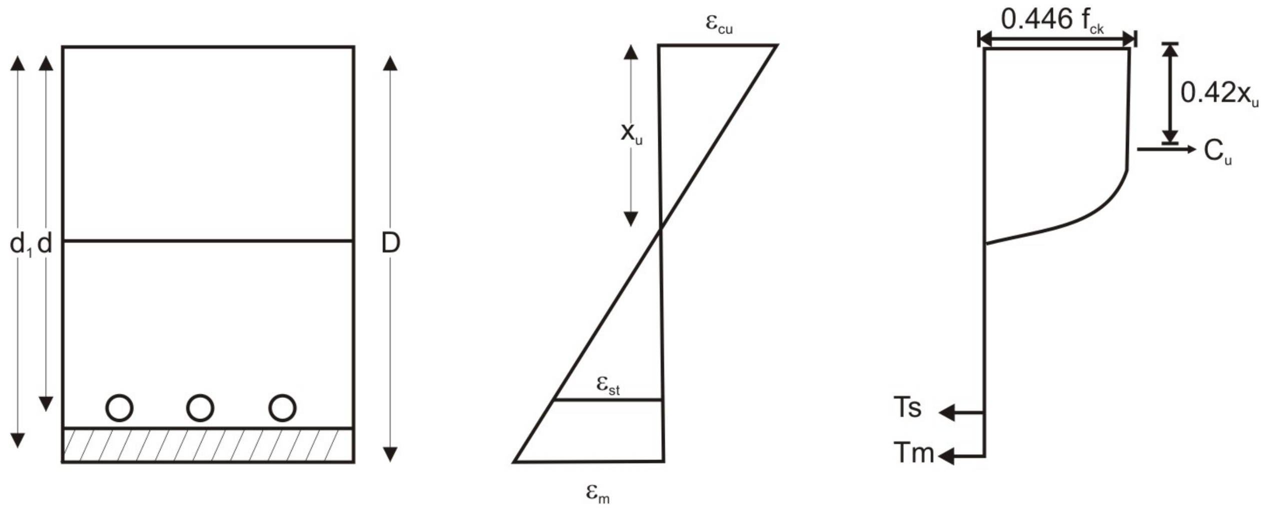
Annexure - 1
Design Stress Block Parameters for Composite Slab



Strain diagram   Stress diagram

The general expressions for C_u, T_s, T_m can be obtained by adopting partial safety factors for concrete, steel and retrofitting material at the bottom respectively.

As per IS 456:2000

$$\frac{x_u}{d_1} = \frac{\varepsilon_{cu}}{\varepsilon_{cu} + \varepsilon_m} = \frac{0.0035}{0.0035+\varepsilon_m}$$

For $\varepsilon_{cu} = 0.0035$

Material	GFRP	MS Plate	Ferrocement
x_u	$0.102d_1$	$0.\ 62d_1$	$0.804d_1$

Where,

ϵ_{cu} = Strain in concrete

ϵ_{st} = Strain in reinforcement bar

ϵ_m = Strain in retrofitted material at the bottom

d = Depth of slab from top up to centre of reinforcement

d_1 = Depth of retrofitted slab from top up to centre of retrofitted material

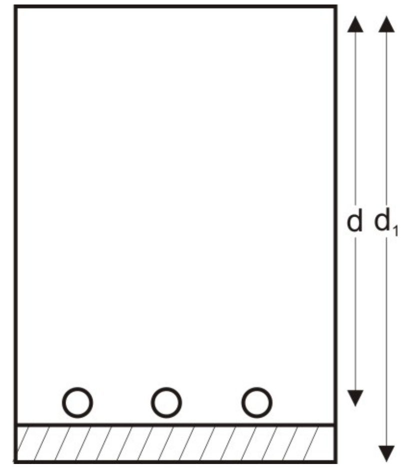
x_u= Depth of neutral axis from top

C_u = compressive force of concrete

T_s = Tensile force of reinforced bars

T_m = tensile force of retrofitted material

GFRP



Thickness of GFRP layer = 0.8 mm

Here d = 56 mm

d_1 = 75.4 mm

As per Bhunga and Arora (2008)

Flexural moment of resistance

$M_u = 0.87\, f_y\, A_{st}\, (d – 0.42\, x_u) + 0.765\, A_f E_f\, \varepsilon_{fe}\, (d_1 - 0.42\, x_u)$

Assume that the above equation is of the form M_u = A + B

Now

M_u = 0.87 x 415 x 188.4 x 56 [1– 0.42 x 0.137] + 0.765 (0.8 x 1000) x 65 x 10^3 x 0.004 (75.4 – 0.42x0.466)

= 2807396.614 + 9658106.64

M_u = 12.46 kNm

Now

$$\frac{M_u - A}{A} = \frac{B}{A}$$

$$\frac{M_u - A}{A} = \text{Damage Index}$$

The expression after solving gives a relation between A_f / A_{st} and Damage Index as explained in Fig. 5.46 in *Chapter 5* on '*Results and Discussion*'.

