OREGON STATE HIGHWAY DIVISION
MATERIALS SECTION

PORTLAND CEMENT CONCRETE
AIR CONTENT STUDY

by

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PORTLAND CEMENT CONCRETE
AIR CONTENT STUDY

INTRODUCTION

This study was undertaken to review current Oregon State Highway Division specifications, other state specifications, and other available literature to determine:

1. If changes to current specified air content levels should be recommended,

2. If adjustments to specified air content levels should be made for certain geographic or climatological areas, and

3. If a price reduction should be assessed against concrete with low air content, and if so, how much.

RESULTS AND CONCLUSIONS

Based on the information gathered in this study, the following results and conclusions were made:

1. Air-Entrained Concrete is more durable than non-air entrained concrete all other factors being equal. It is more resistant to freeze-thaw cycles and deicers than non-air entrained concrete.

The air entrained in concrete is actually entrained in the mortar paste and provides protection against failure of the paste under freeze/thaw conditions.

2. "There is general agreement that cement paste can be made completely immune to damage from freezing temperatures by means of entrained air, unless special conditions result in filling of the air voids. However, air entrainment alone does not preclude the possibility of damage of concrete due to freezing; freezing phenomena in aggregate particles must also be taken into consideration." ACI 201-77 Manual of Concrete Practice

Because it only affects the mortar paste, air entraining does not improve durability of the aggregate. Sound aggregate must still be used in air-entrained concrete. Other important factors are water/cement ratio (the less water in the mixture the less there is to freeze), adequate curing , proper finishing and design of the structure to minimize exposure to moisture.

3. Vulnerability of a concrete to cyclic freezing is greatly influenced by the degree of saturation.

4. There is limited evidence to relate air content directly to reductions in service life or increases in maintenance cost (see Figure 9). Although numerous studies over the years do demonstrate that air-entrained concrete is more durable under freeze-thaw conditions than non-air entrained concrete, there are too many variables to say with any degree of certainty exactly how much entrained air will improve the durability of any particular concrete.

5. Based on the information provided in this study, the current OSHD specifications for air content might be slightly too low for concrete under severe exposure. However, they appear to be adequate providing a penalty system is adopted that would induce producers to target air content closer to the middle of the specified air content range (4-7 percent) than they do now.

6. No adjustment in air content for climatological region or geographical area is recommended. While some states make such adjustments, Oregon would benefit from a reduced air content level only within the limited range of the Willamette Valley, and even this area needs some resistance to freeze/thaw exposure. Coastal area concrete would have greater resistance to chloride intrusion with the current air content specifications even though freeze/thaw resistance is not needed. All of the mountain areas, southern Oregon area, and central and eastern Oregon areas experience moderate or severe freeze/thaw exposure and require a minimum air content consistent with current specifications.

CURRENT OSHD SPECIFIED AIR CONTENT

Current OSHD Specifications are 4-7 percent air for those applications requiring air. These are:

1. All cast-in-place concrete except seals, roadway, and sidewalk slabs, curbs and parapet rails.(sic -- future specifications will be modified to delete the exception)

2. Cast-in-place roadway and sidewalk slabs, curbs and parapet rails.

3. Precast concrete piling

4. Precast slabs, T-beams, box beams or other type construction where any part of the members becomes a part of roadway or sidewalk surface.

5. Concrete paving

ACI RECOMMENDED AIR CONTENTS

The amount of entrained air recommended by ACI for the concrete mix is based on the theory that the air content of the mortar alone should be 9 percent +/- 1 percent for best protection against freeze-thaw damage in severe exposure. An air content of 7 percent in the mortar would provide protection against freeze/thaw under moderate exposure. A tolerance range is normally specified because of the difficulty in exactly controlling air content in the field.

