OVERVIEW OF THE NCHRP PROJECT PROVISIONAL SPECIFICATION

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ABSTRACT

Various countries such as France (Laboratoire Central Ponts et Chaussées 1990), Germany (Forschungsgesellschaft et al. 1995; BASF AG 1995), Japan (Public Works Research Institute 1992), Norway (Public Roads Administration 1980; 1992a; 1992b; 1992c), and the United Kingdom (Sanders and Seedhouse 1994) have developed design guidelines and manuals to design an embankment on soft soil incorporating EPS-block geofoam. However, despite the extensive and continuing worldwide use of EPS-block geofoam, there is a lack of specific design guidelines and specifications for use of EPS-block geofoam in roadway embankments in the United States (U.S.). As a result, an objective of the National Cooperative Highway Research Program (NCHRP) Project No. HR 24-11 titled "Guidelines for Geofoam Applications in Embankment Projects" is to develop design guidelines and construction specifications for the use of geofoam in roadway embankments and bridge approaches over soft ground. The specification is presented herein and should facilitate the use of geofoam in civil engineering projects by providing engineers with a combined material, product, and construction specification.

KEYWORDS: Embankment, Expanded Polystyrene, Geofoam, Lightweight Fill, Quality Control, Quality Assurance, Specification

INTRODUCTION

The overall objective of NCHRP Project 24-11 is to develop a consistent design methodology and specification to optimize performance and cost of EPS - block geofoam as lightweight fill in road embankments. The final product of the research will include both recommended design guidelines and material specifications in the American Association of State Highway and Transportation Officials (AASHTO) format. It is anticipated that the results of this research will encourage engineers to consider design alternatives incorporating EPS - block geofoam as a lightweight fill more in the future than they have in the past. Phase I of II of the NCHRP project was completed in April 2000 and the results can be found in an interim report (UIUC 2000). The objective of Phase I was to develop a provisional design methodology for the use of EPS-block geofoam for road embankments through the preparation of provisional (interim) design guidelines and specifications. These provisional documents are based solely on an assessment of existing technology and literature. Phase II is currently being performed. The objective of Phase II is to develop a refined version of the design methodology and specification including development of design charts to facilitate usage in practice.

The proposed design methodology is based on the assumption that the EPS-block geofoam meets a set of minimum material and construction standards. Therefore, a complementary provisional specification was developed. The provisional specification is a combined material, product, and construction specification covering block-molded expanded polystyrene (EPS) for use as lightweight fill. The specification is intended to be used in conjunction with the provisional design guidelines also included in the interim report. Because of space constraints, this paper only provides an overview of the provisional specifications.

BASIS OF THE PROVISIONAL SPECIFICATION

Currently, ASTM Standard C 578 (American Society for Testing and Materials 1995) is the primary standard utilized in practice as a material specification for EPS-block geofoam. The standard was written primarily for the use of polystyrene in thermal insulation applications and not lightweight fill. Therefore, the overall basis of the ASTM C 578 standard may not be applicable nor sufficient for load-bearing applications. The overall quality of block-molded EPS is more critical in lightweight fill applications than other applications because no other application has such significant load-bearing requirements. Two problems related to the use of ASTM Standard C 578 have emerged.

First is the tendency by EPS block molders to use as much regrind (recycled) material and to reduce the amount of virgin expandable polystyrene raw material to make the EPS-block geofoam blocks less costly and more cost competitive with other soft ground treatment alternatives. The percentage of in-plant regrind and post-consumer recycled material and how it is fused into blocks may have varying affects on the mechanical properties (Bartlett 1986; Bartlett undated) and on the time-dependent (creep behavior) of block-molded EPS. For example, tests have revealed that EPS with an average density of the order of 16 kg/m^3 had virtually the same compressive strength with up to 50% regrind content yet the initial tangent Young's modulus was reduced by a factor of approximately two between samples with no regrind and 50% regrind (UIUC 2000). Therefore, MQC/MQA compression tests should also include reporting of the elastic limit stress and initial tangent Young's modulus to more accurately measure the impact of regrind content on the stress-strain behavior. The elastic limit stress is defined as the compressive stress at 1% strain as measured in a standard rapid-loading test (Horvath 1995). The slope of the initial (approximately) linear portion of the stress-strain curve is defined as the initial tangent Young’s modulus. Additionally, the flexural strength test is a useful MQC/MQA test in conjunction with compressive strength tests to evaluate pre-puff and fusion quality, especially when regrind material is used (Bartlett 1986; Bartlett undated).

