Structural Concrete and Steel

Syllabus

1- Concrete Basics
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4- Serviceability
5- Flexure: Design of Beams and one-way Slabs.
6- Shear Design of Beams and one-way Slabs
7- Behavior and analysis of continuous Beams and slabs.
8- Design and analysis of two-way Slabs.
9- Design and analysis of Columns.
10- Design and analysis of steel members.

References

1- Reinforced concrete Design (A practical Approach)
By: Svetluna Brzev & John Pao.
2- Structural Design for Architecture
By: Angus J. Macdonald
3- إنشاءات خرسانية / الادارة العامة لتصميم وتطوير المناهج /
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4- Steel designer's Manual / By: B. Davison & G.W. Owens ; 6th Edition - 2003

Introduction

Reinforced concrete is one of the principal building materials used in engineering structures. The economy, efficiency, durability, modability, and rigidity make it an attractive material for a wide range of applications.

- Advantages of R.C.

1- The relatively low cost.
2- Good weather and fire resistance.
3- Good compressive strength.
4- Excellent formability of concrete.
5- Good tensile strength and much ductility and toughness of steel.

- Disadvantages of R.C.

1- Concrete is brittle material whose tensile strength is small, therefore need steel.
2- Need forms to support the structure to reach its designed strength.
3- High dead load from concrete in structures with long span.
4- Properties of concrete widely depends on the properties of mix.

Definitions :-

- **Aggregate :** Granular material, such as Sand, gravel, crushed Stone, and iron-blast-furnace slag.
- **Aggregate, lightweight :** Aggregate with a dry, loose weight of 1120 Kg/m^3 or less.
- **Concrete :** Mixture of Portland cement or any other hydraulic cement, fine aggregate, coarse aggregate, and water, with or without admixtures.
- **Concrete, all-lightweight :** lightweight concrete containing only light-weight aggregates.
- **Concrete, Lightweight :** concrete containing lightweight aggregate and an equilibrium density, between 1140 and 1840 kg/m^3.
- **Plain concrete :** Structural concrete with no reinforcement or with less reinforcement than the minimum amount specified for reinforced concrete.
- **Plain reinforcement :** Reinforcement that does not conform to definition of deform reinforcement.
- **Reinforced concrete :** Structural concrete reinforced with no less than the minimum amounts of Steel reinforcement.

⊛ Concrete Strength :-

The main measure of concrete strength is its compressive strength (f'c or fcu).

① compressive strength :

Compressive strength of concrete is high and can be measured by testing of 150 mm diameter x 300 mm height cylinders or 150 x 150 x 150 mm cubes under standard laboratory conditions at age of 28 days.

② Tensile strength :

The tensile strength of concrete is relatively low about (10 - 15) % of the compressive strength. Tensile strength is difficult to measure and results vary according to the type of test.

⊛ Reinforcing steel strength :

Compared with concrete, steel is a high strength material. The useful strength of steel bars is tension as well as compression. The yield strength is about 15 times the compressive strength of common structural concrete, and well over 100 times its tensile strength. On the other hand, steel is a high cost material compared with concrete, so that the two materials are best used in combination if the concrete is made to resist the compressive stress and the steel resists the tensile stress.

Properties of Concrete and Steel re-bars :-

Concrete and steel were used together make good performance for reinforced concrete, as shown in table below:

Property	Concrete	re-bar
Tensile strength	very low	very good
Compressive Strength	good	good
Shear strength	Moderate	good
Durability	very good	low
fire resisting	good	low

The main features which make steel and concrete working together are the following:

