STRUCTURAL SAFETY

3.1 Introduction

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3.4 Structural Safety and Cost

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Quality Control

Safety cannot be accomplished solely in the design stage. A close supervision of the construction is as important as the design itself. As a matter of fact, construction faults and poor material quality have been the cause of most of the failures reported.

QUALITY CONTROL

According to TS-500, concrete quality should be controlled by taking samples from the concrete used on the site.

- At least 3 cylinder samples should be taken for each 50 m^3 of concrete placed (or 3 samples from every floor).
- For concrete grades higher than C25, the number of samples taken should be doubled.
- A detailed description how the samples should be taken, placed, compacted and cured are given in the related Turkish Standards (TS-2940, TS-3068 and TS-3351). Testing procedure is described in TS-3114.

QUALITY CONTROL

For the acceptance of concrete the following inequalities should be satisfied (TS-500):

$$\bar{f}_{cm} \geq f_{ck} + 1.0\,MPa \quad \text{and} \quad f_{cmin} \geq f_{ck} - 3\text{ MPa}$$

In these equations f_{cm} is the average of strengths obtained from three cylinders. f_{cmin} is the minimum strength obtained from the three samples tested

If these equations are not satisfied, then the member capacities should be recalculated using the actual concrete strength, which is lower than the specified value. If it is concluded that the capacity of some members have decreased significantly, then necessary precautions should be taken.

QUALITY CONTROL

The variation in strength of concrete can be expressed in terms of "coefficient of variation" in place of the standard deviation.

$$\upsilon = \frac{\overline{\sigma}}{f_{cm}} \quad \text{or} \quad f_{cm} = \frac{f_{ck}}{(1 - u\upsilon)}$$

Supervision	Very good	Good	Average	Unsatisfactory
Coefficient of variation	< 0.10	0.10-0.15	0.15-0.20	> 0.20

Example 3.1

The design of building is based on a concrete grade of C20 (cast in place). Using the TS-500 provisions compute the design strength, f_{cd} and the mean strength, f_{cm} to be specified to the contractor.

- a) If the standard deviation is estimated to be 4 MPa
- b) If the standard deviation cannot be estimated

EXAMPLE 3.1

Solution:

a) f_{ck}=20 MPa

From Eq. (3.22) $$f_{cm} = f_{ck} + 1.28\,\overline{\sigma}$$

$$f_{cm} = 20 + 1.28x4 = 25 \text{ MPa}$$

From Eq. (3.21) $$f_{cd} = \frac{f_{ck}}{\gamma_{mc}} = \frac{20}{1.5} = 13.3 \text{ MPa}$$

b) From Eq. (3.23) $$f_{cm} = f_{ck} + \Delta f$$

$$f_{cm} = 20 + 6 = 26 \text{ MPa}$$

$$f_{cd} = 13.3 \text{ MPa}$$

EXAMPLE 3.2

The cracking strength of a reinforced concrete beam (C25, f_{ck} = 25 MPa) with a rectangular cross-section having a width of "b_w" and depth of "h" can be expressed by;

$$M_{cr} = \frac{f_{ctf} I}{y} = \frac{f_{ctf} \frac{1}{12} b_w h^3}{h/2} = \frac{f_{ctf} b_w h^2}{6}$$

A simply supported beam with a span of 6 meters carries a uniformly distributed load of g = 4 kN/m (dead load) and q = 2 kN/m (live load). The beam has a rectangular cross-section (250 mm x 600 mm). Will the beam crack under the given loads?

a) Use TS-500-2000, $f_{ctf} = 2x0.35\sqrt{f_{ck}}$, to make a ULS check.

b) Use TS-500-2000, $f_{ctf} = 2x0.35\sqrt{f_{ck}}$, to make a SLS check.

EXAMPLE 3.2

Solution:

a) TS500-2000: Ultimate Limit State Check

Factored Load $P_d = 1.4\ (g) + 1.6\ (q) = 1.4\ (4) + 1.6\ (2) = 8.8$ kN/m

Design Moment $$M_d = \frac{1}{8} P_d \ell^2 = \frac{1}{8}(8.8)(6)^2 = 39.6 \text{ kN-m} = 39.6 \times 10^6 \text{ N-mm}$$

Cracking Moment (the resistance of the beam) $$M_{cr} = \frac{f_{ctf}}{\gamma_{mc}} b_w \frac{h^2}{6}$$

$$= \frac{0.7 \times \sqrt{25}}{1.5} \times \frac{250 \times 600^2}{6}$$

$$= 35 \times 10^6\ N \cdot mm$$

$M_{cr} = M_{cr} > M_d$ beam cracks. ULS is violated. Increase the size of the beam.

EXAMPLE 3.2

b) TS-500-2000: Serviceability Limit State Check

Factored Load $P_d = 1.0(g) + 1.0\ (q) = 6.0$ kN/m

Design Moment

$$M_d = \frac{1}{8} P_d \ell^2 = \frac{1}{8}(6.0)(6)^2$$
$$= 27.0\text{kN} - \text{m}$$
$$= 27.0\text{x}10^6\ \text{N} - \text{mm}$$

Cracking Moment

$$M_{cr} = \frac{1}{\gamma_{mc}} 0.35x2\sqrt{f_{ck}}\, b_w h^2 \frac{1}{6}$$
$$= \frac{1}{1.5}(0.70)\sqrt{25}(250)(600)^2 \frac{1}{6}$$
$$= 35x10^6\, N - mm$$

$M_d < M_{cr}$ does not crack.

EXAMPLE 3.2

Samples from a RC building reveal that the strength distribution is normal with f_{cm} = 30 MPa and σ = 2.5 MPa.

What is the probability of having a concrete with $f_{ci} \leq 20$ MPa?

Solution:

$f_{cm} - f_{ci}$ = 30 - 20 = 10 MPa;

$$u\overline{\sigma} = f_{cm} - f_{ci} = 10$$

$$u = \frac{10}{\overline{\sigma}} = \frac{10}{2.5} = 4$$

From the table in Figure 3.1 for u = 4.0, (1-F) = 3.17 x 10^{-5}. Then the probability of having $f_{ci} \leq 20$ MPa is 3.17 x 10^{-5}.