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16. ABSTRACT

While Mr. Swayze is scheduled to discuss "Types of Cement Made in U.S.A." and Mr. Harry Gonnerman will discuss the "Development of Cement Performance Requirements", it is necessary that I discuss briefly both of the above topics in order to present some background of current user requirements in the U.S.A.

The work and the publications of the research conducted by the U.S. Bureau of Standards, including the 1933 and 1940 papers by P.H. Bates, and the reports on the cement investigations for Hoover Dam, which covered the field of influence of chemical composition, fineness of grinding and method of manufacture of cement upon heat of hydration, strength, volume changes and durability of mortars and concrete; combined with reports on subsequent studies relative to the beneficial effects of air entrainment in concrete as well as of the adverse performance of certain cement-aggregate combinations and means of correction, have probably exercised a greater influence on the thought and specifications of cement users in the U.S.A. during the last two decades than developments during all of the years preceding 1930.

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TECHNICAL REQUIREMENTS FOR CEMENTS IN U.S.A.*

By Thomas E. Stanton
Materials and Research Engineer
California Division of Highways

While Mr. Swayze is scheduled to discuss "Types of Cement Made in U.S.A." and Mr. Harry Gonnerman will discuss the "Development of Cement Performance Requirements", it is necessary that I discuss briefly both of the above topics in order to present some background of current user requirements in the U.S.A.

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Review of Cement Specifications Currently Used Throughout the U.S.A.

To ascertain the extent to which the developments recited above have influenced cement specifications nationally, a questionnaire was recently submitted to all State Highway Departments and some of the other major users of cement, such as the U.S. Bureau of Public Roads, the U.S. Engineers, the Metropolitan Water District of Southern California, Board of Water Supply of the City of New York and the Department of Water and Power of the City of Los Angeles.

The bulk of this report consists of an analysis of the

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replies from the above agencies.

Development of the Sulphate Resistant Cements

As a result of the work done during the twenties and the early thirties by the National Bureau of Standards in cooperation with the Portland Cement Association and by other independent investigators on the "Influence of Composition on Volume Constancy and Salt Resistance of Portland Cement", numerous user agencies early in the third decade of this century began including special composition requirements in their cement specifications based on the findings recorded in the published data, particularly those relating to the composition of low heat cements as specified and used in the Hoover Dam and the moderate sulphate resistant cements used in the construction of the San Francisco-Oakland Bay Bridge.

The first structural specifications for the San Francisco-Oakland Bay Bridge in 1933 limited the C_3A content of the cement to 8%.

Subsequently the American Association of State Highway Officials (AASHO) adopted a moderate sulphate resistant cement under the designation M60-38. This designation was dropped when ASTM adopted specifications for five types of cement and AASHO M60-38 became ASTM Type II.

Accelerated durability tests in concentrated sea water solutions and in an alkali soil high in sodium sulphate from the vicinity of Willows, California, which had destroyed a section of concrete pavement about twelve years previously, were started in 1932.

The results of these tests were fully described in the paper on "Resistance of Cements to Attack by Sea Water and by Alkali Soils" published in the A.C.I. Journal, March-April, 1938. In the report it was shown that cements similar to current ASTM Type II are materially more resistant to sulphate attack than the corresponding standard higher C_3A cements of the same brands.

The California Division of Highways specifications were therefore changed to require a moderately low C_3A (8%) cement in construction along the sea coast and in the interior valleys whenever it was anticipated that the concrete might be subject to sulphate attack.

A.S.T.M. Standard Specifications C150 state that Type II cement is "For use in general concrete construction exposed to moderate sulphate action or where moderate heat of hydration is required."

Mr. Frank Jackson, Principal Engineer of Tests for the United States Bureau of Public Roads, in a paper presented at the First Pacific Area National Meeting of the American Society for Testing Materials held in San Francisco, California, in October, 1949, pointed out that in spite of the above limitation in scope "there has been a marked tendency on the part of many consumers to consider Type II as an improved general purpose cement, particularly with respect to resistance to freezing and thawing.

He concludes however that, based partly on a study of four of the projects of the Long Time Study which had up to that time been exposed for periods up to 8 years, there is little choice between the Type I and II as regards influence of cement upon durability *when the only severe exposure conditions are freezing and thawing*. Jackson further states that the results of the "Long Time Study" confirm many years experience in observing the behavior of concrete pavements in service. He does not deny that the quality of the cement is important but states that in his judgment merely specifying the present A.S.T.M. Type II cement will not in itself insure more weather resistant concrete than would the use of some Type I cements higher in C_3A content. The writer concurs with this conclusion.

However, notwithstanding Mr. Jackson's conclusions, there has been a trend nationally during recent years towards the mandatory use of Type II cement as standard.

The usual reason given is that a Type II cement is a closely controlled material with limited compound composition. and, therefore, an unusually uniform cement even when made by different mills.

Incidents are recited of more durable concrete following change to Type II as compared with previous work in which typical Type I cements of the same brand were used.

At the same time when a Type II cement is specified some modifications in ASTM Standards are frequently made, such as increasing the permissible C_3S content to as much as 60% in order to accomodate some local situation. This change is justified on the ground that the C_3S content has no demonstrated relation to durability. At the same time one eastern state which refuses to adopt ASTM Standards permits up to 15% C_3A but limits the C_3S to 50%.

To repeat, those who specify Type II as Standard, are of the opinion that when either a Type II cement is specified or special composition requirements are made, greater care is exercised in the manufacturing, operations with a resultant superior product.

The contention is that if this "superior" product can be secured at no penalty in price, why not require a Type II or special composition cement.

