Chapter 4
Concrete Materials and Proportions

4-1. Materials

a. Cement.

(1) Color. The cement used for architectural concrete must come from the same source for the duration of the project to prevent major changes in color. Minor color changes can still occur from a single source of cement when the concrete construction requires a long period of time. These minor changes will normally become uniform due to weathering. Difference of color due to differences in cements is illustrated in Figure 4-1 which contains precast units having cements from different sources. As many of the metropolitan ready-mix plants receive cement shipments from more than one company, special precautions will be required to maintain one source. If a special brand or source is specified to obtain a light or buff-colored cement, provisions must be made to ensure that the cement will be available for the entire period of construction.

(2) Type. Generally, all types of cement meeting ASTM requirements can be used for architectural concrete. Due to chemical composition, Type V cements will, generally, produce darker concretes than Type I or III cements and require longer periods of weathering to blend out differences in color.

b. Aggregates.

(1) General requirements. Most aggregates meeting the requirements of ASTM C 33 (ASTM 1993) are satisfactory for architectural concrete. Oxidation and hydration of ferrous compounds in clay ironstone and iron sulfides in limestones and shales are known to have caused popouts and staining in concrete. Metallic iron particles in blast furnace slags may oxidize, when exposed near the concrete surface, resulting in minor pitting and staining. Popouts may develop on any surface directly exposed to moisture and freezing and thawing. Chert particles of low specific gravity, limestone clay, and shalely materials are well-known for this behavior. Petrographic analysis can identify these materials and reactive materials. Reviewing the history of a proposed aggregate for reactivity with the cement alkalies can prevent future problems of expansion in the architectural concrete. These materials should be avoided in architectural concrete, unless properly designed concrete mixtures are used.

Figure 4-1. Color variations in precast panels due to use of different cements

(2) Architectural requirements. For exposed aggregate architectural concrete, source, color, and shape of the aggregate are additional requirements to be included in the specifications. Viewing distance of exposed aggregate textures may require a larger maximum size in order to be seen. Cubical or rounded aggregate provide the best area coverage and are generally self-cleaning during weathering. Crushed aggregate is more likely to pick up airborne dust and contaminants. As durability of exposed aggregate is more critical, more rigid standards of density and absorption should be considered.

c. Admixtures.

(1) General. Admixtures, other than air-entraining admixtures, require additional testing in the field mockup composed of concrete using all the planned concrete materials, form release agents, and curing process to determine any staining or other deleterious effect to the architectural concrete. Since most of the architectural treatments require high-density forming, concretes containing the higher dosages of air entrainment tend to be sticky and result in higher amounts of bugholes due to difficulty of removal by vibration. In mild climates, use of the minimum 3 percent air entrainment for workability will decrease the stickiness and the amount of bugholes. For severe climates, air contents should be specified in accordance with the recommendations of ACI 201.2R-92 (ACI 1992C). Calcium chloride is not recommended, as it may cause discoloration in the concrete or affect the efficiency of any surface retarders. The new superplasticizers have assisted the placement of architectural concrete in steel congested areas. However, their use should be checked with all ingredients when casting the field mockup.

(2) Color. Exposed aggregate architectural concrete color is usually achieved by use of fine or coarse aggregate in various proportions which produce the desired color in the concrete. Architects may desire to achieve a color through use of pigments in the concrete. This may be for as-cast finishes or in conjunction with a subsequent treatment such as sandblasting. The pigments are usually finely ground natural or synthetic mineral oxides. Some may react with compounds used on the forms or to clean the surface. This reaction should be discovered if the field mockup is properly constructed with all proposed materials and methods. Additions more than 5 percent by weight of cement do not increase the intensity of the color and additions more than 10 percent will affect the quality of the concrete. In order to produce better uniformity of color, some manufacturers now produce what is known as a colored admixture. The colored admixture is a blended mixture of pigment, a mineral filler, and a water-reducing admixture which tends to produce uniform-colored concrete through the usual specified range of slump. Most lamp blacks are not as durable or long-lasting as metal oxides producing a black color, and tend to be incompatible with air-entraining agents. Carbon in lamp-black will attack the foaming agents, causing the collapse of the air bubbles. Therefore, the compatibility of the entraining agents and lampblack should be established by appropriate tests prior to their inclusion in the concrete mixture.