ACI Recommended Air Contents (for the mix)

	Average Air Content*	
Max Agg. Size	Severe Exposure	Moderate Exposure
3/4	6% (4.5-7.5)	5% (3.5-6.5)
1 1/2	5.5% (4.0-7.0)	4.5% (3.0-6.0)

* Tolerance for air content in field construction (+/- 1 1/2)

Severe exposure is defined as outdoor exposure in a cold climate where the concrete may be in almost continuous contact with moisture prior to freezing or where de-icing salts are used. Examples are pavements, bridge decks, sidewalks and water tanks.

Moderate exposure is defined as outdoor exposure in a cold climate where the concrete will be only occasionally exposed to moisture prior to freezing and where no de-icing salts will be used. Examples are certain exterior walls, beams, girders and slabs not in direct contact with soil.

ANALYSIS OF AIR CONTENT LEVELS

Concrete mixes using maximum 1 1/2-inch aggregate have less mortar so they require less total air in the mix. Although OSHD 3/4-inch mix designs do have a little more mortar than the 1 1/2-inch designs the difference on average is not great.

To test the amount of entrained air that would be required to achieve ACI recommended levels, 5 mix designs were examined in each of two size ranges, 1 1/2-inch and 3/4-inch aggregates. It was found that the 1 1/2-inch mixes have an average of 56 percent mortar while the 3/4-inch mixes have an average of 59 percent mortar.

The 1 1/2-inch mixes would require 5.0 percent overall air content to have 9 percent in the mortar and 3.9 percent overall air content to have 7 percent in the mortar.

Similarly, the 3/4-inch mixes would require 5.3 percent overall air content to have 9 percent air in the mortar and 4.1 percent overall to have 7 percent in the mortar.

A 1954 PCA publication suggests that air contents as low as 3 percent are nearly as effective as higher air contents in reducing freeze/thaw damage. Below 3 percent, resistance to freezing and thawing decreases rapidly.

Although there are good reasons to increase minimum air content requirements to 4.5 or 5 percent (and perhaps to make the requirement variable depending upon aggregate size and climate at the project site), a penalty for air content below the current OSHD specified minimum of 4 percent should induce producers to keep air contents closer to 5 percent. This should provide good freeze-thaw protection in extreme exposure without increasing the minimum air content. Also, a single specification would be easier to administer and easier for producers to work with. Therefore, it is recommended that no change be made in the current OSHD specifications for minimum air content and that a penalty for air content be considered instead.

ANALYSIS OF RECOMMENDED PENALTIES

Only two states were found to be using price adjustments for low air content. These were Colorado and South Dakota (see attachment). Both had price adjustment penalties similar in amount and range. These price adjustments were used as the basis for OSHD recommended price adjustments.

When the air content is measured by volumetric means, the gauge is accurate to tenths of a percent from 0 to 4 percent air, and to two-tenths percent above 4 percent. The instruments are calibrated to read within one-tenth percent of actual air content. Because of the potential error in measuring, any proposed penalty for air content between 3.8 percent and 4 percent should be minimal. Also there should be no penalty for air contents higher than specified because the detrimental effects of high air is low strength and the contractor is already penalized for low strength.

The OSHD recommended penalties were designed so that it would be more cost-effective for a producer to use more air entraining agent (at approximately $2.50 per gallon) to increase the air content rather than accept the penalty for low air. Also, the penalty is severe enough that it would also be more cost-effective to keep air content within specifications and accept a penalty on strength than it would be to try to increase strength by reducing air content.