Replies to the recent questionnaire shows that eight western and ten eastern State Highway Departments or approximately 35% of all states now require Type II cement and that an additional three western and four eastern states specify Type II for use under special conditions of exposure.

Air Entrainment

It is unnecessary to review the history of the development of air entraining cements but simply to discuss the current scope of use.

The original tests with air entrained concrete conclusively demonstrated the great benefits of air entrainment as a protection against concrete disruption through freezing and thawing or surface scaling through salt applications.

When the program for the Portland Cement Association sponsored "Long Time Study of Cement Performance in Concrete" was under consideration, it was decided that tests should be conducted in alkali soils of the type encountered in the portion of the Sacramento Valley south of Willows which had been the cause of the early pavement failure previously referred to.

The tests are fully described in Chapter 5 of the Long Time Study published in 1949 by A.C.I. in cooperation with the Portland Cement Association.

One of the outstanding developments of this alkali soil test, (in addition to other important developments checking previous conclusions regarding the effects of composition of cement and richness of mix,) was the substantial improvement in durability of concrete through air entrainment when exposed to attack by the sulphates in either alkali soil or sea water.

As a result of the earlier demonstration of the great benefit of air entrainment in concrete exposed to freezing and thawing as well as the improvement in resistance to sulphate attack, air entrainment is coming more and more into general use in the U.S.A.

As of the present time air entrainment is customarily required in 28 states, usually not required in 14 and generally required for certain classes of work in the other five states.

Thirty-four states, or 70%, express a preference for the addition of the A.E.A. at the mixer; five states prefer mill addition, and eight states express no preference.

The overwhelming evidence therefore is in favor of addition at the mixer. The expressed feeling is that better control of the air content is attained by adding the A.E.A. on the job.

Development of Specifications for Low Alkali Cement (0.6% as Na_2O)

Most cement manufacturers and users are familiar with the background for the Low Alkali Cement requirements; namely, the adverse experience in sections of the United States with certain combinations of cement and aggregate which were shown to be the cause of excessive expansion and cracking of the concrete.

In 1939 the trouble was traced in California to a reaction between the alkali in the cement and an amorphous silica in the aggregate in the form of an opaline chert. The story was first published in 1940.*

The first tests indicated that excessive expansion occurred under an accelerated test procedure only when the alkali content of the cement (Na_2O equivalent) exceeded 0.5%. Hence the 1939 California Special Provisions limited the alkali content to 0.5%.

During a careful check on analytical procedure in cooperation with Mr. W.C.Hanna of the California Portland Cement Company, it developed that the procedure then followed in the California Division of Highways Laboratory had resulted in determining approximately 0.1% less alkali than determined by the best analytical procedure.

This development indicated that we could apparently safely raise the permissive alkali content to 0.60% in so far as the California cements and California reactive aggregates were concerned.

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*Thomas E. Stanton, "Expansion of Concrete Through Reaction Between Cement and Aggregate", Proceedings, American Society Civil Engineers, December 1940, p. 178.

This determination and subsequent change in specifications was made before the A.S.C.E. paper was published in December, 1940 hence the conclusion stated therein was that the intensity of the reaction was negligible when the alkali content was less than 0.6%.

This figure was subsequently adopted by others and is the present generally specified limitation on alkali content, although, based on subsequent extensive test data, there is reason to believe that some lower percentage may on occasion be desirable and possibly even necessary for the reason that while the original tests failed to indicate excessive expansion at early ages with cements containing less than 0.60% alkali, it is a fact that with at least some reactive aggregates, excessive expansion may be developed in accelerated laboratory tests with cements containing somewhat less than 0.6%.

We are watching the situation on our California Highways where many miles of pavement and numerous structures have been constructed with the same type of reactive aggregates and with cements containing between 0.5% and 0.6% alkali but which have developed no signs of distress up to twenty years or more. Hence we have no present intention of lowering the current 0.6% limitation on alkali content unless later experience indicates otherwise.

The U.S. Bureau of Reclamation apparently considers that it is unnecessary to lower the 0.6% alkali limit at least when pozzolanic admixtures are used. These admixtures serve a multiple purpose and their use is not solely influenced by fear of the expansive reaction.

Nine western and three eastern states now require the mandatory use of a low alkali cement; five states require low alkali only in the presence of reactive aggregates and the other 31 states place no limitation usually on the grounds that the local aggregates are not reactive, based on experience.

Pozzolanic Cements and Pozzolana Additions

While the virtues of some siliceous admixtures for improving durability and reducing the heat of hydration as well as possibly lowering the cost of concrete had been given some consideration prior to 1940 the determination in that and subsequent years of the beneficial aspects of many pozzolans in counteracting the excessive expansion resulting from high alkali cement-reactive aggregate combinations gave a new impetus to the work of the A.S.T.M. Sponsoring Committee on Blended Cements, leading up to the "Symposium on Use of Pozzolanic Materials in Mortars and Concrete", presented at the Pacific Area National Meeting of the

American Society for Testing Materials in San Francisco, California, October 10-14, 1949 (A.S.T.M. Special Technical Publication No. 99).

There are at present no A.S.T.M. Standard or even Tentative Standard Specifications covering Pozzolanic cements generally and there is apparently very little current demand for such specifications on the part of the general user.

However, just as in the case of type of cement, air-entrainment and low alkali requirements a demand may develop overnight, particularly if A.S.T.M. adopts specifications for blended cements.

This trend can become extensive if blended cements can be developed which are minus high shrinkage characteristics and with proven protection against excessive expansion through any reaction between the cement and aggregates combined with greater resistance to sulphate attack and in general greater durability against all adverse exposure conditions.

Pozzolanic additions are now used extensively by the U. S. Bureau of Reclamation, which strongly favors use of pozzolans and prefers a blended portland-pozzolan cement to incorporating the pozzolan at the mixer.

