

CODE

permitted in 19.3.3.6, air content shall conform to Table 19.3.3.1.

Table 19.3.3.1—Total air content for concrete exposed to cycles of freezing and thawing

Nominal maximum aggregate size, mm	Target air content, percent	
	F1	F2 and F3
9.5	6.0	7.5
12.5	5.5	7.0
19	5.0	6.0
25	4.5	6.0
37.5	4.5	5.5
50	4.0	5.0
75	3.5	4.5

19.3.3.2 Concrete shall be sampled in accordance with **ASTM C172**, and air content shall be measured in accordance with **ASTM C231** or **ASTM C173**.

19.3.3.3 Wet-mix shotcrete subject to freezing-and-thawing Exposure Classes F1, F2, or F3 shall be air entrained. Dry-mix shotcrete subject to freezing-and-thawing Exposure Class F3 shall be air entrained. Except as permitted in 19.3.3.6, air content shall conform to Table 19.3.3.3.

Table 19.3.3.3—Total air content for shotcrete exposed to cycles of freezing and thawing

Mixture type	Sampling location	Target air content, percent		
		F1	F2	F3
Wet-mix shotcrete	Before placement	5.0	6.0	6.0
Dry-mix shotcrete	In-place	N/A ^[1]	N/A ^[1]	4.5

^[1]Entrained air is not required in dry-mix shotcrete for these exposure classes.

COMMENTARY

included in the Code, based on guidance provided for proportioning concrete mixtures in **ACI 211.1**. Entrained air will not protect concrete containing coarse aggregates that undergo disruptive volume changes when frozen in a saturated condition.

R19.3.3.2 The sampling of fresh concrete for acceptance based on air content is usually performed as the concrete is discharged from a mixer or a transportation unit (for example, a ready mixed concrete truck) to the conveying equipment used to transfer the concrete to the forms. **ASTM C172** primarily covers sampling of concrete as it is discharged from a mixer or a transportation unit, but recognizes that specifications may require sampling at other points such as discharge from a pump. Table 19.3.3.1 was developed for testing as-delivered concrete. **ASTM C231** is applicable to normalweight concrete and **ASTM C173** is applicable to normalweight or lightweight concrete.

If the licensed design professional requires measurement of air content of fresh concrete at additional sampling locations, such requirements should be stated in the construction documents, including the sampling protocol, test methods to be used, and the criteria for acceptance.

R19.3.3.3 Adding air-entraining admixtures improves freezing-and-thawing resistance of wet-mix shotcrete (**ACI 506R**). Having air contents before placement as specified in Table 19.3.3.3 will provide required performance in freezing and thawing. Air contents greater than those specified will not improve shotcrete performance because once adequate air content for durability is achieved, there is no further benefit. As in all concrete, too much in-place air will reduce strength.

Dry-mix shotcrete without air entrainment has performed well in freezing-and-thawing environments with no exposure to saltwater or deicing salts (**ACI 506R**; **Seegebrecht et al. 1989**). For exposure to saltwater or deicing salts, air-entraining admixtures, in either a wet or dry form, can be added to dry-mix shotcrete to provide the required air content for durability in these exposures (**Bertrand and Vezina 1994**). The higher air content of wet-mix shotcrete sampled at the point of delivery accounts for expected air losses during shooting.