The following table documents the recommended price adjustment factors developed in this study:

Portland Cement Concrete
Recommended Price Adjustment Factors

Air Content (Percent)	Proportional Part of Contract Unit Price Allowed
4.0 - 7.0	100 %
3.8 - 3.9	98 %
3.6 - 3.7	95 %
3.4 - 3.5	92 %
3.2 - 3.3	89 %
3.0 - 3.1	85 %
< 3.0	80 % or full rejection

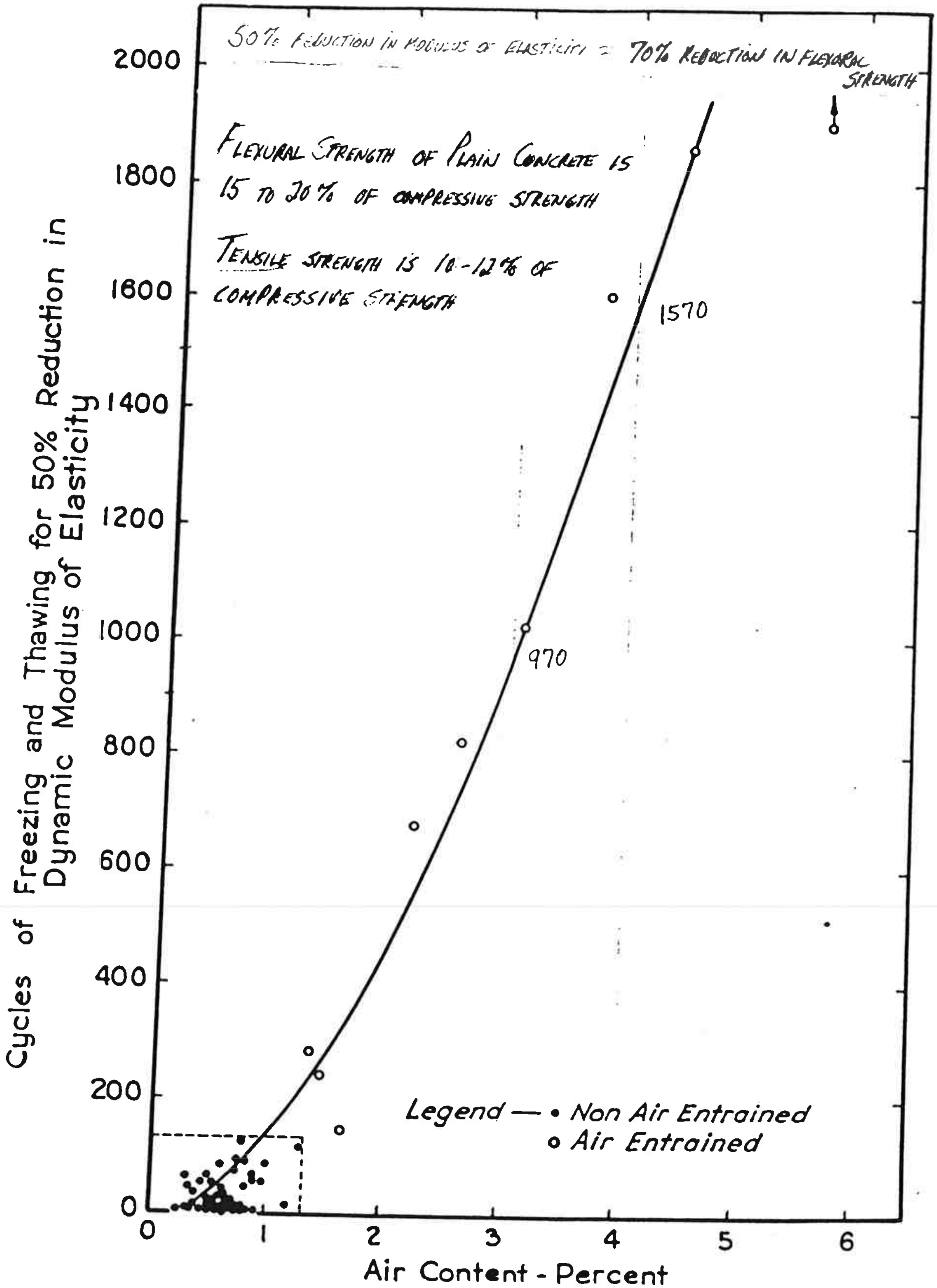

Fig 9 - Effect of Air Entrainment on the Resistance of Concretes to Freezing and Thawing

Specimens cured 28 days moist and 3 days in water prior to freezing.