The second problem is the tendency of the EPS industry to misinterpret the ASTM Standard C 578 density requirements. The standard corresponds to the specification of the minimum acceptable material properties (including density) for the five standard grades of block-molded EPS covered by that standard. However, the standard is sometimes misinterpreted by the EPS industry to apply to a whole block instead of a specimen cut from a block. For example, if a customer specifies EPS with an average density of 20 kg/m^3, ASTM C 578 allows any particular specimen cut from a block tested for MQC/MQA purposes to have a density as low as 18 kg/m^3 which is approximately 10% less. Molders in the U.S. have sometimes misinterpreted ASTM Standard C 578 so that the lower bound density provided in the ASTM standard is applied to a whole block instead of a specimen. Thus a block with an overall density as low as 18 kg/m^3 is sometimes incorrectly considered as complying with ASTM C 578 and thus acceptable. The lesson learned from this emerging problem is that the applicability of lower-bound property values for either a given test specimen versus a block as a whole needs to be explicitly specified because it has important ramifications in load bearing capacity applications.

The basic philosophy adopted in the development of the provisional specification is to utilize the standard densities in ASTM Standard C 578 and add provisions related to the properties and behavior of EPS block that are necessary for a load bearing capacity application. Because lightweight fills are composed of entire blocks of EPS, the overall properties and behavior of an entire block are of primary importance. Second, EPS-block geofoam density can be used as an index property to estimate some mechanical and thermal properties provided the EPS meets a set of minimum standards. Third, the proposed design methodology is based on maintaining the long-term compressive stresses below the elastic-limit stress (within the elastic range) to keep long-term compressive strains within acceptable levels to limit both creep and plastic deformations. The proposed specification specifies lower-bound properties, i. e., density, compressive strength, flexural strength, elastic limit stress, and initial tangent Young’s Modulus, for a given MQC/MQA test specimen, not a block as a whole. For example, the average density of an entire block must equal or exceed a density that is slightly (approximately 10%) greater than the minimum allowed for an individual test specimen.

PROPOSED EPS MATERIAL DESIGNATION AND MINIMUM ALLOWABLE VALUES OF MQC/MQA PARAMETERS

The material designation system selected in the proposed specification refers to EPS-block geofoam as "EPSx" where "x" is either two or three integers defining the minimum elastic limit stress of the block as a whole in kilopascals. Thus, construction documents could indicate "EPS50 geofoam". The designation notation identifies both the geofoam material (EPS) as well as the minimum elastic limit stress (50 kPa) which is the design value. Furthermore, a designer would know that initial tangent Young's modulus for use in compression calculations was approximately 100 times this value, i.e. 5000 kN/m^2.

Table 1 shows the correlation between the proposed EPS-block geofoam designations and ASTM Standard C 578 material types. Also shown are the corresponding minimum allowable densities for every block as a whole and for any MQC/MQA test specimen trimmed from a block. For a given material type, the dry density of each EPS block (as measured for the overall block as a whole) after a period of seasoning shall equal or exceed that shown in Table 1. The dry density shall be determined by measuring the mass of the entire block by weighing the block on a scale and dividing by the volume of the block.

