Notes by-

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Methods of Design of RC Section

① Methods based on experimental investigations. [Empirical]
② Working stress Method [WSM]
③ Limit state Method [LSM]

① Working stress Method :- [IS:456-2000 - Pg. 80]

stresses due to worst combination of Working loads ≯ Allowable stresses.

Allowable stress or permissible stress = $\frac{\text{Limiting stress}}{\text{Factor of safety}}$.

Allowable stresses in concrete : IS:456-2000 / Table 21 / Pg. 81.
Allowable stress in steel : IS:456-2000 / Table 22 / Pg. 82

Disadvantages of WSM:-

① Stress - strain curve for concrete is continuous curve, not a straight line.
② MS (Fe 250) behaves as an elastic material but HYSD bars do not behaves elastically but exibit an almost continuous curve.
③ FOS did not gives "true margin" of safty against failure of structure.
for eg. FOS = 3 for concrete does not mean that, str. will fail at 3 times the working load.
④ Creep & shrinkage which are major time dependent effects on str. are not considered in elastic theory.
⑤ The additional load carrying capacity due to redistribution of moments is not considered.

② Limit state Method (LSM) [IS:456-2000 - Pg. 67]

There are 3 main types of Limit state.

① Limit state of collapse :- Collapse may occur due to - rupture of member, format° of mechanism, loss of equilibrium.
② Limit state of serviceability → LS of deflection ($\frac{L}{d}$ Ratio) ; → LS of cracking. LS take care by providing safty factors.
③ Limit state of durability → LS of fire resistance
→ LS of environmental & chemical action
→ LS of resistance to accidental or catastrophic collapse.

GATE

* Partial safety factor :- (γ)

Variation in → Load
→ Material strength

∴ Safety of str. depends on each of the two design factors i.e. load & matl. strength, which are not function of each other. Hence two different FOS one for load & other for matl, are used, as both two contributes partially to safety, they are known as "Partial safty Factors".

∴ ① Partial Safety factor for load (γ_f)
② Partial safety factor for matl. strength (#) (γ_m)

① Partial safty factor for loads γ_f (γ_f)

∴ Design load = γ_f x characteristics load.

where, characteristic load = $F_k + F_m + 1.64 \cdot S$

F_m = Mean value of load
S = standard deviation.

characteristic load : (IS : Pg : 67/cl. 36.2) characteristic load is defined as the value of load which has 95% probability of not being exceeded during the service life span of the structure.

characteristic strength :- (IS:456-2000/ Pg. 67, / Cl. 36.1) : It is that value of material strength ~~whi~~ below which not more than 5% test results are expected to fall.

i.e. Cht. strength has 95% reability.
i.e. There is only 5% probability of actual strength is less than cht. strength.

f_{ck} = characteristic strength = $f_m - 1.64 S$

Partial safety factors for loads takes in to account -

① Variation in load due to unforeseen increase in load,
② construction inaccuracies.
③ Different loading ~~conditions~~. combinations.

(GATE) Load factors: IS: 456-2000 ; Pg.68/Table 18

Partial Safety factors for loads (γ_f)

Load combination	LS of collapse			LS of serviceability		
	DL	LL	WL	DL	LL	WL
DL + LL	1.5	1.5	–	1.0	1.0	–
DL + WL	1.5 or 0.9	–	1.5	1.0	–	1.0
DL + LL + WL	1.2	1.2	1.2	1.0	0.8	0.8

Load factors for structural stability :-

a) Overturning :-

	DL	LL
Load causing overturning	1.2	1.4
Load Preventing overturning	0.9	0

∴ overturning moment = 1.2DL + 1.4LL
Restoring moment = 0.9DL ≫ overturning mmt i.e. (1.2DL + 1.4LL)

b) Sliding :-

∴ FOS = 1.4 for worst combination of characteristic loads.
& characteristic Dead load = 0.9DL.

② Partial Safety Factors for materials strength (γ_m) [IS: 456: 2020/ Pg.68/ Cl.36.4.2]

Partial safty factors for material are introduced to account for –

① constructional faults.
② Bad workmanship & supervision.

$$\therefore \text{Design strength} = \frac{\text{characteristic strength}}{\gamma_m}$$

Partial safety factor for strength of material (γ_m)		
	LS of collapse	LS of serviceability
concrete	1.5	1.0
steel	1.15	1.0

V. Imp Interview Que.

Partial safety factor for matl. strength of concrete (1.5) is much greater than steel (1.15). Why?