FROM "BASIC PRINCIPLES OF AIR-ENTRAINED CONCRETE" PCA

6-19-51
S-342-1

TABLE 5.3.3 — APPROXIMATE MIXING WATER AND AIR CONTENT REQUIREMENTS FOR DIFFERENT SLUMPS AND NOMINAL MAXIMUM SIZES OF AGGREGATES

	Water, lb per cu yd of concrete for indicated nominal maximum sizes of aggregate							
Slump in.	3/8 in.*	1/2 in.*	3/4 in.*	1 in.*	1-1/2 in.*	2 in.†*	3 in.†‡	6 in.†‡
Non-air entrained concrete								
1 to 2	350	335	315	300	275	260	220	190
3 to 4	385	365	340	325	300	285	245	210
6 to 7	410	385	360	340	315	300	270	–
Approximate amount of entrapped air in non-air-entrained concrete, percent	3	2.5	2	1.5	1	0.5	0.3	0.2
Air-entrained concrete								
1 to 2	305	295	280	270	250	240	205	180
3 to 4	340	325	305	295	275	265	225	200
6 to 7	365	345	325	310	290	280	260	–
Recommended average§ total air content, percent for level of exposure:								
Mild exposure	4.5	4.0	3.5	3.0	2.5	2.0	1.5**††	1.0**††
Moderate exposure	6.0	5.5	5.0	4.5	4.5	4.0	3.5**††	3.0**††
Extreme exposure‡‡	7.5	7.0	6.0	6.0	5.5	5.0	4.5**††	4.0**††

*These quantities of mixing water are for use in computing cement factors for trial batches. They are maxima for reasonably well-shaped angular coarse aggregates graded within limits of accepted specifications.

†The slump values for concrete containing aggregate larger than 1½ in. are based on slump tests made after removal of particles larger than 1½ in. by wet-screening.

‡These quantities of mixing water are for use in computing cement factors for trail batches when 3 in. or 6 in. nominal maximum size aggregate is used. They are average for reasonably well-shaped coarse aggregates, well-graded from coarse to fine.

§Additional recommendations for air-content and necessary tolerances on air content for control in the field are given in a number of ACI documents, including ACI 201, 345, 318, 301, and 302. ASTM C 94 for ready-mixed concrete also gives air content limits. The requirements in other documents may not always agree exactly so in proportioning concrete consideration must be given to selecting an air content that will meet the needs of the job and also meet the applicable specifications.

**For concrete containing large aggregates which will be wet-screened over the 1½ in. sieve prior to testing for air content, the percentage of air expected in the 1½ in. minus material should be as tabulated in the 1½ in. column. However, initial proportioning calculations should include the air content as a percent of the whole.

††When using large aggregate in low cement factor concrete, air entrainment need not be detrimental to strength. In most cases mixing water requirement is reduced sufficiently to improve the water-cement ratio and to thus compensate for the strength reducing effect of entrained air concrete. Generally, therefore, for these large maximum sizes of aggregate, air contents recommended for extreme exposure should be considered even though there may be little or no exposure to moisture and freezing.

‡‡These values are based on the criteria that 9 percent air is needed in the mortar phase of the concrete. If the mortar volume will be substantially different from the determined in this recommended practice, it may be desirable to calculate the needed air content by taking 9 percent of the actual mortar volume.

5.3.2 *Step 2. Choice of maximum size of aggregate.* Large maximum sizes of well graded aggregates have less voids than smaller sizes. Hence, concretes with the larger-sized aggregates require less mortar per unit volume of concrete. Generally, the maximum size of aggregate should be the largest that is economically available and consistent with dimensions of the structure. In no event should the maximum size exceed one-fifth of the narrowest dimension between sides of forms, one-third the depth of slabs, nor three-fourths of the minimum clear spacing between individual reinforcing bars, bundles of bars, or pretensioning strands. These limitations are sometimes waived if workability and methods of consolidation are such that the concrete can be placed without honeycomb or void. When high strength concrete is desired, best results may be obtained with reduced maximum sizes of aggregate since these produce higher strengths at a given water-cement ratio.

