USE OF FLY ASH IN CONCRETE BY STATE TRANSPORTATION AND HIGHWAY DEPARTMENTS

by

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(The opinions, findings, and conclusions expressed in this report are those of the author and not necessarily those of the sponsoring agencies.)

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SUMMARY

This report provides a summary of replies to a questionnaire on the use of fly ash and blended cement (Type IP) in concrete. The questionnaire was directed to members of the Subcommittee on Materials of the American Association of State Highway Officials. The states' representatives on this subcommittee are usually the state materials engineers. The subcommittee also includes associate members from some of the provinces of Canada and some federal agencies involved in roadway or airport construction.

Fifty-nine agencies responded to the questionnaire. These included all of the state highway and transportation departments, the District of Columbia, three provinces of Canada, and five federal agencies.

Twenty-four agencies reported that they made no use of either fly ash added to the concrete as an admixture (FAC) or of concrete made with Type IP blended cement (IPC). The remaining 35 agencies permitted the use of either IPC or FAC, or both, usually at the option of the contractor. However, only 4 states had placed more than 100 lane-miles of FAC, and only two states had placed more than 100 lane-miles of IPC.

This lack of large usage of FAC or IPC is believed to reflect a lack of significant economic incentives for use by a state or contractor under present circumstances. The initial capital investment for the required separate silos or storage bins for fly ash deters a small contractor from using FAC, as does the increased quality control testing. IPC is not attractive since the blended cement (Type IP) usually costs the same as regular portland cement. Accordingly, the more familiar product (regular portland cement) is selected for use when both types are available.

The states making substantial use of either FAC or IPC all report satisfactory performance. The primary control problem reported is that of assuring the proper amount of entrained air. When fly ash is used, more air-entraining agent is required to entrain the desired amount of air than is required for similar concrete without fly ash.

Prior approval of the source of the fly ash is required by almost all agencies. The specification most often cited by all agencies is ASTM Specification C618 — Class F (fly ash). However, in all cases the loss on ignition is limited to a maximum of 6.0% in lieu of the 12.0% limit given in C618. Some state specifications also differ from C618 in the limitations on chemical composition but it is likely that all materials being used would meet C618 requirements, except where fly ash high in calcium oxide is encountered.

USE OF FLY ASH IN CONCRETE BY STATE TRANSPORTATION AND HIGHWAY DEPARTMENTS

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This report summarizes the replies to a questionnaire concerning the use of fly ash concrete sent to members of the Subcommittee on Materials of the American Association of State Highway and Transportation Officials (AASHTO). The membership of this subcommittee includes representatives of the highway or transportation departments of all the states and the District of Columbia. Represented by associate members are several provinces of Canada, Guam, Puerto Rico, and three federal agencies (the Federal Highway Administration [FHWA], Forest Service [FS], and Federal Aviation Administration [FAA]). Replies to the questionnaire were received from all state agencies, the District of Columbia, the FS, FAA, each of three units of the FHWA involved in direct construction, and the provinces of New Brunswick, Nova Scotia, and Ontario in Canada.

Of the 59 agencies responding, 24 reported that they made no use of either fly ash in concrete or blended cements for any purpose. These included 19 state agencies, the District of Columbia, the provinces of New Brunswick and Ontario, the FS, and Region 8 of the FHWA. Some of these cited the nonavailability of either fly ash or blended cement as the reason for not using them. The remaining 35 agencies permit either blended cements or fly ash as an admixture for some applications. However, a number of these have not made any appreciable use of the material.

Table 1 is a summary of the replies by each agency with respect to the extent of usage and any pertinent comments made. Some reported highway mileage as lane-miles and others listed only mileage. Some also indicated interstate mileage. The number of lane miles shown in the table is two times the mileage given when only mileage was stated and four times the mileage given when interstate use was indicated. N. P. indicates "not permitted" when the response to a question was no. A zero indicates all cases in which the contractor has the option to use fly ash or IP cement but no projects have been built. Except as noted, when the use of fly ash or IP cement is permitted, the use is at the option of the contractor. However, agency approval is usually required before the work is done. When these materials are used, the agencies have special provisions in their specifications that apply to such use.