The minimum allowable values of the other design and quality control parameters are given in Table 2. Note that these are for individual test specimens and not the block as a whole. The compressive and flexural strength values were adopted from ASTM Standard C 578. The elastic limit stress and initial tangent Young's modulus were developed from observed correlations with the minimum density values from individual test specimens also shown in Table 2. These values of elastic limit stress and initial tangent Young's modulus would be the values used in analysis and design. The minimum allowable values of the various material parameters corresponding to each AASHTO material type shown in Table 2 are to be obtained by testing specimens prepared from samples taken from actual blocks produced for the project for either MQC by the molder or MQA by the owner's agent. Sampling of EPS block is typically done by cutting samples from various locations of an EPS block perpendicular to the longitudinal axis of the block. Specimens for testing are then trimmed from these samples. The test specimens shall be seasoned and dry density, compressive strength and flexural strength shall be measured as specified in ASTM C 578.

The specimens used for compressive testing shall be cubic in shape with a 50 mm face width. A strain rate of 10% per minute shall be used for the compressive strength tests. Both the elastic limit stress and initial tangent Young's modulus shall be determined in the same test used to measure compressive strength. The elastic-limit stress is defined as the measured compressive normal stress at a compressive normal strain of 1% (Horvath 1995). The initial tangent Young's modulus is defined as the average slope of the compressive stress versus compressive strain curve between 0% and 1% strain.

There are three main benefits to the proposed designation system. First, it decreases the importance of compressive strength and focuses on the most important aspect of block-molded EPS for load bearing capacity applications: the small-strain load-carrying capability. The parameter of compressive strength for EPS-block geofoam materials is not the key design parameter in practice because the compressive strength of EPS is defined arbitrarily, EPS does not fail in the traditional sense of material rupture and compressive strength does not provide any insight into the creep behavior. Second, the proposed specification parallels the proposed design methodology that maintains the long-term compressive stress below the elastic-limit stress. Third, the proposed designation system also decreases the relevance on density which can be a misleading indicator especially if regrind is used. Fourth, this designation system will allow manufacturers maximum flexibility because it does not proscribe how much regrind material they can use but simply holds them accountable to the compressibility characteristics of the final material. However, the influence of regrind content on creep behavior is not yet well understood because of the lack of test data on EPS with varying quantities of regrind.

A new sampling and testing protocol is also recommended in Figure 1. It is based on the assumption that the gradients (variation) in both density and fusion within an EPS block tend to be predominantly within planes oriented perpendicular to the longitudinal axis of a block. Therefore, sampling and testing should focus on material variations in this plane. However, the qualitative distribution of these gradients (as done historically and reflected in the Norwegian (Horvath 1995) and German (Forschungsggesellschaft et al. 1995; BASF AG 1995) design manuals) cannot be reliably assumed in advance. Therefore, test specimens must be prepared and all necessary parameters (listed in Table 2) tested at each of the three locations (A. B and C) shown in Figure 1 to allow for any gradients in both density and fusion. At each of the three locations, the test parameters must equal or exceed the minimum allowable values given previously in Table 2.

BASIS OF THE PROPOSED MANUFACTURING QUALITY CONTROL (MQC) AND MANUFACTURING QUALITY ASSURANCE (MQA) PROCEDURE

To begin the process of developing a meaningful MQC/MQA procedure, the properties of EPS-block geofoam that are critical to its use as lightweight fill in road applications were identified. These properties include: (1) The EPS should be flame-retardant. (2) Each block must be appropriately seasoned with respect to outgassing of the blowing agent (which will typically be pentane in the U.S.). (3) All blocks must meet the criteria for geometric tolerances with regard to both dimensional variation, orthogonality, and face warp. (4) The average density of each block delivered for a given project must equal or exceed the specified minimum allowable given in Table 1. (5) The density of any test specimen prepared from a sample cut from a production block for a given project must equal or exceed the specified minimum allowable given in Table 2 (which will generally be approximately 10% less than the overall allowable minimum for an entire block). (6) The small-strain stiffness parameters used for design (elastic limit stress and initial tangent Young's modulus) must equal or exceed the specified minimum allowable given in Table 2. (7) The traditional quality control parameters of compressive and flexural strength must equal or exceed the specified minimum allowable given in Table 2. The quality control mechanisms are implemented in two phases, one prior to shipment from the molding plant and the other during construction after delivery of blocks to the project site. Table 3 presents an overview of the two-phased system.