As will be noted from Table 2, many states, as well as the U. S. Engineers, have for some time used blends of Portland and natural cements and some use or permit the use of blast furnace slag cements.

Premature Stiffening or Flash Set

The Bureau of Reclamation and some others are concerned over the occurrence of premature stiffening of the concrete on some projects and have drafted specifications designed to eliminate the difficulty.

Similar difficulties were experienced by the California Division of Highways about 25 years ago at which time a paragraph was added to the specifications providing that the cement when mixed with water at a temperature above one hundred fifty degrees (150°) F. should not attain a final set in less than thirty (30) minutes.

No premature stiffening or flash set had been experienced during recent years until a case within recent months when premature stiffening occurred on one job. On investigation it was found that much, if not all, of the calcium sulphate had been inadvertently omitted from some of the cement.

None of the other states have reported similar difficulty in answer to the recent questionnaire, which, however, neglected to ask a specific question regarding any observation of premature stiffening and precautions taken to avoid the occurrence.

Policies of Some Large Public Users Other than State Highway Departments

Basically, the U.S. Engineers and the Bureau of Reclamation use Type II cement conforming with Federal Specifications SS-C-192 with slight modifications. Federal Specifications SS-C-192 do not differ materially from A.S.T.M. Standards.

Both of the above agencies usually use an air-entraining agent and limit the alkali content to 0.6% when reactive aggregates are encountered.

Reclamation uses considerable pozzolan and, in fact, prefers a pozzolan with corrective properties to low alkali as a means of inhibiting an adverse reaction.

The U.S. Engineers likewise favor pozzolanic or natural cement admixtures.

The New York Board of Water Supply uses special specifications which produce a modified Type II cement. The principal modifications follow lines developed by the late Thaddeus Merriman, in which limits are placed on the alkalinity and the free alkali content of the cement which, according to N. T. Stadtfeld, Division Engineer, has kept the percentage of total alkalies, figured as Na_2O below 0.54%. The specifications further provide for sugar solubility and sodium sulphate tests and that kilns shall operate at about 2700 degrees Fahrenheit. There are other manufacturing restrictions essential in the opinion of the Board of Water Supply Engineers to the consistent production of a uniformly compounded and sound product.

The New York Board of Water Supply specifications have been followed on occasion by other large agencies, such as the Metropolitan Water District of Southern California and the Department of Water and Power of the City of Los Angeles but not to any great extent.

The writer is not aware of any other extensive use of the New York specifications although such may exist.

CONCLUSIONS

1. The specification of Type II cements as standard is rapidly assuming substantial proportions and there appears to be no doubt but that the trend in this direction will continue unless the published results of long time tests disprove any demonstrable benefits under natural weathering conditions of a limitation in the C_3A and C_3S content or there is a temporary relaxation due to war conditions.

2. The benefits of air-entrainment, in so far as protecting concrete under normal as well as adverse exposure conditions is concerned, is receiving general recognition and the trend appears definitely toward specifying air-entrained concrete as standard with preference for addition of the A.E.A. at the mixer.

3. A limited number of users require low alkali cement as standard.

   Should future studies determine that the lower alkali cements are better all purpose cements, the publishing of a few papers by recognized research agencies could easily develop a trend towards a mandatory limitation on alkali similar to the trends in the direction of Type II cements and air entrainment.

4. There does not appear to be any indication of an early trend towards the extensive use of siliceous additions (pozzolanic or otherwise) except in connection with natural cement blends in the east and in mass concrete where there is a five fold objective, namely, (1) lower heat development, (2) lower cost, (3) correction of any tendency towards an excessive expansion due to an adverse reaction between the cements and aggregate, (4) Potential improved workability and cohesiveness, and (5) reduced segregation and bleeding.

   The above conclusion regarding the future of pozzolanic type cements is based on the present known attributes, bad as well as good, of this type of cement. Some of the adverse characteristics such as high shrinkage, lower abrasive resistance and some difficulties of handling may be overcome.

   Undoubtedly with the adoption of A.S.T.M. Standards covering pozzolan or blended cements, such cements will be used on a much wider scale.

There is considerable test data indicating that not over 5% of certain siliceous (Pozzolanic) materials may be sufficient to correct any adverse reaction between the cement and most, if not all, commercial aggregates of the reactive type. In fact, the evidence in this respect is of sufficient significance to justify further extensive tests and serious consideration of a modified cement for general use which conforms substantially with a standard Type I cement but containing 5 percent of a suitable pozzolanic material for corrective purposes.