5.3.3 *Step 3. Estimation of mixing water and air content.* The quantity of water per unit volume of concrete required to produce a given slump is dependent on the maximum size, particle shape and grading of the aggregates, and on the amount of entrained air. It is not greatly affected by the quantity of cement. Table 5.3.3 provides estimates of required mixing water for concretes made with various maximum sizes of aggregate, with and without air entrainment. Depending on aggregate texture and shape, mixing water requirements may be somewhat above or below the tabulated values, but they are sufficiently accurate for the first estimate. Such differences in water demand are not necessarily reflected in strength since other compensating factors may be involved. For example, a rounded and an angular coarse aggregate, both well and similarly graded and of good quality, can be expected to produce concrete of about the same compressive strength for the same cement factor in spite of differences in water-cement ratio resulting from the different mixing water requirements. Particle shape per se is not an indicator that an aggregate will be either above or below average in its strength-producing capacity.

Table 5.3.3 indicates the approximate amount of entrapped air to be expected in non-air-entrained concrete in the upper part of the table and shows the recommended average air content for air-entrained concrete in the lower part of the table. If air entrainment is needed or desired, three levels of air content are given for each aggregate size depending on the purpose of the entrained air and the severity of exposure if entrained air is needed for durability:

D. Shoulders, Curbs, Gutters ____________

E. Median Barriers ____________

F. Other (please specify) ____________

All agencies responded to this question, although not all categorized their limits as to type of structure. Summaries of these specifications are given in Table A-1 for state transportation agencies and in Table A-2 for other agencies.

Average limits, ranges, and midpoints are given at the bottom of each table. It is easily seen that all limits are remarkably similar for each category of structure. This indicates that, in general, little distinction is made between various types of structures when specifications on air content are developed. For state transportation departments, average limits run from about 4 to 7 percent. The average midpoint, or what might be considered as the "target value" runs from 5-1/2 to 6 percent. Values of limits for the other agencies surveyed are only marginally

FROM TRANSPORTATION RESEARCH BOARD REPORT #258

CONTROL OF AIR CONTENT IN CONCRETE

Table A-1 Current Air Content Specifications 1981 Survey - State Transportation Departments