PRODUCT MANUFACTURING QUALITY CONTROL (MQC) REQUIREMENTS

The primary components of the provisional specification are the product manufacturing quality control (MQC) requirements, product manufacturing quality assurance (MQA) requirements, product shipment, and construction quality requirements to include construction quality control (CQC) and construction quality assurance (CQA) requirements. An overview of each of these components is subsequently presented.

MQC is the primary responsibility of the molder. The MQC parameters are the same parameters that will be measured as part of manufacturing quality assurance (MQA) to be conducted by the owner's agent. Allowable raw material, flame retardant requirements, seasoning requirements, and EPS block dimensional tolerances are also addressed. Table 2 indicates the proposed material designations and the minimum allowable values of MQC/MQA parameters for individual test specimens. The EPS-block geofoam shall consist entirely of expanded polystyrene. At the discretion of the molder, the EPS-block geofoam may consist of some mixture of virgin raw material (expandable polystyrene a.k.a. bead or resin) and recycled EPS (regrind). If regrind is to be used, this shall be identified by the molder as part of the Phase I MQA pre-certification process subsequently discussed. The source of the regrind (block-versus shape-molded EPS, in-plant versus post-consumer) should also be identified.

Although the practice in some countries is to use normal (non-flame-retardant) expandable polystyrene raw material for cost reasons, the recommended practice in the provisional specifications is to require the use of flame retardant EPS, which is currently the standard practice in the U.S. Thus, all EPS-block geofoam shall satisfy the product flammability requirements specified in ASTM C 578. A flammability concern is the potential of ignition of residual blowing agent that outgasses after block placement and collects in the joints between blocks. Outgassing of post-molding residual blowing agent is addressed by requiring an adequate seasoning period, three days (72 hours), prior to delivery of the EPS blocks to the project site. Seasoning is defined as storage in an area suitable for the intended purpose for a minimum of 72 hours after an EPS block is released from the mold. The recommended 72 hour seasoning period is based on available published information (Coughanour 1988) as well as anecdotal information obtained by personal communication with both resin suppliers and block molders in the U.S.

Because of the various types of molding equipment currently in use in the U.S., different dimensional variations may occur between blocks produced by different molders. The provisional specification incorporates physical and dimensional tolerances used in Norway which are based on decades of experience. Dimensional tolerances are defined by three geometric variables. (1) Variations in linear dimensions: The thickness, width and length dimensions of an EPS block are defined herein as the minimum, intermediate and maximum overall dimensions of the block, respectively, as measured along a block face. These dimensions of each block shall not deviate from the theoretical dimensions by more than ±0.5%. (2) Deviation from perpendicularity of block faces: The corner or edge formed by any two faces of an EPS block shall be perpendicular, i.e. form an angle of 90°. The deviation of any face of the block from a theoretical perpendicular plane shall not exceed 3 mm over a distance of 500 mm. (3) Overall warp of block faces: Any one face of a block shall not deviate from planarity by more than 5 mm when measured using a straightedge with a length of 3 m.

PRODUCT MANUFACTURING QUALITY ASSURANCE (MQA)

