A rectangular beam that must carry a service live load of 2.47 kips/ft. and a calculated dead load of 1.05 kips/ft. (without self-weight) on an 18-ft. simple span is limited to 10 inches width and 20 inches total depth for architectural reasons. If $f_y = 60000$ psi and $f'_c = 4000$ psi. What steel area must be provided? Draw sketch of your final design.

Question #(1)

Sol:-

Design load = 1.2 D.L + 1.6 L.L

= 1.2 (1.05) + 1.6 (2.47)

P_u = 7.09384 Kips/ft

P_u = 49.2627 psi

Moment = $M_u = \frac{wl^2}{8} \times 12$

$= \frac{49.2627 (18)^2}{8} \times 12$

= 23941.7 psi

Reinforcement ratio:

$$\rho = \frac{0.85 f_c'}{f_y} B_1 \frac{\varepsilon_c}{\varepsilon_c + \varepsilon_s}$$

$$\rho = \frac{0.85 (4000)}{60000} \times 0.85 \frac{0.003}{0.003 + 0.009}$$

$\rho = 0.022$ or 2.2%

Area of steel:

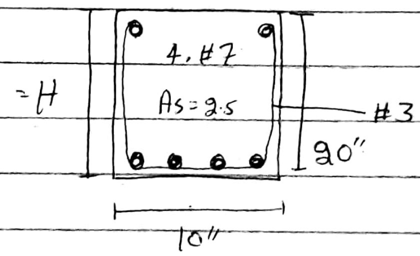
$A_s = \rho b d$

$As = 0.019 \times 10 \times 20 = 2.5 in^2$

Bar#	Area sqin	No's	Selec
#4	0.196	13	
#6	0.441	6	
#7	0.601	4	
#8	0.785	3	

use 4 #7

Total height:



$H = 20'' + 0.5'' + 3/8'' + 0.875$

$H = 21.75$

Detail checking.

$\rho_{design} = \frac{As}{bd} = \frac{2.5}{20 \times 10} = 0.012$

$\rho_{min} = 0.0033$ **OK**

Scanned with CamScanner

a) Briefly describe Bond stress and Development length.
b) In which conditions doubly reinforced beam can be used?
c) Differentiate between T-beam analysis and rectangular beam analysis.
d) Write short note on the effect of strength reduction factor on flexural strength.
e) Briefly describe design methods, which one of them can be best used foı design of different structural members and why?

Bond stress:

The stress which is acting on the outer interface of steel to the surrounding concrete is called bond stress. This stress helps in keeping bond between reinforcement and concrete together. Bond stress resists any force that tries to pull out the rods from the concrete.

When you try to pull out the reinforcement bar from hardened concrete, then this Bond stress resists the bar to come out.

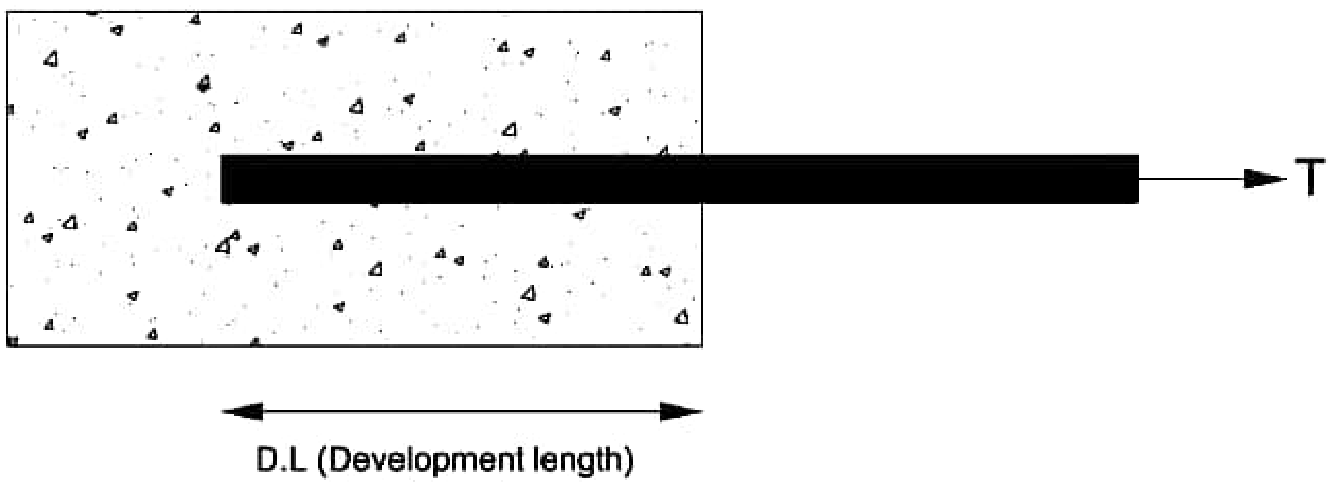
By the way different grades of concrete has different bond stress.

Anchorage bond:-

This bond is seen when a bar carrying certain force is removed. In such cases, it is necessary to transfer this force in the bar to the surrounding concrete over a certain length.

This length of bar required to transfer the force in the bar to the surrounding concrete through bond is called "Development length (D.L.)"

Development length (DL) is determined by performing Pull out Test.



It is clear from the above image, that reinforcing bar is embedded in concrete and subjected to a pull **T**

T = Design Stress x area of bar = 0.87 Fy x (Pi/4) x d2

d= Dia of bar

This force must be transferred from steel to concrete through bond acting over the interface (perimeter) of the bar over a length (D.L.)