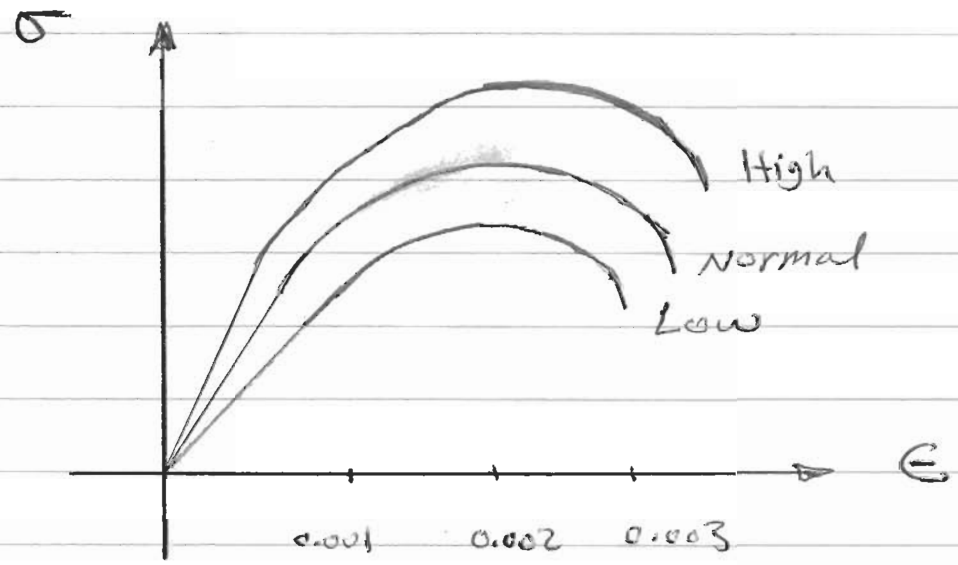
1- The thermal expansion coefficient of the two materials are sufficiently close, about 65×10^{-7} for steel and 55×10^{-7} for concrete.

2- While the corrosion resistance of steel re-bars are low, the concrete which surrounding the bars provides excellent corrosion protection, see clause 7.7 in ACI code.

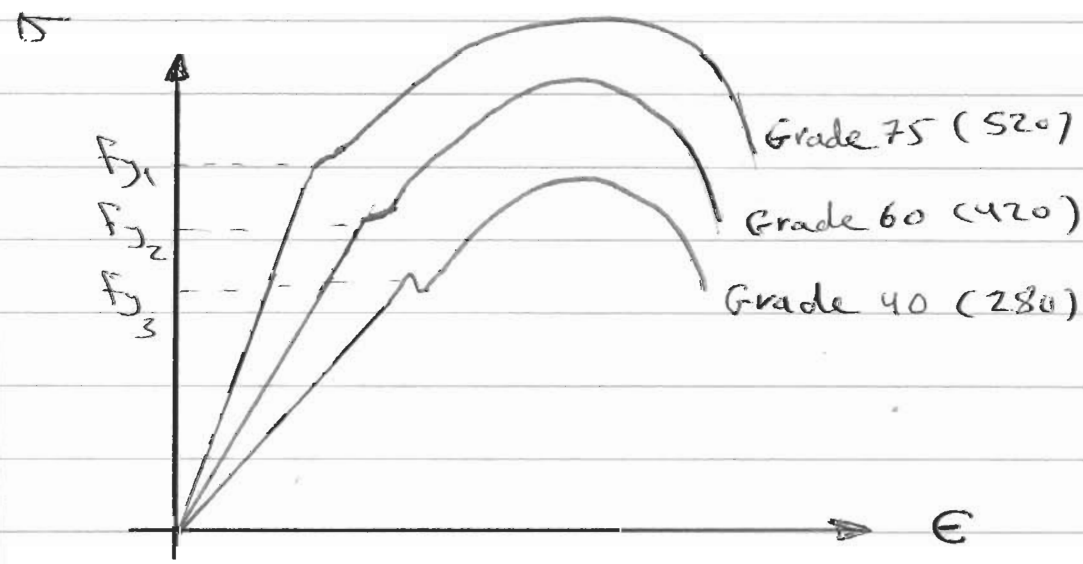
3- The fire resistance of steel re-bars are low, the concrete cover provides sufficient thermal insulation for the embeded bars.

Stress-Strain curve :

Performance of a structure under load depends to a large degree on the stress - strain relationship of the material from which it's made. Since, concrete is used mostly in compression, it's compressive stress-strain curve is primary interest. While, the steel almost used in tension regions, it's tensile stress-strain curve is significant to determine.



(Stress-Strain curve for Concrete)



(stress - strain curve for steel)

Concrete

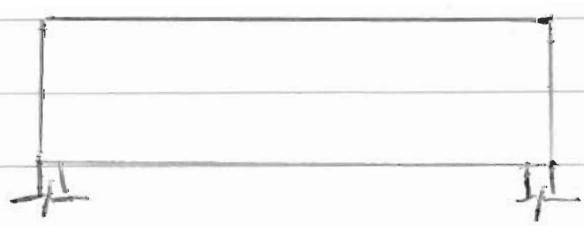
Concrete is artificial stone made from two main components: cement paste and aggregates. Aggregates usually consists of natural sand and gravel or crushed stone. The paste hardens as a result of the chemical reaction between cement and water, and ~~bond~~ glues the aggregates into a rock-like mass. The concrete manufacturing process is quite complex and includes a number of steps, such as proportioning, batching, mixing, placing, compacting, finishing, and curing. Also the fact that fresh concrete has no form of its own until it hardens. Concrete has a high compressive strength; however, its tensile strength is low (only about 10% of its compressive strength), for this reason concrete is rarely used without the addition of steel reinforcement.

