ENGINEERING AND ENVIRONMENTAL SPECIFICATIONS OF STATE AGENCIES FOR UTILIZATION AND DISPOSAL OF COAL COMBUSTION PRODUCTS: VOLUME 1 – DOT SPECIFICATIONS

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ABSTRACT

The objective of this report is twofold. The first is to present a state-by-state comparison of U.S. Department of Transportation (DOT) specifications governing the use of coal combustion products. Because of a lack of resources, namely, time and funding, most transportation and materials engineers cannot fully research all of the current technologies of coal ash utilization. This compilation allows these professionals to become familiar with other department practices and to identify areas where specifications need to be developed within their own transportation offices. Engineering practices are slow to change for many reasons. To facilitate changes, a systematic approach must be taken. The results from this effort will help familiarize DOT engineers and officials with coal ash use applications and will help the coal ash industry develop a plan to work with these departments and individuals in expanding their knowledge and familiarity while expanding coal ash markets.

The second goal is to establish a comparison of state environmental laws and regulations as they pertain to utilization and/or disposal. As a result of the interpretation of the Bevill Amendment, utilization and disposal are not regulated at the federal level. These issues have been left to the states. Many states have enacted laws, adopted regulations, or both governing the utilization and disposal of coal combustion by-products. These laws and regulations vary widely. Thus a particular utilization authorized in one state may not be authorized in the adjoining state.

TABLE OF CONTENTS

INTRODUCTION 1

EXECUTIVE SUMMARY 1

EXPERIMENTAL 2

RESULTS AND DISCUSSION 3

STATE COAL ASH SPECIFICATIONS AND GUIDELINES 7
- Alabama 7
- Alaska 8
- Arizona 8
- Arkansas 9
- California 10
- Colorado 11
- Connecticut 13
- Delaware 13

FEDERAL LANDS HIGHWAYS 13
- Florida 14
- Georgia 17
- Hawaii 18
- Idaho 18
- Illinois 19
- Indiana 20
- Iowa 22
- Kansas 23
- Kentucky 23
- Louisiana 24
- Maine 25
- Maryland 25
- Massachusetts 26
- Michigan 27
- Minnesota 28
- Mississippi 29
- Missouri 29
- Montana 30
- Nebraska 31
- Nevada 36
- New Hampshire 36
- New Jersey 36

Continued . . .

TABLE OF CONTENTS (continued)

New Mexico 38
New York 39
North Carolina 40
North Dakota 41
Ohio 41
Oklahoma 41
Oregon 42
Pennsylvania 43
Rhode Island 44
South Carolina 44
South Dakota 45
Tennessee 46
Texas 47
Utah 47
Vermont 48
Virginia 49
Washington 49
West Virginia 49
Wisconsin 50
Wyoming 51
District of Columbia 51

CONCLUSION 52

PERSONAL CONTACTS 52

LIST OF TABLES

1 ASTM C618-03 Chemical and Physical Specifications 4

2 AASHTO M295-98 Chemical and Physical Specifications 5

3 State Department of Transportation Specifications 32

ENGINEERING AND ENVIRONMENTAL SPECIFICATIONS OF STATE AGENCIES FOR UTILIZATION AND DISPOSAL OF COAL COMBUSTION PRODUCTS: VOLUME 1 – DOT SPECIFICATIONS

INTRODUCTION

The efforts on this project were made possible by funding from the National Energy Technology Laboratory Combustion Byproducts Recycling Consortium (NETL CBRC) with industry support from the American Coal Ash Association (ACAA) and the Utility Solid Waste Activities Group (USWAG). Although the twofold objectives of this report are similar in presentation (state by state comparisons), the contents are very distinct from one another. For these reasons, this report will be presented in a two-volume series. This portion of the report, Volume 1, will present existing Department of Transportation engineering specifications as they pertain to the use of coal combustion products. Volume 2 details the environmental statutes and regulations for each state as they pertain to utilization, handling, and disposal of coal combustion products. Specifications for the utilization and disposal of coal combustion products are continuously being updated and modified to express the trends for a particular state. The results here are but a summary of current specifications at the present time of publication of this report.

EXECUTIVE SUMMARY

The objective of this report is to present a state-by-state comparison of U.S. Department of Transportation (DOT) specifications governing the use of coal combustion products. Because of a lack of resources, namely, time and funding, most transportation and materials engineers cannot fully research all of the current technologies of coal ash utilization. This compilation allows these professionals to become familiar with other department practices and to identify areas where specifications need to be developed within their own transportation offices. Engineering practices are slow to change for many reasons. To facilitate changes, a systematic approach must be taken. The results from this effort will help familiarize DOT engineers and officials with coal ash use applications and will help the coal ash industry develop a plan to work with these departments and individuals in expanding their knowledge and familiarity while expanding coal ash markets.

A survey letter was sent to all highway departmental offices in the United States and Canada in August of 1992 to look at the differences between state and provincial DOT specifications for coal by-product utilization. Since that time, numerous changes have occurred in these departments so it was decided an update was needed. An extensive survey was begun in 2004 to obtain specifications from all state DOT offices. All information was obtained through Internet searches and personal contacts within respective departments.

Although specifications and practices varied between states, several similarities were noted. The specifications used in all reported cases for fly ash were ASTM International (American Society for Testing and Materials) C618 and AASHTO (American Association of State Highway and Transportation Officials) M295. The title for both specifications is “Coal Fly

Ash and Raw or Calcined Natural Pozzolan for Use in Concrete." Under both classification systems, fly ash is defined as "a finely divided residue that results from the combustion of ground or powdered coal." In addition to concrete, numerous states have used fly ash as a mineral filler in asphaltic concrete and soil stabilization, with many more states beginning to use fly ash in flowable mortar applications.

Another material often cited for use as a cement supplement was Ground Granulated Blast Furnace Slag. At one time, slag was generally only used as a blasting grit, skid or traction applications, or as aggregate in asphaltic concrete. However, now many DOTs allow its use in the production of portland cement concrete. Most states included specifications for the allowable use of blended hydraulic cements. The specifications for these were ASTM C595 and AASHTO M240. The descriptions and definitions of these cements varied considerably.

The use of silica fume was often grouped into the same category as fly ash and ground granulated blast furnace slag as a mineral admixture in portland cement concrete. The specifications for silica fume are AASHTO M307 "Microsilica for Use in Concrete and Mortar" and ASTM C1240 "Use of Silica Fume as a Mineral Admixture in Hydraulic-Cement Concrete, Mortar, and Grout." Generally very small amounts of silica fume were specified for used in a concrete mix design. These specified amounts were usually from 3% to 10% of the total cementitious material.

EXPERIMENTAL

A survey letter was sent to all highway departmental offices in the United States and Canada in August of 1992 to look at the differences between state and provincial DOT specifications for coal by-product utilization. Since that time, numerous changes have occurred in these departments, so it was decided an update was needed. An extensive survey was begun in 2004 to obtain specifications from all state DOT offices. All information was obtained through Internet searches and personal contacts within respective departments. Specifications on the use of coal by-products in their construction procedures were requested. As was the case in 1992 there were three main specification criteria:

- Physical and chemical specifications for coal by-products
- Applications which utilize coal by-products and their corresponding specifications
- Quantities of by-products which may be allowed in each application

The first step was to evaluate existing specifications as they appeared on Internet Web sites. The most utilized Web site was http://fhwapap04.fhwa.dot.gov/nhswp/index.jsp, which is maintained by the U.S. Federal Highway Administration (FHWA). This site consists of a searchable library of highway specifications from across the country. This site also features discussion forums to enhance communication and interaction in the development and use of various types of construction specifications. The FHWA Web site is not necessarily complete with all specification updates so other DOT sites had to be utilized. Two of these other

Internet sources of DOT specifications were http://www.transdata.com/dots.htm and http://www.fhwa.dot.gov/webstate.htm. These sites established links directly to DOT offices. These DOT Web sites were often a good source of establishing personal contacts as well as checking specification updates. A summary was made for each state as to its existing specifications for utilization of coal by-products.

After a state summary was completed, an e-mail copy was sent to an appropriate representative from that state. The e-mail message was designed to accomplish two objectives. The first was to determine if there were any current specification updates that were not reflected on the available Web sites. The second was to establish a personal contact, with an e-mail address, within each transportation office. Today many industries rely on the Internet, and in some cases, an e-mail address is as important and useful as a telephone number.

The information obtained is presented in two forms. First, specific guidelines are given in a summarized text format. Second, the data are also presented in a series of tables allowing quick reference between states and comparison of their different specifications. This facilitates evaluation of similarities and experiences in coal ash utilization on a state-by-state basis. This information is intended to be used as a means of basic comparison and not to serve as a comprehensive design manual. In addition, a contact name with personal information is included in the appendix for each DOT office.

RESULTS AND DISCUSSION

Although specifications and practices varied between states, several similarities were noted. The specifications used in all reported cases for fly ash were ASTM International (American Society for Testing and Materials) C618 and American Association of State Highway and Transportation Officials (AASHTO) M295. The title for both specifications is “Coal Fly Ash and Raw or Calcined Natural Pozzolan for use in Concrete.” Under both classification systems, fly ash is defined as “a finely divided residue that results from the combustion of ground or powdered coal.” Likewise, pozzolans are defined as “siliceous or siliceous and alumininous materials which in themselves posses little or no cementitious value but will, in finely divided form and in the presence of moisture, chemically react with calcium hydroxide at ordinary temperatures to form compounds possessing cementitious properties.” These materials are then divided into three classifications: Class N, Class F, and Class C. Class N materials are raw or calcined natural pozzolans which may or may not be processed by calcination to induce satisfactory properties.

Class F fly ash is normally produced from burning anthracite or bituminous coal and has pozzolanic properties. Class C fly ash is normally produced from lignite or subbituminous coal. This last class of fly ash, in addition to having pozzolanic properties, also has some cementitious properties. Excerpts from the two classification systems, ASTM C618 and AASHTO M295, are given in Tables 1 and 2, respectively. The specification from AASHTO M295 is based on a previous ASTM C618 specification from 1996. Since that time, ASTM C618 has been updated to the more recent version portrayed in this report.

Table 1. ASTM C618-03 Chemical and Physical Specifications

	Mineral Admixture Class		
Chemical Requirements	N	F	C
Silicon Dioxide, Aluminum Oxide, Iron Oxide (SiO_2 + Al_2O_3 + Fe_2O_3), min., %	70.0	70.0	50.0
Sulfur Trioxide (SO_3), max., %	4.0	5.0	5.0
Moisture Content, max., %	3.0	3.0	3.0
Loss on Ignition, max., %	10.0	6.0[A]	6.0
[A] The use of Class F pozzolan containing up to 12.0% loss on ignition may be approved by the user if either acceptable performance records or laboratory test results are made available.			
Physical Requirements	N	F	C
Fineness: Amount Retained When Wet-Sieved on 45 µm (No. 325) sieve, max., %[A]	34	34	34
Strength Activity Index: [B] with Portland Cement at			
7 day, min. % of control	75[C]	75[C]	75[C]
28 day, min. % of control	75[C]	75[C]	75[C]
Soundness Water Requirement, max., percent of control	115	105	105
Autoclave Expansion or Contraction, max., %	0.8	0.8	0.8

[A] Care should be taken to avoid the retaining of agglomeration of extremely fine material.

[B] The strength activity index with portland cement is not to be considered a measure of the compressive strength of concrete containing the fly ash or natural pozzolan. The mass of fly ash or natural pozzolan specified for the test to determine the strength activity index with portland cement is not considered to be the proportion recommended for the concrete to be used in the work. Strength activity index with portland cement is a measure of reactivity with a given cement and may vary as to the source of both the fly ash or natural pozzolan and the cement.

[C] Meeting the 7- or 28-day strength activity index will indicate specification compliance.

[D] If the fly ash or natural pozzolan will constitute more than 20% by weight of the cementitious material in the project mix design, the test specimens for autoclave expansion shall contain that anticipated percentage.

Transportation departments will often change their specification from the indicated ASTM C618 and AASHTO M295 to reflect regional practices and preferences. One example of this is the requirement for loss on ignition (LOI). The lowest maximum level of LOI allowed by either specification is 5%. However, many states specified LOI values to be much lower. States such as Delaware, New York, North Carolina, Rhode Island, as well as the District of Columbia, indicated a maximum allowable LOI of 4%. Still others, such as Arizona, Hawaii, Indiana, Idaho, Illinois, Kentucky, Missouri, Minnesota, New Jersey, New Mexico, North Dakota, Oregon, Ohio, South Dakota, Utah, Washington, and Wisconsin, accepted even lower maximum LOI values.

A similar situation also existed in the case for maximum levels of moisture content and fineness in states where DOT specifications are more restrictive than ASTM C618 or AASHTO M295. According to these specifications, the maximum percent retainment allowed on the number 325 mesh sieve is 34% and the maximum acceptable moisture content is 3.0%. Several states such as Alaska, Indiana, New Mexico, Oregon, and South Dakota, were more restrictive in either one or both of these parameters.

Additionally, state specifications may undergo a series of alterations dependent on changes in national standards and field experiences. Other isolated differences in state specifications from national standards included maximum allowable autoclave expansion, maximum level of

Table 2. AASHTO M295-98 Chemical and Physical Specifications

	Mineral Admixture Class		
Chemical Requirements	N	F	C
Silicon Dioxide, Aluminum Oxide, Iron Oxide (SiO_2 + Al_2O_3 + Fe_2O_3), min., %	70.0	70.0	50.0
Sulfur Trioxide (SO_3), max., %	4.0	5.0	5.0
Moisture Content, max., %	3.0	3.0	3.0
Loss on Ignition, max., %	5.0	5.0	5.0
Available Alkalies, as Na_2O, max., percent[A]	1.5	1.5	1.5
[A] Applicable only when specifically required by the purchaser for mineral admixture to be used in concrete containing reactive aggregate and cement to meet a limitation on content of alkalies.			
Physical Requirements	N	F	C
Fineness: Amount Retained When Wet-Sieved on 45 µm (No. 325) sieve, max., %[A]	34	34	34
Strength Activity Index: [B] with Portland Cement at			
7 day, min. % of control	75[C]	75[C]	75[C]
28 day, min. % of control	75[C]	75[C]	75[C]
Soundness' Water Requirement, max., percent of control	115	105	105
Autoclave Expansion or Contraction, max., %	0.8	0.8	0.8

[A] Care should be taken to avoid the retaining of agglomeration of extremely fine material.

[B] The strength activity index with portland cement is not to be considered a measure of the compressive strength of concrete containing the mineral admixture. The strength activity index with portland cement is determined by an accelerated test and is intended to evaluate the contribution to be expected from the mineral admixture to the longer strength development of concrete. Strength activity index with portland cement is a measure of reactivity with a given cement and may vary as to the source of both the mineral admixture and the cement.

[C] Meeting the 7- or 28-day strength activity index will indicate specification compliance.

[D] If the fly ash or natural pozzolan will constitute more than 20% by weight of the cementitious material in the project mix design, the test specimens for autoclave expansion shall contain that anticipated percentage.

magnesium oxide (MgO), and a minimum calcium oxide (CaO) level. In Colorado, fly ash would only be accepted from a preapproved source, not at all an unusual DOT requirement, but preapproval required submission of a report from the supplier documenting the results of testing the fly ash from that source in accordance with the toxicity characteristic leaching procedure (TCLP).

Fly ash use as a partial cement replacement in concrete was the most frequently indicated application. In most instances, 15% partial replacement of cement in a concrete mixture is allowed. The amount of fly ash used in place of the cement would either be added on a pound-for-pound basis or as additional weight. The most common practice was to replace 15% of the cement with 20% fly ash. This was a practice originally specified in FHWA publications many years ago and was commonly incorporated into state DOTs across the country. However, in the past several years, many states have allowed for larger levels of replacement, depending on the applications. Other partial replacement levels were based on weight ratios varying from 1.0 to 1.35 portions of fly ash for every 1.0 portion of cement. In states which have access to both Class C and Class F fly ash, the percentage of partial replacement and the amount of fly ash used as the replacement material would often be dependent on the fly ash classification. It was also commonly specified that the blending of different ash sources was prohibited.