State	Bridge Decks	Pavements	Abutments, Piers, Girders	Shoulders, Curbs, Gutters	Median Barriers	Other(s)
Alabama	4-6	3-5	3-5	3-5[a]	3-5	Underwater concrete: 3-5
Alaska	5-9	(b)	3-7	3-7	3-7	
Arizona[1]	4-6	4-6	4-6[c]	4-6	4-6	
Arkansas	3-7	3-7	-	-	-	
California[2]	5-8	5-8	5-8	5-8	5-8	Deck overlays: 5-8
Colorado	5-7	4-7	5-7	4-7	4-7	Special projects: 5-9
Connecticut	5-7	4-6	4-6	5-7	5-7	
Delaware	5-8	4-7	4-7	4-7	5-8	
District of Columbia	5.5-7.5	5.5-7.5	5.5-7.5	5.5-7.5	5.5-7.5	
Florida	5-7	3-6	3-6	3-6	3-6	
Georgia	2.5-6	2-6.5	2.5-6	2-7.5	2.5-6	
Hawaii	2-4	2-4	-	-	-	
Idaho	5-8	4-7	5-8	5-8	5-8	Prestressed girders: 2-6
Illinois	5-8	5-8	5-8	5-8	5-8	
Indiana	5-8	5-8	5-8	5-8	5-8	
Iowa	5.5-7.5	5-8	5-8	5-8	5-8	Pavement patching: 5-8
Kansas	5.5-7.5	4-8	4-8	4-8	4-8	
Kentucky	4-7	4-7	4-7	4-7	4-7	
Louisiana	4-6	3-7[d]	3-7[d]	3-7[d]	3-7[d]	Prestressed: 3-7
Maine	5-7	5-7	5-7	5-7	5-7	
Maryland	5-8	5-8	5-8	5-8	5-8	Lightweight concrete: 6-9, Prestressed: 2.5-5.5
Massachusetts	5-7	5-7	3.5-5.5	4-6	4-6	Prestressed beams: 4.5-6.5
Michigan	5-8	5-8[e]	5-8	5-8	5-8[e]	Latex modified deck overlays: 3.5-6.5
Minnesota	4-7	4-7	4-7	4-7	4-7	Low slump overlays: 5-8
Mississippi	3-6	3-6	3-6	3-6	-	Lightweight concrete: 4-7
Missouri	4-7	4-7	4-7	4-7	4-7	Lightweight concrete: 5-9
Montana	5-7	5-7	5-7	5-7	5-7	
Nebraska	5-7	5-7.5	5-7.5	5-7.5	5-7	High density overlays: 5.5-7.5, Prestressed girders and Precast Barriers: 3-6
Nevada	5-7	4-6	4-7	4-7	5-7	
New Hampshire	5-8	(b)	4-7	-	5-8	
New Jersey	4-5-7.5	4.5-7.5	4.5-7.5	4.5-7.5	4.5-7.5	
New Mexico	4-7	4-7	4-7	4-7	4-7	
New York	4-8	4-8	4-8	4-8	4-8	
North Carolina	4.5-7.5	3.5-6.5	4.5-7.5	4.5-7.5	4.5-7.5	Prestressed concrete: 2-6
North Dakota	-	5-8	5-8	5-8	-	
Ohio	4-8	4-8	4-8	4-8	4-8	
Oklahoma	5-7	5-7	5-7	5-7	5-7	High density overlays: 5.5-7.5
Oregon	4-6	3-6	3-6	4-6	3-6	Members where any face is a wearing surface: 3-6 , LSDC 5-7%
Pennsylvania	4.5-7.5	4.5-7.5	4.5-7.5	4.5-7.5	4.5-7.5	Prestressed beams: 3-6
Rhode Island	5-7	2.5-4.5	3.5-5.5	-	3.5-5.5	
South Carolina	3-6	3-6	3-6	3-6	3-6	
South Dakota	5-7	4.5-7.5	4.5-7.5	4.5-7.5	4.5-7.5	Concrete patches: 5-9
Tennessee	3-8	3-8	3-8	3-8	3-8	
Texas	5-7	5-7	5-7	5-7	5-7	
Utah	5-7	5.5-7.5	5-7	4-6	5-7	
Vermont	5-7	4-6	4-6	4-6	-	Prestressed units: 4.5-5.5
Virginia	5-8	4-8	4-8	4-8	4-8	Prestressed and tremie concrete: 2-6
Washington	3.5-6.5	3.5-6.5	3.5-6.5[f]	3.5-6.5	3.5-6.5	Latex modified concrete: 3-6, Dense overlays: 5.5-7.5
West Virginia	4-10	4.5-9.5	4-10	4-10	4-10	
Wisconsin	4.5-7.5	4.5-7.5	4.5-7.5	4.5-7.5	4.5-7.5	Prestressed box beams: 3.5-6, Prestressed I-beams: 6 max., Deck Overlays: 5-7
Wyoming	4-6	4-7	4-7	4-7	4-7	
Number of Responses	50	49	49	47	46	
Average Limits	4.5-7.2	4.1-7.0	4.1-7.0	4.2-7.2	4.3-7.2	
Average Range	2.7	2.9	2.9	3.0	3.0	
Average Midpoint	5.8	5.6	5.5	5.7	5.7	

(1) Air entrainment specified at elevations greater than 3,000 feet

(2) Air entrainment specified in freeze-thaw areas only

(a) No air specified for curbs or gutters

(b) No p.c.c. pavement specified

(c) Precast-prestressed girders below deck slab not air-entrained

(d) Usually not specified as air-entrained

(e) Slipform pavement and median barriers specified at 4.5-8% air

(f) Air-entrainment not specified for precast girders higher than for the states.

