RSSB-JE 2020

Rajasthan Staff Selection Board

Combined Junior Engineer Direct Recruitment Examination

Civil Engineering

Design of RCC and Masonry Structures

Well Illustrated **Theory** *with*
Solved Examples and **Practice Questions**

MADE EASY Publications

Design of RCC and Masonry Structures

Contents

CHAPTER 5

Design for Bond in Reinforced Concrete

5.1 Introduction

In the previous chapters, we made an assumption that there exists a perfect bond between the steel and the surrounding concrete in order to have strain compatibility. In this chapter, we will elaborate this assumption along with the concept of development length. We will look into the fact that why anchoring of tensile bars are essential, how tor/deformed bars are better than plain bars, when the question of bond arises? We will understand what does 'bond stress' means along with the concept of 'bond strength'.

5.2 Bond in Reinforced Concrete

'Bond' in reinforced concrete is the adhesion (adhesive force) between the reinforcing steel bar and the surrounding concrete. Due to this bond only it is possible to transfer the axial force from the reinforcing steel to the surrounding concrete thus thereby introducing strain compatibility, composite/combined action of steel and concrete which avoids slippage of reinforcing bars from within the concrete. The basic assumption of flexural theory that plane sections remain plane before and after the bending is valid only if bond between the concrete and the steel is effective.

REMEMBER:

In the absence of bond, the reinforcing bar in concrete is just like a string only wherein the stress is constant at all the points on the string.

It is because of the bond only that the axial stress (tensile, compressive) in the reinforcing bar vary along its length from point to point. This is essential to accommodate the variation in bending moment along the length of flexural member.

5.3 Mechanism of Force Transfer Through Bond

Transfer of force due to bond in reinforced concrete is achieved by the following mechanisms:

1. Chemical adhesion due to sticky glue like properties of certain products of hydration of cement in concrete.
2. Frictional resistance due to surface roughness of reinforcement and the grip exerted by the surrounding concrete.
3. Mechanical interlocking due to surface protrusions/ribs on deformed reinforcing bars which is in fact not available for plain reinforcing bars.

5.4 Bond Stress

Bond resistance is achieved by development of tangential (shear) stress along the interface (contact surface) between the reinforcing bars and the concrete. The stress developed at the interface of steel and concrete is called as bond stress.

5.5 Various Types of Bond in Reinforced Concrete

There are two major types of bond according to the types of loading as:

1. **Flexural bond:** It comes into play in flexural members on account of shear or variation in bending moment. This in turn causes a variation in the axial tension along the length of reinforcing bar.

   Flexural bond is critical at locations where shear $\left(V = \frac{dM}{dx}\right)$ is significant.

2. **Anchorage/development bond:** It arises over the length of anchorage provided for a bar or at the end of reinforcing bar. This bond resists the pulling out of bar if it is in tension or pushing in of the bar if it is in compression.

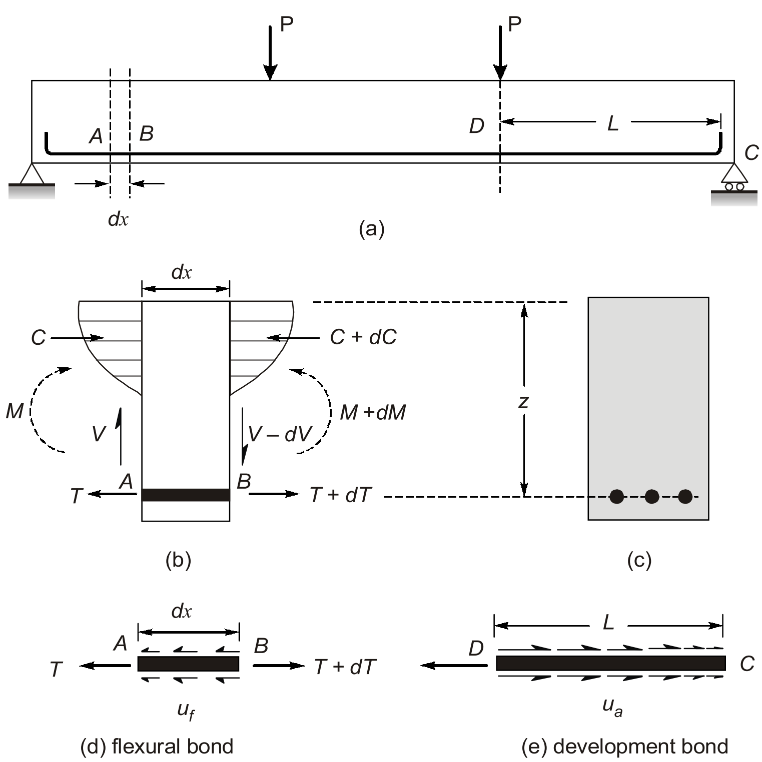


Fig. *Different types of bond in reinforced concrete*

5.6 Flexural Bond

The variation in tension along the length of reinforcing bar owing to varying bending moment is due to flexural bond. Consider two sections on a beam distant 'dx' apart as shown in the figure, which are acted upon by a differential moment 'dM'. If 'z' is the lever arm then,

At section A, $M = Cz = Tz$

and at section B, $M + dM = (C + dC)z = (T + dT)z$

From above two equations, $dT = \dfrac{dM}{z}$ ...(i)

Therefore, force 'dT' which is the unbalanced force in the bar actually gets transferred to the surrounding concrete. This force transfer through this mechanism is called as **flexural bond**. This force gets developed along the interface of reinforcing bar and the surrounding concrete.