Table 1

Use of Fly Ash in Concrete by Various Transportation Departments

Agency	Fly Ash Concrete			IP Cement Concrete		
	Amounts used in:		Special Conditions & Comments	Amounts used in:		Special Conditions and Comments
	Pavements, lane-miles	Structures, yd.^{3}		Pavements, lane-miles	Structures, yd.^{3}	
Alabama	1,200	>1,000	Use required in pavements	0	1,000	
Alaska	N. P.	N. P.		N. P.	N. P.	
Arizona	0	30		0	>1,000	
Arkansas	N. P.	N. P.		N. P.	N. P.	Permitted in stabilized bases.
California	36	>1,000		0	< 10	Used in one structure.
Colorado	2	500,000	Used in tunnels	0	0	
Connecticut	N. P.	N. P.		N. P.	N. P.	
Delaware	N. P.	N. P.		N. P.	N. P.	
Dist. of Columbia	N. P.	N. P.		N. P.	N. P.	
Florida	0	0		200	0	
Georgia	340	>1,000		10	0	
Hawaii	N. P.	N. P.		N. P.	N. P.	
Idaho	N. P.	N. P.		N. P.	N. P.	
Illinois	N. P.	N. P.		30	0	N. P. Oct. 15 - Apr. 1
Indiana	N. P.	N. P.		N. P.	N. P.	Would consider experimental use at contractor request.
Iowa	12	N. P.	All projects research	N. P.	N. P.	
Kansas	N. P.	N. P.		N. P.	N. P.	
Kentucky	N. P.	N. P.		N. P.	N. P.	
Louisiana	N. P.	N. P.		N. P.	0	Minor structures and precast items. No wearing surfaces.
Maine	N. P.	N. P.		N. P.	N. P.	
Maryland	N. P.	0	Permitted for small incidental structures	N. P.	N. P.	
Massachusetts	N. P.	N. P.	No fly ash available at present	N. P.	N. P.	
Michigan	20	200	N. P. October 15 - April 1.	--	< 10	Cement used in 10% mileage last 4 yrs. N. P. Oct. 15 - Apr. 1.
Minnesota	300	>1,000	N. P. in bridge decks. N. P. in winter.	40	>1,000	
Mississippi	0	0	Experimental pavement — pipe culverts only	0	100	Pipe & box culverts — no bridges.
Missouri	N. P.	N. P.		N. P.	0	Approved for pipe.
Montana	N. P.	N. P.		N. P.	N. P.	
Nebraska	45	N. P.	F. A. required with high alkali cement.	N. P.	N. P.	
Nevada	N. P.	N. P.		N. P.	--	Can use in sidewalks, curbs, etc. Project-by-project approval. Amount used in structures not given.
New Hampshire	N. P.	N. P.		N. P.	N. P.	
New Jersey	N. P.	N. P.		N. P.	N. P.	
New Mexico	20	0		0	0	
New York	N. P.	N. P.		N. P.	N. P.	
North Carolina	N. P.	N. P.		N. P.	N. P.	
North Dakota	250	N. P.	N. P. after September 15.	0	N. P.	