When limits for individual states are inspected, it can be seen that there have been only marginal changes in limits as compared to those in force at the time of a 1975 PCA survey on pavement specifications (40). Table A-3 compares the results of these two surveys.

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Table A-2 Current Air Content Specifications 1981 Survey - Other Agencies

Agency	Bridge Decks	Pavements	Abutments, Piers, Girders	Shoulders, Curbs, Gutters	Median Barriers	Other (s)
FHWA-East	4-8	-	4-8	4-8	4-8	
FHWA-CDFD	4-6	4-7	4-6	4-6	-	Culvert headwalls 4-6
FHWA-West	5-7	-	5-7	-	-	
TVA	3.5-7.5	4-7	4-7	4-7	4-7	
USBR	5-7	5-7	5-7	5-7	5-7	
Corps of Engineers	4.5-7.5	-	4.5-7.5	4.5-7.5	-	
Manitoba	5-7	5-7	5-7	5-7	5-7	
New Brunswick	5.5-7.5	5.5-7.5	5.5-7.5	5.5-7.5	6-7.5	
Nova Scotia	5-8	5-8	4-7	5-8	5-8	
Ontario	4.5-7.5	4.5-7.5	4.5-7.5	4.5-7.5	4.5-7.5	
Hydro-Quebec	4-7	4-7	4-7	4-7	4-7	
Transport Canada	5-8	4-6	5-8	5-8	5-8	
Number of Responses	12	9	12	11	9	
Average Limits	4.6-7.3	4.5-7.1	4.5-7.2	4.6-7.3	4.7-7.4	
Average Range	2.8	2.6	2.7	2.7	2.7	
Average Midpoint	5.9	5.8	5.9	6.0	6.1	

Table A-3 Comparison of 1975 and 1981 Surveys

Number of States Having Lower Limit[1/] Equal to/	1975	1981	Number of States Having Upper Limit[1/] Equal to/	1975	1981
2%	2	2	3%	1	0
3%	8	9	4%	0	1
4%	19	18	5%	0	2
5%	16	18	6%	9	8
6%	1	1	7%	17	18
			8%	18	18
			10%	1	1

1/ In those cases where fractional value was encountered, it was rounded to the next highest integer.

Effects of Air Content on Other Properties of Concrete

Air entrainment has been found to have a beneficial effect on most properties of fresh and hardened concrete provided that the mixture is well proportioned and advantage has been taken of the effects of air entrainment on slump and workability of the mix. If this is done, workability can be increased, bleeding decreased, finishing expedited, and a more uniform product obtained. Entrained air has only minor effects on such properties as shrinkage, creep, fatigue, bond strength, and abrasion resistance of hardened concrete. The ability of concrete to withstand attack by sulfates and internal degradation by reactive aggregates is enhanced by air entrainment. The only properties that are deleteriously affected by entrained air are strength and elastic modulus. These effects can be minimized by proper mix design, although some loss of strength is still to be expected, especially in high strength concrete mixtures.

Overall, the synthesis describes in detail the many factors that may influence air content and the air void system in field production of air-entrained concrete. Armed with a knowledge of these factors and an appreciation for high quality workmanship, the practitioner will be able to produce durable, uniform, air-entrained concrete under most conditions. Many effects lie relatively unexplained, however, and there exists a need for research in many areas within the technology of air entrainment in concrete.

