Some Thoughts on What Engineers are Responsible for
The oldest building provision

Laws of Hammourabi, Babylon, 2200 BC

- If a builder builds a home for a man and does not make its construction firm and the house collapses and causes the death of the owner of the house, that builder shall be put to death.
Causes of Structural Failures

- Bad Design
- Faulty Construction
- Foundation Failure
- Extraordinary Loads
- Unexpected Failure Modes
- Combination of Causes
The 1940 Tacoma Narrows Bridge was a suspension bridge in the U.S. state of Washington that spanned the Tacoma Narrows ...

- **Longest span**: 2,800 feet (853.4 m)
- **Opened**: July 1, 1940
- **Collapsed**: November 7, 1940
- **Cause**: Gusts caused resonance in tortional mode
Collapse of Ronan Point

A progressive collapse can be triggered by accident actions, including....

- Fire hazard
- Gas explosion
- Terrorist attack
- Vehicle collision
Follow the Loads to Firm Soil

This sums up the Engineer’s Task
In the process, we need to address all the ‘Probable Failure Modes’
During Construction &
During its expected life-time
Our ‘THREE’ Concerns

Strength & Stability
Serviceability
Durability
Strength - 1

Step I - Analysis

Analyze the Structure
under all Loads & Load Combinations
By any acceptable Methods of Analyses –

STADD, Moment Distribution like,
Approximate Methods (like Portal, Cantilever),
Coefficients given in Code
Strength - 2

Step II - Design

Sizing of Members/Elements based on Acceptable Methods of Design by the Relevant IS Codes like 456 – Working Stress Design (WSD) Limit States Design (LSD)
Limit States Design (LSD)

Features of LSD –

• Characteristic Loads & Strengths
• Partial Safety Factors – Loads & Strengths
• Limit States of Collapse – Bending, Shear, Compression, Torsion & Combinations of above
• Limit States of Serviceability – Deflection & Crack width
Characteristic Values
Ultimate Limit State in Flexure

Assumptions:

- Plane Sections remain plane after bending
- Maximum compressive strain in concrete is 0.0035
- Tensile strength in concrete is ignored
- The ultimate strain in Steel shall not be less than Yield Strain
Limiting $p_t$ & $M_{ult}$

(a) $p_{t,lim}$ values

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<th>M 20</th>
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(b) $M_{u,lim}/bd^2$ values (MPa)

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Ultimate Shear

Concrete takes some Shear (Code allows)

Forget about shear requirement in slabs & Footings. Concrete takes care.

However, you may ignore concrete (except in deep beams) and cranked bars while computing the shear reinforcement.
Diagonal Tension

(a) Shear and diagonal stresses: (a) Diagonal tension; (b) Diagonal compression; (c) Tension in beams.
Serviceability

Stiffness of structure is of concern for the structure to be serviceable

Span/250 or Span/350 under the Service Loads

When the depths of beams do not satisfy $d/l_{efe}$ Ratios (– 7, 20, 26) ask for deflection computations.
IS 456-2000 Focuses on Durability

Depending on the Exposure Category (Mild to Extreme)

- Minimum Grade in RCC - M20 to M40
- Minimum Clear Cover 20 to 75mm
- Minimum Cement Content – 300 to 360 kg/m³
- Maximum Water-Cement Ratio 0.55 to 0.40
- Acceptable Surface Crack Widths – 0.1 to 0.3mm
Placement of Reinforcement
Elastic Curves
Shear in Span AB
Moment at B
Moment in Span AB
Beam from an End Column

See table A 5.1

See table A 5.9

$\ell_{db}$

$\ell_{hb}$
or $\ell_{dh}$

$3\frac{1}{2}''$, if hooks interfere with column bar

2'' min.

(a)  
(b)  
(c)  

See table A 5.8
Detailing in Continuous Beams
Detailing in Cantilevers

- R.C.C. Column
- Greater of 0.5L or L_d
- Stirrups
- 0.5A_{st}
- 0.25A_{st} (min. 2 bars)
- L_d/3
- L

1, 2
3