In addition to concrete, numerous states have used fly ash as a mineral filler in asphaltic concrete and soil stabilization, with many more states beginning to use fly ash in flowable mortar applications. In the cases of fly ash for use in asphalt, the test procedure ASTM D242 “Mineral Filler for Bituminous Paving Mixtures” was commonly cited. This specification assesses fly ash for retainment on the No. 30-, 50-, and 200-mesh sieves and for organic impurities and plasticity indexes.

In soil stabilization, ASTM C593 “Fly Ash and Other Pozzolans for Use with Lime” is generally cited as a material specification. ASTM C593 provides evaluation criteria for fly ash by durability testing according to compressive and vacuum saturation strengths. In soil stabilization applications, it is the CaO contained in the fly ash that is being exploited for its potential engineering use. Thus there is usually a minimum level of CaO associated with fly ash being used in this application. There are several forms of what could be considered soil stabilization, such as cement treated base, subgrade stabilization, subbase stabilization, and base course. States with some type of specification for soil stabilization include Arkansas, Illinois, Indiana, Mississippi, Nebraska, North Dakota, Oklahoma, Pennsylvania, Tennessee, Texas, Virginia, and Wisconsin, as well as Washington, D.C., and the federal lands highways.

Flowable mortar fill, also known as controlled low-strength materials (CLSM) and control density fill, is a low-strength flowable slurry for use as an economical fill or backfill material. It is generally placed by pouring from a commercial ready-mix concrete truck. The applications of CLSM mixtures include sewer trenches, utility trenches, bridge abutments, conduit trenches, retaining walls, foundation subbases, subfootings, floor slab bases, abandoned underground storage tanks and wells, and voids under pavement. Flowability can be measured by the standard slump cone method for concrete (ASTM C143) with measurements generally at 8 inches or higher. Another method of measuring flowability is ASTM C934 "Flow of Grout for Preplaced Aggregate Concrete Flow Cone Method). CLSM are self-leveling and can be placed with minimal effort and no vibration or tamping. Long-term compressive strengths can vary from 50 to 1200 psi. Flowable CLSM mixtures are an economical alternative because of the savings of labor and time over placing and compacting soil or granular materials. This technology was once considered relatively new, and few state transportation departments have specifications for flowable mortar applications. However, several now have standing specifications for CLSM and flowable density fills which often specify the use of fly as one of the constituents.

Another material often cited for use as a cement supplement was ground granulated blast-furnace slag (GGBF slag). At one time, slag was generally only used as blasting grit, in skid or traction applications, or as aggregate in asphaltic concrete. However, now many DOTs allow its use in the production of portland cement concrete. The replacement levels of cement with GGBF slag varied from 20% to 50%. It was also not uncommon to allow it to be blended with fly ash in concrete. The materials specification cited for GGBF slag was ASTM C989 or AASHTO M302 “Ground Granulated Blast-Furnace Slag for Use in Concrete and Mortars.” Three main definitions are listed under this specification. Blast-furnace slag is the nonmetallic product that is developed in a molten condition simultaneously with iron in a blast furnace. Granulated blast-furnace slag is the glassy granular material formed when molten blast-furnace slag is rapidly chilled as by immersion in water. Slag is granulated blast-furnace slag that is ground to cement fineness. The two most common specified grades of GGBF slag were Grades 100 and 120.

Most states included specifications for the allowable use of blended hydraulic cements. The specifications for these were ASTM C595 and AASHTO M240. The descriptions and definitions of these cements varied considerably. A Type IS cement (portland blast-furnace slag cement) was an intimate blending of cement and granulated blast-furnace slag in which the slag constituent is between 25% and 70% of the mass of portland blast-furnace slag cement. A Type I(SM) cement (slag-modified portland cement) is a cement in which the slag constituent is less than 25% of the mass of the slag-modified portland cement.

A portland-pozzolan (Type IP) cement consisted of an intimate and uniform blend of portland or portland blast-furnace slag cement and fine pozzolan, in which the pozzolan constituent is between 15% and 40% of the mass of the portland-pozzolan cement. A Type I (PM) cement (pozzolan-modified portland cement) is a blend of portland cement, or portland blast-furnace slag cement and fine pozzolan, in which the pozzolan constituent is less than 15% of the mass of the portland-modified portland cement.

The use of silica fume was often grouped into the same category as fly ash and GGBF slag as a mineral admixture in portland cement concrete. The specifications for silica fume are AASHTO M307 “Microsilica for Use in Concrete and Mortar” and ASTM C1240 “Use of Silica Fume as a Mineral Admixture in Hydraulic-Cement Concrete, Mortar, and Grout.” Generally very small amounts of silica fume were specified for use in a concrete mix design. These specified amounts were usually from 3% to 10 % of the total cementitious material.

Several states made references to not allowing the blending of two or more sources of fly ash and to only allowing the use of ash that had been evaluated by Cement and Concrete Reference Laboratories (CCRL). It is customary for DOTs to use the CCRL evaluation report as a means of rating their own laboratory testing capabilities and personnel. In several state DOTs, it is a customary practice to use cutoff dates for when fly ash is not to be used in concrete pavements. The cutoff dates are dependent on the region of country but can generally begin in early fall and extend to late spring.

STATE COAL ASH SPECIFICATIONS AND GUIDELINES

Alabama

Fly ash may be used in any concrete mix design except where it is specified otherwise by the plans or proposal. It must meet the requirements of AASHTO M295, including the optional requirements in Table 2 of that procedure. If fly ash is used, a master proportion table is furnished as a guideline in proportioning the mix components. Fly ash may be substituted for cement up to a maximum substitution rate of 20% for Class F fly ash and 30% for Class C fly ash by weight. The minimum substitution ratio of fly ash to the cement it replaced will be one to one. Fly ash is also allowed to be used as a mineral filler in asphalt and pressure grouting. In addition, ponded ash (bottom ash and fly ash) is allowed to be a selected material for use in roadbed and base stabilization.

GGBF slag may be used in any concrete mix design except where it is specified otherwise by the plans or proposal, and it must meet the requirements of AASHTO M302, Grade 100 or 120. GGBF slag may be substituted for cement up to a maximum substation rate of 50% by weight expect that when the ambient air temperature is 45°F or less; the maximum substitution rate will be 25% by weight. The minimum substitution ratio of GGBF slag to cement it replaces will be one to one. GGBF slag shall not be substituted for a portion of Type IP cement or for portland cement in high-early-strength concrete. GGBF slag shall not be used in fly ash and/or microsilica mixtures.

Microsilica may be used in any concrete mix design except where it is specified otherwise by the plans or proposal. It must also meet the requirements of AASHTO M307. Microsilica may be used in mixes with fly ash. Microsilica may be substituted for cement up to a maximum substitution rate of 10% by weight. The minimum substitution rate of microsilica to the cement it replaces will be one to one. The substitution rate shall be fixed at 25% fly ash and 10% microsilica by weight.

Alaska

Fly ash can be used in concrete only with the engineer's approval. Fly ash is used as a partial cement replacement up to a maximum of 20% by weight of portland cement. Fly ash cannot be used in high-early-strength concrete. Either Class C or Class F fly is allowed as long as it meets AASHTO M295 specifications including optional requirements, except for the following changes:

- Moisture content is 1.0% maximum
- Amount retained on the No. 325 sieve is 30% maximum

Cement can be replaced with fly ash according to the following ratios:

- Class F fly ash can have a replacement ration for cement of 1.25 lb/1.0 lb cement
- Class C fly ash can have a replacement ration of 1–1.25 lb/1.0 lb cement.

Microsilica is also allowed in concrete as long as it meets ASSHTO M307 specifications except for the following changes:

- Maximum loss on ignition is 4.0%
- Maximum total of other chemical compounds is 7.0%
- Minimum surface area is 15 m^2/g

Arizona

A maximum of 20% fly ash replacement of cement with fly ash is allowable in portland cement concrete. Arizona DOT specifications do not address any coal by-products other than fly ash. Fly ash must conform to the requirements of ASTM C618 for Class C or F mineral admixture, except that the loss on ignition shall not exceed 3.0%. A minimum of 1.2 pounds of fly ash shall replace each 1.0 pound of portland cement removed.

Fly ash, when used as a replacement for portland cement, shall have an R factor less than 2.5. The R factor is defined as (C – 5%)/F, where C is the calcium oxide content expressed as a percentage and F is the ferric oxide content expressed as a percentage. Fly ash shall not contain more than 1.5% available alkali as defined in ASTM C311.

Arkansas

Unless otherwise specified, portland cement conforming to the requirements of AASHTO M85 Type I shall be furnished. This applies to both portland cement concrete pavement and concrete for structures. One of the following blended cements may be used in lieu of Type I:

- Portland-pozzolan cement, AASHTO M240, Type IP (20% maximum)
- Pozzolan-modified portland cement, AASHTO M240 Type I (PM)
- Slag-modified portland cement, AASHTO M240, Type I (SM)

Fly ash or GGBF slag shall not be substituted for blended cements. Fly ash for use with portland cement concrete shall comply with the requirements of AASHTO M295, Class C or Class F. Mixing of Class C and Class F fly ashes will not be permitted. Fly ash may be used as a partial replacement for Type I cement, not exceeding 20% by weight, in all classes of concrete except Class B.

GGBF slag shall comply with the requirements of AASHTO M302, Grade 100. GGBF slag may be used as a partial replacement for Type I cement, not exceeding 25% by weight. Substitution shall be made at a rate of one kilogram (pound) of GGBFS for each kilogram (pound) of cement replaced. GGBFS will not be allowed as a substitute for high-early-strength or blended cements.

Flowable fill mixtures, containing cement, fly ash, sand, and water, are allowable for backfilling bridge abutments, pipe culverts, box culverts, structural plate pipe and arches, or other uses as approved by the engineer. One cubic yard of flowable fill may contain 45–60 kg (80–100 pounds) of cement and 220–300 pounds of fly ash.

For use in cement treated base course, the cement shall comply with AASHTO M85 for portland cement Type I, AASHTO M240 for blended hydraulic cement, Type IP (20% maximum), pozzolan-modified portland cement, AASHTO M240, Type I (PM), or slag-modified portland cement, AASHTO M2540, Type I (SM). Fly ash or GGBF slag may be used as a partial replacement for the cement. Replacement amounts, not exceeding 25% by weight, shall be determined through trial batch investigations using the specific materials proposed for the project. Mixtures with fly ash shall meet the same requirements as mixtures without fly ash. Mixing of Class C and Class F fly ashes will not be permitted. Fly ash will not be allowed as a substitute for high-early-strength or blended cements. For in-place stabilization, the fly ash and cement shall be blended to form a homogeneous mixture before application on the roadway.

California

The California DOT has established a list of approved admixtures for use in concrete. This list was last revised on March 19, 2004, and includes 13 fly ash sources from four different companies. All the fly ashes are classified as Class F and have total calcium oxide contents of less than 10.0%.

The cementitious material in a concrete mix shall be either:

- "Type IP (MS) Modified" cement.
- A combination of "Type II-Modified" portland cement and mineral admixture.
- A combination of Type V portland cement and mineral admixture.

In addition, "Type IP (MS)-modified" cement and "Type II-modified" portland cement shall conform to the following requirements:

- The cement shall not contain more than 0.60% by mass of alkalies, calculated as the percentage of Na_2O plus 0.658 times the percentage of K_2O, when determined by either direct intensity flame photometry or by the atomic absorption method. The instrument and procedure used shall be qualified as to precision and accuracy in conformance with the requirements in ASTM Designation: C114.

- The autoclave expansion shall not exceed 0.50%.

- Mortar, containing the cement to be used, and Ottawa sand, when tested in conformance with California Test 527, shall not expand in water more than 0.010% and shall not contract in air more than 0.048%, except that when cement is to be used for precast prestressed concrete piling, precast prestressed concrete members, or steam cured concrete products, the mortar shall not contract in air more than 0.053%.

- Mineral admixtures—coal fly ash; raw or calcined natural pozzolan as specified in ASTM Designation C618; silica fume conforming to the requirements in ASTM Designation: C1240, with reduction of mortar expansion of 80%, minimum, using the cement from the proposed mix design.

Required uses of mineral admixtures:

- Unless otherwise specified, mineral admixture shall be combined with cement to make cementitious material. The calcium oxide content of mineral admixtures shall not exceed 10%, and the available alkali, as sodium oxide equivalent, shall not exceed 1.5% when determined in conformance with the requirements in ASTM Designation C618.

The amounts of cement and mineral admixture used in cementitious material shall be sufficient to satisfy the minimum cementitious material content requirements specified below:

- The minimum amount of cement shall not be less than 75% by mass of the specified minimum cementitious material content.

- The minimum amount of mineral admixture to be combined with cement shall be determined using one of the following criteria:

  – When the calcium oxide content of a mineral admixture is equal to or less than 2% by mass, the amount of mineral admixture shall not be less than 15% by mass of the total amount of cementitious material to be used in the mix.

  – When the calcium oxide content of a mineral admixture is greater than 2%, the amount of mineral admixture shall not be less than 25% by mass of the total amount of cementitious material to be used in the mix.

  – When a mineral admixture that conforms to the provisions for silica fume is used, the amount of mineral admixture shall not be less than 10% by mass of the total amount of cementitious material to be used in the mix.

  – When a mineral admixture that conforms to the provisions for silica fume is used and the fine and coarse aggregates are listed on the approved list as specified in these special provisions, then the amount of mineral admixture shall not be less than 7% by mass of the total amount of cementitious material to be used in the mix.

The total amount of mineral admixture shall not exceed 35% by mass of the total amount of cementitious material to be used in the mix.

Laboratories performing ASTM Designation C1260 shall participate in the CCRL Pozzolan Proficiency Sample Program and shall have received a score of 3 or better on the shrinkage and soundness tests of the previous two sets of pozzolan samples.

When the aggregate is tested in conformance with the requirements in California Test 554 and ASTM Designation C1260, the average of the expansion at 16 days shall be less than or equal to 0.15%.

Use only for precast members that are not in contact with soil, submerged in water, nor in a corrosive environment. Edit type of precast member(s), if other than girders are to be used.

Unless otherwise specified, mineral admixture will not be required in portland cement concrete used for precast concrete girders. The contractor will be permitted to use Type III portland cement for concrete used in the manufacture of precast concrete members.

Colorado

Where either Type I or Type II portland cement is required, blended hydraulic cement conforming to ASTM C595 Type IP or Type IP (MS) may be used, except that the blended cement shall consist of no less than 70% portland cement. Where Type II portland cement is

required, blended hydraulic cement conforming to ASTM C595 Type IP (MS) may be used, except that the blended cement shall consist of no less than 70% portland cement. Where blended hydraulic cement is used, the substitution of fly ash for the blended hydraulic cement is not allowed. Where either Type I or Type II portland cement is required, hydraulic cement conforming to ASTM C1157 Type GU or Type MS may be used. Where Type II portland cement is required, hydraulic cement conforming to ASTM C1157 Type MS may be used.

For concrete where Class F fly ash is required, blended hydraulic cement conforming to ASTM C595 Type IP or Type IP (MS) may be used, except that the blended cement shall consist of no less than 70% portland cement and no less than 20% Class F fly ash by weight. The weight of blended hydraulic cement must equal the weight of portland cement plus fly ash.

For paving concrete where Class F fly ash is required, blended hydraulic cement may be substituted for the cement plus fly ash. The weight of blended cement must equal the weight of cement plus fly ash. The blended cement must conform to one of the following:

- ASTM C595 Type IP or Type IP (MS) where 15% to 25% Class F fly ash has been blended with Type I or Type II cement. The Type I or Type II shall meet the requirements of ASTM C150, Table 2. The Class F fly ash shall conform to ASTM C618 including all chemical requirements of Table 1 except for footnote A.