Ohio	0	N. P.	Conc. base only. N. P. Oct. 1 - Apr. 1.	25	N. P.	
Oklahoma	N. P.	N. P.		N. P.	N. P.	
Oregon	N. P.	90,000	N. P. in bridge decks or where 4,000 psi strength in 28 days specified.	N. P.	N. P.	
Pennsylvania	0	N. P.	Recent specification change	N. P.	N. P.	
Rhode Island	N. P.	N. P.		N. P.	N. P.	
South Carolina	N. P.	N. P.		8	2,000	
South Dakota	80	N. P.		N. P.	N. P.	
Tennessee	N. P.	N. P.		N. P.	N. P.	Permitted in aggregate-cement bases.
Texas	N. P.	N. P.		N. P.	N. P.	
Utah	20	N. P.		N. P.	N. P.	
Vermont	N. P.	N. P.		N. P.	N. P.	
Virginia	N. P.	N. P.	Some experimental projects — curbs, etc.	0	0	
Washington	N. P.	N. P.		N. P.	N. P.	
West Virginia	40	N. P.		0	0	
Wisconsin	32	N. P.		N. P.	N. P.	
Wyoming	N. P.	N. P.		N. P.	N. P.	Permitted in cement treated bases.
Canada						
New Brunswick	N. P.	N. P.	Fly ash not available — will investigate potential	N. P.	N. P.	
Ontario	N. P.	N. P.		N. P.	N. P.	
Nova Scotia	0	0		0	0	
Forest Service	N. P.	N. P.		N. P.	N. P.	
FAA	0	0	Some use in runways permitted — no report on amount	0	0	Some use in runways permitted — no report on amount.
FHWA						
Region 8	N. P.	N. P.		N. P.	N. P.	
Region 10	0	0	Potential for use — being considered	0	0	
Region 15	N. P.	N. P.		0	0	Standard specifications permit use when approved in contract.

NOTE: N. P. indicates use not permitted in present specifications. A zero entry indicates use permitted but no projects built.

Table 2 provides a summary of the number of state agencies (including the District of Columbia) permitting the use of fly ash for the several purposes listed and the extent to which the material has been used. For convenience, the term "fly ash concrete" (FAC) is used when referring to concrete to which the fly ash has been added as a separate ingredient at the mixer. The term "IP concrete" (IPC) is used for concrete prepared with Type IP blended cement where the pozzolan is fly ash.

Judging from the comments made in reply to the questionnaire and the extent of use in various states, it is evident that the options of using fly ash as an admixture (separate ingredient) or of using blended cements are often not being exercised by the contractor unless there is a shortage of portland cement. The need for additional capital expenditures for fly ash storage and handling, along with additional control problems, often negates the economic value of using FAC, even though the fly ash itself is considerably cheaper than the portland cement that it replaces. Blended cements can be utilized much like regular portland cements, but they often are not available and they usually cost the same as portland cements. Consequently, there is little or no economic incentive for using IPC when both types of cement are available.

There are, however, some special situations which make it desirable to utilize the special properties of concrete containing fly ash. There are also come circumstances under which fly ash concrete can be economical.

Alabama has used fly ash in its concrete since the 1950's. The state's present specifications require the use of 12 pounds of fly ash per bag of the Type I or Type II cements in their pavement concrete, or the use of Type IP blended cement having fly ash as the pozzolan. The principal reason for use in Alabama is to provide some protection against potentially reactive aggregates. The requirement is also considered to provide additional protection against sulfate damage where the concrete is exposed to seawater.

Nebraska reported recent changes in their specifications that will require the use of FAC where potentially reactive aggregates may be used. Nebraska's use is designed to counteract any potential effects of increasing the permissible alkalies in the state's cement specifications from 0.6% to 0.7% (equivalent Na_2O).

Minnesota has recently made considerable use of FAC to extend the available supply of cement. In this case, the use of fly ash has proved to be economical. Minnesota's procedure is to pretest fly ash as it fills a silo, and the silo is then reserved for state use exclusively. The fly ash being used in Minnesota contains about 13% to 14% CaO and is derived from western coals. Its loss on ignition is around 1%.

Table 2

Extent of Use of Fly Ash in Concrete by Highway or Transportation Departments of 50 States and D. C.