CURRENT AIR CONTENT SPECIFICATIONS

All 50 states, the District of Columbia, and 12 other agencies received questionnaires (App. A), in which information concerning current specifications on air content was requested. Responses from individual agencies are included as Tables A-1 and A-2. Table 1 summarizes the responses, which are separated into various categories of uses of concretes.

It is readily seen that specification limits are remarkably similar for each category of structure. This indicates that, in general, little distinction is made between various types of structures when specifications on air content are developed. For the state transportation departments, average limits run from about 4 to 7 percent, which encompasses a range of close to 3 percentage points. The average midpoint, or what might be considered as the "target value," runs from 5-1/2 to 6 percent. Values of specification limits for the other agencies surveyed are only marginally higher than for the states.

Further information on the distributions of these limits for one category of concrete, that used in pavements, is given in Table 2.

Only two states have lower limits less than 3 percent, while only three states have upper limits less than 6 percent. The bulk of the lower limits lies between 3 and 5 percent, and the bulk of the upper limits lies between 6 and 8 percent. These specification limits are not materially different from those published by the Portland Cement Association (40) in a survey conducted in 1975. Thus, it appears that there has been little change in specification on air content over the past 7 years, at least for those grades of concrete used in pavement construction.

RESULTS OF QUESTIONNAIRE

In addition to obtaining information on current air content specifications, a questionnaire was circulated to state transportation departments and other agencies to obtain information on problems in control of air content currently being

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Table 1. Summary of Air Content Specifications.*

	Type of Structure				
States	Bridge Decks	Pavements	Abutments, Piers, Girders	Shoulders, Curbs, Gutters	Median Barriers
No. of Responses	50	49	49	47	46
Average Limits	4.5-7.2	4.1-7.0	4.1-7.0	4.2-7.2	4.3-7.2
Average Range	2.7	2.9	2.9	3.0	3.0
Average Midpoint	5.8	5.6	5.5	5.7	5.7
Other Agencies					
No. of Responses	12	9	12	11	9
Average Limits	4.6-7.3	4.5-7.1	4.5-7.2	4.6-7.3	4.7-7.4
Average Range	2.8	2.6	2.7	2.7	2.7
Average Midpoint	5.9	5.8	5.9	6.0	6.1

*All average data are given as percent by volume of concrete.

RESULTS FROM LOW AIR PRICE ADJUSTMENT QUESTIONNAIRE

STATE	P.A. POLICY	MIN. REC. AIR	COMMENTS
MONTANA	NO	4 %	FOR 1-INCH AGGREGATE / ALLOWS ADDITIONAL ADMIX AT SITE
OAKLAHOMA	NO	4 %	
CALIFORNIA	NO	4.5 %	AT ELEV. > 3000 fT. / ADD ADMIX AT SITE OR REJECT
UTAH	NO	4.5 %	REJECTS OUT OF SPEC CONCRETE
NEVADA	NO	5-6 %	
ARIZONA	NO	3-4 %	ONLY AT ELEV. > 3500 fT
TEXAS	NO	3-4 %	
COLORADO	YES		
SOUTH DAKOTA	YES	6 +/- 1½%	

COLORADO POLICY

DEVIATION FROM SPEC AIR	PAY FACTOR
Up to 0.2%	98 %
0.3 - 0.4 %	96 %
0.5 - 0.6 %	92 %
0.7 - 0.8 %	84 %
0.9 - 1.0 %	75 %
over 1 %	remove or no pay

SOUTH DAKOTA POLICY

AIR DEVIATION %	PAY FACTOR DECKS & LOW SLUMP	PAY FACTOR EXPOSED CONC.	PAY FACTOR UNEXP CONC.
0.0 to -0.5 or 0.0 to +1.0	95-100%	96-100%	98-100%
-0.5 to -1.0 or +1.0 to +2.0	85-95%	90-100%	94-98%
-1.0 to -2.0 or +2.0 to +4.0	65-85%	75-90%	85-94%

Low strength in addition to air deviation- addtional 10% Price Adjustment