Stoppings: Technology Developments and Mine Safety Engineering Evaluations
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Abstract

Advances in materials technology have resulted in newer products for the construction of stoppings used in USA underground coal mines. Some of the newer materials were developed for the construction industry and were consequently introduced into the mining industry. . Ventilation control devices such as stoppings, overcasts and undercasts have traditionally been constructed of concrete block or metal panels. Efforts to reduce material and labor costs in the construction of stoppings and other ventilation controls have led to the introduction and use of "nontraditional" materials. The "nontraditional" or newer materials may consist of lightweight blocks composed of various cement-type compounds or panels composed of gypsum or other mineral-type compounds, and plastic membrane and steel fabricated designs. Reduced labor and material costs may be derived from such materials, while required safety properties are maintained.

An MSHA engineering evaluation program was developed to assess the suitability of such newer products in terms of the safety standards for fire endurance and flexural strength as specified in USA Title 30, Code of Federal Regulations, Part 75.333. The engineering evaluation program is described and a short description of the fire endurance and flexural strength tests is presented. A discussion of the newer materials evaluated is included.

Introduction

When permanent ventilation controls such as stoppings, overcasts, and undercasts are installed in underground coal mines, they are required to meet the safety standards specified in USA Title 30, Code of Federal Regulations, Part 75.333 [1]. This safety standard requires that permanent ventilation which includes overcasts, undercasts, shaft partitions, permanent stoppings, and regulators be constructed of noncombustible material. Noncombustible material is defined in Part 75.301 [1] as a material which when used to construct a ventilation control results in a control that will continue to serve its intended function for one hour when subjected to a fire test incorporating an American Society for Testing and Materials, International, ASTM E-119-88 temperature/time heat input, or equivalent [2]. Additionally, the ventilation control must meet a flexural strength that is equal to or greater than a conventional 20.32-centimeter hollow core concrete block stopping. The 20.32-centimeter hollow core concrete block with mortared joints has been tested and shown to have a minimum strength of 190.42 kilograms per square meter. The ASTM E-72-80 is used to determine the flexural strength [3]. Also, sealants or coatings applied to ventilation controls to reduce air leakage must have a flame spread index of 25 or less. The flame spread index test specified in Part 75.333 is the ASTM E-162-87 [4].

The basis for the safety standard of fire endurance and flexural strength relates to concrete block. Concrete block has been a long time traditional material for the construction of mine stoppings. However, the construction of a concrete block stopping is labor intensive and time consuming. The blocks are heavy and injuries from carrying and lifting the blocks can result. Developments in materials technology have resulted in newer, lighter materials to replace the use of concrete block, particularly for the construction of stoppings. As an engineering aid in evaluating newer materials and designs for ventilation controls to assess their suitability as replacement for conventional materials, a program was developed by the MSHA Approval & Certification Center. Details are subsequently presented on the evaluation program and the newer materials evaluated.

Newer construction materials

As a result of advances in materials technology, newer products have become available for the construction of ventilation controls, particularly for stoppings used in underground coal mines. Some of the newer materials were developed for the building and construction industry and were subsequently introduced into the mining industry. Another development was the use of fly ash as a component in the manufacture of lightweight blocks. Ventilation control devices such as stoppings, overcasts and undercasts have traditionally been constructed of concrete block or steel panels.

Efforts to reduce material and labor costs in the construction of stoppings have led to the introduction of newer lightweight materials for the construction of ventilation controls. Traditional stoppings are usually constructed of hollow-core concrete blocks by dry stacking or by binding with mortar between the block joints. A difficulty with using concrete blocks is they are heavy. A typical 20.32-cm wide by 20.32-cm high by 40.64-cm long hollow core concrete block weighs on average about 18 kg. Today, comparable lightweight blocks weigh much less, which can be one third or less weight, or around 12 kg or less. The lightweight blocks are generally available in various sizes from 15.24 cm thick and 20.32 cm or 30.48 cm high and 60.96 cm long.

Some of the “nontraditional” or newer materials consist of lightweight blocks composed of various cement-type compounds or mixtures which may include fly ash or inorganic oxides such as calcium oxide and sand. Sometimes a small amount of plastic fibers are used in cement-type block mixtures to prevent micro cracks from developing into macro cracks. There are also block units made from autoclaved aerated concrete mixture. This type of unit is based on calcium silicate hydrates in which low density is acquired from reaction of the formulated materials to produce macroscopic voids in the finished product.