Let, Σo = Total perimeter of all the reinforcing bars at the beam section under consideration

dx = Elementary length of the beam under consideration

u_f = Flexural bond stress

Thus, $u_f(\Sigma o)dx = dT$ ...(ii)

From equations (i) and (ii),

$$u_f = \frac{\dfrac{dM}{z}}{(\Sigma o)dx} = \frac{V}{(\Sigma o)z} \quad \text{...(iii)}$$

where, V = Transverse shear force at the section = $\dfrac{dM}{dx}$

Thus flexural bond stress is high at locations of high shear force (V) and the term (Σo) in the denominator indicates that flexural bond stress can be reduced by using small diameter of large number of bars.

5.6.1 Factors Affecting The Flexural Bond Stress

The actual flexural bond stress gets affected by the following factors:

1. Appearance of flexural cracking.
2. Local slip of reinforcing bars in concrete.
3. Splitting of concrete and other secondary effects.

5.7 Anchorage/Development Bond

This anchorage/development bond gets developed at the extreme cut-off end of the bar subjected to tensile force/ compressive force.

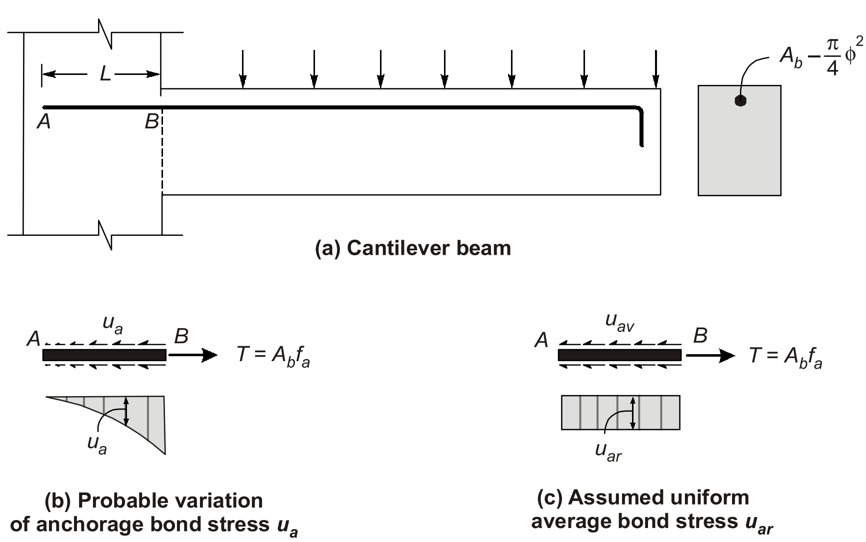


Fig. *Anchorage/development bond in reinforced concrete* by 60% for HYSD bars. The stress in the HYSD reinforcing steel bars in tension, σ_s = 360 MPa. The required development length 'Ld' for HYSD bars in terms of bar diameter 'ϕ' is_______

(a) 46.875 ϕ (b) 89.235 ϕ
(c) 56.213 ϕ (d) 82.345 ϕ

Q.4 In limit state design, permissible bond stress in the case of deformed bars is more than that in plain bars by

(a) 60% (b) 50%
(c) 40% (d) 25%

Q.5 For bars in tension a standard hook has an anchorage value equivalent to a straight length of

(a) 8ϕ (b) 12ϕ
(c) 16ϕ (d) 24ϕ

[Chandigarh-JE : 2016]

Q.6 Match **List-I** (Reinforcement type) with **List-II** (Anchorage requirement) and select the correct answer using the codes given below the lists:

List-I
A. Footing slab, tensile reinforcement
B. Cantilever beam, tensile reinforcement
C. Simply supported beam, tensile reinforcement
D. Beam, shear stirrup

List-II
1. $\frac{L_d}{3}$ into the support
2. 6ϕ for 135° bend
3. L_d into the support
4. L_d from the column face

Codes :

	A	B	C	D
(a)	1	3	4	2
(b)	1	2	4	3
(c)	4	3	1	2
(d)	4	2	1	3

Q.7 Lap length of reinforcement in compression shall not be less than

(a) 30ϕ (b) 24ϕ
(c) 20ϕ (d) 15ϕ

where ϕ = diameter of bar.