Type of Use	Extent of Use	Number of States
Pavements — fly ash as admixture	Lane-miles in place	
	<10	6
	10-100	9
	>100	4
Total permitting use		19
Total not permitting use		32
Blended cements	<10	11
	10-100	3
	>100	2
Total permitting use		16
Total not permitting use		35
Structures — fly ash as admixture	Cubic yards used	
	<10	4
	10-1000	2
	>1000	6
Total permitting use		12
Total not permitting use		39
Blended cements	<10	11
	10-1000	2
	>1000	4
Total permitting use		17
Total not permitting use		34

There is considerable emphasis at the federal governmental level on the use of fly ash concrete in all applications as well as in highway pavements and structures. The Resources Conservation and Recovery Act was passed by Congress to conserve natural resources and to utilize to the extent possible waste materials and by-products. As a part of its functions under the act, the Environmental Protection Agency (EPA) has issued a proposed set of guidelines for the procurement of concrete containing fly ash in all projects supported by the federal government. If these had been adopted as first written, states receiving federal aid for highway construction would have been required to use fly ash in their concrete, unless fly ash were not available or the cost of the FAC should exceed that of regular concrete. Also, an exception would have been made if it could have been shown that the FAC was not technologically adequate for the purpose intended. Although the EPA has apparently dropped, for the time being, the idea of mandatory use by agencies using federal funds, there remains considerable pressure to increase the use of fly ash in all concrete. Its utilization tends to conserve resources and energy and also avoids environmental problems that could arise from accumulations of the huge volumes of coal ash generated each year.

A narrative summary of the replies and comments by individual states is given in the Appendix.

APPENDIX

SUMMARY OF COMMENTS FROM STATES

Alabama

Long recognized as the state using most fly ash in concrete for pavements and structures.

Has used FAC since 1954. Over 300 miles (probably 1,200 lane miles) constructed.

No problems with scaling or durability.

Reports some problems obtaining proper amount of entrained air when carbon (loss on ignition) content exceeds 4%. Can be corrected by using more air entraining agent.

Fly ashes in use generally run 2-1/2% to 3-1/2% loss on ignition. Specification permits maximum of 6%.

Uses own state specification — materials probably would meet C-618. Has a requirement that pH cannot be greater than 7.0. No reason for requirement could be determined.

State approves source of fly ash. At present, three sources approved. Contractors must buy from approved source.

Specifications for pavement concrete require 12 lb. fly ash per sack of cement in FAC or use of IPC with Class F fly ash as pozzolan.

Contractors have not generally exercised option of using IP cement in pavements but some use made in structures.

Alaska

Use not permitted. Fly ash is not available in Alaska.

Arizona

Permits use on selected projects, either as FAC or IPC. Contractors have opted to use IPC to date. Consequently, no FAC has been placed.

Most use has been made in minor cast-in-place pipe, minor precast structures such as cattle guards, catch basins, median barriers, wingwalls, and other small, miscellaneous, non-prestressed concrete members.

When Type IP cement is used to replace Type III, an additional 1/2 sack of IP cement per cubic yard of concrete is required. Use is confined to items not under traffic loading.

IP cement accepted on same basis as portland cement. Certification and weekly samples at plant.

For FAC, maximum allowable replacement is 15% of cement. Replacement of fly ash at ratio of 1.2 lb. fly ash for 1 lb. cement removed.

Fly ash must conform to C-618, except pozzolanic activity index with lime is 650 psi minimum at 7 days. Total alkali content of cement and pozzolan after combined in proportions used shall not exceed 0.60% calculated as Na_2O. Requires certification of compliance.

Arkansas

Permits IP cement in cement-stabilized base, but little used. Not permitted in other applications.

California

Permits replacements up to 15% of cement in FAC. In paving, fly ash is weighed in separate weigh hopper and introduced simultaneously with cement into mixer proportionally with the aggregate. Fly ash and IP cement not permitted in cement-stabilized bases.

Colorado

FAC permitted in highways and structures, but no IP cement is available to state; consequently, it is not now permitted. Very large quantities of fly ash used in Eisenhower Tunnel and Johnson Bore as pumping aid.

Experience with ready mixed FAC limited — three suppliers and one source of fly ash. Have had problems with rapid slump loss and retarded final set — attributed to sodium carbonate added at power plant to control emissions.

Connecticut

Use not permitted. Costs to contractor would be increased.

Delaware

Use not permitted. Most concrete plants in state not interested. Quality of fly ash is concern.

District of Columbia

Use not permitted. Concerned with problems of control of fly ash concrete.