- ASTM C1157 Type GU or Type MS which conform to Option R (Low Reactivity with Alkali-Reactive Aggregates)

Where Type V portland cement is required, one of the following may be used: Type II portland cement with no more than 5.0% C3A content and no more than 25% [C4AF + 2 (C3A)], Type II portland cement with no more than 0.040% expansion at 14 days when tested in accordance with ASTM C 452, Type II portland cement with at least 15% of the cement replaced with an approved Type F fly ash, ASTM C595 Type IP (MS) blended hydraulic cement consisting of no less than 70% portland cement and at least 15% Type F fly ash, and ASTM C1157 Type HS hydraulic cement. Class C fly ash is not permitted when Type V cement is required.

Class H and HT concrete (bare concrete bridge deck mixes) shall contain cementitious materials in the following ranges: 450–500 lb/yd^3 Type II portland cement, 90–125 lb/yd^3 fly ash, and 20–30 lb/yd^3 silica fume. Blended cement may not be substituted. Up to 20% ASTM C 618 Class C fly ash may be used in all concrete mixes except pavements and Class H and HT mixes. Up to 30% ASTM C 618 Class F fly ash may be used in all concrete mixes except Class H and HT mixes. Concrete used for pavement shall contain 20%–30% ASTM C618 Class F fly ash; blended cement may be substituted.

Fly ash for concrete shall conform to the requirements for ASTM C618, Class C or Class F. All chemical requirements of ASTM C618 Table 1-A shall apply, with the exception of Footnote A, and the loss on ignition shall not exceed 3%. Class C fly ash will not be permitted where sulfate-resistant cement is required.

Fly ash shall be from a preapproved source. Preapproval shall include submission of a report from the supplier documenting the results of testing the fly ash from that source in accordance with the TCLP. Fly ash can also be used for pretensioned and combination tensioned products, structural concrete, and concrete pavement. Fly ash cannot be used as a mineral filler in asphalt mixtures, only limestone dust.

GFBF slag is included as one of several allowable materials in bed course for sidewalks, curbing, and bikeways and for slope protection or riprap filter blanket. GFBF slag can also be used as a filter material for quick-draining applications. Silica fume for concrete shall conform to the requirements of ASTM C1240, and it must be from a preapproved source list.

Connecticut

Connecticut DOT standard specifications specifically mention fly ash as a substitute for portland cement. Both Class C and F fly ash can be used in concrete, at a maximum of 15% replacement of cement.

CLSM shall be composed of a mixture of portland cement, aggregate, and water with the option of using fly ash, air-entraining agents, and other approved admixtures. The minimum compressive strength of the CLSM material shall be 30 psi, and the maximum strength of CLSM shall be 150 psi after 56 days.

Delaware

Blended cements shall conform to AASHTO M240 specifications. The two types of blended cements allowed to be used are Types IP (IPM) and IS (ISM).

Fly ash may be used as a mineral additive in concrete and as a partial replacement for portland cement at a maximum replacement level of 20%. Fly ash shall conform to the requirements of AASHTO M295, Class C or F, with the following modifications. The maximum loss on ignition shall be 4%. The strength activity index shall be a minimum of 85% of the control after 7 days and a minimum of 100% of control after 28 days. Traces of ammonia and oil shall be absent from the fly ash. Currently, however, no producers are using fly ash, and no fly ash has been used in concrete for at least the last 5–7 years.

FEDERAL LANDS HIGHWAYS

The office of the Federal Lands Highway is part of the Department of Transportation, Federal Highway Administration, and is located in Washington, D.C. The office is responsible for administering the Federal Lands Highway Program (FLHP) for the FHWA. The primary purpose of the FLHP is to provide funding for a coordinated program of public roads that serve the transportation needs of federal and Indian lands which are not a state or local government responsibility. The Federal Lands Highway Offices (Central, Eastern and Western) use the Standard Specifications for Construction of Roads and Bridges on Federal Highway Projects

(FP). In addition, each Division has their own Standard Contract Requirements (SCR's) which amend and supplement the FP.

Fly ash must conform to AASHTO specification M295. GGBF slag must conform to AASHTO M302 Grade 100 or 120. Silica fume must conform to AASHTO M307. In structural concrete, fly ash, GGBF slag, or silica fume may partially replace cement as follows in any mix design except for prestressed concrete; however, generally only fly ash is permitted:

- Class F fly ash: Not more than 20% of the minimum mass of portland cement may be replaced with Class F fly ash at the rate of 1.5 parts fly ash per 1 part cement.

- Class C fly ash: Not more than 25% of the minimum mass of portland cement may be replaced with Class C fly ash at the rate of 1 part fly ash per 1 part cement.

- GGBF slag: Not more than 50% of the minimum mass of portland cement may be replaced with the GGBF slag at the rate of 1 part slag per 1 part cement.

- Silica fume (microsilica): Not more than 10% of the minimum mass of portland cement may be replaced with silica fume at the rate of 1 part silica fume per 1 part cement.

Fly ash is also allowed for use in aggregate stabilization, treated aggregate courses, and subgrade stabilization (at proportions of 6 to 20 %). It is generally not used in asphalt in that hydrated lime (at least 1%) is mandated in the design of hot-mix asphalt (to guard against stripping). Lean concrete is allowed for backfill and fly ash may be used as part of the lean concrete backfill.

Fly ash is allowed for use in the production of hydraulic cement mortar and grout. The contractor must furnish a mixture of portland cement, fine aggregate, water, expansive admixture, and/or fly ash conforming to the following:

- 7-day compressive strength, min. 600 psi
- Flow (time of flux), 16–26 seconds

The following product certification also must be submitted:

- Mill certificates for the cement

- Physical and chemical analyses of the pozzolan

- Independent laboratory results for 1-, 3-, and 7-day compressive strengths; flow cone times; shrinkage and expansion observed; and time of initial set.

Florida

Unless a specific type of cement is designated elsewhere, use Type I, Type IP, Type IS, Type IP (MS), Type II, or Type III cement in all classes of concrete. Use only the types of

cements designated for each environmental condition in structural concrete. A mix design for a more aggressive environment may be substituted for a lower environmental condition.

In bridge superstructures, blended cements are allowed in slabs, barriers, precast, and prestressed applications exposed to moderately aggressive environments. In extremely aggressive environments, the recommended cementitious mixtures are Type II cement with fly ash or GGBF slag. For bridge substructures, drainage structures, and other structures, the recommendations are basically the same.

Pozzolans and slags can be used as desired on an equal weight replacement basis. It is allowable to use fly ash, silica fume, Metakaolin, other pozzolans, and slag materials as a partial cement replacement in all classes of concrete, with the following limitations:

- Mass concrete:
  - Fly ash – ensure that the quantity of cement replaced with fly ash is 18% to 50% by weight.
  - Slag – ensure that the quantity of cement replaced with slag is 50% to 70% by weight. Ensure that slag is 50% to 55% of total cementitious content by weight of total cementitious materials when use in combination with silica fume and/or metakaolin.
- Drilled shaft:
  - Fly ash – ensure that the quantity of cement replaced with fly ash is 33% to 37% by weight.
  - Slag – ensure that the quantity of cement replaced with slag is 58% to 62% by weight.
- For all other concrete uses not covered in “mass concrete” and “drilled shaft” above:
  - Fly ash – ensure that the quantity of cement replaced with fly ash is 18% to 22% by weight.
  - Slag – ensure that the quantity of cement replaced with slag is 25% to 70% for slightly and moderately aggressive environments and 50% to 70% by weight when used in extremely aggressive environments. Ensure that slag is 50% to 55% of total cementitious content by weight of total cementitious materials when used in combination with silica fume and/or metakaolin.
- Type IP (MS): Ensure that the quantity of pozzolan in Type IP (MS) is in the range of 15% to 40% by weight.
- Silica fume and metakaolin

- Cure in accordance with the manufacturer's recommendation and approved by the engineer.

- Silica fume – ensure that the quantity of cement replaced with silica fume is 7% to 9% by weight.

- Metakaolin – ensure that the quantity of cement replaced with metakaolin is 8% to 12% by weight.

For reinforced concrete that does not require Type II cement plus slag or pozzolan(s), all applications that require Type II cement plus pozzolan(s), and prestressed concrete, there is a table specifying the maximum chloride content limits for each of the concrete applications.

A flowable fill mixture, which is designed to be excavatable, is not allowed to contain fly ash, contain 75–100 pounds of cement per cubic yard, and have a maximum 28-day strength of 100 psi. A flowable fill mixture, designed to be nonexcavatable is to contain 75–100 pounds of cement and 150–600 pounds of fly ash per cubic yard and have a maximum 28-day strength of 125 psi.

Fly ash derived from the combustion of ground or powdered coal shall meet the requirements of ASTM C618 for Class C or Class F. Sampling and testing shall follow the requirements of ASTM C311. Fly ash resulting from the combustion of coal and petroleum coke shall meet the physical and chemical requirements of ASTM C618 Class F fly ash. Fly ash shall not include the residue resulting from the burning of municipal garbage or any other refuse with coal or the burning of industrial or municipal garbage in incinerators. Fly ash resulting from the combustion of timber bark ash and coal shall meet the physical and chemical requirements of ASTM C618 Class F fly ash.

GGBF slag shall meet the requirements of ASTM C989. Sampling and testing procedures shall follow the requirements of ASTM C989. Microsilica shall meet the requirements of ASTM C1240 using the referenced test methods and frequencies.

Metakaolin shall meet the requirements of ASTM C618 Class N with the following modifications:

- The sum of $SiO_2 + Al_2O_3 + Fe_2O_3$ shall be at least 85%.
- The loss on ignition shall be less than 3.0%.
- The available alkalies, as equivalent Na_2O, shall not exceed 1.0%.
- The amount of material retained on a No. 325 mesh sieve shall not exceed 1.0%.
- The strength activity index, at 7 days, shall be at least 85%.

When metakaolin is used in concrete, the test results shall verify improved or comparable strength, sulfate resistance, corrosion protective properties, and other durability performance properties of concrete, as compared to the performance of silica fume concrete.

The suppliers of fly ash, GGBF slag, and microsilica are required to furnish, at the time of shipment, certification of test results from samples of the material taken during production or transfer to ensure compliance to applicable ASTM requirements. In the case of the fly ash, the laboratory performing the fly ash testing is required to be inspected by the CCRL on a regular basis as a fly ash testing laboratory and shall have corrected any deficiencies noted at the previous inspection. The laboratory must authorize the CCRL to send a copy of the inspection report to the state Materials Office.

When a Class C fly ash is used in moderately or extremely aggressive environments, tests made by the supplier shall verify improved sulfate resistance of the concrete in accordance with ASTM C1012 and improved corrosion protective properties as compared to similar concrete made with the Class F fly ash. No mix designs will be approved in advance of satisfactory completion of such tests.

For sources where the fly ash is not derived solely from ground or powdered coal combustion, certified test results performed by an independent approved laboratory shall be submitted by the supplier. Only GGBF slag grade 100 or better (28-day index) will be permitted. For slurried or densified microsilica, tests shall be made on the raw microsilica from which these products were made.

Neither fly ash nor slag shall be used in conjunction with Type IP or Type IS cements. Acceptance of fly ash, slag, microsilica, and metakaolin from sources operating under an approved quality control plan shall be based on certified testing meeting the appropriate ASTM requirements for each material. When the loss on ignition exceeds 5% for fly ash, the uniformity requirements in the supplementary optional physical requirement shall be mandatory.

Georgia

The contractor may use fly ash as an additive in concrete to promote workability and plasticity. The contractor may use fly ash as a partial replacement for portland cement in concrete if the following limits are met:

- Replace no more than 15% of the cement by weight.
- Replace cement with fly ash at the rate of 1.0 to 1.5 lb (1.0 to 1.5 kg) of fly ash to 1.0 lb (1.0 kg) of cement.
- Ensure that the fly ash mix meets the state requirements for “portland pozzolan cement” and “fly ash.”
- Calculate the water–cement ratio based on the total cementitious material in the mix including fly ash.
- Do not use Type IP cement in mixes containing fly ash.

If high-early-strengths are unnecessary, the contractor may use GGBF slag as a partial replacement for portland cement in concrete if the following limits are met:

- Replace no more than 50% of the cement by weight.
- Replace the cement with slag at the rate of 1.0 lb (1.0 kg) of slag to 1.0 lb (1.0 kg) of cement.
- Ensure that the slag mix meets the state requirements for "portland blast-furnace cement" and "granulated iron blast-furnace slag."
- Calculate the water–cement ratio based on the total cementitious material in the mix, including granulated iron blast-furnace slag.
- Do not use Type IP cement or fly ash in slag mixes.

Hawaii

Portland cement shall be either Type I or Type IP. Type IP cement shall conform to Type IP cement in ASTM C595. Type IP cement includes an intimate mixture of Type I cement and not more than 20% of a pozzolan material. The contractor may use mineral admixtures to replace a portion of the required portland cement.

Mineral admixtures must conform to ASTM C618 specifications, except that the loss on ignition shall not exceed 3%. The engineer will permit the contractor to replace up to 15% by weight of the required portland cement other than Type IP with a mineral admixture in concrete except where the contract specifies high-early-strength or where the contract prohibits the use of mineral admixtures. The weight of mineral admixture used shall be equal to or greater than the weight of portland cement replaced.

Idaho

Natural pozzolans and fly ash shall conform to AASHTO M295 except that loss on ignition shall not exceed 1.5% for all classes. When the contract or source approval requires fly ash concrete, Class F fly ash shall be used, and available alkalies in the fly ash (as Na_2O) shall not exceed 2%. In addition, calcium oxide (CaO) content shall not exceed 9%.

A table is referenced of basic mix design parameters when fly ash concrete is required. There are several mix designs with a minimum fly ash content of 20% for partial cement replacement. If additional cement and fly ash are needed to meet minimum strength requirements, they shall be added at the ratio of 1 lb fly ash per 4 lb cement.

Class F fly ash shall be used. Fly ash shall not exceed 25% of the total cementitious material (fly ash + cement). It may not always be possible to produce concrete using the minimum fly ash content that will ensure mortar bar expansion does not exceed 0.10% expansion when tested in accordance with AASHTO T303. If addition fly ash is needed to meet the mortar

bar expansion requirements, it may be added without a corresponding increase in cement provided the strength requirement is met.

Illinois

At the contractor's option, fly ash from approved sources may partially replace portland cement in concrete mixtures except when blended cements are used. A mix design consisting of cement, fly ash, and GGBF slag may be used only when specified by the DOT.

If Class F fly ash is used, the amount of cement replaced shall not exceed 15% by weight and the replacement ration (fly ash:cement replaced) shall be a minimum of 1.5:1. If Class C fly ash is used, the amount of cement replaced shall exceed 20% by weight, at a minimum replacement ration of 1.25:1. For Class C fly ash, the minimum replacement ration may be reduced to 1:1 if the fly ash calcium oxide is 18% or greater, the fly ash loss on ignition is less than 2%, and a water-reducing or high-range water-reducing admixture is used.

For bridge decks, parapets, pier and abutment caps, backwalls, wingwalls, and upper 2.5 ft. of solid piers, the amount of cement replaced shall not exceed 15% by weight at a minimum replacement ratio of 1.5:1, regardless of the type of fly ash used.

Fly ash shall not be used in concrete mixtures when the air temperature is below 40°F without permission of the engineer. The contractor may be required to reduce the quantity of fly ash, increase the cement, or eliminate the cement factor reduction for a water-reducing or high-range water-reducing admixture. Fly ash with an R factor greater than 3.0 shall not be used in concrete which will be subjected to high sulfate concentrations on soil or water. High-sulfate soils shall be those with a concentration of water-soluble sulfate (as SO_4) greater than 0.10%, and high-sulfate waters shall be those with sulfate concentrations (as SO_4) greater than 150 mg/L.

At the contractor's option, GGBF slag may partially replace portland cement in concrete mixtures, except when blended cement is used. The amount of cement replaced by GGBF slag shall not exceed 30% by weight. The replacement ratio (GGBF slag:cement replaced) shall be a minimum of 1 to 1. GGBF slag shall not be used in concrete mixtures when the air temperature is below 40°F.