TABLE I

TECHNICAL REQUIREMENTS FOR CEMENT

IN THE UNITED STATES

JUNE 1951

STATE OR AGENCY	BASIC TYPE SPECIFIED		AIR-ENTRAINMENT					ALKALI LIMITATION			EXPERIENCE WITH POZZOLANS OR BLENDED CEMENTS
			Policy		Preferred Method of Addition						
	I	II	Reqd.	Not Usually Required	Mill	Mixer	Either	All Work	Reactive Agg. Only	Never	
Alabama	x			x		x		0.6%			Some slag cement as blend O.K.
Arizona	x		x			x		0.6%			None
Arkansas	x		Pvt.	Struc.		x				x	None
California	x			x		x			0.6%		Very little. AEA used few cases.
Colorado		x	x			x				x	None
Connecticut		x	x			x				x	Blend in Struc. Natural Cement.
Delaware		x		x		x				x	None. AEA few projects only.
Florida	x		x			x			0.6%		None
Georgia	x			x		x		0.6%			None
Idaho		x	x			x		0.6%			None
Illinois	x		x			x				x	None
Indiana	x		x				x			x	None. AE Cement Pavements. Some in Struc.
Iowa	x		Some Work				x			x	None
Kansas	x			x		x				x	Special work only to date.
Kentucky	x		Pvt.	Struc.			x			x	Limited Exp. Type I and Natural Cement.
Louisiana	x			x	x					x	None
Maine		x	x				x			x	None. No comments.
Maryland	x		x			x				x	None
Massachusetts	x		x			x				x	None. Some Natural.
Michigan	x		x			x				x	Very little.
Minnesota	x		x			x			0.6%		Pavement: Optional. 85% Standard PC, 15% Nat.
Mississippi	x			x		x			0.6%		None. Some slag cement.
Missouri	x			x		x				x	None
Montana		x	x			x		0.6%			None
Nebraska	x		x			x			0.6%		Limited
Nevada		x	x			x		0.6%			None
New Hampshire		x	Str.	Pvt.		x				x	Pavements 6 Sacks Type II + 1 Sk. (85#) Nat.
New Jersey		x	x			x				x	None
New Mexico		x	x			x		0.6%			None
New York		Mod.	x		x					x	Natural Cement Blend 7:1.
No. Carolina	x		x			x				x	None
No. Dakota	x		Pvt.	Struc.			x			x	None
Ohio	x		x				x			x	Portland-Pozzolan used two projects.
Oklahoma	x			x		x				x	None
Oregon	x		x			x		0.6%			None
Pennsylvania	Special		x		x					x	None
Rhode Island		x	x		x					x	None. Some Natural blended with Type II.
So. Carolina		x		x		x		0.6%			None
So. Dakota	x		x			x				x	None
Tennessee	x			x			x			x	None
Texas	x			x		x				x	None
Utah		x	x			x		0.6%			None
Vermont		x	x		x					x	P.C. - Natural blend 5:1.
Virginia		x		x		x				x	None
Washington (State)		x		x		x		0.75%	0.6%		None
West Virginia	x		x			x				x	None
Wisconsin	x		x				x			x	None
Wyoming		x	x			x		0.6%			None
Met. Water Dist. of So. Calif.		x		x		x			0.6%[1]		Limited
Dept. of Water & Power - City of Los Angeles		Mod.		x					0.6%[2]		
Board of Water Supply - City of New York		Mod.		x				0.54%[3]			
U. S. Bureau of Reclamation		x	x			x			0.6%		Prefers a Blended Portland-Pozzolan.
U. S. Engineers	.	x	x				x		0.6%		Trying out various blends.

1 Rarely
2 Major structures only
3 Through the limitation on titration value for free alkali, the New York City Board of Water Supply Specifications automatically keeps the percentage of alkalies figured as Na_2O below 0.54%.

NOTE: See Table 2 for summary of comments by different reporting agencies.

TABLE 2

COMMENTS BY U.S.A. AGENCIES REPORTING ON CURRENT PORTLAND CEMENT SPECIFICATION REQUIREMENTS

STATE HIGHWAY DEPARTMENTS

Alabama

Prefer adding A.E.A. on job, better control of air content.

Limitation on alkalies at present 0.6%; however, collecting quite a bit of information that troubles can be traced to some factor other than alkalies.

Have used slag cement as blend successfully.

Arizona

Prefer to add A.E.A. at mixer thus enabling adjustment of amount of air within limits of specifications. Endeavor to hold to 3% in desert areas.

Arkansas

Experience indicates preferable to add A.E.A. at mixer for better control.

Colorado

Durability of Type II cement believed better than Type I; more uniform; better control from bin storage; desirable for moderate sulphate resistance necessary in some areas of the state.

Alkali-aggregate reactions not evidenced.

Connecticut

The only special cement used is a natural cement made in New York State. This, however, must meet A.S.T.M. Specifications.

Cement Type II and natural used in structures.

A.E.A. added at mixer.

Delaware

The Department believes that a more durable type concrete is produced with Type II cement.

When A.E.A. is specified shall be added at mixer. More uniform concrete.

Florida

Experience with air entraining agents is that admixtures added at the time of mixing the concrete give more uniform and dependable results.

Georgia

Maximum C_3S in Type II cement 60%.

On occasions where air-entrained concrete is specified special provisions requiring the air-entraining agent to be added at mixer. Only on very rare occasions is air-entraining portland cement permitted and in such cases the contractor is required to have regular cement and an air-entraining agent available to maintain a specified air content.

Idaho

While the Standard Specifications permit either Type I or Type II, they also place a limit of 0.6% on the alkali content. This automatically requires a Type II cement as Type I cement available to Idaho is high in alkali.

Illinois

Feel that addition of the air-entraining agent during the process of mixing will provide superior opportunity for control of the air content.

Kansas

Of the opinion that all air-entraining agents should be added at the mixer. With regard to pozzolans have some test sections under observation but due to the fact that they are only approximately two years old, have very little data on them.

Louisiana

Do not use air-entraining cements at this time. Have had practically no experience but preferred to have the agent added at the mill.

Maryland

Concerning the problem of interground air-entraining agent versus adding at the mixer, problem has been given consideration but no conclusions. However, inclined to believe that a more consistent product will result with the air-entraining agent added at the mixer, provided satisfactory dispensing equipment is used for the purpose. This also has the obvious advantage of being able to adjust the air content in the mix.

Massachusetts

Type II originally adopted for moderate resistance to freezing and thawing on basis A.S.T.M. Specifications. 1951 Specifications changed to permit Type I or II alternative on basis P.R.A. reports.

Feel that the addition of an A.E.A. at the mixer provides better control of the air content under the different conditions existing on various jobs, such as different mixes, lengths of haul, brands of cement, gradations of aggregates, slump, etc. It is also more practical on account of the limited supply and storage capacity for cement in most transit mix plants.