Q.8 The development length in compression for a 20 mm diameter deformed bar of grade Fe 415 embedded in concrete of grade M25 whose design bond stress is 1.40 N/mm^2, is

(a) 1489 mm (b) 1289 mm
(c) 806 mm (d) 645 mm

Q.9 Lapped splices in tensile reinforcement are generally not used for bars of size larger then

(a) 18 mm diameter
(b) 24 mm diameter
(c) 30 mm diameter
(d) 36 mm diameter

[DDA-JE : 2018]

Q.10 The development length in compression for a 20 mm diameter deformed bar of grade Fe-415 embedded in concrete of grade M-25, whose design bond stress is 1.40 N/mm^2 is

(a) $\frac{20\times0.87\times415}{4\times1.40}$ mm

(b) $\frac{20\times0.87\times415}{4\times1.25\times1.40}$ mm

(c) $\frac{20\times0.87\times415}{4\times1.6\times1.40}$ mm

(d) $\frac{20\times0.87\times415}{4\times1.25\times1.6\times1.40}$ mm

Q.11 For bars in compression, the values of bond stress for bars in tension shall be increased by

(a) 10% (b) 15%
(c) 20% (d) 25%

[Haryana-JE : 2018]

Q.12 In limit stage design, permissible bond stress in case of deformed bars is more than that in plane bars by

(a) 25% (b) 40%
(c) 45% (d) 60%

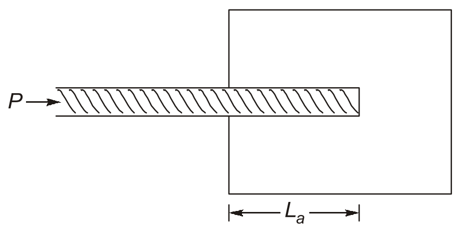
[PMB-JE : 2018]

ANSWER KEY // **STUDENT'S ASSIGNMENT**

1. (*) **2.** (b) **3.** (a) **4.** (a) **5.** (c)
6. (c) **7.** (b) **8.** (d) **9.** (d) **10.** (d)
11. (d) **12.** (d)

HINTS & SOLUTIONS / STUDENT'S ASSIGNMENT

1. (*)



A_s = Area of cross-section

f_s = Compressive stress in the bar

$$P = f_s\, A_s = f_s \frac{\pi}{4}\phi^2$$

This compressive force P, should be transferred from steel to concrete through bond.

P = Perimeter × $L_a \times f_{bd} = \pi\phi\, L_a\, f_{bd}$

$$f_s \frac{\pi}{4}\phi^2 = \pi\phi L_A f_{bd}$$

$$L_a = \frac{f_s\phi}{4 f_{bd}}$$

f_{bd} is taken 25% more according to clause 26.2.1 of IS 456 : 2000 in case of compression

$$\therefore \quad L_a = \frac{f_s\phi}{4\times 1.25 f_{bd}} = \frac{f_s\phi}{5 f_{bd}}$$

2. (b)

$$\text{Bond stress } (\tau_{bd}) = \frac{\text{Tensile force}}{(n\pi\phi)\sigma_{st}}$$

τ_{bd} should be less than permissible value, if it is greater than $(\tau_{bd})_{\text{permissible}}$ then best economical solution is to reduce the diameter of bar and increase its number.

Also bond strength is dependent on the surface area of bar. Hence for providing the same A_{st} we can choose smaller diameter bars and increase their number and hence surface area will increase.

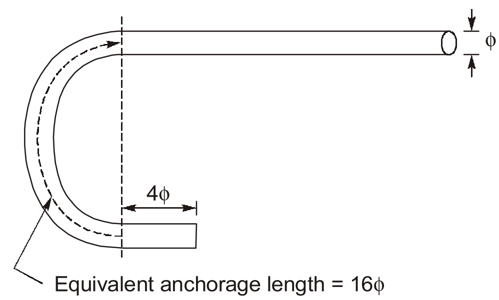
3. (a)

$$L_d = \frac{\phi\sigma_{st}}{4\tau_{bd}} = \frac{\phi\times 360}{4\times 1.2\times 1.60} = 46.875\ \phi$$

4. (a)

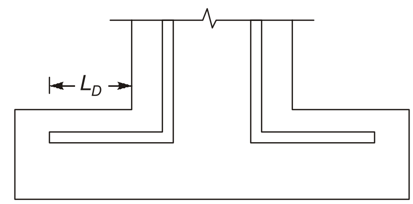
As per **IS 456 : 2000, clause 26.2.1**, for deformed bars, the bond stress shall be increased by 60% of the values for plain bars in tension. For bars in compression, the values of bond stress for bars in tension shall be increased by 25%.

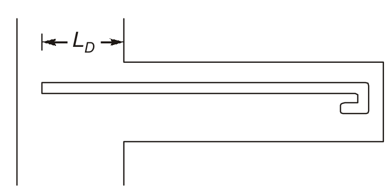
5. (c)



6. (c)

- In footing anchorage requirement is L_d from column face.
- In cantilever beam anchorage requirement is L_d into the support.
- For simply supported beam it is $\frac{L_0}{3}$ into the support.





For shear stirrup in beam anchorage length is

(i) 8ϕ for 90° bend

(ii) 6ϕ for 135° bend

(iii) 4ϕ for 180° bend

7. (b)

Lap length in compression shall not be less than 24 ϕ

Lap length in flexural tension shall be greater of L_d or 30 ϕ

Lap length in direct tension shall be greater of $2L_d$ or 30 ϕ.

where L_d is the development length.