(3) Mineral admixtures. Mineral admixtures include flyash, other pozzolanic materials, limestone flour, and other finely ground fillers. In some cases a locally produced pozzolan has been used as an admixture to the concrete for coloring. As most flyashes tend to darken a concrete, prior trials should be made to determine the effect of flyash on the color of the architectural concrete. Other than color, mineral admixtures should not harm the architectural concrete.

d. Water. Water for architectural concrete cannot contain iron, rust, or other chemicals in sufficient quantity to cause staining in light, white, or colored concretes. The field sample concrete should include water from the concrete production source. If water is used for curing, it must also meet this criterion.

e. Recycled wash water. Due to environmental requirements, metropolitan ready-mix concrete firms may be using recycled wash water. Past experiences indicate that color of the concrete will not be significantly affected when a small amount of recycled wash water is used. If recycled water causes problems with the color of the field sample concrete, its use should be stopped.

4-2. Proportions

a. General. Proportioning of architectural concrete mixtures is similar to structural concrete unless a higher percentage of aggregate is desired in exposed aggregate finishes. Some adjustments may be required to diminish size and quantity of bugholes or substitution of an admixture or cement due to incompatibility with another ingredient or procedure. ACI Committee 303 (ACI 1974) recommends the maximum water-cement ratio to be 0.46 by weight of cement. Concrete with higher water-cement ratios tends to have more surface defects.

b. Gap-grading (cast-in-place). In some instances, cast-in-place architectural concrete specifies

an exposed aggregate texture having a preponderance of coarse aggregate, which can only be produced by a concrete mixture described as gap-graded. A typical gap-graded mix consists of only one size coarse aggregate, graded to allow all particles of sand to be able to pass through the voids of the compacted aggregate. Maximum size is still limited by the spacing of the reinforcing steel. Generally, for a 19-mm (3/4-in.) maximum size, the 9.5-mm to 4.75-mm (3/8-in. to No. 4) sieves are omitted. For a 37.5-mm (1-1/2-in.) maximum size, the 19-mm to 4.75-mm(3/4-in. to No. 4) sieves are omitted. The sand (masonry sand) contains only the material passing the 2.36-mm (No. 8) sieve. A recommended ratio of fine to coarse aggregate is 1:2.5 to 1:3 by weight. By volume of the total aggregate, the range of sand varies between 25 percent and 35 percent, depending on whether the aggregate is rounded or crushed. Air entrainment is required for workability. Gap-graded mixes can be consolidated easily with internal vibration with the proper proportions. Segregation can be prevented by using the lowest slump needed for consolidation and placement.

c. Gap-grading (precast). Precast units usually contain exposed highly decorative and costly imported aggregates. These units will be manufactured with a thin facing mix of the decorative aggregate and white cement and a backup mix of ordinary gray structural concrete. Both mixes are designed for a compressive strength of 41.4 MPA (6,000 psi) at 28 days. The facing mix has a proportion of cement to fine aggregate of at least 1:3 but not more than 1:1 and approximately the same proportion of total aggregate to cement as the backup mix for equal shrinkage and thermal coefficients. The ratio of fine to coarse aggregate ranges from 1:2.5 or 3. Backup mixes are approximately 1:2.5. The coarse aggregates used in facing mixes are generally of one size, such as 12.5 mm by 19.0 mm (1/2 in. by 3/4 in.) or 6.3 mm by 9.5 mm (1/4 in. by 3/8 in.).

d. Slump. Normal slumps for cast-in-place architectural concrete should be 100 mm (4 in.) ± 25 mm (1 in.) unless a superplasticizer is used to produce flowing concrete. Gap-graded mixtures can vary from 0 to 75 mm (3 in.) dependent on the thickness of the section, amount of reinforcing steel, and the height of the forming. Horizontal precast work can be placed successfully using a 100-mm (4-in.) slump facing mix and a no-slump backup mix to absorb the extra water from the facing mix. In some cases the slump of precast work is dependent on the special needs for manufacture of an exposed aggregate product. In both cast-in-place and precast architectural concrete, best results are achieved if the concrete slump is kept uniform for the entire production of the architectural product.

e. Temperature requirements. With uniform operations and in accordance with recommended practices, the color of architectural concrete will be uniform if placed between temperatures of 18.3° and 29.4° C (65° and 85° F). Above 26.7° C (80° F), decreased setting times may result in cold joints, visible lift lines, and mottled sandblasted surfaces, unless concrete delivery is carefully planned. Cold weather requires additional strengthening of the forming system to withstand the necessary additional vibration required for architectural concrete and the higher pressure heads caused by slower-setting concrete. Form stripping times must be delayed to prevent damage to the surface which has lower strengths than normal.