Fly ash and wet-bottom boiler slag, in place of aggregates, may be used for pozzolanic stabilized subbases. The activator for pozzolanic stabilized mixtures shall either be cement or lime. The amount of pozzolanic stabilized mixture constructed shall be limited to that which can be surfaced during the current construction season. The cement or lime, pozzolan, and aggregate shall be proportioned within the following approximate limits on a dry weight basis: boiler slag (54%–79.5%), cement (3%–6%), lime (3.5%–6%), and pozzolan (18%–40%).

At least 60 days prior to the start of placing cement aggregate mixture, the contractor shall submit samples of material for proportioning and testing. The mixture shall contain a minimum of 200 lb of portland cement per cubic yard, except that a maximum of 15% of cement may be replace by fly ash at a 1:1.5 cement to ash ration. For pozzolanic mixtures, fly ash shall meet the

requirements of AASHTO M295, Class C or Class F, except that if dampened for the purpose of transportation, the loss on ignition shall not exceed 10%. Fly ash moisture content shall not exceed 35%. For cement aggregate mixtures, the fly ash shall meet the standard AASHTO M295, Class C or F. A limitation of available alkalies, as Na_2O, of 1.5% shall apply to fly ashes with alkali-reactive aggregates. When fly ash is used as a mineral filler, the fly ash shall meet the requirements of AASHTO M295, Class C or F, except if dampened, the loss on ignition shall not exceed 12%.

Fly ash is allowed for use in controlled low-strength applications. Of the three preapproved mix designs, two utilize fly ash. The compressive strength at 28 and 180 days must be between 30 and 150 psi. For all precast concrete products, Class F fly ash shall not exceed 15% by weight of the total portland cement, Class C fly ash shall not exceed 20% by weight, and GGBF slag shall not exceed 25% by weight.

For drilled shafts, Class C or F fly ash may replace Type I or II cement. The cement replacement shall not exceed 15% by weight at a minimum replacement ratio of 1.5:1. The fly ash shall not be used in combination with GGBF slag. Grade 100 or 120 GGBF slag may replace Type I or II cement, and the replacement shall not exceed 25% by weight at a minimum replacement ratio of 1:1.

Indiana

Several types of blended cements are allowed as long as they conform to their respective specifications:

- Air-entraining portland blast-furnace slag cement – AASHTO M240, Type ISA
- Air-entraining portland-pozzolan cement – AASHTO M240, Type IP-A
- Portland blast-furnace slag cement – AASHTO M240, Type IS
- Portland-pozzolan cement AASHTO M240, Type IP

Type IS or Type IP portland pozzolan cements may only be incorporated into concrete placed between April 1 and October 15 of the same calendar year. This time period restriction will not apply if traffic is not anticipated on the concrete or if silica fume is used as a portion of the total cementitious material.

The exceptions to AASHTO M240 are as follows:

- The amount of pozzolan shall be limited to 20% and 25% by weight of the portland-pozzolan cement for Types IP and IP-A.

- The pozzolan in portland-pozzolan cement, Types IP and IP-A, shall be in accordance with ASTM C618, Class C or Class F, with the loss on ignition of the pozzolan limited to a maximum of 3%.

- The pozzolan in the portland-pozzolan cement, Types IP and IP-A, shall be interground with the portland cement clinker.

Fly ash will be accepted from one of the sources on the DOT's list of approved fly ash and GGBF slag sources. The fly ash shall be in accordance with AASHTO M295 for Class C or Class F, with the following exceptions:

- Loss on ignition, maximum %.....3.0
- Autoclave expansion or contraction, maximum %.....0.5
- Fineness: amount retained when wet-sieved on 45-µm sieve (No. 325) maximum %.....30

On days when fly ash is being accumulated for use as a pozzolan, the supplier shall obtain a minimum of one sample a day and furnish test results for moisture content, loss on ignition, and 45-µm (No. 325) sieve residue for each sample. The testing procedures followed shall be in accordance with ASTM C311 or other methods approved in writing by the DOT. All instruments used for rapid chemical analysis shall comply with applicable requirements of ASTM C114 using NIST fly ash reference materials.

GGBF slag will be accepted from one of the sources on the DOT's list of approved fly ash and GGBF slag sources. GGBF slag from different sources or different grades shall not be mixed or used alternately in the sample construction unless approved in writing. The GGBF slag shall be in accordance with ASTM C989 for Grade 100 or 120.

Silica fume will be accepted from one of the suppliers on the DOT's list of approved pozzolanic suppliers. Silica fume from more than one of these suppliers shall not be mixed or used alternately in the same construction unless authorized in writing. The silica fume shall be in accordance with AASHTO M307 with the following exceptions:

- Reactivity with cement alkalies shall not be required.
- ASTM C1240 shall be conducted on the oversize, the amount of contaminating materal retained on the 45-µm sieve.
- The oversize amount retained on the 45-µm sieve shall not be more than 10%.
- Accelerated pozzolanic activity index in accordance with ASTM C1240 shall be conducted in lieu of strength activity index.
- The accelerated pozzolanic activity index shall be a minimum of 85% at 7 days.
- The increase of drying shrinkage of mortar bars at 28 days shall not be more than 0.10%.
- The increase of drying shrinkage of mortar bars at 28 days shall be conducted in accordance with ASTM C1240.

Quality assurance/quality control (QA/QC) superstructure concrete has the following restrictions on the use of mineral admixtures:

- Fly ash will not be permitted in conjunction with the use of Type IS or IP cements or with GGBF slag.

- When silica fume is used, the following criteria shall be used:

  - The minimum portland cement content shall be 530 lb/yd^3.

  - The minimum and maximum cementitious content with silica fume shall be 650–715 lb/yd^3.

  - Class F or C fly ash may be used as part of the total cementitious content.

  - The maximum portland cement/fly ash ratio shall be 6.4 by weight.

  - The water/cementitious ratio shall be no less than 0.370 and shall not exceed the maximum of 0.420.

  - The minimum compressive strength at 28 days shall be 5800 psi.

Iowa

Blended cements are allowed as long as they meet ASTM C595 specifications and the following requirements:

- The pozzolan constituent of Type IP cement shall not be more than 25% by weight of the portland-pozzolan cement.

- The slag constituent of Type IS cement shall not be more than 35% by weight of the portland blast-furnace slag cement.

- Type IP or I (PM) cement shall not contain Class C fly ash.

- Blending cements produced with Type I clinker or Type I cement shall contain 20% GGBF slag or at least 20% Class F fly ash. All other blended cements shall be produced with Type II clinker.

Fly ash may be partially substituted for portland cement. The substitution rate shall not be more than 15% by weight. Fly ash to be substituted for portland cement in concrete shall comply with AASHTO M295, either Class F or Class C, including the supplementary options' chemical requirements. Sources with fly ash between 1.5% and 2.5% available alkalies may be approved. For Class C fly ash, the pozzolanic activity test with lime will not be required.

GGBF slag may be partially substituted for portland cement. The substitution rate for GGBF slag as a mineral admixture shall not exceed 35% by weight. GGBF slag to be substituted for portland cement in concrete shall comply with ASTM C989 Grade 100 or 120.

Kansas

Several types of blended cements are allowed in construction of bridge decks wearing surface and concrete pavement. The Kansas DOT has prequalified source lists for GGBF slag, silica fume, fly ash for use in concrete pipe, and fly ash for subgrade stabilization, cold recycle bituminous, and subgrade modification. The preapproved fly ash sources are all Class C fly ashes.

The substitution of fly ash for Type IS or Type III cement is not allowed. Fly ash is only permitted in concrete for pavement and concrete for precast pipes. The approved source of fly ash cannot be changed during the project. Substitute 1 pound of fly ash for 1 pound of cement. Substitution with Class C fly ash is limited to a maximum of 10%, by weight, of the specified amount of cement. Substitution with Class F fly ash is limited to a maximum of 20%, by weight, of the specified amount of cement. If fly ash is substituted for Type IP or Type I (PM) cement, the amount of pozzolan in the blended cement plus the amount of fly ash substituted cannot exceed 30% of the total.

Results must be provided of the mortar expansion tests performed according to the requirements of ASTM C441. Use Pyrex glass aggregate and the same fly ash and cement proposed for use on the project at the time of mixing. The expansion for the mixture may not exceed the maximum of 0.020% at 14 days.

The concrete mix design may include GGBF slag from an approved source as partial replacement for Portland cement or blended cement. The substitution of GGBF slag for Type III cement is not allowed. Substitute 1 pound of GGBF slag for 1 pound of cement. Substitution with GGBF slag is limited to a maximum of 35%, by weight, of the specified amount of cement. If GGBF slag is substituted for Type IL or Type I (SM) cement, the amount of GGBF slag in the blended cement plus the amount of GGBF substituted cannot exceed 35% of the total. Requirements for mortar expansion tests are the same for utilizing GGBF slag as they are for fly ash.

Kentucky

Blended cements are allowed for use provided that Type IP or Type IPA conform to ASTM C595 and the following additional requirements:

- The pozzolan constituent shall be fly ash. Ensure that the loss on ignition of the fly ash does not exceed 3%.

- Ensure that the fly ash does not exceed 20% of the portland-pozzolan cement by weight.

- The cement manufacturer shall furnish the results of tests performed on the fly ash used in the manufacture of the Type IP cement shipped to the project. The test shall cover the chemical and physical properties listed in ASTM C618.

Fly ash used in portland cement concrete shall conform to ASTM C618 for Class F or Class C except the loss on ignition shall not exceed 3%. Fly ash and GGBF slag suppliers are placed on a preapproval list. There are 19 sources on the fly ash list, with 11 of them being Class F fly ash and the rest Class C. Class F fly ash and Grade 100 and 120 GGBF slag will be allowed for use in structural mass concrete provided that:

- Substitution of Class F fly ash for cement is at the rate of 25% to 30%, by weight, applying a substitution rate of 1.0 to 1.25 lb of fly ash added.

- Substitution of GGBF slag for cement is done up to a maximum of 50%, by weight, applying a substitution rate of 1.0 lb of GGBF slag for each pound of cement.

- Mixes with both GGBF slag and Class F fly ash permit up to but no more than 20% of the 50% GGBF slag maximum as Class F fly ash.

Fly ash is allowed to be used in mortar or grout but its quantity is not to exceed 20% by weight of the cement. There are two applications for the use of fly ash in flowable fill; they are for Pipe Backfill and Bridge End Bent Backfill. The mixture for Pipe Backfill allows only Class F fly ash to be used at a fly ash to cement ratio of ten to one. For Bridge End Bent Backfill, both Class C and F fly ashes are allowed at a fly ash to cement ratio of three to one. When fly ash is used in flowable fill applications, the loss on ignition for Class F fly ash is not to exceed 12%.

Although fly ashes, which fail to meet ASTM C618 requirements, are not allowed to be used, there are circumstances when a nonspecification fly ash is found to have been incorporated in a concrete mixture. When this occurs, there are a series of tables which identify price reductions on the contractor's invoice based on the extent the fly ash is out of specification. The DOT also maintains a list of approved microsilica admixtures. The microsilica material must meet AASHTO M307 chemical and physical specifications.

Louisiana

Blended cements from preapproved sources can be used. Portland-pozzolan cement shall comply with AASHTO M240, Type IP, and shall contain 20 ± 5% by weight fly ash (or bottom ash provided it is interground with the cement clinker). The alkali content of portland-pozzolan cement calculated as sodium oxide equivalent shall not exceed 0.60% by weight. Fly ash or bottom ash shall comply with ASTM C618, Class C or F, except that loss on ignition shall not exceed 6%.

Portland blast-furnace slag cement shall comply with AASHTO M240 requirements for Type IS cement and shall contain up to 50% by weight of portland blast-furnace slag. The alkali content of portland blast-furnace cement calculated as sodium oxide equivalent shall not exceed 0.60% by weight. Grade 120 GGBF slag for use in Type IS cement shall comply with AASHTO M302. Type IP and IS cements are allowed for use in general construction and prestressed or precast concrete and mass concrete placement. Fly ash is also used as a component in flowable fill.

The contractor may use up to a maximum of 20% fly ash by weight of cement for minor structures and concrete pavement and up to 15% fly ash by weight of cement for structural concrete. When substituted at the ready-mix plant, the contractor may use the substitution rate of Grade 120 ground iron blast-furnace slag to up to 45% by weight of cement for minor structures and pavement. The combination of slag and fly ash or any cement containing fly ash shall not be allowed as partial substitution for cement.

Maine

A Type IP (MS) portland-pozzolan cement (blended hydraulic cement with moderate sulfate resistance) meeting the requirements of AASHTO M240 may be used instead of Type II or where Type I portland cement, meeting the requirements of AASHTO M85, is allowed.

Fly ash shall conform to the chemical and physical requirements for mineral admixtures, Class F, as listed in AASHTO M285. These physical requirements are fineness, strength activity index with portland cement, autoclave expansion, and uniformity requirements. The chemical requirements are silicon dioxide plus aluminum oxide plus iron oxide meeting a minimum 70%, sulfur dioxide, moisture content, and loss on ignition.

There is no specific application which requires the inclusion of fly ash by specification. Fly ash is allowed to be used in all classes of cast-in-place concrete, flowable fill, and precast concrete. The allowable partial replacement level of cement for fly ash is a 30% maximum for Class F fly ash.

GGBF slag shall conform to the chemical and physical requirements for mineral admixtures Grade 120 as listed in AASHTO M302. The maximum level of partial replacement of cement for GGBF slag is 50%. Silica fume material for use in portland cement concrete shall be one of the products listed on the DOT's approved list. There is no replacement rate for silica fume as it is treated as an addition much like an admixture. Regardless of which pozzolan is used, the total cementitious materal per cubic yard is limited to 660 lb. The maximum allowable cement content is 635 lb per cubic yard.

Maryland

Written in this section for the state of Maryland are specifications pertaining to the use of coal by-products in the state's DOT. However, after personal contact was established with official representatives of MDOT, it was stated that the only possible coal by-product Maryland uses is steel slag as a partial replacement for aggregate. It was never clarified why several specifications were listed on the FHWA Web site identifying the use of blended cements, fly ash, microsilica, GGBF slag, and pozzolans. It was decided that it was appropriate to go ahead and list these specifications with the understanding that they were obtained from an appropriate Internet source at the time of this report.

Blended cement shall conform to ASSHTO M240, Type I (PM) containing 15% to 25% pozzolan by weight of cement. Maximum loss on ignition shall be 3%, and GGBF slag shall not

be used for blending. The requirement of a manufacturer's written statement of the chemical composition is waived.

Concrete admixtures shall not contribute more than 200 ppm of chlorides based on the cement content when tested as specified in Maryland Standard Method of Tests (MSMT) 610. Only prequalified admixtures are allowed for use. A pozzolan and Type I (PM) or Type IP cement shall not be used in the same mix.

The contractor may request the use of pozzolans to control alkali silica reactivity or for other reasons. When a pozzolan is used, the minimum cement factor and water/cement ration shall be determined on the basis of the combined weight of cement or pozzolan. The variable amounts of cement which can be replaced by a mineral admixture are 15%–25% Class F fly ash, 25%–50% ground iron blast-furnace slag, and 5%–7% microsilica.

Fly ash shall conform to AASHTO M295, pozzolan C or F, except that the maximum permissible moisture content shall be 1%. GGBF slag shall conform to AASHTO C302, Grade 100 or 120. Microsilica shall conform to ASTM C1240, except that the oversize requirement is waived.

Massachusetts

All cement concrete masonry and precast/prestressed concrete products are required to be alkali silica reactivity-resistant. Concrete mixes are to include materials that meet either the aggregate's requirement or alkali-silica reactivity (ASR) mitigation criteria listed in a table entitled Tests and Criteria for Proposed Aggregates. Nonreactive aggregates are to be selected based on the criteria of this table. If nonreactive aggregates are used for portland cement concrete mix, 15% by mass of the cementitious content shall be fly ash meeting AASHTO M295 Type F specification.