Because variation in strength of concrete depends on number of uncontrolable factors (as concrete is prepared at site - generally) while steel is rolled in factories, due to which probability of variation in strength is much less.

Interesting

★ Note on Basic statistics & Theory of Probability

Statistics is a science of making decisions on INCOMPLETE informations or on random variables.

The random variable (eg. strength of concrete, LL on floor etc.) is a numerical variable whose "EXACT value" is not known before an experiment.

"Data Reduction":

Collected data of random variable consist of different values which have different probability of occurance. It is necessary to replace this data by a single value [Same as, we convert area of steel in to equivalent area of concrete i.e. m. AsL → Details - see RCC Notes) & further computations are made.

The "MEAN VALUE" is commonly used to represent the data. It is "arithmatic mean" of all values.

"TRUE MEAN":- An infinite No. of values called as population are requred to predict the correct probable value known as 'true mean.'

For eg: We normally cast number of precast units of col^m or beam. But test only some of them to failure to determine ultimate strength.

The entire group of precast units is called as "population", while tested specimen (which are a part of populatio) are known as "sample".

Sample is a representative of population – (Details see Enviromental notes). The conclusion are often drawn from analysis of sample. The mean value obtained from sample is known as "sample mean".

$$\therefore \text{Sample mean } (\bar{x}) = \frac{x_1 + x_2 + x_3 + \cdots + x_n}{n} = \sum_{i=1}^{n} \frac{x_i}{n}$$

Where $x_1, x_2, \ldots, x_n$ = observed value of variable x.
n = Total No. of observations.

This sample mean value is a measure of "CENTRAL TENDENCY" or in other words it is the "CENTRE OF GRAVITY" of data.

* **Standard deviation:-**

$$S = \sqrt{\frac{\sum_{i=1}^{n} (x_i - \mu)^2}{n}}$$

where μ = True mean
n = No. of observation

The true mean is usually unknown, so 'S' is determined from sample mean. But 'S' from sample mean is less than true mean. Therefore it should be corrected by dividing $(n-1)$ instead of 'n'.

$\therefore$ Estimation of std. deviation from sample mean is given by –

$$S = \sqrt{\frac{\sum_{i=1}^{n} (x_i - \bar{x})^2}{(n-1)}}$$

Pl. Note:- In Irrigation Engg. while calculating optimum (min.) number of rain gauge station this formula is used. [In Fx-82 onwards calculator, it can be directly calculated]

* Coefficient of variation = $\frac{S}{\bar{x}} \times 100$.

The coeff. of variation is convenient for comparing relative dispersion of more than one kind of data.

* **Note on limit state of serviceability:-**

1) Limit state of deflection:-

Effects ~~causes~~ of excessive deflection:-
① Feeling of lack of safety.
② Spoiling the appearance of structure.
③ Cracking of walls.
④ Cracking ceiling finishes.
⑤ Ponding of water on roofs etc.

In LS of important structures, it is attended by insuring

Actual deformation ≯ Maximum allowable deformation
(Deflection) (Deflection)

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This is further simplified by providing max span By depth ratio.
i.e $\left(\frac{L}{d}\right)$ Ratio-

~~We calculate~~

NOTE : while designing a structure ; Make a habbit that — Calculate d from $\left(\frac{L}{d}\right)$ ratio given by IS: 456 : 2000/ Pg. 37/ Cl. 23.2

∴ No need of check for deflection is reqd.
Logically ; $y_{actual} < y_{allowable}$.
∴ O.K.

② Limit state of Cracking :-

Effects :- ① Spoiling the appearance of exposed surfaces.
② Leakage problems.
③ Corrosion of steel.
④ Reduction in stiffness of member $\left(\frac{I}{L}\right)$ → from TOS notes.
⑤ Lack of safety.

LS of cracking is taken care by specifying max. permissible crack width "for important structures" only - given in IS : 456 - 2000 / Pg - 95/ Annex F & for other structures, it is attended by following "detailing Rules"

* Limit State of durability :-

Durability is defined as the ability of structure to maintain its level of reliability & serviceability during intended life span.
LS of durability refers to action & forces of nature such as fire, rain, water, weathering, chemical action & humidity change etc., and depending upon case are sub divided as —
① LS of fire resistance
② LS of environmental & chemical action
③ LS of resistance to accidental or catastrophic collapse.

Interview Que

In practice, it is not possible to evaluate effect of all LS i.e. collapse, serviceability & durability by quantitatively. A recouse is therefore taken to design the structure for most critical limit state; which is "LS of collapse" for majority of str. & check is given for remaining two.