Here

f_y = grade of steel

A_f = cross-section area of FRP

E_f = modulus of elasticity of FRP

A_{st} = area of tensile reinforcement per meter run

ε_{fe} = Effective strain in GFRP

Ferrocement

Thickness of Ferrocement = 25 mm

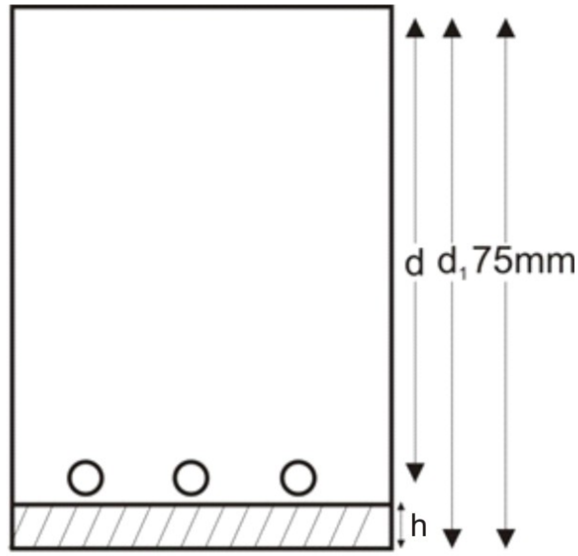
Diameter of bars = 8 mm

d = 56 mm

d_1 = 87.5 mm

Overall depth = 75 + 25 = 100 mm

h = 25 mm



As per Harvinder Singh (2001)

$$M_u = 0.36 f_{ck}bd^2 \left(\frac{x_u}{d}\right)\left(1-0.42\frac{x_u}{D}\right) + f_{ck}bd^2\left(0.87\,\sigma_m k\frac{h}{4\sigma_{ck}d}\left(\frac{d_1}{d}-1\right)\right)$$

Assume that the above equation is of the form $M_u = A + B$

Here k = constant = $S_F\,\phi$

S_F = specific surface factor = $\frac{s\sigma_y}{\sigma_m}$

s = specific surface area= $\frac{n\pi\phi}{Bh}$

n = no. of bars per meter width

ϕ = diameter of wire mesh

σ_y = tensile strength of wire mesh

σ_m = tensile strength of cement mortar

b = width of the slab

h = thickness of ferrocement layer

σ_{ck} = characteristic strength of concrete

$$s = \frac{15 \times 3.14 \times (0.7)}{1000 \times 25} = 0.00131$$

$$S_F = \frac{0.00131 \times 1010}{42} = 0.031$$

$$k = S_F \phi = 0.031 \times 0.7 = 0.022$$

$$\frac{x_u}{d_1} = 0.804 \text{ (for ferrocement)}$$

and

$$\frac{x_u}{D} = 1.25$$

Therefore,

$$M_u = 0.36 \times 20 \times 1000 \times 56^2 \times 1.25\,[1 - 0.42 \times \quad 1.25] \quad + 20 \times 1000 \times 56^2 \left(0.87 \times 42 \times \frac{0.039 \times 25}{4 \times 20 \times 56} \left(\quad 1.56\text{-}1\right)\right)$$

$$= 28224000\,[1 - 0.525] + 62720000 \left(\frac{20.09}{4480} \quad (0.56)\right)$$

= 13406400+157505.6

= 13563905.6

= 13.56 kNm

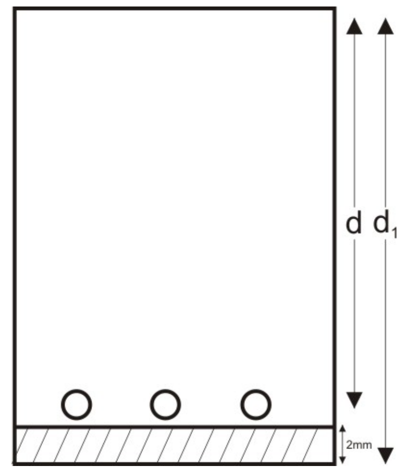
Now

$$\frac{M_u - A}{A} = \frac{B}{A}$$

$$\frac{M_u - A}{A} = \text{Damage Index}$$

The expression after solving gives a relation between (σ_m kh) and Damage Index as explained in Fig. 5.47 in *Chapter 5* on *'Results and Discussion'*.

MS Plate



Thickness of MS plate = 2 mm

Here d = 56 mm

d_1 = 76 mm

y_1 = Distance of c.g from bottom = 29.54 mm

If I = Moment of Inertia

Z= Section modulus

Flexural moment of Resistance

$M_u = \sigma Z = \sigma I/y_1 = 2.91 \times 7.61 \times 10^6$

$= 16.6$ kNm

For S1 Slab

$M_u = A + B$

$$\frac{M_u - A}{A} = \frac{B}{A}$$

$$\frac{M_u - A}{A} = \text{Damage Index}$$

Where A = Moment of control slab

B = Moment of retrofitted portion

= 5 + 0.87 x (2 x t) x 250 x 76 [1 – 0.42 x 0.62]

= 2.44t

Similarly for S2 Damage Index = 2.84t

The thickness of mild steel plate can be found out for different values of Damage Index as given in Fig. 5.48 in *Chapter 5* on ‘*Results and Discussion’*.

For Slab S1

Property / Material	M.O. R (M_u) (kNm)	Control Slab (M_u) (kNm)	Difference in flexural strength (M_u) (kNm)
GFRP	12.46	5	7.46
MS plate	13.56	5	8.56
FC	16.6	5	11.6

For Slab S2

Property / Material	M.O. R (M_u) (kNm)	Control Slab (M_u) (kNm)	Difference in flexural strength (M_u) (kNm)
GFRP	12.46	4.37	8.09
MS	13.56	4.37	9.19
FC	16.6	4.37	12.23