Reinforced Concrete

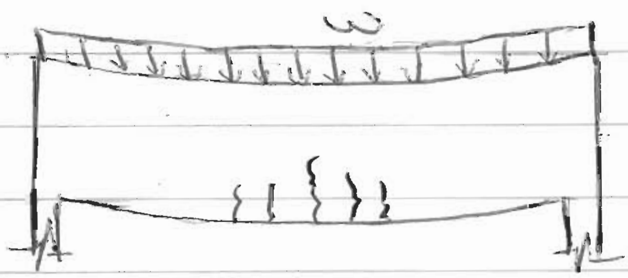
Reinforced concrete structures utilize the best qualities of concrete and steel; concrete's high compressive strength and steel's high tensile strength. The concept of reinforced concrete will be explained in an example.

Consider the following ~~simply~~ R.C. beam subjected to U.D.L, the beam deforms under the load and flexural (bending) stresses develop throughout the span. The top portion of the beam is subjected to compression, whereas the bottom is under tension.

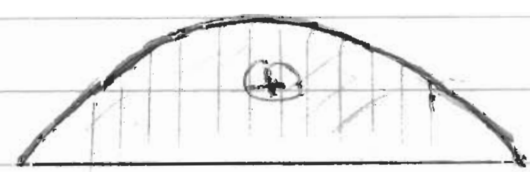
The concrete has a limited ability to carry tension so it cracks once its tensile strength has been reached. The cracks develop in the region of maximum bending moments (M_{max}), in this case around the beam mid-span. A plain concrete beam will fail in the mid-span region shortly after the cracks have developed. To prevent such behaviour, steel reinforcement is placed inside the beam near the bottom to resist the tensile stresses.



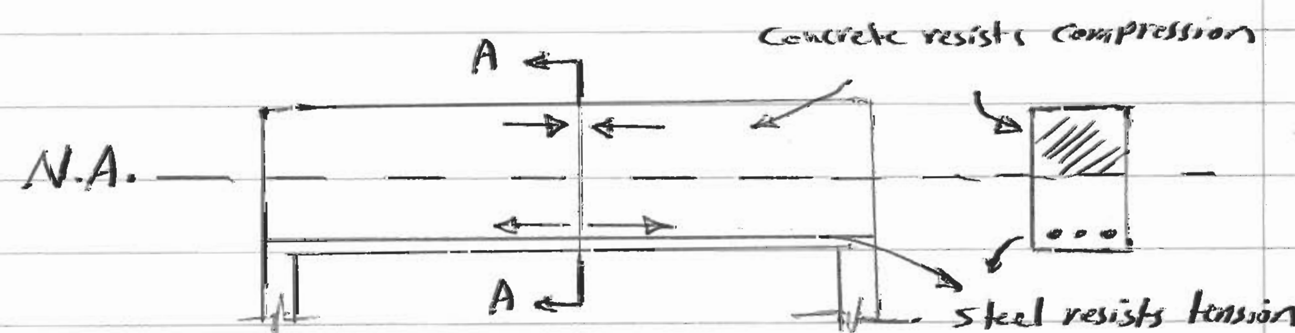
Beam



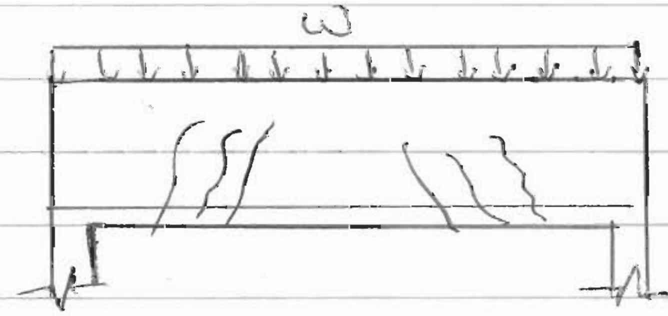
Beam + UDL



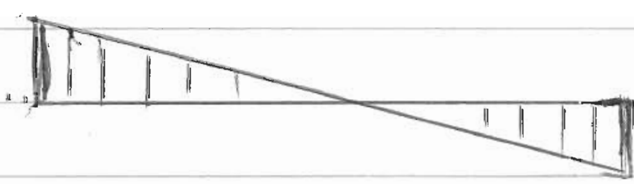
B.M.D.



