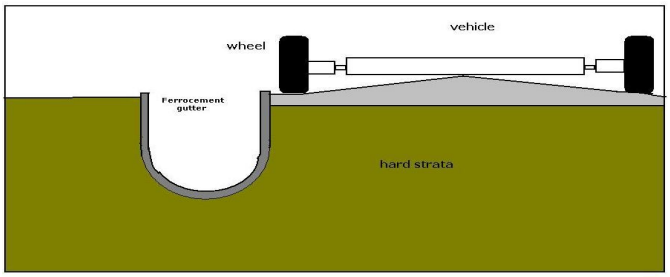
Test result for loose soil

S.r.no	Type of vehicle	Wt in kg	Recorded deflection
1	2 Wheeler	125 kg	0.53
2	4 wheeler	1040kg	1.30
3	Heavy vehicle (bus)	5.25tons	2.53

Test result for compacted soil

S.r.no	Type of vehicle	Wt in kg	Recorded deflection
1	2 Wheeler	125kg	0mm
2	4 wheeler	1040kg	0.93mm
3	Heavy vehicle (bus)	5.25tons	1.93mm

3.8Theoretically calculated deflection



1) Fig.no. 3.3 – Lateral Loading Due to Vehicle: While calculating the deflection test theoretically the other side of gutter is consider as fixed so because of load the whole gutter can't move and end near road side is considered as free end.

PHOTO 3.20 – Placing of gutter & Deflection test.

The theoretically calculated deflection by using moment area method due to lateral load 7.49 so our practically observed deflection is less so the designed gutter section is safe.

VIII. CONCLUSION AND RECOMMENDATIONS

In this investigation ,Ferrocement were used to gutter section.This work present result of 2 gutter section with using ferrocement. The result of this experimental work pointed out a general improvement in terms of durability, life ,cost of gutter section

A. Leakage Test;-this experiment conducted to check the water tightness of the gutter section .The losses observed are less, that is because of evaporation as discussed in result.

B. Siltation test;-This test is carried to the velocity of 0.4 m/s to check the siltation ..(Organic matter, sand, silt).there is no siltation is observed for this test hence the gutter section is safe against siltation.

C. Scouring Test...For this test velocity is assumed 0.4m/s we check the scouring of gutter section for 2 days but for this velocity no scouring is observed. So the gutter section is safe against scouring.

D. .Deflection test;-the experimental deflection of ferrocement gutter ranges between 0.5 to 4.which is compared theoretically that is 7.49mm by moment area method. Hence safe against deflection

E. Deflection for Loose Soil

Two wheeler (125 kg)	0.20mm
Four Wheeler(1040kg)	1.30mm
Four Wheeler heavy bus(5.25Tons)	2.53mm

F. Deflection for Compacted Soil

Two wheeler (125 kg)	00mm
Four Wheeler(1040kg)	0.93mm
Four Wheeler heavy bus(5.25Tonne)	1.93mm

G. The compressive strength of mortar (1:2) is 24 N/mm^2 Compare with I.S. Code predict 20 N/mm^2 Hence safe to design.

H. The cost comparison between concrete gutter and R.C.C. gutter leads towards economy.

I. Cost for 1 m Piece of ferrocement gutter-3704./-

J. Cost for 1 m Piece of Concrete gutter-5770/-

K. From the above discussion,it is observed that, the ferrocement gutter is durable .economical ,feasible ,than other gutters.

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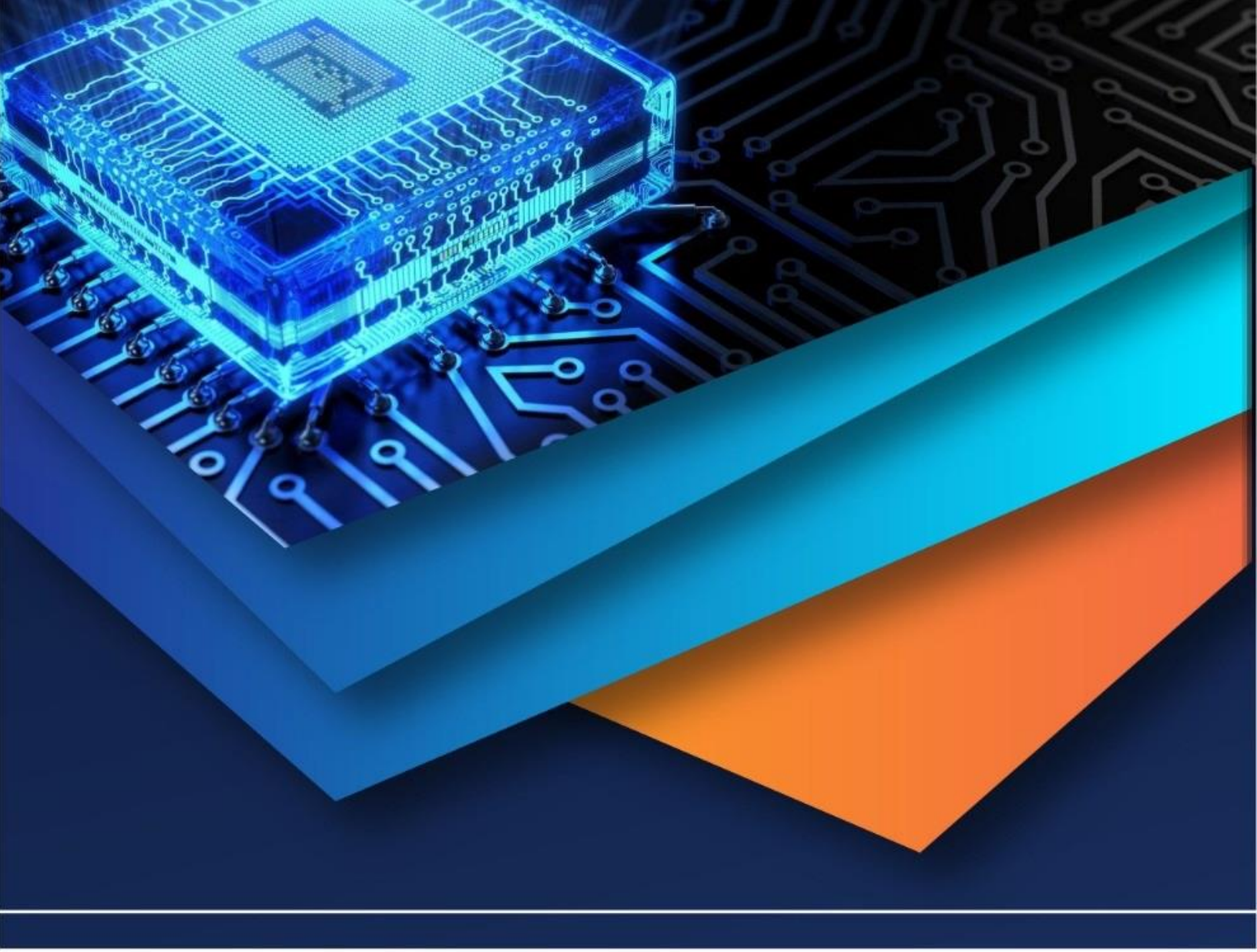

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