Three forms of MQA that can be used include pre-delivery, post-delivery, or some combination of the two. Pre-delivery MQA typically consists of third-party certification. Four issues or problems currently exist with current third-party certification procedures. First, many EPS block molders in the U.S.A. now subscribe to third-party certification by an inspection organization dedicated to providing that service. However, typically such certification does include specific testing of products destined for a specific project but on overall manufacturing operation. Thus civil engineers have been reluctant in some cases to accept third-party certification as the sole MQA procedure because it is not project specific. Second, third-party certification is typically set up for compliance with existing standards, most notably ASTM Standard C 578. However, EPS-block geofoam to be used for the function of lightweight fill has requirements for material stiffness that are not included in ASTM Standard C 578 or any other known standard. Therefore, third-party certification as it typically exists for block-molded EPS may not be sufficient for lightweight fill applications. Third, there is recent project experience in the U.S. to indicate that third-party certification is not foolproof. Specifically, there is anecdotal information, reportedly based on independent post-delivery testing by at least two state DOTs, that suggests that EPS-block geofoam of overall quality not meeting specifications has been delivered to projects. Fourth, EPS-block geofoam is still a novel construction material to most civil engineers and most state DOTs in the U.S. Therefore, there is a reluctance to accept this material without at least some post-delivery testing, especially in view of the fact that this is the historical method for performing MQA for EPS-block geofoam.

The primary difficulty with post-delivery testing is that it can be time consuming and delay geofoam placement. This is an important issue because on many projects the EPS blocks are placed directly from the delivery truck. Thus it would be time consuming and costly to exhume a group of blocks placed days or even weeks earlier if the test results were unacceptable. However, this would have to be done if necessary.

Although third-party certification is not perfect, it offers some level of quality assurance. Therefore, it is reasonable to treat EPS molders who subscribe to a recognized third-party certification agent and program differently from those who do not. Thus, a key aspect of the proposed MQA procedure is the implementation of a two-tier MQA system, one for molders with third-party certification and the other for those without. The proposed MQA procedure requirements indicated in Table 3 shows an overview of the proposed two-tier MQA procedure.

The purpose of MQA of the EPS-block geofoam product is to verify the molder's MQC procedures. The owner's agent will have primary responsibility for all MQA unless the owner notifies the contractor otherwise. As indicated previously, the proposed MQA program consists of two phases. Phase I MQA consists of pre-certification of the molder and shall be conducted prior to shipment of any EPS blocks to the project site. Phase II MQA shall be conducted as the EPS blocks are delivered to the project site. Phase I and all four subphases of Phase II MQA are performed regardless of whether or not the EPS molder has third-party certification.

The purpose of the pre-certification procedure of Phase I is to verify that the molder has the ability to provide EPS-block geofoam of the desired quality. If the molder has a third-party certification program, the molder should provide the owner’s agent written notification that a third-party certification program is in force, identify the organization providing this service, provide detailed information as to the procedure and tests used by this organization to verify the molder’s compliance with the project specifications, and provide written certification that all EPS blocks supplied to the project will meet the requirements specified in the project specifications. Acceptance of the molder's third-party certification by the owner's agent will waive the need for pre-construction product submittal and testing required for a molder without an approved third-party certification. If the molder does not have an approved third-party certification program or the certification is deemed unacceptable by the owner's agent, the contractor shall deliver a minimum of three full-size EPS blocks for each AASHTO EPS-block geofoam type that will be used on a project. The owner's agent will weigh, measure, sample, and test a random number of blocks to evaluate the ability of the molder to produce EPS-block geofoam of desired quality. The sampling and testing protocol will be the same as for Phase IIc MQA. The molder will be required to submit a letter stating that all EPS blocks supplied for the project are warranteed to meet specification requirements along with a description of MQC measures they employ, i.e., in-plant testing.

Phase II MQA consists of four subphases and shall be conducted as the EPS blocks are delivered to the project site and will be performed by the owner's agent. Phase IIa consists of on-site visual verification of the physical condition of the EPS blocks as well as visual verification of the index properties to be included on the labeled information on each block. The required labeled information is described in the Product Shipment section of this paper. The purpose of Phase IIa MQA is to check the post-delivery condition of the blocks and to check that the proper blocks are being shipped to the project site. The CQA agent should inventory each block from each truckload. Any blocks with damage or not meeting specifications to include the minimum density specified in Table 1 should be rejected.