If Tbd = Avg Design bond stress

Then Ultimate Bond force = Pull out force

Tbd (Pi x d) x D.L. = 0.87 Fy [(Pi/4 x d^2)]

D.L = [0.87 x Fy x d] / [4 Tbd]

hence all bars should extend to a distance of (DL) beyond the section where they are required to take full design force.

it is not possible to provide straight bars at all the times due to lack of space at supports. In such scenarios we provide them as hooks and bends.

The anchorage value (hook length) = **16d**

The anchorage value (Bend length) =**4d** **(45degree angle)**

Doubly reinforced beams are provided because of the following reasons :-

1. Doubly reinforced beams are provided in order to increase the moment carrying capacity of the section. **We also know that we can increase the moment carrying capacity of beams by increasing it's depth but it is not always possible to increase the depth of beam because of Architectural and Aesthetic restrictions.** Moreover increasing the depth of beam will result into the more self weight (Dead Load).

2. Minimum compression reinforcement is provided to hold the Shear Reinforcement (**stirrups**) in position and for increasing the ductility of beam.

3. **Most important reason** for providing the doubly reinforced beams is to ensure **safety against reversal of stresses** in the structure due to Wind Forces, Seismic Forces and temperature stresses.

The main difference between a rectangular beam and a T beam in reinforced concrete is

1. Geometry
2. Flexural capacity
3. Design procedure

In terms of geometry it's very clear one is rectangular and the other is T. But here you should not that the T beam offers more moment of inertia.

2. The flexural capacity of T beam varies based on the sign of moment (positive or negative). The resistance of T beam is higher for positive moment because the flange section would be in compression. But for negative moment it yields the same strength as an equivalent beam without the flange. While the rectangular section only dedepends on the location of rereinforcement to yield the flexural capacity.

3. The design procedure of T beam depends on the location of moment as the case of its flexural strength. For positive moment we have three cases to be checked to proceed with design one of the neutral axis is within the Flange two neutral axis outside of the flange or in the web and three doubly reinforced T beam. So you neeed to make sure which case is your beam before proceeding to design.

Methods of Structural Design

- **Working stress method (WSM)**
- **Ultimate load method (ULM)**
- **Limit state method (LSM)**

1. Working stress method (WSM)

The method basically assumes that the structural material behaves as a linear elastic manner, and that adequate safety can be ensured by suitably restricting the stresses in the material induced by the

This was the traditional method of design not only for reinforced concrete, but also for structural steel and timber design.

expected **“working loads”** on the structure.

As the specified permissible stresses are kept well below the material strength, the assumption of linear elastic behavior is considered justifiable. The ratio of the strength of the material to the permissible stress is often referred to as the **factor of safety.**

Many factors are responsible for this such as a long term effort of creep and shrinkage, the effects of stress concentrations, and other secondary effects. All such effects resulting significant local increases in a redistribution of the calculated stresses.

The design usually results in relatively large sections of structural members, thereby resulting in better serviceability performance under the usual working

2. Ultimate load method (ULM)

With the growing realization of the shortcomings of **WSM** in reinforced concrete design, and with increased understanding of the behavior of reinforced concrete at ultimate loads, the ultimate load of design is evolved and became an alternative to WSM.

This method is sometimes also referred to as the load factor methods are the ultimate strength. In this method, the stress condition at the site of impending collapse of the structure is analyzed, and the nonlinear stress-strain curves of concrete and steel are made use of.

The concept of ‘modular ratio’ and its associated problems are avoided entirely in this method. The safety measure design is introduced by an appropriate choice of the load factor, defined as the ratio of the ultimate load to the working load.

The ultimate load method makes it possible for different types of loads to be assigned different load factors under combined loading conditions, thereby overcoming the related shortcoming of **WSM.**

This method generally results in more slender sections, and often economical designs of beams and columns, particularly when high strength reinforcing steel and concrete are used. However, the satisfactory 'strength' performance at ultimate loads does not guarantee satisfactory **‘serviceability’** performance at the normal service loads.

The designs sometimes result in excessive deflections and crack-widths under service loads, owing to the slender sections resulting from the use of high strength reinforcing steel and concrete.

The distribution of stress resultants at ultimate load is taken as the distribution at the service loads, magnified by the load factor(s); in other words, analysis is still based on linear elastic theory.

3. Limit state method (LSM)

The philosophy of the limit state method of design represents a definite advancement over the traditional design philosophies.

Unlike WSM which based calculations on service load conditions alone, and unlike ULM, which based calculations on ultimate load conditions alone, LSM aims for a comprehensive and rational solution to the design problem, by considering **safety** at ultimate loads and **serviceability** at working loads.

The LSM philosophy uses a multiple safety factor format which attempts to provide adequate safety at ultimate loads as well as adequate serviceability at service loads, by considering all possible service loads, by considering all possible 'Limit State'.

Limits States

A limit state is a state of impending failure, beyond which a structure ceases to perform its intended function satisfactorily, in terms of either safety of serviceability i.e. it either collapses or becomes unserviceable.There are two types of limit states:

to perform its intended function satisfactorily, in terms of either safety of serviceability i.e. it either collapses or becomes unserviceable.There are two types of limit states:

Ultimate limit states (limit states of collapse):- which deal with strength, overturning, sliding, buckling, fatigue fracture etc.

Serviceability limit states: – which deals with discomfort to occupancy and/ or malfunction, caused by excessive deflection, crack width, vibration leakage etc., and also loss of durability etc.