Florida

Permits fly ash as an admixture to replace not more than 10% by weight of cement in pavements. Twenty-percent replacement permitted for culverts, etc. However, no usage in pavements has occurred. IPC has been used in about 200 lane miles.

Georgia

Permits fly ash to replace 7% of cement by weight for pavements and 8% by weight for superstructures. Fly ash is added at rate of 1-1/2 to 2 lb. per 1 lb. of cement replaced. Approximately 85 miles of interstate (340 lane miles) have been built with FAC.

Reports some difficulty in controlling air content of FAC, but no difference in performance as compared to that of regular concrete has been noted.

Uses C-618 as basic specification but requirements are modified (more restrictive). Fly ash must be on approved list. One test a month made from each source. Ignition loss and fineness tested for each 10,000 tons per random spot checks.

Hawaii

Use not permitted. No interest.

Idaho

Use not permitted. In-house trials did not indicate benefits.

Indiana

Use not permitted. Interested in IPC. This approach would avoid problems associated with local sources of fly ash.

Iowa

Permits FAC in pavements but not in structures. Does not use IPC. To date all projects have been research. About 20 miles of new projects are scheduled for 1980 construction season.

Reported no difficulty in controlling air entrainment, but indicated slightly more air entraining agent was required.

Specification C-618 used with additional limitations. Loss on ignition is 5% maximum.

Approval of source required. Utility must use single source of coal. Fly ash from plants using limestone injection to control stack gases is not acceptable. Acceptance is on lot basis after completion of tests prior to use. Pressure meter used for measuring air content.

Kansas

Use not permitted. Currently studying durability of FAC.

Kentucky

Use not permitted. Experimental projects (1965-69) still good. Has permitted use of IPC on a few paving projects.

Illinois

FAC not permitted. IPC permitted at option of contractor. About 30 miles of pavement built with IPC but no structures. Reported difficulty in controlling air in placement as well as performance different from that of regular concretes. However, no elaboration was given. Does not use IPC between October 15 and April 1.

Louisiana

FAC not permitted. Recently changed specifications to permit IPC in minor structures, cast-in-place concrete, and prestressed or precast structural elements except wearing surfaces on bridge decks. IPC not now permitted in wearing surfaces in pavements but has 4-mile experimental section under test. Makes tests on all shipments of IP cement.

Maine

Use not permitted. Fly ash not now available. Power company may switch to coal.

Maryland

Use of FAC very limited. Use in pavements primarily as aid in placement of harsh mixes at request of contractor. No reduction in cement content. Specifications recently changed to permit use on incidental structures. In this case maximum substitution is 15% of weight of cement. Fly ash required to meet C-618, Class "F" with exceptions: pH - 7.0 min., loss on ignition 6%, moisture 1%.

Massachusetts

Use not permitted.

Michigan

Permits use of both FAC and IPC, except between October 15 and April 1. Estimates that 10% mileage placed in last 4 years used IP cement (from one producer); only one experimental project has used FAC to date. FAC in structures not permitted prior to 1979. Has 4% maximum limit on loss on ignition. This generally eliminates problems with controlling air entrainment. C-618, Class F specified with additional restrictions for loss on ignition and lower amount retained on No. 325 sieve. Fly ash accepted on certification with occasional check tests.

Air content in pavement concrete checked every two hours. Air content for structures tested at rate of one every hour or every third truck, whichever comes first.

State does not expect fly ash to be used extensively as an admixture by paving contractors and small ready-mix suppliers because of cost of separate bins. Further use of Type IP cement is restricted by its limited availability.

Minnesota

Either FAC or IPC can be used. State is largest northern user of FAC in pavements and structures. Used in about 300 miles of pavement. Also used in 40 structures (20,000 cu. yd.). IPC used in about 40 miles of pavements. IPC also used in 15 structures (5,000 cu. yd.).

Reports no trouble in controlling air but uses higher dosage of air entraining agent. Easier finishing for FAC.

Fly ash being used is from western coal and has 13% to 15% CaO — considerably higher than fly ash from eastern coals. Also has a very low loss on ignition — usually around 1%.