Michigan

Originally favored the use of air-entraining cement. Experience with this method of entraining air, however, has not been entirely satisfactory. Now prefer an air-entraining admixture because it is possible to adjust the amount of air-entraining agent for the particular conditions under which it is used. Are considering a specification revision to require the air-entraining admixture method but will very likely continue to permit either method through the 1951 construction season.

Minnesota

Specifications give the contractor the option of using either an air-entraining agent added at the mixer or interground in the cement on concrete construction (except bridges). On bridge construction where the specifications require the use of air-entrained concrete, the air-entraining agent must be added in the mixer at the site of the work.

On concrete pavements the contractor has the option of using a blend of 85% standard Type I Portland Cement and 15% natural cement. This blend is not permitted in structures.

Missouri

Air-entrained concrete for bridge super-structures and pavements in urban areas where cities handle ice removal and may use salts to excess. Agent added at job.

Montana

Use Type II because the local mill makes Type II with a total alkali content under 0.6% while the total alkalies in their Type I are high.

Special provisions do not allow the use of interground air-entraining agents. With the local cement containing an air-entraining agent the results were not consistent; the desired air content could not be obtained without considerable difficulty including occasional supplemental additions of air-entraining agents at the mixer.

Nebraska

The contractor has the option of using Type I-A cement or Type I with an air-entraining admixture. With some aggregates Type I-A entrains more air than permitted. Therefore, most concrete with air-entraining admixture.

Type I + Fly Ash used in an experimental project.

Nevada

Air-entraining required everywhere except extreme southern part of State. Air-entraining agent always added on job. However, time and trouble could be saved by having the A.E.A. ground with cement at mill.

New Hampshire

Type II cement used in structures as result of P.C.A. recommendation*. Pavement 6 bags Type II to 1 bag natural cement (85#). Do not permit the use of ground-in air entraining agents.

New Jersey

State has been using cement similar to A.S.T.M. Type II for 18 years. Service records highly satisfactory.

New York

A.S.T.M. Standards for Portland Cement not used. Cement similar to Type II used for durability exclusively.

No reactive aggregates. High alkali cements have given best service.

Cement in pavement concrete either Type 2A or Portland cement Type 2, blended with Natural cement Type N or P proportioned by volume 7:1.

North Carolina

Type II was required for all concrete work until September 1950. Have never found a concrete job which failed due to Type I cement. This experience combined with the paper by F. H. Jackson on "Why Type II Cement" and the Napierville Farm (P.C.A. Long Time Study)* influenced change to Type I.

Specifications, however, limit C_3S in both Types I and II to 55% and C_3S in Type I to 15%.

North Dakota

The use of an interground air-entraining agent is considered much more satisfactory than adding at the mixer. On occasion,

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*Note that New Hampshire quotes P.C.A. as exponent of Type II and that North Carolina quotes P.C.A. Long Time Study (Napierville Farm) in support of changing specifications to permit Type I.

however, found necessary to add additional A.E.A. at the mixer to bring air content to requirements.

This condition generally corrected in subsequent cement shipments.

Ohio

Specifications require 3% to 6% air. On some contracts necessary to add additional A.E.A. to the A.E. cement in order to entrain at least 3% air. Majority of contractors use A.E. cement.

Experience with pozzolanic materials in concrete pavements confined to two projects built with portland-pozzolan cement. These projects now in worse condition than sections built with straight Portland cement and A.E.-P.C. or blends of natural and Portland cement with or without A.E.A.

Oklahoma

No specification limitation on alkali content of cement but cements used contain less than 0.6%.

Oregon

Type II used east of Cascade Mountains, because of high temperature differential and existence of more reactive aggregates in that area. 25% Type II cement. 0.6% alkali limitation on Type II cement. Type I not limited but commonly found less than 0.6%.

Do not permit use of interground A.E.A. but require that the agent be added at the job. In this way get much better control.

Pennsylvania

Pennsylvania has its own cement specification. All concrete is made with an A.E. cement. No additives permitted at the mixer. Present Type C Specification developed prior to 5 A.S.T.M. types. With adoption of present specification including A.E. are getting a uniformly better cement.

Type C (normal P.C.) limits C_3S to 50% and C_3A to 15% but with further provision that the sulphur trioxide (SO_3) shall not exceed 2.5% when the C_3S exceeds 8%. The reason for this provision is not entirely clear as the standard limits the SO_3 to 2.0%.

Type B cement is normal strength air-entraining, Portland Blast Furnace Slag Cement.

Rhode Island

Type II is used because of slower set and usually more uniform in chemical analysis.

Felt that A.E. interground at mill has slight edge over adding at mixer, however, only when aggregates are consistent in gradation and quality. Sudden changes in gradation of fine aggregate sometimes influences the percentage of air.

Also have had excellent results with addition of natural cement to regular Type II Portland cement.

South Dakota

Specifications allow either A.E. cement or addition of A.E.A. at mixer. Believe better control can be obtained by adding at mixer.

Texas

It is felt that if an air entraining agent is used, better to add at mixer affording better means of controlling air content.

Utah

Type II cement specified because of better control over chemicals in addition to greater resistance to alkali or sulphate attack.

All A.E.A. added at job. Mill addition would be approved provided discrepancies could be corrected on job.

To insure against possible reactive aggregates low alkali cement is specified for all work.

Vermont

Either Type II A or Type II + Blend with natural cement, 5:1 is used.

Virginia

Specifies Type II cement because believed closely controlled throughout and quite uniform in composition.