Other newer products are panels composed of gypsum or other mineral-type compounds, and plastic membrane and steel fabricated designs. Reduced labor and material costs may be derived from the use of lightweight blocks or the newer materials and designs, while the required safety properties are maintained. One factor in determining whether to use the "nontraditional" or newer materials would be the mine conditions and ventilation control factors. Will the stopping construction resist heaving and crushing? Are the newer materials readily available and affordable? Also, the most cost-effective ventilation controls are not necessarily those built in the shortest possible time. The steel and composite-type designs may require more effort to install. They are not advantageous for use where the openings are non-uniform, since additional materials and effort will be needed to close openings and gaps. Cost effectiveness is maximized by incorporating those qualities into ventilation controls that will minimize air loss. Ventilation controls that are well constructed will reduce air loss, power and fan maintenance costs. In the future, there may also be "smart materials" used in the construction of stoppings and other ventilation controls. The "smart material" would have sensors and components to monitor and determine movement and structural integrity of a ventilation control. Such a material, known as a "smart brick" for use in building construction is being developed at the University of Illinois [5].

Engineering Evaluation Program

Because of the newer materials and designs being introduced for the construction of ventilation controls, an engineering program was established by the MSHA Technical Support, Approval & Certification Center to assess the suitability of the newer products [6]. The program has been in effect for several years. The engineering evaluations are intended to provide information to mine operators and mine inspection personnel on those "nontraditional" or newer types of ventilation control materials that meet the safety standards prescribed in Part 75.333. "Nontraditional" ventilation controls may consist of, but are not limited to, flexible plastic membrane materials, unique steel fabricated designs, or lightweight blocks composed of fly ash and cement-type materials.

The engineering evaluation program is not intended to evaluate the "traditional" ventilation controls, such as hollow core or solid concrete block. The program is voluntary. The MSHA regulations do not require a manufacturer of materials to be used for stoppings or other ventilation controls to be submitted for approval. The manufacturer or mine operator would have to produce evidence to MSHA enforcement personnel that the materials used in the construction of a permanent ventilation control meet the prescribed requirements. The MSHA voluntary program is designed as a mechanism or aid to the mine operator and MSHA enforcement personnel about those newer materials that have been found suitable.

The application procedure for an engineering evaluation can be acquired from MSHA's home page at http://www.msha.gov/techsupp/acc/application/asap5006.pdf.

In addition, test guidelines and performance criteria for the evaluation of "nontraditional" ventilation controls can be acquired from MSHA's home page at http://www.msha.gov/techsupp/acc/application/acri5001.pdf.

An hourly fee is charge by the MSHA Approval and Certification Center for the engineering evaluations made. If a “nontraditional” ventilation control is found to be suitable by MSHA from the engineering evaluation, then a suitability number will be issued to the applicant.

The type of information and data that an applicant would need to provide consists of a description of the product and trade name; composition of the materials used to construct the stopping or ventilation control; test data from an independent laboratory with the results of the flexural strength test and the fire endurance test; instructions for use of the product; and program to maintain product compliance with the specified safety requirements.

Fire Endurance and Flexural Strength Tests

The American Society for Testing and Materials, ASTM E-119-88 is used for determining the fire endurance (noncombustibility) of a “nontraditional” stopping. The test specimen, which is to be representative of the proposed in-mine construction, is exposed to a furnace or heat source of the E-119 test method. The area of the test specimen exposed to the radiant heat of the furnace is specified as not less than 9.29 m^2, with neither dimension less than 2.74 m. The criteria to meet the fire endurance requirement is that the test specimen must remain in place and not permit the passage of visible flames during the one-hour exposure period. Also, openings in excess of two square inches must not develop in the test specimen during the one-hour exposure period. Figure 1 is an illustration of the time/temperature heat input in the ASTM E-119 test method.

The ASTM E-72-80 is used for determining the flexural strength of a “nontraditional” stopping. Three test walls of the stopping are prepared and separately tested using the ASTM E-72 test. The width of each test wall is nominally 1.22 m and the height conforms to approximately 2.44 m. The stopping must exhibit an average transverse strength of at least 190.42 kg/m^2. An example of an E-72 test being conducted on a lightweight block stopping is shown in Figure 2.

