**2.1.** The specified concrete strength $f'_c$ for a new building is 5000 psi. Calculate the required average $f_{cr}$ for the concrete (*a* ) if there are no prior test results for concrete with a compressive strength within 1000 psi of $f'_c$ made with similar materials, ( *b* ) if 20 test results for concrete with $f'_c$ = 5500 psi made with similar materials produce a sample standard deviation $s_s$ of 560 psi, and ( *c* ) if 30 tests with $f_c$ = 4500 psi made with similar materials produce a sample standard deviation $s_s$ of 540 psi.

**Solution:** $f'_c$= 5000 psi
**a)** No prior results

$f'_{cr} = f'_c + 1200$ psi = 5000+1200= 6200 psi

**b)** 20 prior tests for concrete with $f'_c$ within 1000 psi of $f'_c$ of the project and $s_s$ = 560 psi. From Table 2.1, k = 1.08 and $ks_s$ is 1.08*560 = 605 psi.
Because $f'_c$ = 5000 psi, use eqs (2.1) and (2.2a)

$f'_{cr} = f'_c + 1.34\ ks_s$ = 5000 + 1.34*605 = 5810 psi

$f'_{cr} = f'_c + 2.33\ ks_s$ -500= 5000 + 2.33*605 - 500= 5910 psi
USE $f'_{cr}$ = 5910 psi

**c)** 30 prior tests for concrete with $f'_c$ within 1000 psi of $f'_c$ for the project. $s_s$ = 590 psi and k is 1.0.

$f'_{cr} = f'_c + 1.34\ s_s$ = 5000 + 1.34*590 = 5790 psi

$f'_{cr} = f'_c + 2.33\ s_s$ -500= 5000 + 2.33*590 -500= 5870 psi
USE $f'_{cr}$ = 5790 psi

COMMENT: in cases b) and c) the $f'_{cr}$ would reasonably be taken as 6000 psi.

**2.2.** Ten consecutive strength tests are available for a new concrete mixture with $f'_c$ = 4000 psi: 4830, 4980, 3840, 4370, 4410, 4890, 4450, 3970, 4780, and 4040 psi.
( a ) Do the strength results represent concrete of satisfactory quality? Explain your reasoning.
( b ) If $f'_{cr}$ has been selected based on 30 consecutive test results from an earlier project with a sample standard deviation $s_s$ of 570 psi, must the mixture proportions be adjusted? Explain.

**Solution:**

**a)** For $f'_c$ = 4000 psi, the strength results indicate satisfactory concrete quality because (1) no individual test I below $f'_c$ – 500 psi = 3500 psi, and (2) every arithmetic average of any three consecutive tests equals or exceeds $f'_c$.

**b)** For $s_s$ = 570 psi, for 30 consecutive tests calculate $f'_{cr}$ using equations 2.1 and 2.2a.

$f'_{cr} = f'_c + 1.34\ ks_s$ = 4000 + 1.34*1*570 = 4760 psi

$f'_{cr} = f'_c + 2.33\ ks_s$ -500= 4000 + 2.33*1*570 - 500= 4830 psi

USE $f'_{cr}$ = 4830 psi
The average of the above tests is (4830+ 4980+ 3840+ 4370+ 4410, 4890+ 4450+ 3970+ 4780 + 4040)/10 = 4460

Because the average strength is less than the target strength, the water/cement ratio must be adjusted by adding cement or reducing water to increase the strength. If the water is reduced, a water reducer admixture would be required to maintain workability.

**2.3.** The specified concrete strength $f'_c$ for the columns in a high-rise building is 12,000 psi. Calculate the required average $f'_{cr}$ for the concrete ( *a*) if there are no prior test results for concrete with a compressive strength within 1000 psi of $f_c$ made with similar materials, (*b* ) if 15 test results for concrete with $f'_c$ = 11,000 psi made with similar materials produce a sample standard deviation $s_s$ of 930 psi, and ( *c* ) if 30 tests with $f'_c$ = 12,000 made with similar materials produce a sample standard deviation $s_s$ of 950 psi.

**Solution:** $f'_c$= 12000 psi
**a)** No prior results

$f'_{cr} = f'_c + 0.1\, f'_c + 700$ psi = 12000+0.1*12000 + 700= 13,900 psi

**b)** 15 prior tests for concrete with $f'_c$ within 1000 psi of $f'_c$ of the project and $s_s$ = 930 psi. From Table 2.1, k = 1.16 and $ks_s$ is 1.16*930 = 1079 psi.
Because $f'_c$ > 5000 psi, use eqs (2.1) and (2.2b)

$$f'_{cr} = f'_c + 1.34\, ks_s = 12000 + 1.34*1079 = 13,450 \text{ psi}$$

$$f'_{cr} = 0.9f'_c + 2.33\, ks_s = 0.9*12000 + 2.33*1709 = 13,310 \text{ psi}$$

USE $f'_{cr}$ = 13,450 psi

**c)** 30 prior tests for concrete with $f'_c$ within 1000 psi of $f'_c$ for the project. $s_s$ = 950 psi and k is 1.0.

$$f'_{cr} = f'_c + 1.34\, s_s = 12000 + 1.34*950 = 13,270 \text{ psi}$$

$$f'_{cr} = 0.9f'_c + 2.33\, ks_s = 0.9*12000 + 2.33*950 = 13,010 \text{ psi}$$

USE $f'_{cr}$ = 13,270 psi