Improvements marked since adoption of Type II. Modified composition (Max. 60% C_3S) because one of the best cements available usually contains 50 - 60% C_3S.

Washington State

Type II cement preferred over Type I because of less drying shrinkage, greater uniformity between mills and greater uniformity from lot to lot from same mill.

With regard to air-entraining agent feel that better control is possible when agents are added at mixer.

Alkali limitation 0.75% all work. Limit 0.6% when reactive aggregates are encountered.

West Virginia

Air-entrained concrete specified for a number of years. Excellent results with interground cements due to fact that aggregates are fairly uniform. Believe, however, that addition at mixer permits much closer control.

Wisconsin

Experience over past five or six years has led to confirmation of policy of permitting contractor to either furnish A.E. cement or add the A.E.A. at the mixer.

Wyoming

Do not permit adding A.E.A. at mill.

Metropolitan Water District of Southern California

When it becomes necessary to prepare specifications for projects in regions where the available aggregates may be suspected to be reactive, provision made for limitation on alkali content of the cement.

Department of Water and Power
City of Los Angeles

Specifications for major structures are modeled on New York Board of Water Supply Specifications.

A modified Type II cement is specified with limits on sugar solubility, total alkalies, alkalinity and free alkali.

Standard A.S.T.M. Type II cement specified for other work.

Board of Water Supply
City of New York

Cement differs from Type II A.S.T.M. in that it requires somewhat closer chemical limits and more importantly that the clinker be uniformly well burned.

Alkalinity, free alkali and sugar solubility limitations. Sodium sulphate test.

Alkalies have been limited since 1937. The limit of titration value for free alkalies has kept the percentage of total alkalies, figured as Na_2O, below 0.54%.

Concrete after fourteen years shows every indication of durability, due mainly to the excellent cement obtained under the specifications for which hard burning of the clinker is claimed to have been greatly responsible.

U. S. Bureau of Reclamation

Bureau specifications require air-entrainment for all work except minor construction. It is required that the agent be added to the mix at the job site.

Limitation on alkali content is specified only when aggregate is reactive. Even then low-alkali cement may not be specified if pozzolan is to be used.

Bureau strongly favors use of pozzolans and prefers a blended Portland-pozzolan cement.

U. S. Engineers (Department of the Army)

Type II cement in concrete in major portion of civil works program. Federal Specifications SS-C-192.

The use of air-entraining agent is required in practically all concrete structures built by the Corps of Engineers.

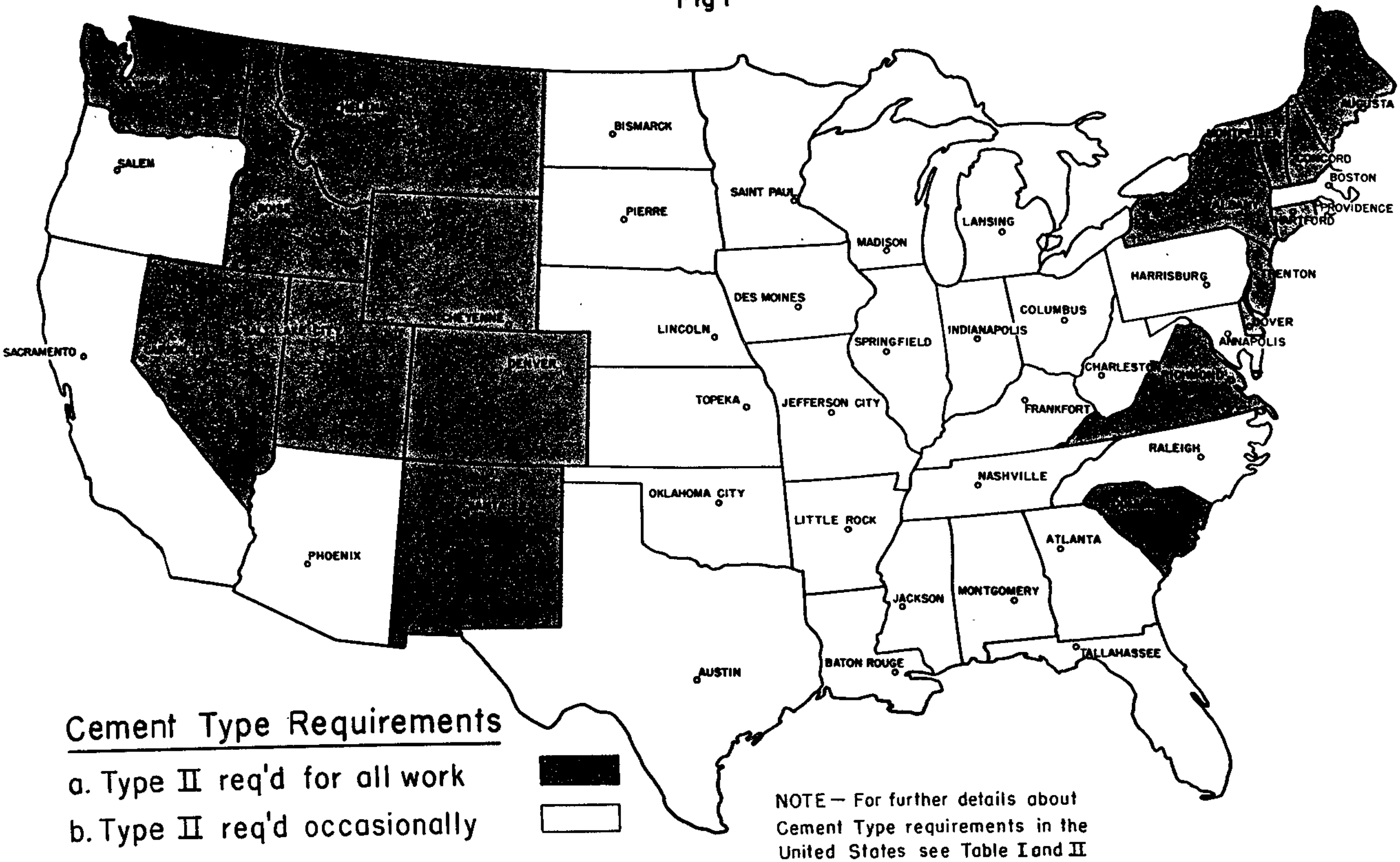
The Corps of Engineers has initiated a comprehensive investigation of the effects of various cements, blends of cements and pozzolans on the quality of concrete. Has used a blend of natural and portland cement in five large dams. It has used a blend of portland and slag cements in the construction of one dam.