A second table, listing mitigation methods for ASR in portland cement concrete, includes materials to be used, specifications each material must meet, and percentage rate each material may be used at. They are as follows:

- Low alkali cement, AASHTO M85, 100%
- Fly ash – Class F, AASHTO M295, 15% minimum to 30% maximum
- Silica fume, AASHTO M307, 5% minimum to 7% maximum
- Slag Grade 100 and 120, AASHTO M302, 25% minimum to 50% maximum

The fly ash, Type F, shall replace 15% by weight of the design cement content, and any additional fly ash will be considered as fine aggregate. The total amount of Type F fly ash and silica fume shall constitute 20% by weight of the cement content, and any additional fly ash will be considered as fine aggregate.

Whichever material or combination of materials shown in either table is used to mitigate ASR, test concrete mixes must be proportioned with reactive aggregates and verified for ASR. Verification testing must be performed according to AASHTO T303 "Accelerated Detection of

Potentially Deleterious Expansion of Mortar Bars Due to Alkali-Silica Reaction" and ASTM C295 "Petrographic Examination of Aggregates for Concrete" to determine the effectiveness of the result mix design against ASR.

Controlled density fill (CDF) fill can substitute for compacted gravel for backfills, fills, and structural fills. There are two main categories of CDFs: excavatable and nonexcavatable with a subcategory of flowable and very flowable. It shall be a mixture of portland cement, fly ash (if very flowable), sand, and water. These categories are as follows:

- Type 1, very flowable (nonexcavatable)
- Type 1E, very flowable (excavatable)
- Type 2, flowable (nonexcavatable)
- Type 2E, flowable (excavatable)

The very flowable mixes (Type I and IE) shall contain a minimum of 115 kilograms per cubic meter of concrete of Class F fly ash or high air (25% plus) and will be self leveling. Excavatable mixes (Type 1E and 2E) shall be hand tool excavatable.

Michigan

Types IS, I (SM), IS-A, and I (SM)-A blast-furnace slag cements must conform to ASTM C595. Type IP, I (PM), IP-A, and I (PM)-A pozzolan cements must also conform to ASTM C595.

GGBF slag must conform to ASTM C989, Grade 100, minimum. It can only be used as a blending material with Type I or Type IA portland cement. Fly ash must meet ASTM C618 requirements for both Class C and Class F, except that the loss on ignition shall not exceed 5% and the supplementary air-entraining admixture uniformity requirement shall apply. Silica fume, dry-densified, must conform to ASTM C1240 specification, and it can only be used as a blending material with Type I or Type IA portland cement.

Mineral filler for bituminous mixtures must be limestone dust, dolomite dust, fly ash collected by an electrostatic precipitation method, slag, or hydrated lime. The free carbon in the fly ash shall not exceed 12% by weight as measured by the loss on ignition test according to ASTM C311. Sources for fly ash must be selected for a qualified products list.

Fly ash may be used in concrete according to a preapproved table for concrete pavement mixture designs. The amount of cement allowable to be partially replaced with fly ash varies depending on its application. For commercial-grade concrete containing 517 lb of cement per cubic yard, the portland cement may be reduced up to 20% by weight when 1 lb of fly ash is substituted for each pound of cement removed. A greater quantity of fly ash or GGBF slag may be used, subject to the following requirements:

- Submit a mix design produced by a testing laboratory conforming to ASTM C1077 for review by the engineer.

- Use Type I or IA portland cement.

- Reduce the cement quantity shown in the preapproved table for mix designs, up to a maximum of 25% for fly ash substitution for up to 40% for GGBF slag substitution.

- The fly ash or GGBF slag weight additions must be equal to 1.0 times the weight of the cement reduction.

- For concrete containing portland cement, fly ash, and GGBF slag in the same mix design, reduce the cement quantity up to 40%, with the maximum fly ash quantity not exceeding 15%.

Minnesota

Portland-pozzolan cement shall conform to AASHTO M240, Type IS, Type IP or Type IP-A except as modified by the following: the fly ash constituent of the interground cement shall not exceed 20% and the fly ash constituent of blended cement shall not exceed 15%.

GGBF slag cement shall conform to AASHTO M302 except that the allowable slag classifications are limited to Grade 100 or 120. MNDOT allows 35% substitution of GGBF slag for cement for all concrete. Occasionally 5% silica fume is allowed for replacement of cement in concrete on bridge decks.

Fly ash for use in portland cement concrete shall conform to ASTM C618, Class F or Class C, except as modified by the following:

- Maximum CaO for Class F is 30%; maximum CaO for Class C is 40%.
- Maximum loss on ignition for both is 3.0%.
- Maximum available alkalies, expressed as Na_2O, for both is 3.0%.
- Minimum air permeability for both is 650 mm^2/kg.
- Maximum retained when wet-sieved on a 45-µm sieve for both is 30.0%.
- Minimum strength activity index with portland cement at 7 days is 75%.
- Maximum variation from established specific gravity value for both is $\pm$ 0.12.

Fly ash produced at plants where the limestone injection process is used for controlling air pollutants will be considered unacceptable for use in portland cement concrete. Fly ash which meets the requirements of both Class C and Class F shall be considered as being Class C. Fly ash is permitted as a partial cement replacement for up to 15% by weight for Class C and Class F in general concrete applications. Special provisions may allow higher percentages of fly ash substitutions. A fly ash substitution rate of 30% is allowed for concrete pavement and high-performance full-depth bridge decks. A list of certified fly ash sources is available. Only ashes from certified sources are allowed to be used. Mixing of fly ash from different sources or of different classes in one storage bin or silo is not acceptable.

Mississippi

When required or permitted in construction, fly ash shall be obtained from an approved source. Different classes of fly ash or different sources of the same class shall not be mixed or used without written permission from the engineer. The temperature of the bulk fly ash shall not be greater than 165°F at the time of incorporation into the work. In addition to these requirements, fly ash shall meet the following specific requirements for the intended use.

Fly ash is allowed up to 25% partial cement replacement in concrete. When used in portland cement in the production of concrete or grout, the fly ash shall meet the requirements of AASHTO M295, Class C or F, with the following exceptions: the loss on ignition shall not exceed 6.0%, and the pozzolanic activity index with portland cement shall be at least 55% of the control mix at 7 days. Fly ash shall not be used with portland cement Type IP. Both Classes, C and F, are used, depending on the desired properties of the mix, but most applications use Class C.

When used with hydrated lime in soil stabilization, the class of fly ash shall be specified in the contract. The fly ash, when mixed with hydrated lime and soil or soil-aggregate, shall produce the minimum design characteristic for the course to be stabilized. Both classes of fly ash are allowed, but most soil stabilization projects use Class F. Most applications specify 12% fly ash by weight in combination with 3% or 4% lime. The fly ash shall meet the requirements of AASHTO M295 for the class specified, except the loss on ignition shall not exceed 10%.

Grout for pressure grouting shall consist of a mixture of portland cement (25%–30%), water, calcium chloride, fly ash (25%–70%), and/or limestone dust (25%–75%), and fine sand (50%–75%). Grout for post-tensioned members shall consist of a mixture of 1 part portland cement, ¼ part fly ash, and ¾ part washed sand. Fly ash can also be used in lime–fly ash-treated courses. This work consists of constructing one or more courses of a mixture of soil, soil aggregate or aggregate, fly ash, lime, and water in accordance with these specifications and in reasonably close conformity with the lines, grades, thickness, and typical cross sections shown on the plans or established by the engineer.

Missouri

All blended hydraulic cement shall conform to the requirements of Type IP, I (PM), IS, or I (SM) of AASHTO M240 with the following modifications. The pozzolan constituent of Type IP shall not exceed 20% by weight of the total portland-pozzolan cement. Type IS or I (SM) cement shall be produced by the same manner as IP or I (PM). The slag constituent of Type IS or I (SM) shall not exceed 25% by weight of the total portland-slag cement. Types I, II, IP, I (PM), IS, or I (SM) shall be used for all general concrete construction.

GGBF slag shall conform to the requirements of AASHTO M302, Grade 100 or 120, except as herein specified. Only GGBF slag from qualified sources are permitted. GGBF slag may only be used with AASHTO M85 Type I or Type II portland cement unless otherwise directed by the engineer. The mixing of different grades and sources of GGBF slag is not permitted. All testing shall be performed by a MoDOT-approved laboratory.

Only fly ash from sources qualified in accordance with the following speciation will be permitted for use in concrete. The mixing of different classes and sources of fly ash will not be permitted. All fly ash shall conform to the requirements of AASHTO M295, Class C or F, except as herein specified. The loss on ignition shall not exceed 1.5%. The percent of each silicon dioxide, aluminum oxide, and iron oxide shall be reported in addition to the total of the three. Cement use by the marketing entity for testing fly ash shall meet the requirements of AASHTO M85. All tests shall be performed in a MoDOT-approved laboratory.

A contractor may use fly ash or GGBF slag in the production of concrete in accordance with these specifications. Approved Class C fly ash may be used as a partial cement replacement in concrete at a rate of up to 25% on a pound-for-pound basis. Class F fly ash may be used at a rate of up to 15%. Approved GGBF slag may be used to replace a maximum of 25% of Type I or II cement on a pound-for-pound basis in all concrete. Fly ash shall not be used as a replacement for Type III, IP, I (PM), IS, or I (SM) cement except for Type IP or I (PM) according to the previously noted exception. The quantity of fly ash shall not exceed 15%, and the quantity pf GGBF slag shall not exceed 25% by weight replacement of the cement.

Fly ash is also allowed for use in reinforced concrete culverts, storm drain and sewer pipe, precast box culverts, precast drainage units, under sealing pavement grout, flowable backfill, and fully grouted rock fill. A grout mix design must be submitted by the contractor for departmental approval.

Montana

When approved, use Type IP cement meeting AASHTO M240 requirements. Fly ash or Type IP cement may be substituted for portland cement provided the following requirements are met:

- Make the substitution at a minimum ratio of 1.2 parts of the substitute to 1 part of portland cement by weight. Do not exceed 20% replacement by weight of the total cement.

- Portland cement meeting AASHTO M85, Table 1, may be used in place of moderate heat of hydration cement where fly ash is substituted.

- Do not exceed a 0.53% water–cement ratio by weight for all concrete classes except for Class BD-modified, which is 0.44%. For calculation purposes, the cement weight is the total weight of Type IP cement or portland cement and replacement fly ash.

The following cementitious materials may be used as partial replacement for portland cement in the mix design:

- Fly ash may be included in the mix design for up to 20% by weight of the total cementitious material. Portland cement meeting AASHTO M85, Table 1, may be used in place of moderate heat of hydration cement where fly ash is substituted.

- Microsilica may be included in the mix design for up to 5% by weight of the total cementitious material when a minimum of 15% fly ash is also included in the mix design or when the mix design used Type IP blended cement.

- Metakaolin may be included in the mix design for up to 20% by weight of the total cementitious material.

- GGBF slag may be included in the mix design for up to 20% by weight of the total cementitious material.

Fly ash must meet AASHTO M295 mineral admixture Class C or Class F chemical requirements of Table 1, and the physical requirements of Table 3 in M295. It must also be from a source on the DOT's approved source list. Microsilica must meet AASHTO M307 specifications. Metakaolin must meet AASHTO M295 mineral admixture Class N, the chemical requirements of Table 1, and the physical requirements of Table 3 in AASHTO M295. Fly ash is also allowed to be use as a mineral filler.

Nebraska

Type IP (portland pozzolan) cement may be used in any application where fly ash-modified concrete is allowed. Type IP cement shall conform to the requirements as prescribed in ASTM C595 and the following requirements:

- The pozzolan content shall be 15% to 25 % of the cementitious materials by weight.

- The pozzolan shall be Class F or Class N natural pozzolan.

- Additional fly ash substitution shall not be allowed with Type IP containing Class F fly ash. If Class N natural pozzolan is used in the Type IP cement, fly ash substitution is allowed to a maximum pozzolan content of 25%.

- A water-reducing admixture shall be used in concrete produced with Type IP cement.

- Type IP cement shall not contain more than 0.80% equivalent alkali.

The only coal by-products used in highway construction are Class C and Class F fly ashes. All fly ash must meet the requirements of ASTM C618 except for Class C that is used for soil stabilization.

Fly ash can be used in flowable fill applications. A mix design is furnished which identifies 200 lb of fly ash and 50 lb cement be used in a cubic yard of flowable fill. Approximate strength should be 85 to 175 psi.

Table 3. State Department of Transportation Specifications

State	Fly Ash (FA)	Fly Ash Use in Concrete	GGBF Slag	Silica Fume (SF)	Other Uses
Alabama	AASHTO M295	Class F: 20% Class C: 30%	AASHTO M302: Grades 100 and 120 Concrete – 50% Temp. < 45°F – 25%	AASHTO M307 Concrete: 10% or 25% FA + 10% SF	Blended cement: IP Mineral filler in asphalt
Alaska	AASHTO M295	Class C and F: 20% 1.25#C/1#cement 1–1.25#F/1#cement		AASHTO M307	
Arizona	ASTM C618	Class C and F 20% 1.2# FA/1#cement			
Arkansas	AASHTO M295 Class C or F	Class C and F: 20%	AASHTO M302: Grades 100 and 120 Concrete – 25%		Blended cement: IP, PM, SM Flowable fill, cement-treated base course
California	ASTM C618 Class F	Class F: 15%–25%		ASTM C1240 Concrete: 7%–10% or 25% FA and 10% SF	Blended cement: IP, MS
Colorado	ASTM C618 Class F	Class F: 20%–30%	Bed course and slope protection	ASTM C1240	Blended cement: IP, MS, GU ASTM C595
Connecticut		Class C and F: 15%			CLSM
Delaware	AASHTO M295	Max. allowed: 20%			Blended cement: IP, I (PM), IS, I (SM) ASSHTO M240
Federal Lands Highways	AASHTO M295 Class C or F	Class F: 20% ratio 1.5/1 Class C: 25% ratio 1/1	AASHTO M302: Grades 100 and 120 Concrete – 50%	AASHTO M307 Concrete: 10%	Fly ash aggregate, soil and subgrade stabilization, mineral filler, grout, masonry mortar
Florida	ASTM C618 Class C or F	Regular concrete: 18%–22% Mass concrete: 18%–55%	ASTM C989, reg. concrete: 25%–70% Mass concrete: 50%–55% Drilled shaft concrete: 58%–62%	ASTM C1240 Reinforced concrete: 7%–9%	Blended cement: IP, IS, MS Drilled shaft grout: 33%–37% fly ash, CLSM
Georgia		Max. allowed: 15% FA/cement ratio: 1.5/1	Max. allowed is 50% on high-early-strength concrete		
Hawaii	ASTM C618	Max. allowed: 15%			Blended cement: IP ASTM C595
Idaho	AASHTO M295 Class F	Class F: 20%–25%			
Illinois	AASHTO M295 Class C or F	Class F: 15% ratio 1.5/1 Class C:20% ratio 1.2/1	Grades 100 and 120, max. allowed: 30%, Precast max. allowed: 25%		Subbase stabilization, CLSM, drilled shaft grout; FA: 15% ratio 1.5/1, GGBF slag: 25%
Indiana	ASTM C618 Class C or F	Class C and F: 20%–25%	ASTM C989: Grades 100 and 120	ASSHTO M307	Blended cement: ISA, IPA, IS, IP AASHTO M240
Iowa	AASHTO M295 Class C or F	Class C and F: 15%	ASTM C989: Grades 100 and 120 Max. allowed in concrete: 35%		Blended cement: IS, IP
Kansas		Class F: 20% Class C: 10%	Maximum allowed in concrete: 35%		Blended cement: IS, IP

Continued. . .