Engineering Evaluations of Nontraditional Ventilation Controls

Engineering evaluations of several different types of “nontraditional” ventilation controls had been made by the MSHA, A&CC. The ventilation controls ranged from steel studding combined with gypsum or cement board, plastic membrane material using construction hardware and sealant, lightweight blocks using fly ash and cement-type constituents, and an innovative design using steel in a folding (book) type stopping. An illustration of a “nontraditional” stopping constructed and being sprayed with a cement-type material in a coal mine is shown in Figure 3.

Those “nontraditional” ventilation controls evaluated by the MSHA, A&CC, and which have been issued a suitability number under the voluntary program are listed on MSHA’s internet site. The list may be accessed at

http://www.msha.gov/TECHSUPP/ACC/lists/ventcontrol/Stoppingsuitabilitynumbers.pdf
.
The list does not include those “nontraditional” ventilation controls evaluated and found suitable by the MSHA, A&CC prior to charging administrative fees for evaluations.

Summary

Newer materials for the construction of ventilation controls, particularly stoppings, continue to enter the mining industry. The emphasis for the newer materials relates to being lighter that conventional hollow core concrete block and quicker installation. Panels composed of gypsum or other mineral-type compounds or plastic membrane and blocks containing fly ash are lighter than standard concrete blocks. Injuries from lifting and handling may be reduced by using these lighter weight materials for construction of stoppings and other ventilation controls. The steel and composite-type designs may require more labor to install. They are not advantageous for use in non-uniform openings without additional materials and effort to close openings and gaps. The most promising of the “nontraditional” ventilation controls evaluated appear to be the lightweight blocks.

Advancements continue to be made in the development of newer, stronger, and lighter materials and improved joint sealing compounds. Newer materials that are developed for other industries will continue to find application as materials for the construction of ventilation controls. The ease of construction and the reduction in labor and material costs for ventilation controls will continue to be overriding factors for greater acceptance of “nontraditional” materials.

References

[1] USA Code of Federal Regulations, Title 30, Part 75, Subpart D—Ventilation, 75.301 and 75.333, July 1, 2005.

[2] Standard Test Methods of Fire Tests of Building Construction and Materials, American Society for Testing and Materials, ASTM E-119-88, 1988.

[3] Standard Methods of Conducting Strength Tests of Panels for Building Construction, American Society for Testing and Materials, ASTM E-72-80, 1980.

[4] Standard Test Method for Surface Flammability of Materials Using a Radiant Heat Energy Source, American Society for Testing and Materials, ASTM E-162-87, 1987.

[5] CBS News: The Osgood File, CBS Worldwide Inc., Developing “smart bricks” for construction, Wednesday, August 11, 2004.

[6] Verakis, Harry C., Engineering Evaluation of “Nontraditional” Ventilation Controls, Society of Mining Engineers Annual Meeting, 2003, February 24-26, Cincinnati, OH, Preprints.