It is contemplating changes in present specifications. No changes will be initiated, however, until the effects of the special cements, blends and pozzolans on the qualities of the concrete are known.

Byram Steele of the Office of the Chief of Engineers states that in his opinion "present day cements as used in general construction such as municipal work, warehouses and all types of building construction, not subjected to the severe weathering experienced by hydraulic structures in nearly all climates, are adequate" but that this opinion does not apply to cements for use in hydraulic structures where imperviousness is a primary factor. He further comments that in his opinion "impermeability in concrete whether it is of the lean massive type used in dams or of the richer cement type used in the construction of intake towers in reservoirs and similar structures, is of far greater importance than any consideration of strength and hence, the permeability phase of the combination of cement and aggregate should receive first consideration and an answer to such problems as enter into this combination obtained, holding all other factors secondary".

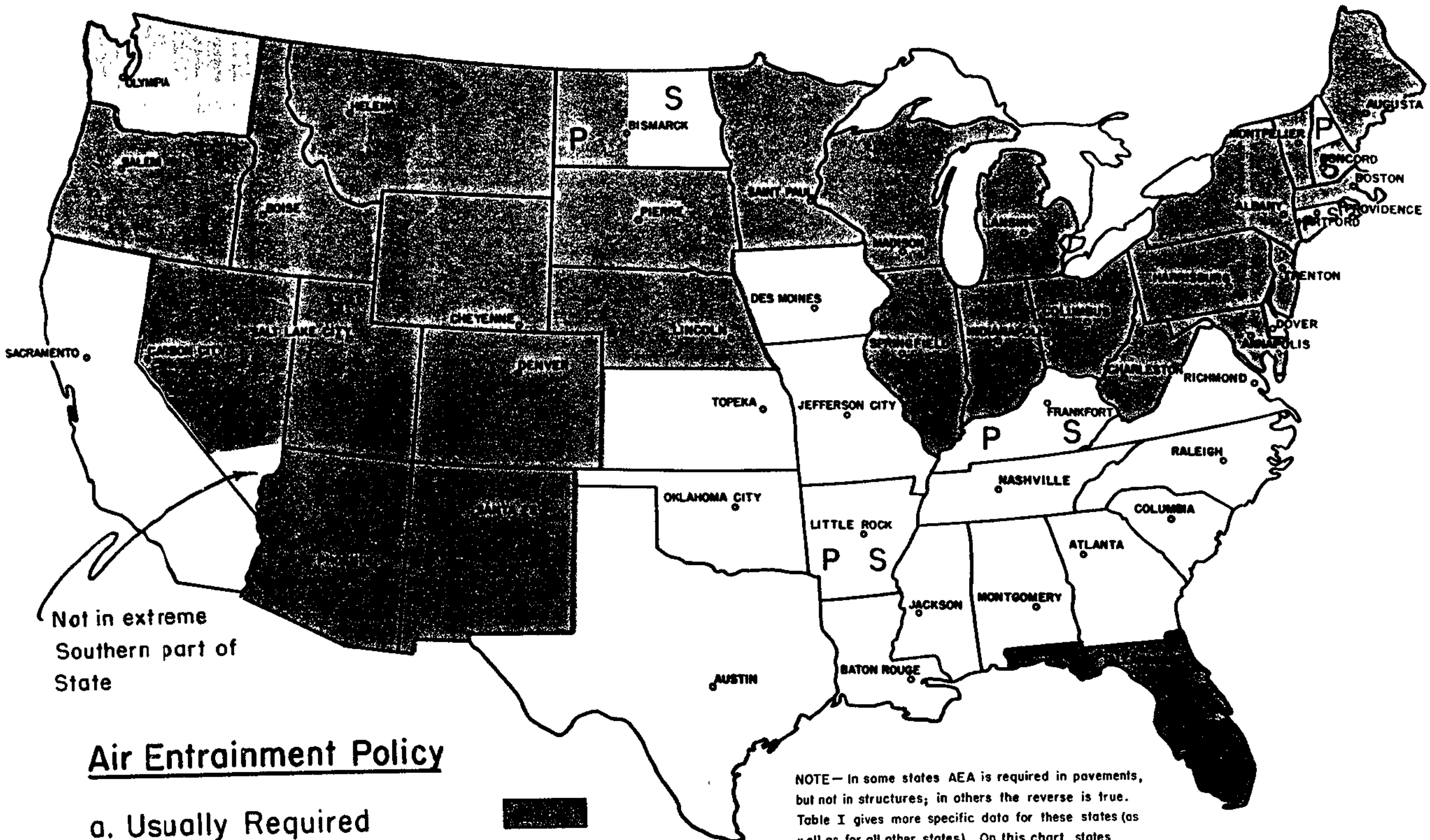
Steele then goes on to state "the present Federal Cement Specifications have five types of cement and yet they are entirely inadequate for the production of a satisfactory cement with which to produce impermeable concrete. Whether such a cement would be a factory produced Portland pozzolanic blend or whether it would be some modification of the present Federal Specifications with provisions for use of pozzolanic admixtures of certain types under certain conditions, is a question for further study."