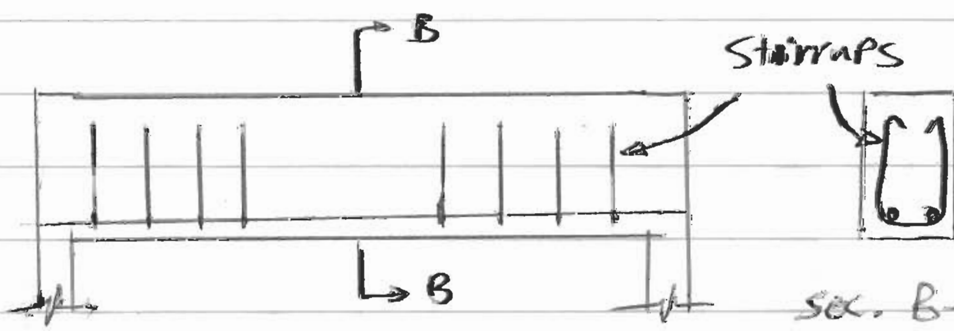
Consider the same simply supported R.C beam subjected to U.D.L. When the beam deflects, shear forces develop in the beam in addition to bending moments. The maximum shear forces (V) and the corresponding shear stresses develop in the support region (See S.F.D.). Diagonal cracks develop in the critical region of high shear stresses. To prevent the diagonal tension cracks, U or ▢ shaped reinforcing bars called stirrups are placed vertically along the beam length in the regions where shear cracks are expected to develop.



Beam + UDL



S.F.D.



sec. B-B

The main idea behind reinforced concrete is to provide steel reinforcement at locations where tensile stresses exist that the concrete can not resist. In general, the area of steel reinforcement amounts for only a small fraction of the overall cross-sectional area of a concrete member, typically on the order of 0.2 % to 2 % for slabs and beams and 1% to 4 % for columns.

In reinforced concrete structures, steel and concrete act (work) together, thus enabling effective load transfer between them. This is an essential feature of reinforced concrete called bond.

– Prestressed concrete

Prestressed concrete is a special type of reinforced concrete in which internal compression stresses are introduced to reduce potential tensile stresses in the concrete resulting from external loads. High-strength tendons are embedded within high-strength concrete and subjected to a tensile forces by special equipments (jacks). A few different types of tendons are used in prestressed concrete construction, such as wires, cables, bars, rods, and strands. The main two methods of prestressed concrete construction are ;

- Pretensioning : when the tendons are tensioned before the concrete has hardened.
- Posttensioning : When the tendons are tensioned after the concrete has hardened.

The concept of prestressed concrete can be explained with an example. Consider a concrete beam subjected to external load U.D.L, the beam deforms and flexural (bending) stresses develop. The top part of the beam is under compression, whereas the bottom part is under tension, concrete is rather weak in tension, and hence it cracks at rather small loads. However, when an axial compressive force (P) is externally applied in the beam ends, compressive stresses develop in the beam, resulting in larger comp. stresses at the bottom of the beam. The effect of prestressing is therefore equivalent to an externally applied axial force. The combined effects of the external load and prestressing result in the compressive stress distribution shown in fig below, so that the major feature and benefit of prestressing is its ability to reduce or eliminate development of tensile stresses, and cracking in concrete sections under service loads. Prestressing members require smaller cross-sectional dimensions than reinforced concrete members with similar span and loads. As a result, prestressed concrete structures are lighter than reinforced concrete.

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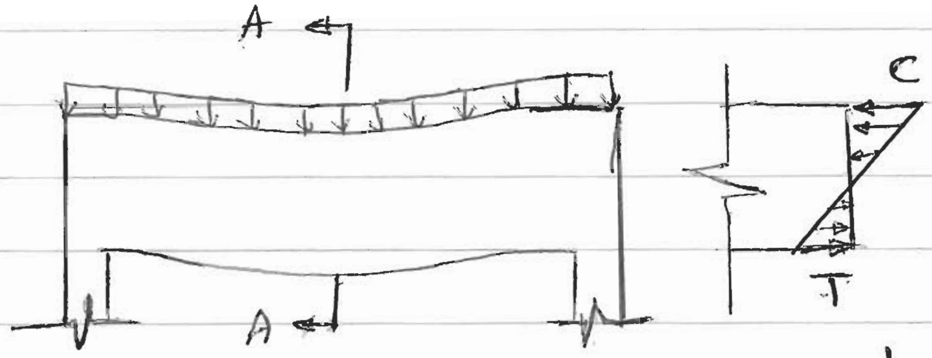