Table 3. State Department of Transportation Specifications (continued)

State	Fly Ash (FA)	Fly Ash Use in Concrete	GGBF Slag	Silica Fume (SF)	Other Uses
Kentucky	ASTM C618 Class C or F	FA: 25%–30% ratio 1.25/1, 20% FA and 30% GGBF slag	Max. allowed in concrete: 50%	ASSHTO M307	Blended cement: IP, IPA ASTM C595, CLSM, grout
Louisiana	ASTM C618 Class C or F	General concrete: 20% Structural concrete: 15%	AASHTO M302: Grade 120 Max. allowed in concrete: 50%		Blended cement: IP, IS AASHTO M240
Maine	AASHTO M295 Class F	Class F: 30%	AASHTO M302: Grade 120 Max. allowed in concrete: 50%	Allowed but no specified rate	Blended cement: IP (MS) AASHTO M240
Maryland	AASHTO M295 Class C or F	Class F: 15%–25%	AASHTO M302: Grades 100 and 120 Max. allowed in concrete: 25%–50%	ASTM C1240 Concrete: 5%–7%	Blended cement: IPM AASHTO M240
Massachusetts	AASHTO M295 Class F	Class F: 15%–30% For ASR mitigation	AASHTO M302: Grades 100 and 120 For ASR mitigation: 25%–50%	AASHTO M307 ASR: 5%–7%	Control density fill
Michigan	ASTM C618 Class C or F	Class F: 15%–30% FA + GGBF slag: 15% + 25%	ASTM C989: Grade 100 Max. allowed in concrete: 40%	ASTM C1240	Blended cement: IS, I (SM), IP, I (PM) ASTM C595, mineral filler
Minnesota	ASTM C618 (very modified) Class C or F	General concrete: 15% Full-depth bridge deck concrete: 30%	AASHTO M302: Grades 100 and 120 Max. allowed in concrete: 35%	Occasionally 5% allowed in bridge decks	Blended cement: IS, IP, IPA AASHTO M240
Mississippi	AASHTO M295 Class C or F	Class C and F: 25%			Soil stabilization (12% fly ash + 3%–4% lime), grout
Missouri	AASHTO M295 Class C or F	Class F: 15% Class C: 25%	AASHTO M302: Grades 100 and 120 Max. allowed in concrete: 25%		Blended cement: IP, IS, IPM, I (SM), AASHTO M240
Montana	AASHTO M295 Class C or F	Class C and F: 20% FA/cement ratio: 1.2/1	Max. allowed in concrete: 20%	AASHTO M307 5% SF w/15% FA	Blended cement: IP AASHTO M240
Nebraska	ASTM C618 Class C or F	Class F: no specified rate			Blended cement: IP, ASTM C595, CLSM, soil stabilization (Class C only)
Nevada	ASTM C618 Class C, F, or N				Blended cement: IP, IP (MS) ASTM C595, crack sealant
New Hampshire	AASHTO M295 Class F	Variable mix designs with fly ash, GGBFS, and SF	AASHTO M302: Grade 120		
New Jersey	ASTM C618 Class C or F	Class C or F: 15%–25%	AASHTO M302: Grade 120 Max. allowed in concrete: 30%	Bridge deck overlays (7 ± 0.5%)	Blended cement: IS, IPM, ISM grout, mineral filler
New Mexico	ASTM C618 Class C or F	Class C or F: 20%	Allowed use in concrete: 25%–50%	Concrete: 5%–12%	Blended cement: ASTM C595, flowable fill
New York	ASTM C618 Class F	General concrete: 20% Precast concrete: 15% Reinforced concrete: 25%	AASHTO M302: Grade 100	AASHTO M307	Blended cement: IP AASHTO M240, CLSM

Continued. . .

Table 3. State Department of Transportation Specifications (continued)

State	Fly Ash (FA)	Fly Ash Use in Concrete	GGBF Slag	Silica Fume (SF)	Other Uses
North Carolina	ASTM C618 Class C or F	Pavement, precast, and prestressed: 20% at a ratio of 1.2#FA/1#cement	AASHTO M302: Grade 100 Max. allowed in concrete: 50%	ASTM C1240 Concrete: 4%–8%	Blended cement: IS, IP – AASHTO M240
North Dakota	AASHTO M295 Class C or F	Max. allowed: 30%			Stabilized soil
Ohio	ASTM C618 Class C or F	Max. allowed: 15%	ASTM C989: Grade 100 Max. allowed in concrete: 30%	ASTM C1240	Blended cement: SM – ASTM C595, CLSM
Oklahoma	AASHTO M295 Class C or F	FA: 15%–20%, FA and other pozzolan: 28%, FA + GGBF slag + SF: 50%	AASHTO M302: Grades 100 and 120 Max. allowed in concrete: 50%	ASTM C1240	Blended cement: M240 – ISM, IPM, IS, and IP, C1157: GU, MS, HS, MH and LH; grouts, CLSM
Oregon	AASHTO M295 Class C or F	Class C or F: 20%–35%	AASHTO M302	AASHTO M307	Blended cement: SM AASHTO M240
Pennsylvania	AASHTO M295 Class C or F	General: 15%, variable mixes w/ASR concerns	ASTM C989 or AASHTO M302: Grades 100 and 120, Max. allowed in concrete: 25%–50%	AASHTO M307	FA w/lime – ASTM C593 Flowable fill with variable FA, bottom ash, and GGBF slag
Rhode Island	AASHTO M295 Class C or F	Max. allowed: 15%	ASTM C989: Grades 100 and 120 allowed in concrete	AASHTO M307 Concrete: 7%	Blended cement AASHTO M240
South Carolina	AASHTO M295 Class C or F	Variable mix designs with FA, GGBF slag, and SF	ASTM C989: Grade 100	ASTM C1240	Blended cement: ISM AASHTO M240
South Dakota	AASHTO M295 Class C or F	Class C or F: 15%–20%			Blended cement: IP, AASHTO M240, grout, mineral filler
Tennessee	AASHTO M295 Class C or F	Class C: 25% Class F: 15% ratio 1.25/1	AASHTO M302; Grade 100s and 120 Max. allowed in concrete: 25%		Blended cement: AASHTO M240 – ISM, IP, soil–lime–FA base course – ASTM C593, CLSM
Texas		General concrete: 35% Reinforced concrete: 20%–35% Class F: 40%			Blended cement: IP, ASTM C595 Lime – FA treated base course, mineral filler
Utah	ASTM C618 AASHTO M295 Class F or N	Class F or N: 20%		ASTM C1240	Blended cement: IP, IPMS, HS – ASTM C595, grout, CLSM
Vermont	AASHTO M295 Class C, F, or N	Class C, F, or N: 20%	AASHTO M302: Grades 100 and 120 Max. allowed in concrete: 25%	Allowed at state DOT specification	Blended cement: IP, AASHTO M240
Virginia	ASTM C618 Class C or F	Class C or F: 30%	ASTM C989: Grades 100 and 120	AASHTO M307 Concrete: 10%	Blended cement: AASHTO M240 IP, IS, lime stabilization – ASTM C593, mineral filler
Washington	AASHTO M295 Class C or F	Class F only: 25%	AASHTO M302, Grades 100 and 120		Blended cement: IP(MS), IP, IS AASHTO M240, CLSM

Continued. . .

Table 3. State Department of Transportation Specifications (continued)

State	Fly Ash (FA)	Fly Ash Use in Concrete	GGBF Slag	Silica Fume (SF)	Other Uses
West Virginia	ASTM C618 Class C or F	Class C or F: 15%–19%	AASHTO M302, Max. allowed in concrete: 30%–45%	AASHTO M307 Concrete: 8%	Blended cement: ASTM C595 – IP, IS, CLSM
Wisconsin	ASTM C618 Class C	General concrete: 30% Superstructure: 15%–25%, reinforced: 5%–25%	ASTM C989: Grades 100 and 120 Slip form: 50%, reinforced: 5%–25% superstructure: 20%–30%, other: 30%		Blended cement: ASTM C595 – IP, FA in stabilized subbase
Wyoming	ASTM C618 Class C or F	Class C: 15% Class F: 20%–25%			Blended cement: AASHTO M240 I (PM)
Washington, D.C.	AASHTO M295 Class C or F	Class C or F: 15%	ASTM C989: Grade 120 Max. allowed in concrete: 50%		Blended cement: AASHTO M240 IS, IP, soil–lime–FA: ASTM C593

Nevada

Type IP blended cement shall conform to ASTM C595. The pozzolan constitute in blended cement must be limited to 20% by weight of the total. The cement shall not contain more than 0.60% by mass of alkalies. Type IP cement which exceeds the allowable alkali content may be used if mortar bars made and tested according to ASTM C227, using the proposed cement and a selected highly alkali-reactive aggregate, show no more than 0.05% expansion at 6 months.

Pozzolanic admixtures can be used in concrete and shall conform to ASTM C618, Type C, Type F, or Type N except the loss on ignition shall not exceed 5%. The laboratory furnishing the test data must be inspected by the CCRL.

If sulfate protection not required, for reinforced concrete pipe, cement may be Type II, Type V, or Type IP (MS). When using type IP cement, the requirement that the pozzolan constituent be only fly ash is waived. These specifications also pertain to precast concrete box culverts.

Fly ash can be used as a crack sealant, to the surface of concrete or masonry, at a rate level of 12% by weight.

New Hampshire

Classes of concrete are divided into a table which specifically includes fly ash, silica fume, or GGBF slag as shown on the plans or ordered. For mixes containing fly ash, silica fume, slag, or any other pozzolanic ore cementitious material, the water/cement ratio of the concrete shall be based on the total cementitious contents. The water to cementitious ratio shall not exceed those listed in the table. Class F concrete, also called flowable fill, shall have a minimum 28-day compressive strength of 30 psi and an 84-day maximum strength of 200 psi.

Fly ash shall conform to Class F as described in AASHTO M295 and shall meet the testing requirements except that in the optional physical requirement, the multiple factor shall be 120% maximum. In addition, the fly ash shall be subjected to the Air-Entrainment of Mortar Test as listed in ASTM C311. GGBF slag shall conform to the chemical, physical, and methods of sampling and testing requirements of AASHTO M302 except that the slag shall meet the requirement for slag activity index Grade 120. If a Class C fly ash is used, the contractor must summit to the department, for its approval, its design mix. Class F fly ash, conforming to AASHTO M295, can be used in reinforced concrete pipe.

New Jersey

Only blended cement types IS, I (PM), and I (SM) may be used. Portland cement may be preblended with a maximum of 15% fly ash, by weight, or a maximum of 10% silica fume by weight, or with a maximum of 50% GGBF slag by weight. If more than 30% GGBF slag is used, a scaling test conforming to ASTM C672 must be completed on the mix design, and the concrete must have a visual rating less than 3 as based on C672 after 50 cycles. When blended portland cement is used, no additional admixtures shall be added.

Fly ash for portland cement concrete shall conform to ASTM C618, Class C or Class F except that the loss on ignition shall not be more than 3%. Fly ash used to control alkali-silica reactivity shall be Class F. Fly ash for other uses shall form to ASTM C593 except that the loss on ignition shall be not more than 10% and the combined content of silica and aluminum oxide shall be a minimum of 50%.

GGBF slag for use as a cementitious material in portland cement concrete shall conform to the requirements of ASHTO M302, Grade 120. GGBF slag may be used as a replacement for portland cement conforming to ASTM C150 or white portland cement up to a maximum replacement level of 30% by weight. When GGBF slag is used, its use shall continue throughout the project so as not to create color inconsistencies in the finished concrete.

Fly ash and GGBF slag are identified as acceptable ingredients in portland cement concrete, mortar, and grout. If fly ash is added, its weight shall not exceed 15% of the minimum cement content and shall not be greater than 25% of the weight of cement replaced. If fly ash is added to control ASR, the minimum amount required shall not be less than 15% to the total cementitious material. If AASHTO T303 standard test method results in an expansion greater than 0.40%, the minimum addition of fly ash shall be 20%. Fly ash may replace no more than 15% of the portland cement; the remaining fly ash will replace fine aggregate. If GGBF slag is used to control ASR, the amount required shall not be less than 25% of the total cementitious material.

Aggregates for under drains shall be of broken stone, washed gravel, or blast furnace slag. Mineral fill for hot mix asphalt shall be broken stone, fly ash, or other inert mineral matter. Silica fume concrete, for bridge deck overlays, shall include the sources of aggregates and the composition of silica fume admixture such as fineness, silica content, total chloride ion content, solids content for slurries, and moisture content for powders. The maximum silica fume content can be 7% $\pm$ 0.5% of the total cementitious content.

Fly ash can be used in lime-pozzolan base course. The amount of fly ash which can be used in a mix is 9% to 24% by weight of total dry material. The lime-to-fly ash ration shall be 1:3 minimum to 1:4 maximum. When tested according to ASTM C311, the limitations for its use are:

- Maximum loss of ignition 10%
- Minimum combined silica and aluminum oxide 60%
- Moisture content 0.5%
- Minimum amount passing No. 200-mesh sieve 85%
- Minimum amount passing No. 325-mesh sieve 80%

Issues in the future that expect to be changed include:

- For high-performance concrete, fly ash and slag can be used at any level, and silica fume will probably be given an upper limit, although that limit has not yet been decided.

- Aggregates for under drains will have blast-furnace slag removed.
- Mineral filler in asphalt will have “other inert material” removed.
- Lime pozzolan base course will be removed.

New Mexico

Blended cements shall meet the requirements of ASTM C595 and ASTM C1157 and shall consist of portland cement uniformly blended with fly ash either by intergrinding the portland cement and fly ash or by blending the portland cement and the fly ash. The blended cement shall contain a minimum of 20% of fly ash by weight.

Fly ash shall conform to the physical and chemical requirement of ASTM C618, including the optional requirements for available alkalies and reactivity with cement alkalies. Both classes of fly ashes shall have maximum values for the following chemical characteristics: moisture content = 1.0%, loss on ignition = 3.0%, magnesium oxide = 5.0%, available alkali = 1.5%, and calcium oxide = 10.0%. The contractor shall use Class F fly ash if either the coarse or the fine aggregate is reactive. If both aggregates are nonreactive, then the contractor may choose to use a C/F blend fly ash or a Class C fly ash. Blending of Class C and Class F fly ashes is permitted. However, the blended fly ash must be preapproved by the DOT. Blended fly ash shall meet all requirements of ASTM C618 for Class F fly ash and may only be used in concrete in which both the coarse and the fine aggregate is nonreactive. Class F fly ash shall be added at a minimum dosage rate of 20% by weight of cement only. When a Class C or C/F blended fly ash is used in place of the Class F fly ash, it may be used at a minimum dosage rate of 25% by weight of the cement.

Class F fly ash shall be added to all concrete mixtures used on DOT projects. If fly ash is the only pozzolan used, it shall be added as a minimum of 20% by weight of cement only. When nonreactive aggregated is used, a Class C or C/F blended fly ash may be used in place of the Class F fly ash at a minimum dosage of 25% by weight of cement. If other pozzolans, such as silica fume, metakaolin, or GGBF slag is used, then the minimum amount of fly ash used may be reduced to 12% for mixtures using Class F fly ash and 15 % for mixtures using Class C ash. When multiple pozzolans are used, the total pozzolan content shall be at least 20% when Class F fly ash is used and 25% when Class C or C/F blended fly ash is used.

Fly ash is specified as an ingredient in flowable fill. Approved Class F, Class C, and Class C/F blended fly ashes are allowed. It is specified that a cubic yard of flowable fill shall contain a maximum of 50 lb of cement and 150–300 lb of fly ash. Fly ash is also acceptable in prestressed concrete members and augured pressure-grouted bearing piles.

If the contractor elects to use an aggregate source which has been designated as potentially reactive, a combination of one or more of the following ASR inhibiting admixtures shall be used to provide a concrete mixture that meets the maximum expansion requirements: Class F fly ash, blended cement, GGBF slag, silica fume, and lithium nitrate. In this application, a minimum of 20% by weight of cement must be used for either the fly ash or the blended cement. GGBF slag

may be used from 25% to 50% by weight of the cement, and silica fume may constitute from 5% to 12% by weight of the cement.