Phase IIb consists of on-site verification that the minimum block dry density as well as the physical tolerances meet specifications. The purpose of Phase IIb MQA is to confirm key physical and index properties of the overall block and EPS, respectively. The weight indicated on the label should be checked using a commercial scale supplied by the contractor with sufficient capacity and precision for weighing EPS blocks. The physical tolerances to check were provided in the Product MQC Requirements section of this paper. If the molder has approved third-party certification, each truckload, approximately 50 to 100 m^3 of geofoam, should be checked. However, initially, only one block per load should be selected and checked. If the selected block meets specification with respect to its size and shape, and the mass agrees with that marked on the block, no further checking of the load for these parameters is required and the shipment is approved conditionally. If the block does not meet specification, then other blocks in the truckload should be checked and none used until the additional checking has determined what blocks are unsatisfactory. At the completion of this subphase, the construction contractor should be conditionally allowed to proceed with installing blocks. However, this should be done with the understanding that EPS blocks may have to be exhumed and removed at a later date if Phase IIc testing indicates problems. If the molder does not have approved third-party certification, each truckload should be checked. For the first load delivered to a project, each block should be checked by the CQA agent. For subsequent loads, at least one block per load should be selected and checked.

Phase IIc consists of sampling the EPS blocks and performing laboratory testing on specimens prepared from these samples. The purpose of Phase IIc MQA is to confirm the EPS engineering design parameters related to stiffness as well as the quality control strength parameters. The CQA agent should sample and test the EPS for compliance with specified requirements with respect to the elastic limit stress, initial tangent Young's modulus, compressive strength, and flexural strength. Sampling will be at the locations shown in Figure 1 and the laboratory tests will check for compliance with the parameters shown in Table 2. The frequency of sampling and testing will vary depending on whether or not the molder has third-party certification. If the molder has approved third-party certification, the owner and the owner's CQA agent can exercise considerable judgement. For example, they may choose to conduct testing only at the beginning of a project to verify that the EPS molder's MQC and third-party certification is achieving the desired goals or even omit testing entirely on a small project. If the molder does not have approved third-party certification, sampling and testing should be applied throughout the entire duration of the project.

For each density of EPS used on a project, at least one block will be selected for sampling from the first truckload of EPS blocks of that density delivered to the job site. Additional blocks may be selected for sampling during the course of the project at the discretion of the owner's agent at a rate of sampling not to exceed one sample for every 250 m^3 of EPS delivered. Portions of sampled blocks that are otherwise acceptable can be used as desired by the contractor. For subsequent truckloads, the construction contractor should be allowed to place blocks while sampling and testing is occurring with the understanding that it may be necessary to exhume and remove blocks not meeting specifications. The owner's agent will make every reasonable effort to conduct the laboratory testing expeditiously. If unsatisfactory test results are obtained, the contractor may be directed to remove potentially defective EPS blocks and replace them with blocks of acceptable quality at no additional expense to the owner.

Phase IId consists of recording where blocks are placed to the greatest extent possible by marking copies of the drawings that show the block layout (either shop drawings or design drawings as appropriate). The purpose of this is to assist in locating blocks that may need to be exhumed at a later date if some question as to manufacturing quality should arise.

PRODUCT SHIPMENT

Prior to delivery of any EPS-block geofoam to the project site, a meeting shall be held between, as a minimum, the owner's agent and contractor. The supplier and/or molder of the EPS-block geofoam may also attend at the contractor's discretion to facilitate answering any questions. The purpose of this meeting shall be to review the Phase I MQA results and discuss Phase II MQA as well as other aspects of construction to ensure that all parties are familiar with the requirements of the specification. After this meeting, the contractor can begin on-site receipt, storage (if desired), and placement of the EPS-block geofoam.

The molder should label each block delivered to the project site with the following minimum information: if multiple plants and/or molders are supplying a given project, the name of the molder and plant location; the date the block was molded; the mass of the entire block (in kilograms) as measured after a satisfactory period of seasoning; the actual dry density (in kilograms per cubic metre); the dimensions of the blocks (in millimetres); and when multiple densities are to be used on the same project, an adequate marking system should be used to identify blocks of different density. If the EPS blocks are to be stockpiled at the project site until placement, a secure storage area shall be designated for this purpose.