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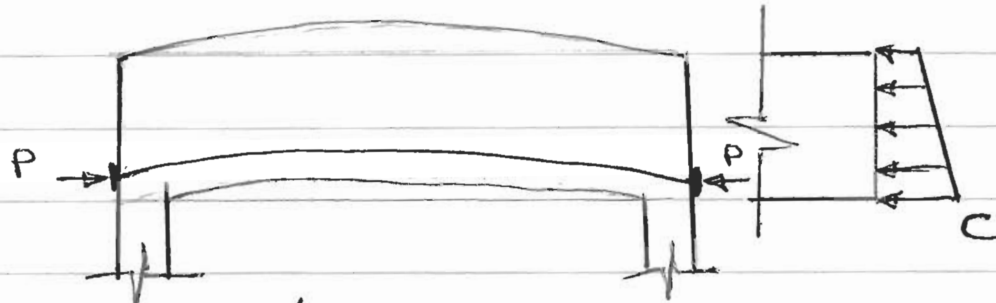

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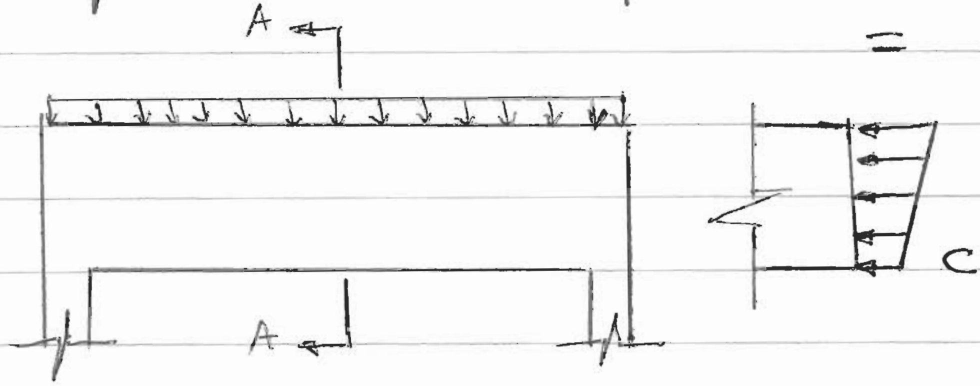

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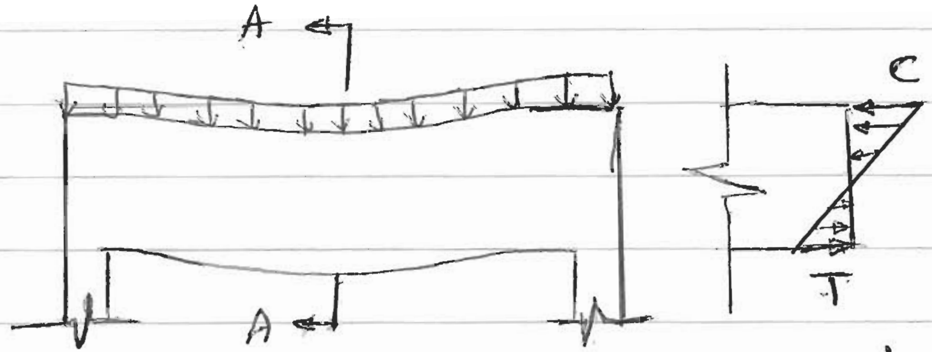

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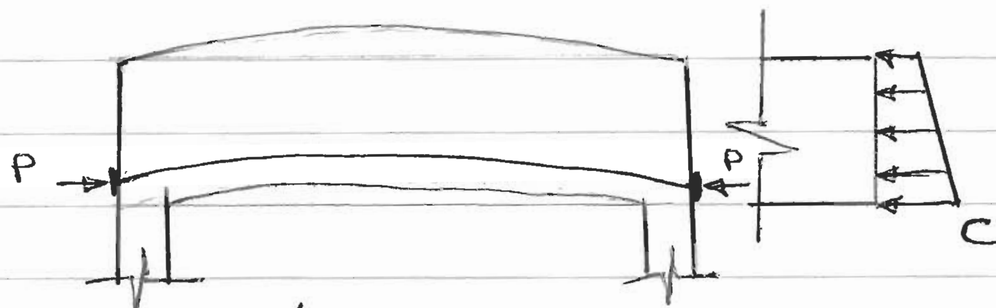

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