New York

Blended cements shall conform to the chemical and physical requirements as described in AASHTO M240. Acceptable types are IP (fly ash content does not exceed 22% by weight of the cement), SF (silica fume does not exceed 10% by weight of the cement), SM (GGBF slag does not exceed 22% by weight of the cement), and Ternary blend cement. This blended cement consist of cement, fly ash, and silica fume in which the total supplementary cementitious content does not exceed 30% by weight. The fly ash portion shall range from 15% to 25%, and the silica fume shall range from 6% to 10% of the total cementitious mass. There are tables of chemical and physical requirements a blended cement must meet before it is allowed to be used.

In general, construction fly ash may be used as a partial cement replacement up to a maximum of 20% of the combined cementitious mass. Fly ash shall conform to the chemical and physical requirements for mineral admixture Class F listed in ASTM C618 including Table 2, except that the loss on ignition shall not exceed 4%. The DOT will consider request to evaluate alternate cement and/or fly ash combinations such as ASTM C618 Type C fly ash, Class N, and ASTM C595 Type IP cement.

GGBF slag may be used as a partial replacement for portland cement in portland cement concrete as long as it conforms to the chemical and physical requirements for Grade 100 slag as described in AASHTO M302. GGBF slag is also allowed for use in local road gravel surface, base, and subbase courses.

Silica fume may be use in portland cement concrete and other mixes. It must conform to the requirements of AASHTO M307 including optional chemical and physical requirements, as well as DOT specified guidelines for uniformity of silicon dioxide content, chloride content, fineness, and uniformity of percent solids.

Fly ash may also be used in general precast concrete up to a maximum of 15% by weight of the total amount of cement plus pozzolan in the mix. Fly ash may be used up to a maximum of 25% by weight of the cementitious material in several classes of reinforced concrete pipe. Specialized overlays for structural slabs can be composed of combinations of cement, fly ash, and silica fume.

Fly ash is used in many CLSM applications except in those instances when the CLSM is contact with cast iron or ductile iron pipes, fittings, or appurtenances.

Allowable lightweight aggregates include those prepared by expanding or sintering materials such as shale, slate, clay, fly ash, or blast-furnace slag. The requirements of ASTM C330 shall apply.

North Carolina

Type IP blended cement or type IS blended cement may be used in lieu of portland cement, and fly ash or GGBF slag may be substituted for a portion of the portland cement.

For concrete pavement, the cement content of the mix design may be reduced by up to 20% and replaced with fly ash at a minimum rate of 1.2 lb of fly ash to each pound of cement replaced. Use a maximum water cement ratio on total cementitious materials of 0.538. As an option, in precast concrete units, the cement content of the mix design may be reduced by up to 20% and replaced with fly ash at a rate of 1.2 lb of fly ash for each pound of cement replaced or reduce the cement content up to 50% and replace with blast-furnace slag on a pound-for-pound basis. Fly ash and GGBF slag can also be used as a partial cement replacement in prestressed concrete members.

Fly ash must meet the requirements of ASTM C618 for Class F or Class C except that the loss on ignition does not exceed 4%. Table 1A, Supplementary Optional Chemical Requirements of ASTM C618, applies to Class F fly ash. Use fly ash also meeting the optional physical requirements for uniformity as shown in Table 2A of ASTM C618. Do not use Class C fly ash in portland cement concrete if the alkali content of the cement exceeds 0.4%. The laboratory which performs the tests are required to be regularly inspected by the CCRL for fly ash testing and is required to authorize CCRL to submit a copy of the inspection reports directly to the NCDOT.

Use blast-furnace slag meeting the requirements of AASHTO M302, Grade 100. Silica fume must meet the requirements of Tables 1, 2, and 3 of ASTM C1240.

For concrete mix designs containing an aggregate that has exhibited alkali-silica reactivity the alkali content of the cement may not exceed 0.4%. However, cement with a higher alkali content not to exceed 1% is allowed if used with Class F fly ash, GGBF slag, microsilica, or other NCDOT-approved pozzolans in the amounts shown below:

- Class F fly ash – 20% by weight of required cement content, with 1.2 lb of Class F fly ash per lb of cement replaced.
- GGBF slag – 35%–50% by weight of required cement content.
- Microsilica – 4%–8% by weight of required cement content, with 1 lb of microsilica per lb of cement replaced.

Type IP or IS blended cements are allowed for the cement-and-fly-ash or cement-and-slag portion of the mix. Use Type IP blended cement meeting the requirements of AASHTO M240 except that the pozzolanic content is limited to between 17% and 23% by weight and the constituents are interground. Use Type IS blended cement meeting the requirements of AASHTO M240 except that the slag content is limited to between 35% and 50% by weight and the constituents are interground.

North Dakota

Fly ash must meet the following specification for the specific type of work:

- Portland cement concrete – AASHTO M295
- Lime fly ash-treated subgrade – ASTM C593
- Econocrete – AASHTO M295
- Aggregate base – ASTM C593

The requirement for loss on ignition in AASHTO M295 (Table 1 chemical requirement) is modified from 5% to 2% maximum. Fly ash shall be from an electrical generating plant using a single coal source. Fly ash produced at plants where the limestone injection process is used for controlling air pollutants will be considered unacceptable for use in portland cement concrete.

Fly ash replacement of cement is allowed on a 1:1 ration, up to a maximum of 30% by weight. Fly ash will not be allowed as a cement substitute when high-early-strength concrete is used. Lime or lime–fly ash mixtures may be used in the top layer of stabilized subgrade.

Ohio

Slag-modified portland cement (SM) must conform to ASTM C595 specification. Micro-silica must meet ASTM C1240 specifications and be approved by the Ohio DOT laboratory. GGBF slag must be a Grade 100 minimum as prescribed by ASTM C989. Fly ash for use in portland cement concrete must conform to ASTM C618, Class C or F, except that the maximum loss on ignition must be 3%.

There are three general classes of concrete mix designs. The concrete proportioning is based on developing an average concrete compressive strength at 28 days of 4000 psi for Class C, 3000 psi for Class F, and 4500 psi for Class S. The cement content in each of these mixes can be reduced 15% by weight and substituted with an equivalent weight of fly ash. GGBF slag can be used at a 30% replacement level of portland cement. These general concrete mixes can only be used between April 1 and October 15 when they include fly ash or GGBF slag.

There are four classes of high-performance concrete which specify the use of mineral admixtures. They are described as HP1 (fly ash), HP2 (GGBF slag), HP3 (fly ash + microsilica), HP4 (GGBF slag + microsilica). Only Class C fly ash can be used in HP concrete mixes.

Class C and F fly ashes can be used for low-strength mortar backfill. Alternate mix designs can be submitted by the contractor, which contain alternate materials, including fly ash that does not meet ASTM specifications.

Oklahoma

Portland cement shall conform to the requirements of AASHTO M85, AASHTO M240, or ASTM C1157. Type I, Type I (SM), Type I (PM), Type IS, Type IP, and Type GU (hydraulic cement for general construction) shall be used in concrete for general construction. Type MS or

Type HS (high-sulfate resistance) shall be used in concrete exposed to moderate sulfate action, and Type IV, Type MH, or Type LH shall be used in concrete to moderate heat of hydration, when specified on the plans or in the proposal. Fly ash shall meet the requirements of AASHTO M295, Class C or Class F. GGBF slag shall meet the requirements of AASHTO M302, Grade 100 or 120. Silica fume shall meet the requirements of ASTM C1240. All other approved substitutes shall be cementitious or pozzolanic in nature and meet the requirements of ASSHTO M295 and be approved by the materials engineer.

There are five classes of preapproved portland cement concrete mixes, based on their applications. Fly ash may be substituted for up to 15% (20% from April through October) of the required cement. A combination of fly ash, pozzolan, or other approved substitutes meeting the requirements of AASHTO M295 may not exceed 28%. GGBF slag may be substituted for up to 50% of the required cement. Silica fume may be substituted for up to 10% of the other required cement. A combination of GGBF slag, fly ash, silica fume, or other approved substitutes may replace up to 50% of the required cement provided none of the above limits is exceeded. Substitution shall be by weight: 1 lb for each 1 lb of cement. No cement substitutions other than silica fume are allowed in Class P concrete (prestressed concrete).

Fly ash is allowed for slurry grouts which are used for stabilizing concrete pavements by undergrouting methods. Fly ash is also used for soil aggregate treated bases and Econocrete CLSM bases. In open-graded portland cement concrete base, fly ash may be substituted for up to 25% of the required cement, with this substitution in the ratio of 1 lb of fly ash for each 1 lb of cement. Fly ash shall not be used November 1 through April 1.

Oregon

Blended hydraulic cement shall be either Type IP portland-pozzolan cement or Type SM slag-modified portland cement conforming to AASHTO M240. The fly ash used shall be Class C, Class F, or Class N and shall conform to AASHTO M295, including Table 2, except that:

- Loss on ignition shall be 1.5% maximum.
- Moisture content shall be 1.0% maximum.
- Amount retained on the 45-µm (No. 325) shall be 30% maximum.

Except for high-performance concrete, fly ash may be used in concrete to replace a portion of the cement and as an additive to increase the total amount of cementitious materials. As a replacement for cement, fly ash may comprise up to 20% of the minimum specified cement content. Additionally, the maximum allowable percentage of fly ash shall be 35% of the total cementitious materials, provided that the mix design contains at least 80% of the minimum specified cement content.

GGBF slag shall meet the requirements of AASHTO M302. Microsilica can be used as a slurry containing microsilica, water, and a high-range water reducer or as a densified powder. The microsilica portion shall conform to AASHTO M307, including Table 1A, Optional Chemical Requirements.

Pennsylvania

For use with portland cement concrete, fly ash must meet AASHTO M295 specifications, for Class C, F, or N, except limit the loss on ignition to a maximum of 6%. For use with lime, fly ash must meet ASTM C593 specifications. GGBF slag must meet AASHTO M302 (ASTM C989) specifications for Grade 100 or 120. Silica fume must meet AASHTO M307 specifications for use in concrete.

Portland cement may be replaced with pozzolan (fly ash or GGBF slag) weighing as much as or more than the portland cement replaced. If pozzolan is used, do not place fly ash and GGBF slag in the sample mix. If fly ash is used, the portland cement portion may be reduced by a maximum of 15%. If GGBF slag is used, the portland cement portion may be reduced by a minimum of 25% to a maximum of 50%.

For use with aggregate deemed potentially reactive, provide a portland cement, blended cement, or portland cement-pozzolan combination conforming to the following requirements:

- Portland cement – conforming to the optional chemical requirement in AASHTO M85 for a maximum alkali content of 0.60%

- Blended hydraulic cement – Type IS or IP according to ASTM C595

- Portland cement-pozzolan combination – furnish a combination of portland cement with an alkali content no greater than 1.40% and fly ash, GGBF slag, or silica fume and qualified by the following criteria:

  – Fly ash – furnish fly ash that conforms to the optional chemical requirement in AASHTO M295 for a maximum alkali content of 1.5% and that produces a 50% minimum reduction in mortar expansion when testing according to ASTM C441. Use a quantity of fly ash equal to a minimum of 15%, by mass, of the total cementitious material. If fly ash is added to reduce alkali-silica reactivity, use a quantity of fly ash between 15% and 25%, by mass, of the total cementitious material. If aggregate expansion, when tested according to ASHTO TP14, is greater than 0.40%, use a quantity of fly ash equal to a minimum of 20%, by mass, of the total cementitious material. Fly ash may replace no more than 15% of the portland cement; the remaining fly ash is to replace the fine aggregate.

  – GGBF slag – furnish slag producing a 50% minimum reduction on mortar expansion when tested according to ASTM C441. Use a quantity of slag between 25% and 50%, by mass, of the total cementitious material. If aggregate expansion, when tested according to AASHTO TP14, is greater than 0.40%, use a quantity of GGBF slag equal to a minimum of 40%, by mass, of the total cementitious material.

  – Silica fume – use a quantity of silica fume between 5% and 10%, by mass, of the total cementitious material. Use of silica fume will be allowed on an experimental basis only, until sufficient experience is gained.

The DOT may waive fly ash or GGBF slag requirements if the contractor presents test results from an independent laboratory showing that a lesser amount of pozzolan will mitigate ASR expansion to below 0.10% when tested according to AASHTO TP14.

Fly ash, GGBF slag, and bottom ash are allowed for use flowable backfill. The fly ash must conform to AASHTO M295 (or ASTM C618) Table 1 requirements except maximum loss on ignition is 16%, and excluding the requirements of Table 1A, 2, or 2A. Bottom ash must be from a preapproved source and have a maximum loss of 20% in the soundness test.

Rhode Island

Blended hydraulic cements shall both conform to the chemical and physical requirements of AASHTO M240 and be listed on the DOT's list of approved materials and suppliers. Fly ash for replacement of portland cement shall conform to the chemical and physical requirements of AASHTO M295, Class C or F, except for the loss on ignition, which is a maximum of 4%. Silica fume shall conform to the chemical and physical requirements of AASHTO M307. GGBF slag shall conform to the chemical and physical requirements of ASTM C 989, Grades 100 or 120.

Mineral admixtures such as fly ash, blast-furnace slag, and silica fume may be permitted as a partial replacement of portland cement in any concrete as approved by the engineer. Mineral admixtures shall be listed on the DOT's list of approved materials and suppliers.

Fly ash can be substituted or added to portland cement in the amounts specified in the contract documents. If no quantity has been so-specified, the contractor has the option of substituting fly ash for portland cement up to 15% by weight on a 1:1 ratio. Fly ash is not allowed to be substituted for portland cement after October 15 and prior to March 15.

Microsilica shall be substituted or added to portland cement in the amounts specified in the contract documents. If the use of microsilica is specified by the engineer, but no quantity has been listed in the contract documents, the microsilica content shall be 7% by weight of portland cement on a 1:1 ratio. Any portland cement concrete mix containing microsilica shall not exceed a water/cement ration of 0.40.

GGBF slag shall be substituted or added to portland cement in the amounts specified in the contract documents. GGBF slag shall not be substituted for portland cement after October 15 and prior to March 15.

Fly ash, microsilica, and GGBF slag are not permitted to be used in Class X (AE) concrete. The department identifies this class of concrete, containing 705 lb of cement per cubic yard of concrete, for prestressed/precast I-beams, cellular slabs, box elements, and structural elements.

South Carolina

Type I (SM) slag-modified portland cement may be used instead of Type I and Type II cement and shall conform to AAASHTO M240. It shall be an intimate and uniform blend of

portland cement and GGBF slag. In any case, the slag constituent shall be less than 25% of the total weight of the slag-modified Portland cement.

Fly ash (Type C or Type F) shall conform to the requirements of AASHTO M295 except that the supplementary optional physical requirements will not apply. GGBF slag shall be Class 100 or higher and shall conform to the requirements of ASTM C989. Silica fume shall meet the general requirements of ASTM C1240. The raw silica fume shall meet the chemical requirements of Table 1 and Table 2 and the physical requirements of Table 3 in ASTM C1240.

Concrete mixes, used with structural steel applications, shall be designed with 600 lb of cement, 140 lb of fly ash, and 42 lb of silica fume. There are two preapproved flowable fill mix designs both specifying 600 lb of fly ash per cubic yard of mix.

Fly ash and GGBF slag may be used in concrete for pipe culverts in accordance with the following requirements:

- Fly ash shall meet ASTM C618 for Type F or C with a maximum Na_2O of 1.5%. GGBF slag shall meet the requirements of ASTM C989, Grade 120.

- The amount of cement to be replaced by fly ash shall not exceed 15%, and the amount to be replaced by GGBF slag shall not exceed 50%. Fly ash shall replace the cement in the ratio of not less than 1.2 to 1 by weight. GGBF slag shall replace the cement in the ratio of no less than 1:1 by weight.

- Fly ash and slag will be accepted only from approved sources.

- Mix designs must show the amount of cement being replaced and be preapproved.

- Storage and handling equipment must be provided for each material.