State tests materials when a silo is being filled and seals silo after approval. Contractors must then use fly ash from this silo.

Minnesota specifications have significantly different chemical requirements from C-618 but pozzolanic activity index at 28 days with portland cement is same. C-618, Class F is cited for general description.

FAC not permitted in bridge decks and other bridge superstructures (this restriction may be removed). Requires approval of specific air entraining agent to be used.

Has restrictions on use in cold weather. In that part of state north of the 46th parallel, no FAC is permitted after September 15, if pavement is to be used in same year. No FAC is used after October 1, regardless of date of opening to traffic. In that part of state south of the 46th parallel, cutoff date is October 1 for same year use and October 15 for any opening date.

Mississippi

Recently has approved use of FAC or IPC on one concrete overlay project. Either FAC or IPC may also be used in concrete pipe and box culverts. Not permitted for bridges. Air entrainment is not required in Mississippi. Fly ash specification cites ASTM C-618, except loss is 6% instead of 12%.

Missouri

Does not permit the use of FAC. As of 1979 permits IPC in items not exposed to deicing salts. Believes uniformity of fly ash to be inadequate within a source and from source to source. IPC not used in pavements or bridge structures because of aging needed before the concrete is exposed to deicing chemicals.

Montana

Use not permitted.

Nebraska

A March 1980 change in policy established the requirement to use FAC in pavements where alkalies in cement are between 0.65% and 0.70%; 0.70% is the maximum permitted. One hundred pounds of fly ash replaces an equal volume of aggregate while maintaining same percentage relationship between coarse and fine aggregate. FAC is not used in structures.

Class F, ASTM C-618 specification cited, except loss on ignition is limited to maximum of 6%. Free carbon limit is 3%. Fly ash produced in furnaces utilizing liming materials are not acceptable. Certified test data showing compliance to specifications must be submitted.

Current source of fly ash contains practically no free carbon and no problems have been experienced with control of entrained air.

No use is made of blended cements.

Nevada

Has made no use of FAC and permits use of IPC for sidewalks, curb and gutters, etc. Requires approval on project-by-project basis.

New Hampshire

Use not permitted. No good present source of fly ash or IP cement.

New Jersey

Use not permitted.

New Mexico

Permits FAC with concurrence of both contractor and state. Used only in pavements to date. Reports some problems with air entrainment but gives no detail. Better workability reported for FAC. FAC not in service long enough to judge performance. Cites ASTM C-618, Class F, except loss on ignition limited to 6%.

New York

Use not permitted in highways and structures. Has used FAC in dams and grouting. Possibility of experimental project in 1981 season.

North Carolina

Use not permitted.

North Dakota

Permits use of FAC and IPC in pavements but not in structures. About 125 miles in place. No problems with air entrainment. Expects performance of FAC to be better than that of regular concrete. Use not permitted after September 15.

Fly ash specifications recognize two Classes: F1 — that which results from burning anthracite or bituminous coal, and F2 — that which results from burning subbituminous and lignite coals.

Fly ash must be certified. Test data by commercial testing laboratory supplied by contractor. Engineer reserves right to sample and test (by state). In such cases results of engineer's sample governs acceptance.

Ohio

Allows use of FAC only in concrete base. Allows IPC in pavements only. Both may be used only between April 1 and October 1. To date IPC has not been used.

IP cement used must meet ASTM C-595, except fly ash shall not exceed 20% by weight. Loss on ignition of fly ash must not exceed 6%.

Fly ash must meet ASTM C-618, Class F, except loss on ignition shall not exceed 6%.

Reports no problems in performance nor with air entrainment.

Oklahoma

Use not permitted.

Oregon

Permits use of FAC in structures only. Does not use IPC. Not used if design strength exceeds 4,000 psi in 28 days. Not used in concrete deck wearing surfaces.

FAC easier to pump. No difference in performance observed. Specification cited is ASTM C-618, Class F.