Fig I



NOTE — For further details about Cement Type requirements in the United States see Table I and II

Fig 2



Air Entrainment Policy

a. Usually Required

b. Usually Not Required

NOTE— In some states AEA is required in pavements, but not in structures; in others the reverse is true. Table I gives more specific data for these states (as well as for all other states). On this chart, states having split requirements are only partially colored, the letter "P" meaning pavements, and "S" meaning structures. For example in North Dakota AEA is required for all pavements, but is not required for structures.

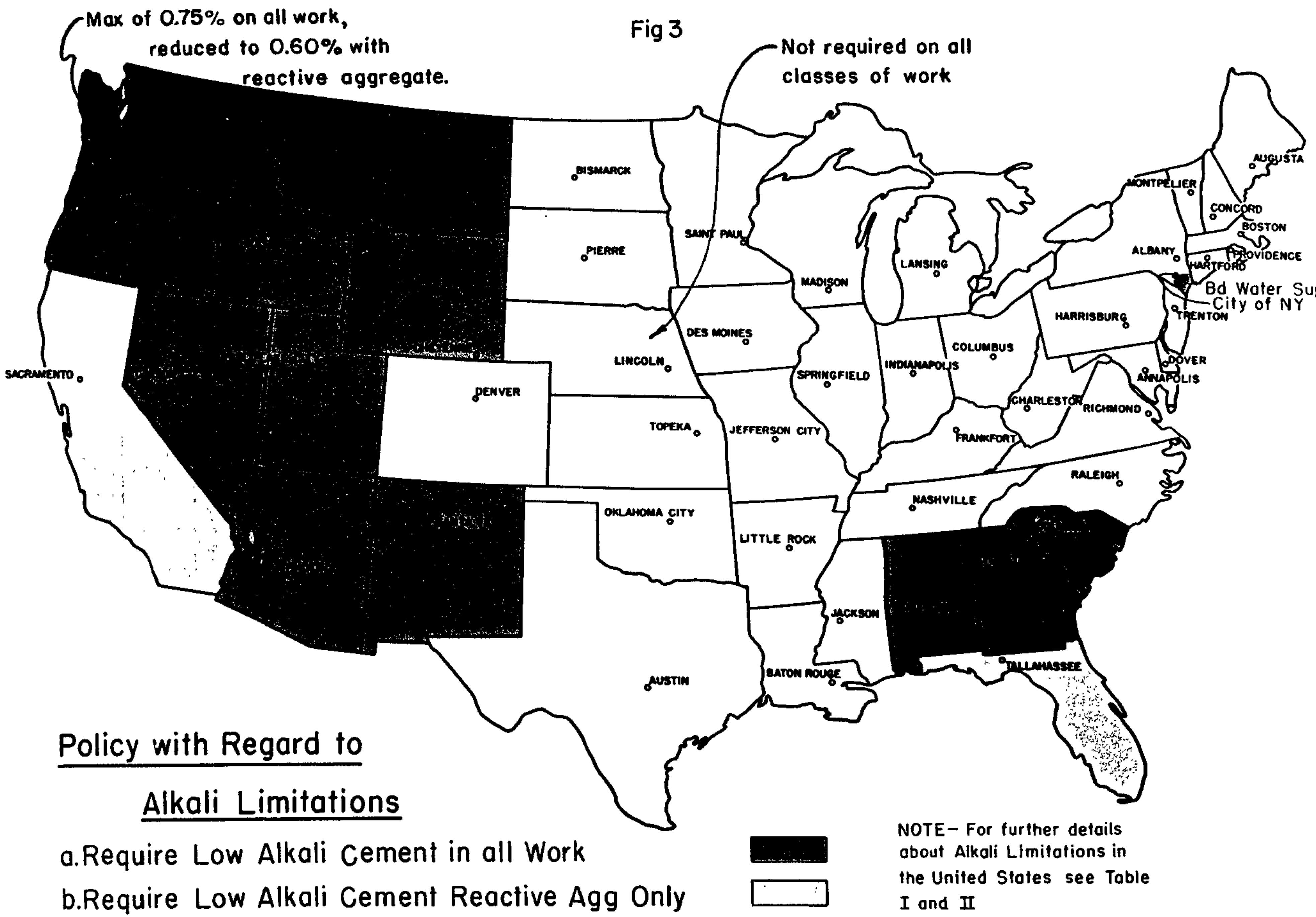

Max of 0.75% on all work, reduced to 0.60% with reactive aggregate.
Not required on all classes of work
AUGUSTA
MONTPELIER
CONCORD
BOSTON
ALBANY
HARTFORD
PROVIDENCE
Bd Water Sup City of NY
TRENTON
HARRISBURG
DOVER
ANNAPOLIS
RICHMOND
CHARLESTON
COLUMBUS
LANSING
MADISON
SAINT PAUL
BISMARCK
PIERRE
DES MOINES
LINCOLN
SPRINGFIELD
INDIANAPOLIS
FRANKFORT
RALEIGH
NASHVILLE
JEFFERSON CITY
TOPEKA
DENVER
SACRAMENTO
OKLAHOMA CITY
LITTLE ROCK
JACKSON
TALLAHASSEE
BATON ROUGE
AUSTIN
Policy with Regard to Alkali Limitations
a. Require Low Alkali Cement in all Work
b. Require Low Alkali Cement Reactive Agg Only
NOTE— For further details about Alkali Limitations in the United States see Table I and II

Fig 3