CONSTRUCTION QUALITY REQUIREMENTS

The contractor is directly responsible for all construction quality control (CQC) and the owner's agent is responsible for providing construction quality assurance (CQA) of the contractor's construction activities. Items covered by CQC/CQA include all earthwork and related activities other than manufacturing and shipment of the EPS-block geofoam. Site preparation, placement of EPS-block geofoam, and pavement construction are items that are incorporated in the CQC/CQA requirements. No debris or large or sharp-edged soil particles and no standing water or accumulated snow or ice should be present on the subgrade surface within the area where EPS blocks are placed at the time of block placement. The subgrade should not be frozen except in the case of intentional construction over continuous or discontinuous permafrost terrain. The subgrade surface on which the EPS blocks will be placed shall be sufficiently planar (smooth) prior to the placement of the first block layer. The required smoothness is defined as a vertical deviation of no more than +/- 10 mm over any 3 m distance.

EPS blocks should be placed at the locations shown on either the contract drawings or approved shop drawings submitted by the contractor. Placement considerations include placement of EPS blocks so that all vertical and horizontal joints between blocks are tight, preventing any vehicle or construction equipment from directly traversing on the surfaces of EPS blocks during or after placement of the blocks, preventing any heat or open flame to be used in proximity to the EPS blocks so as to cause melting or combustion of the EPS, providing sufficient restraint with the use of sand bags or similar "soft" weights to temporarily restrain the EPS blocks against wind, and exercising sufficient care during placement of the cover material so as to prevent any damage to the EPS blocks.

Care must be exercised when constructing the pavement system so that the separation layer (if one is used) and/or EPS blocks are not damaged. Generally the most critical phase is the placement and compaction of the initial lift or layer of soil on the separation layer or EPS blocks. Earthmoving equipment must not directly traffic on the EPS blocks or separation layer (even if a Portland cement concrete slab is used as it is still possible to overstress the underlying EPS). Relatively lightweight equipment should be used to push approximately 300 mm (minimum) of soil or aggregate onto the EPS blocks or separation layer before compacting the material. Placement of additional unbound and bound layers of the pavement system can then be placed in the normal manner although trafficking of the surface by trucks or heavy equipment of all types should be minimized or avoided altogether until the pavement is completed.

SUMMARY

The provisional specification is a combined material, product, and construction specification covering block-molded expanded polystyrene (EPS) for use as lightweight fill in road embankments and related bridge approach fills on soft ground. The provisional specification is intended to be used in conjunction with the provisional design guidelines also included in the interim report (UIUC 2000). The provisional specification is considered to be provisional for interim use only until Phase II of NCHRP Project HR 24-11 is completed. The report for Phase II is intended to include final design guidelines that will present more detailed design aids to facilitate design of a cost-effective solution.

The primary components of the provisional specification include the product manufacturing quality control (MQC) requirements, product manufacturing quality assurance (MQA) requirements, product shipment, and construction quality requirements to include construction quality control (CQC) and construction quality assurance (CQA) requirements. The key features of the provisional specification include the proposed EPS material designation system shown in Table 1 and the minimum allowable values of MQC/MQA parameters shown in Table 2. A new sampling protocol shown in Figure 1 and a two-phased MQA procedure were developed. Phase I of the MQA procedure is to be performed prior to shipment of EPS blocks to the project site and Phase II is to be performed as the EPS blocks are delivered to the project site. Another key aspect of the proposed MQA procedure is the implementation of a two-tier MQA system, one for molders with third-party certification and the other for those without. This paper presents a provisional specification that will undoubtedly undergo an evolutionary process that includes input from and dialog between EPS molders, their customers (usually a construction contractor), the design engineer, and the ultimate owner. A goal of this paper is to assist in initiating such a dialog by presenting relevant issues to be addressed by MQA.