South Dakota

Fly ash for portland cement concrete pavement shall conform to AASHTO M295 Class C or F, including the optional requirements, except as modified by the following:

- Loss on ignition, 2.0% maximum
- Moisture content, 2.0% maximum
- Available alkali as, Na_2O 1.5% maximum

Fly ash shall be from approved base-loaded electric generating plants using a single coal source. Plants using a limestone injection process for controlling air pollutants are not acceptable. Fly ash from the start-up and shutdown of the plant shall not be used. For normal pavement concrete, the maximum replacement limit of fly ash for cement is 20%, and it is replaced on a 1:1 rate per pound. Class C fly ash is only allowed for pavement jacking, undersealing, flowable fill, etc. Class F modified fly ash is required for normal concrete applications.

Available alkalies up to 2% may be used, provided mortar expansion test results at 14 days is less than or equal to that of the control sample. The expansion test shall be run in accordance with modified ASTM C441.

Fly ash will not be permitted, when Type III cement is used. Pozzolan-modified cement, if used, shall conform to AASHTO M240. Fly ash may not be substituted for a portion of pozzolan-modified portland cement. If fly ash is substituted for cement in concrete, the minimum amount of cement to be replaced is 15%, and the maximum amount is 20% by weight. For concrete pavement, the 28-day compressive strengths of concrete with fly ash shall be at least 95% of the 28-day compressive strength obtained using the design mix with cement only.

Fly ash is allowed in structural concrete, which is used in bridges, box culverts, and miscellaneous structures. Grout mixtures, for pavement jacking, are proportioned as 1 part portland cement with 3 parts fly ash. Mineral filler, for mineral aggregates in asphalt concrete, shall consist of finely ground particles of stone, fly ash, lime, or portland cement.

Tennessee

Type I, Type I-SM, or Type I cement with either fly ash or GGBF slab as a partial cement replacement shall be used unless otherwise specified or permitted. Portland-pozzolan cement, Type IP, shall meet the requirements of AASHTO M240.

Fly ash shall meet the requirements of AASHTO M295, Class F or Class C, for the class specified. Fly ash of different classes or sources used as a partial cement replacement in Type I, portland cement concrete will not be permitted on the same project. The maximum variation from the average of the loss on ignition for Class F and C fly ash shall be no greater than 1%. The minimum cement pozzolanic activity index, at 7 days for Class C and F fly ash, is 60%. The minimum cement pozzolanic activity index, at 28 days for Class C and F fly ash, is 75%.

GGBF slag shall meet the requirements of AASHTO M302, Grade 100 or 120. GGBF slag of different grades or sources used as a partial cement replacement in Type I Portland cement concrete will not be permitted on the same project.

Both fly ash and GGBF slag shall not be used as a partial cement replacement on the same project. When Type I (SM) cement is used on a project, neither fly ash nor GGBF slag as partial cement replacement will be permitted.

For the design of portland cement concrete with Type I cement modified by the addition of fly ash or GGBF slag, the following is the limitation for maximum replacement rate (by weight) and minimum substitution ratios (by weight) for the type of modifier; GGBF slag may replace a maximum of 25% of the cement at a 1:1 minimum replacement ratio. Class F fly ash may replace a maximum of 15% of the cement at a 1.25:1 minimum replacement ratio. Class C fly ash may replace a maximum of 25% of the cement at a 1:1 minimum replacement ratio.

Fly ash is allowed for use in aggregate–lime–fly ash stabilized base course. Fly ash shall meet the requirements of ASTM C593 except that loss on ignition shall not exceed 10% and the

combined silicon dioxide (SiO_2), aluminum oxide (Al_2O_3), and iron oxide (Fe_2O_3) shall be more than 60%. The lime, fly ash, and aggregate design shall be proportioned within the following limits based on dry weight: lime (3.5%), fly ash (11%), aggregate (85.5%). Fly ash used in flowable fill shall be proportioned as follows for a cubic yard of material: Type I portland cement (100 lb), fly ash – Type C or F (minimum 250 lb), fine aggregate (2800 lb), and water (approx 60 gal).

Texas

Type IP portland-pozzolan cement shall conform to all the requirements of ASTM C595, with the following modifications:

- Portland-pozzolan cement shall be a uniform blend of portland cement and pozzolan produced by intergrinding portland cement clinker and pozzolan, in which the pozzolan constituent is between 20% and 35% of the portland-pozzolan cement.

- The pozzolan shall conform to the DOT material specification for Type A.

Fly ash may be used as a mineral filler in asphalt. There are no maximum limits in the standard specifications for hot-mix asphalt. Fly ash may also be used for lime–fly ash (LFA) treatment for materials used as subgrade and base courses. There are no maximum limits for ash used for subgrade and base treatment, as the percentage used is based on a mix design or previous experience. In reinforced concrete pipe, the contractor has the option of using portland cement or portland cement plus fly ash. The fly ash may constitute 20% to 35% of the cementitious volume. Fly ash may replace up to 35% of the cement in a general concrete application. The specification limit for Class F fly ash limits the maximum fly content to 40%.

Utah

Type IP blended cement may be substituted for Type I cement and must conform to ASTM C595 specifications. Type IP (MS) blended cement may be substituted for Type II cement. Type HS blended cement may be substituted for Type V cement and must conform to ASTM C595 specifications. Do not use fly ash as a replacement for any blended cement.

Fly ash must conform to ASTM C618 Class F specifications with the following modifications: loss on ignition not to exceed 3% and the maximum allowable CaO content not to exceed 15%. When used as partial portland cement replacement, the fly ash may replace 20% of the cement by weight. Fly ash may only be used from the list of UDOT prequalified sources.

Natural pozzolan must conform to ASTM C618. It may be used instead of fly ash provided that the 14-day expansion test (ASTM C1260) with the job aggregates and job cement does not exceed that for the same aggregates and cement with a UDOT-approved Class F fly ash. Silica fume must conform to ASTM C1240.

Fly ash may be used in grout mixtures for "Approach Slab Jacking." The fly ash must meet the requirements specified in AASHTO M295. For use in "Flowable Fill," the fly ash must meet the requirements specified in ASTM C618.

Vermont

Portland-pozzolan cement shall conform to the requirements of AASHTO M240, Type IP except that the pozzolan constituent shall not be more than 20% of the total mass of the Portland-pozzolan cement. Blended silica fume cement shall conform to the requirements of ASTM C1157.

Pozzolans and fly ash shall conform to the requirements of AASHTO M295. The supplier shall provide the state with the test results of the ten consecutive samples preceding the one submitted for approval to demonstrate compliance with the uniformity requirements shown in Table 2 of AASHTO M295. The combining of different types of fly ash or the mixing of the same type of fly ash from different sources will not be permitted. GGBF slag shall conform to the requirements of AASHTO C302

The contractor may substitute fly ash up to a maximum of 20% of the required portland cement. The flay ash shall be substituted at a minimum ration of 1 lb of fly ash for 1 lb of portland cement. Fly ash shall not be substituted for Type IP cement. The use of fly ash in high-early-strength concrete will not be permitted. The contractor may substitute GGBF slag, Grade 100 or 120 for portland cement. The substitution rate will be limited to a maximum of 25% of the required portland cement for concrete. The GGBF slag shall be substituted at a minimum ratio of one unit of GGBF slag for one unit of Portland cement. Fly ash and GGBF slag will not be permitted in the same concrete mixture.

Silica fume shall conform to the following chemical and physical requirements:

- Silicon dioxide, minimum %.....85.0
- Sulfur trioxide, maximum %.....3.0
- Moisture content, maximum %.....3.0
- Loss on ignition, maximum %.....6.0
- Available alkalies as Na_2O, maximum %.....1.5
- Specific surface area, m^2/kg.....6000

Pozzolanic activity index:

- With cement at 28 days, minimum %.....100
- Autoclave expansion, maximum %.....0.8

Specific gravity:

- Variation from average, maximum %.....5.0

Virginia

Cementitious materials shall be a blend of mineral admixtures and portland cement or a blended cement. The blended hydraulic cement shall conform to the requirements of AASHTO M240, Type I (P) or Type I (S). GGBF slag shall conform to the requirements of ASTM C989, Grade 100 or 120. Silica fume shall conform to the requirements of AASHTO M307. As a portion of the cementitious material, the fly ash content shall not exceed 30% for both Class C and Class F, the GGBF slag shall not exceed 50%, and the silica fume content shall not exceed 10%. Fly ash used in hydraulic cement concrete shall conform to the requirements of ASTM C618, Class F or Class C. Fly ash used in lime stabilization shall conform to the requirements of ASTM C593. Fly ash is also allowed as a mineral filler in asphalt.

Washington

Blended hydraulic cement shall be either Type IP (MS) or Type I (SM)(MS), or Type I (PM)(MS) cement conforming to AASHTO M240 with the additional requirements that the use of portland blast-furnace slag cement and pozzolans other than fly ash are not allowed in Type IP (MS) and Type I (PM)(MS) cement and that the maximum amount of fly ash in Type IP (MS) is limited to 25% by weight of the cementitious materials.

Fly ash shall conform to the requirements of AASHTO M295 Class C or F including optional chemical requirements as set forth in Table 1A and with a further limitation that the loss on ignition shall be a maximum of 1.5%. If fly ash is used, the contractor shall provide test results from ASTM C441 that show the fly ash does not cause an expansion reaction greater than that of the comparison control mixture prepared with cement of alkali between 0.40% and 0.60%. GGBF slag shall meet the requirements of AASHTO M302, Grade 100 or Grade 120.

Fly ash, if used in cement concrete pavement, shall be limited to Class F with a maximum CaO content of 15% by weight. The fly ash shall be limited to 25% by weight of the total cementitious material. As an alternative to the use of fly ash and cement as separate components, a blended hydraulic cement may be sued.

Fly ash is prescribed for use in controlled density fill. For a cubic yard of material, 50 lb of cement is mixed with 3300 lb of fine aggregate and 300 lb of Class F fly ash. If Class C fly ash is used, then 50 lb of cement is mixed with 3500 lb of fine aggregate and 150 lb of fly ash.

West Virginia

Blended hydraulic cement shall conform to the requirements of ASTM C595 for portland blast-furnace slag cement, Type IS, or portland-pozzolan cement, Type IP. For latex-modified concrete and microsilica concrete, fly ash may be substituted for cement to a maximum of 1¼ bags per cubic yard. The microsilica concrete will contain 50 lb of silica per cubic yard of concrete.

Fly ash, in portland cement concrete, shall conform to ASTM C618 requirements for fineness, loss on ignition, and maximum oxide ($SiO_2 + Al_2O_3 + Fe_2O_3$) value for Class C or F.

GGBF slag shall conform to the requirements of AASHTO M302, Table I and II, except that the slag activity index requirements of Table II do not apply. Microsilica shall conform to the requirements of AASHTO M307 except Table 2 shall not apply.

A preapproved concrete mix design table lists five types of concrete classes. Depending on the class of concrete specified, fly ash may be substituted for cement at a 15% or 19% replacement level. Likewise GGBF slag replacement levels can be 30% and 45%, and microsilica can be used in all classes at an 8% replacement level.

Bottom ash and fly ash may be use in CLSM applications. There is no maximum or minimum specified amount of either of these materials. This is up to the supplier when formulating a mix design. GGBF slag has also been used as a backfill material.

Wisconsin

Blended cements must conform to ASTM C595 specifications for Type IP (except maximum loss on ignition is 2%), Type IS, and Type I (SM). In concrete, the fly ash must conform to ASTM C618 Class C, including the supplemental optional requirements provided, except loss on ignition is limited to a maximum of 2%. GGBF slag, conforming to ASTM C989, Grade 100 or 120, is allowed for use in several grades of concrete. Fly ash is also an approved material to stabilize subbases.

In concrete pavements, the minimum cement content shall be 565 lb per cubic yard of concrete. Fly ash may be used as a partial replacement of portland cement at a replacement ration of not less than 1 lb of fly ash per 1 lb of cement up to a maximum fly ash content of 30% of total cementitious material. Alternatively, slag may be used as a partial replacement for cement at a replacement ration of not less than 1 lab of slag per 1 lb of cement. For slipformed concrete pavement, the maximum slag content shall be 50% of the total cementitious material. For concrete pavement placed by methods other than slipformed, the maximum slag content shall be 30% of total cementitious material.

Class C fly ash or Grade 100 or 120 slag shall be used as a partial replacement of portland cement for all superstructure and substructure concrete. Class C fly ash shall be used at a replacement ratio of not less than 1 lb fly ash per 1 lb cement, in such quantity so that fly ash content is within the range of 15% to 25% of total cementitious material. Alternately, Grade 100 or 120 slag shall be used at a replacement ratio of not less than 1 lb slag per 1 lb of portland cement, in such quantity so that the slag content is within the range of 20% to 30% of total cementitious material.

When providing reinforced concrete pipe storm sewers, the concrete mixture must contain not less than 565 lb of cementitious materials per cubic yard. One of the following combinations of cementitious materials must be used in the concrete:

- Portland cement only
- Portland blast-furnace slag cement only

- Portland pozzolan cement only

- A combination of portland cement and fly ash where the fly ash is between 5% and 25% by weight of the total cementitious material

- A combination of portland cement and GGBF slag where the slag is between 5% and 25% by weight of total cementitious material

For reinforced concrete pipe culverts, the alternatives for mineral admixtures include a combination of portland cement and fly ash where the fly ash is between 15% and 35%, a combination of portland cement and GGBF slag where the slag is between 15% and 35%, or a combination of portland cement, fly ash, and GGBF slag where the combined weight of the fly ash and GGBF slag is between 15% and 35% by weight of total cementitious material.

Wyoming

Blended hydraulic cement shall meet the requirements of AASHTO M240 for Type I (PM) cement. Fly ash, used in concrete pavements, shall conform to the requirements of ASTM C618 (including Table 1A) for either Class C or Class F. For aggregate sources that are determined to be reactive by the Materials Program, requirements will included the use of ASTM C618 Table 2A, Supplementary Optional Physical Requirements. Fly ash used in concrete and for blended cement must be evaluated by standard procedures detailed in ASTM C311.

An optional substitution of Class C fly ash for portland cement up to a maximum of 15% by mass may be made on a 1:1 replacement ratio when approved by the Materials Program. The substitution rate for Class F fly ash is 20%; as much as 25% has been allowed in special cases.

A list of approved fly ashes is maintained by the DOT. Some, but not all, Class F ashes are approved for use in ASR mitigation. Class C ash is not allowed for ASR mitigation. The DOT uses ASTM C1260 expansion tests to qualify an ash for ASR mitigation. Level I paving (e.g., Interstate) requires the use of 20% Class F fly ash replacement.

District of Columbia

Blended cement shall conform to AASHTO M240 for Type IS or IP. Fly ash may be substituted for cement such that not more than 15% by weight of cement is removed. The mix may require more fly ash added than cement removed. GGBF slag, when used as a substitute for portland cement shall conform to the requirements of ASTM C989, Grade 120. GGBF slag is allowed to replace up to 50% of the total cementitious material.

Fly ash and other pozzolans shall conform to the requirements of ASTM C593, when used with lime and a mixture of soil, soil aggregate, or aggregate. Fly ash used in portland cement concrete shall meet the requirements of AASHTO M295, Class C or Class F, except that maximum loss on ignition for Class C and F shall be 4%.

CONCLUSION

All states had in place specifications pertaining to coal combustion products and their applications. The single most noted application is the partial replacement of cement in concrete. For this reason, the most commonly referenced specifications were ASTM C618 or AASHTO M295. Both are designed as methods of verifying if an ash can be used as a partial cement replacement in concrete. It was common practice for transportation departments to often change their specification from the indicated ASTM C618 and AASHTO M295 to reflect regional practices.

The most significant changes in DOT specifications from 1992 were the additions of specifications for CLSM, GGBF slag, and blended cements. During the earlier comparison study, most states were aware of CLSM applications, but few had in-place specifications for its uses. The specified use of blended cements is an indication of the increased use of fly ash within the cement industry, as is also the case for GGBF slag. Some states have already adopted, or are currently in the process of doing so, updated specifications for utilizing coal combustion products. Differences between DOT specifications still varied greatly between states, even neighboring ones. A transition in material specifications to performance specifications will gradually blur the lines between state specifications.

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