Pennsylvania

Permits use of FAC in pavements but not structures. IPC permitted in both, but as of yet no projects have been built. Cites ASTM Specification C-618, Class F, except loss on ignition shall be 6%. Fly ash must be from approved source.

Rhode Island

Use not permitted.

South Carolina

Permits use of IPC only. Some use in both pavements and structures.

Reports difficulty in controlling air content — variations of as much as 150% of the amount of agent are used to get the required air content.

South Dakota

Permits use of FAC only in pavements. No IPC used. Indicates no difficulty in controlling air entrainment. Specifications cite ASTM C-618, Class F, but composition requirements differ. Permit $SiO_2 + Al_2O_3 + Fe_2O_3$ to be minimum of 45%. SO_3 maximum is 12% and CaO maximum is 35%. Loss on ignition limited to 5%. Must be from approved source.

Tennessee

Use not permitted in concrete. Some use of IP cement in aggregate-cement base.

Texas

Use not permitted. Some experimental installations of FAC.

Utah

Has used FAC on only one project.

Is considering specification that would limit the use of fly ash to projects involving reactive aggregate.

Reports some difficulty in controlling air entrainment. Also reports difficulty in maintaining a consistent slump. Believe FAC may be less durable, but project has not been in place long enough to allow evaluation. Harshness noted in finishing FAC.

Source of fly ash must be approved. Fly ash sampled from truck when delivered. Sieve analysis and carbon determined on each load. Further analyses on each 400 tons ASTM Specification C-618, Class F used.

Vermont

Use not permitted. IP cement may become available.

Virginia

Does not permit regular use of FAC but has built some experimental projects with curbs, gutters, etc. Will permit IPC in some structures, but not in pavements or on bridge decks. Very little used to date.

Reports increased scaling for FAC used in curbs and gutters on project. All of concrete in this project was sound after 25 years' use. Some failure of FAC observed in another project where air entrainment was deficient. ASTM Specification C-618, Class F with modifications used in special provision for experimental project. Loss on ignition 6%; separate requirement for minimum SiO_2 and Al_2O_3.

Washington

Use not permitted. Plans in-house research with locally available fly ash.

West Virginia

Permits use of FAC in pavements but not structures. Fly ash can be substituted by volume for portland cement up to an amount equal to 1 bag of cement per cubic yard. IPC permitted in both pavements and structures, but none has been used to date. Fly ash must meet ASTM C-618, Class F, except that maximum loss on ignition is 6%.

Wisconsin

Permits use of FAC in pavements only. IPC not permitted. Reports no difficulties in controlling air entrainment and placement; notes slower strength gain of FAC. Fly ash must conform to ASTM C-618 Class F, except loss on ignition is limited to a maximum of 5%.

Fly ash must be prequalified. Manufacturer of fly ash or his agent must submit results of tests made by independent laboratory showing fly ash is in compliance with specification. Engineer has option of sampling and testing.

FAC cannot be placed after September 15. Limits opening of FAC pavements to traffic based on ambient temperature. When temperature is 70°F or higher, limit is 7 days for vehicles weighing 6,000 lb. or less and 10 days for vehicles with weights up to legal limit. When temperatures are generally not less than 60°F, limits are 10 and 14 days, respectively. If the temperatures are generally lower than 60°F, engineer sets limits up to 21 days.

Wyoming

Use not permitted in concrete. Has 20 miles of cement-treated base with 15% cement replaced with fly ash.

Provinces of Canada

New Brunswick: Fly ash not available. Starting to investigate.

Nova Scotia : Use permitted, but no projects reported. Cites Specification CSA CAN3-A266.3-M78.

Ontario : Use not permitted. Fly ash locally produced not considered suitable for use in concrete; carbon too variable.

Federal Agencies

Forest Service: Use not permitted

FAA : Use permitted in runways, but no information available on extent of use.

FHWA : (Direct Construction Units)

Region 8 — Use not permitted

Region 10 — Use permitted, but no construction reported. Is reviewing possible use and impact.

Region 15 — FAC not permitted. Would permit blended cements when specifically approved in contract.