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TABLES

Table 1. Correlation between Current ASTM and Proposed AASHTO EPS Material Designations (UIUC 2000).

Material Designation		**Minimum Allowable Density, kg/m^3 (lbs/ft^3)**	
AASHTO (proposed)	**ASTM C 578**	**Each Block as a Whole**	**Any Test MQC/MQA Specimen**
EPS40	I	16 (1.0)	15 (0.94)
EPS50	VIII	20 (1.25)	18 (1.12)
EPS70	II	24 (1.5)	22 (1.37)
EPS100	IX	32 (2.0)	29 (1.81)

Table 2. Minimum Allowable Values of MQC/MQA Parameters for Individual Test Specimens (UIUC 2000).

Material Designation	**Dry Density, kg/m^3 (lbs/ft^3)**	**Compressive Strength, kPa (psi)**	**Flexural Strength, kPa (psi)**	**Elastic Limit Stress, kPa (psi)**	**Initial Tangent Young's Modulus, MN/m^2 (psi)**
EPS40	15 (0.94)	69 (10)	173 (25)	40 (5.8)	4 (580)
EPS50	18 (1.12)	90 (13)	208 (30)	50 (7.2)	5 (725)
EPS70	22 (1.37)	104 (15)	276 (40)	70 (10.1)	7 (1015)
EPS100	29 (1.81)	173 (25)	345 (50)	100 (14.5)	10 (1450)

Table 3. Proposed Manufacturing Quality Assurance (MQA) Procedure for EPS-Block Geofoam Used for the Function of Lightweight Fill in Road Embankments.

Phase	Subphase	Start of Phase	Description	Comparison of Requirements Based on Two-Tier System
I	None	Prior to shipment to the project site	Pre-certification of the molder	Will vary between molders who subscribe to an approved third-party certification procedure and molders that do not.
II	IIa	As the EPS blocks are delivered to the project site	On-site visual inspection of each block delivered to the project site to check for damage as well as visually verify the labeled information on each block	No difference
	IIb		On-site verification that the minimum block dry density as well as the physical tolerances meet specifications	Will vary between molders who subscribe to an approved third-party certification procedure and molders that do not.
	IIc		Confirming the EPS engineering design parameters related to stiffness as well as the quality control strength parameters	Will vary between molders who subscribe to an approved third-party certification procedure and molders that do not.
	IId	As the EPS blocks are placed	As-built drawing(s)	No difference

FIGURE

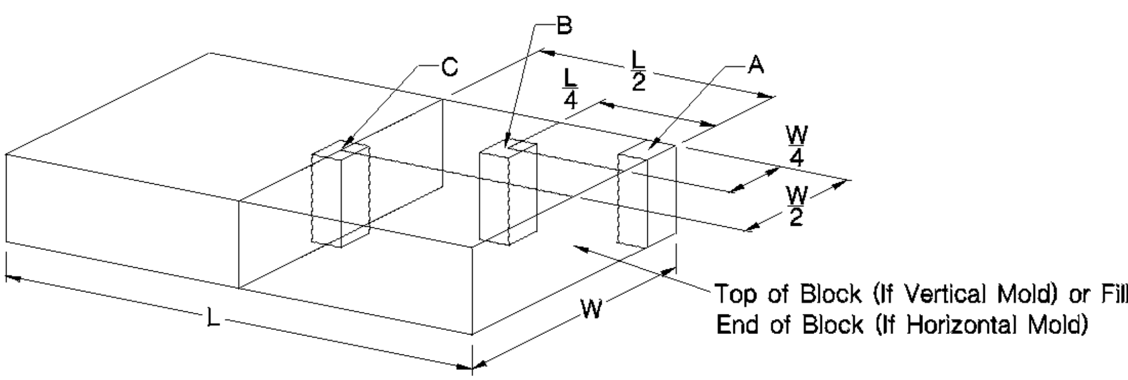

Figure 1. Recommended Block Sampling (UIUC 2000).