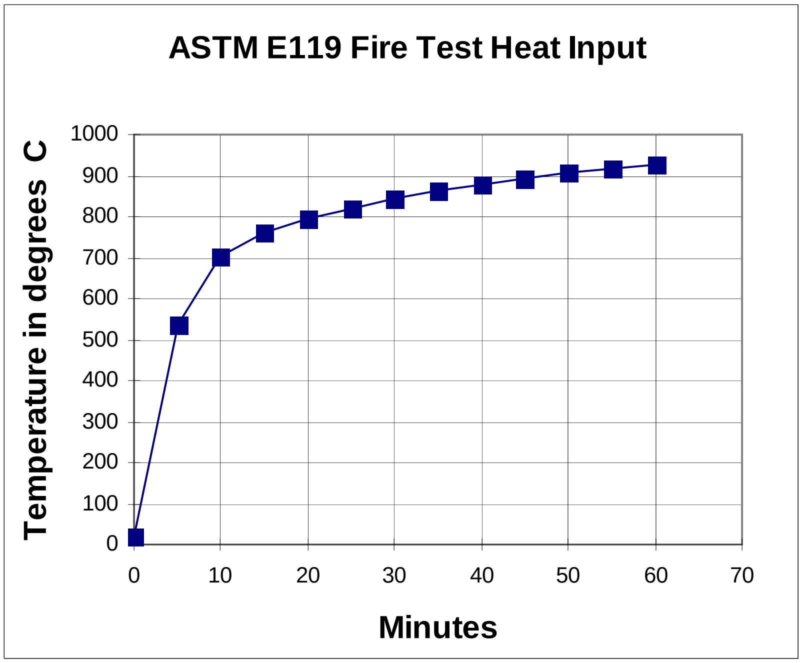

Figure 1 – Time/temperature Heat Input for the ASTM E-119 Test Method

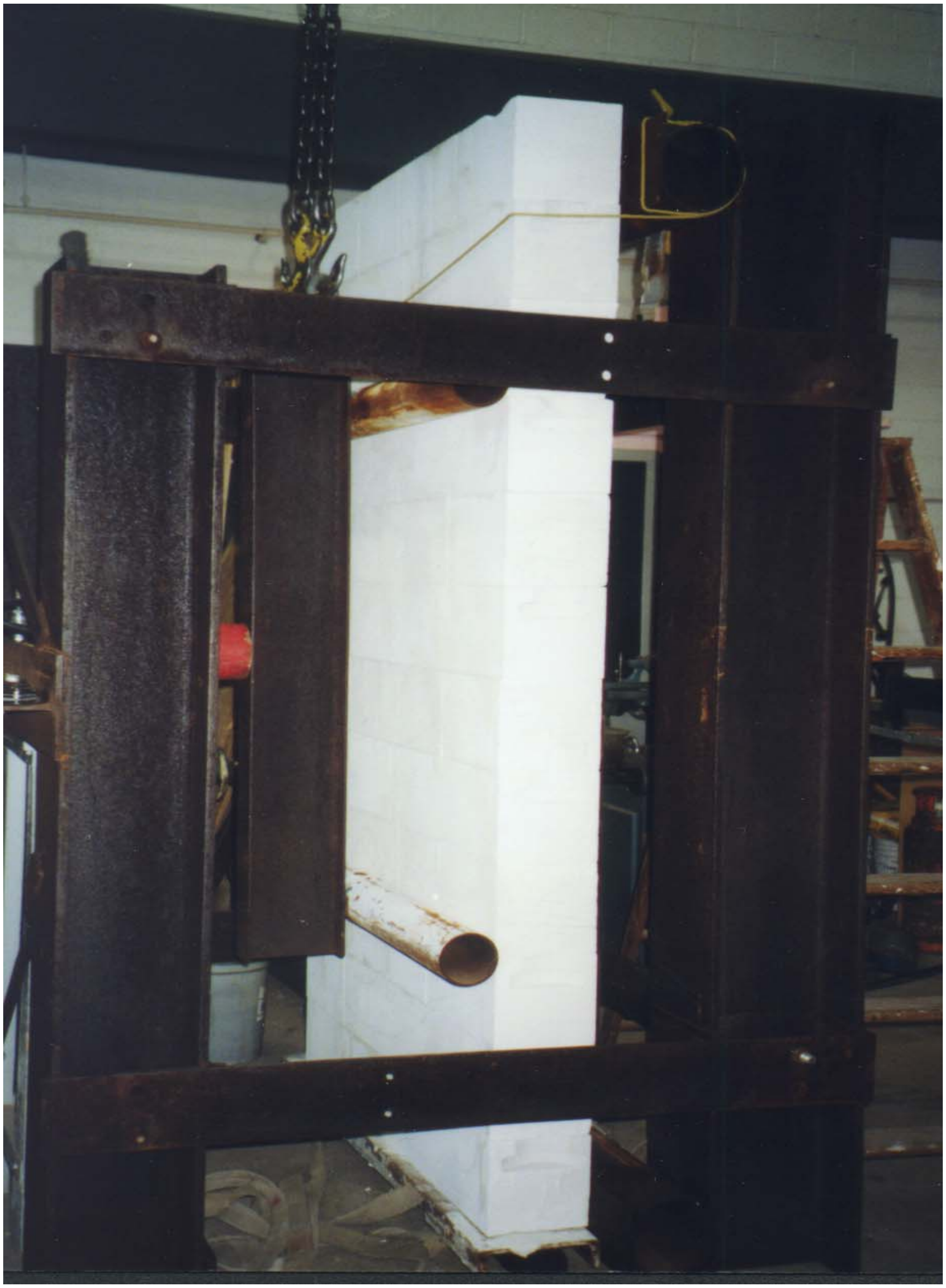

Figure 2 – Flexural Strength Test, ASTM E-72, on Lightweight Block

Figure 3 - A "Nontraditional" Stopping Constructed and being Sprayed with Cementatious Material in a Coal Mine

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