Table 6.1—Strength versus cement content

Specified 28-day compressive strength, psi (MPa)	Cement content as batched, lb/yd^3 (kg/m^3)
3000 (21)	500 to 650 (295 to 385)
4000 (28)	550 to 700 (325 to 415)
5000 (35)	650 to 850 (385 to 505)

Specified requirements:
28-day compressive strength: 4000 psi (28 MPa)
Maximum-size aggregate: 1/2 in. (13 mm)

English unit example
Cement, Type I
Preliminary design: Assume in-place wet density 145 lb/ft^3
Therefore: total weight per cubic yard = 145 × 27 = 3915 lb/yd^3
Select cement content as 650 lb/yd^3
Estimate *w/cm* as 0.35 (the *w/cm* for dry-mix shotcrete is typically between 0.30 and 0.40)
Therefore: water required is 230 lb/yd^3
Aggregate content (coarse aggregate + sand) = 3915 – 650 – 230 = 3035 lb/yd^3

Metric unit example
Cement, Type I
Preliminary design: Assume in-place wet density 2320 kg/m^3
Select cement content as 385 kg/m^3
Estimate *w/cm* as 0.35 (the *w/cm* for dry-mix shotcrete is typically between 0.30 and 0.40)
Therefore: water required is 135 kg/m^3
Aggregate content (coarse aggregate + sand) = 2320 – 385 – 135 = 1800 kg/m^3

The amount of water calculated above should be adjusted for surface moisture in the aggregate. Admixture dosages have not been included; refer to Section 2.7.

6.4—Preconstruction testing

For preconstruction studies, shooting test panels that simulate actual job conditions, such as reinforcing bar congestion, provides a sufficiently reliable indication of the quality to be expected in the structure. A panel is fabricated by shooting onto a back form of heavy plywood or steel plate in accordance with ASTM C 1140. A separate panel should be fabricated for each mixture proportion being considered, and also for each shooting position to be encountered in the structure such as horizontal, vertical, or overhead. Results of previous tests with similar materials, mixture proportions and applications may be acceptable to the engineer instead of preconstruction testing.

Separate test panels should be fabricated for mixture proportion evaluation and for nozzle operator qualification. The mixture proportion test panels should be 24 x 24 x 3-1/2 in. (610 x 610 x 89 mm) with flared sides and no reinforcement. The nozzle operator qualification test panel should be large enough to simulate the actual project conditions with a minimum size of 30 x 30 x 3 in. (760 x 760 x 75 mm) and should be reinforced to simulate the size and complexity of the reinforcement to be shot on the project. Both types of test panels should be cored or sawn to obtain 3 in. (75 mm) diameter cores or 3 in. (75 mm) cubes. The unreinforced cores or cubes should be tested for compressive strength. Cube strengths may be reported as determined or converted to equivalent cylinder strengths by multiplying by 0.85. ACI 506.2 lists requirements for testing.

The cut surfaces of the specimens should also be carefully examined, and additional surfaces should be exposed by sawing or breaking the panel when necessary to check the soundness and uniformity of the material. All cut and broken surfaces should be dense and free from laminations, voids, and sand pockets.

Tests for modulus of rupture, flexural toughness of fiber-reinforced shotcrete, absorption, drying shrinkage, resistance to freezing and thawing, and other properties may also be conducted if required by the specifications, using appropriate specimens cored or sawed from the panel. All tests should be performed by an agency meeting the requirements of ASTM E 329.

The procedures described previously should determine the optimum proportions to consistently achieve the result specified. Once the mixture proportions have been established by the engineer, they should be monitored. It may be permissible, however, to make the test panels concurrent with the start of construction, or cores can possibly be taken from the first shotcrete placed in the structure. On relatively small jobs and where the materials, mixture proportions, equipment, and personnel have given satisfactory results on previous work, preconstruction studies may not be justified.

CHAPTER 7—BATCHING AND MIXING

7.1—Introduction

Proper batching and mixing are extremely important steps in the production of quality shotcrete.

7.2—Batching

Shotcrete materials can be batched by weight or volume. For projects with difficult access, small volumes of shotcrete or low placement rates, volume batching of aggregate, and cement batching by bag may be more practical and is common in some areas. It is also possible to use preblended dry cement and aggregate for dry-mix. The crew should predampen the batch before introducing it to the shotcrete delivery equipment unless a long nozzle (as described in Section 3.7.1) is used.

Specifications for batching tolerances are available in ASTM C 94 for weight batching and ASTM C 685 for volume batching. These tolerances are seldom necessary for shotcrete batching, as experience shows that quality shotcrete can be produced with less restrictive tolerance values. ACI Committee 506 recommends that the tolerances in ASTM C 94 be increased to:

- Cement: ±2% of mixture proportion weights;
- Aggregate: ±4% of mixture proportion weights; and
- Admixtures: ±6% of mixture proportion weights.

Instead of weighing, cement may be measured by bags (94 lb [43 kg]), while the aggregates may be batched volumetrically, provided weight checks are made as described previously. Weight batching can be accomplished at a central concrete