Designation: D 6684 – 01

Standard Specification for Materials and Manufacture of Articulating Concrete Block (ACB) Revetment Systems[1]

This standard is issued under the fixed designation D 6684; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ϵ) indicates an editorial change since the last revision or reapproval.

1. Scope

1.1 The purpose of this Standard is to provide specifications for articulating concrete block (ACB) revetment system structural components, material composition and physical properties, manufacturing methods and testing requirements.

1.2 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory requirements prior to use.*

2. Referenced Documents

2.1 *ASTM Standards:*

C 33 Specification for Concrete Aggregates[2]

C 39 Test Method for Compressive Strength of Cylindrical Concrete Specimens[2]

C 42 Test Method for Obtaining and Testing Drilled Cores and Sawed Beams of Concrete [2]

C 67 Test Methods for Sampling and Testing Brick and Structural Clay Tile [3]

C 140 Test Methods of Sampling and Testing Concrete Masonry Units and Related Units[3]

C 150 Specification for Portland Cement[4]

C 207 Specification for Hydrated Lime for Masonry Purposes[4]

C 331 Specification for Lightweight Aggregates for Concrete Masonry Units [2]

C 595 Specification for Blended Hydraulic Cements [4]

C 618 Specification for Coal Fly Ash and Raw or Calcined Natural Pozzolan for use as a Mineral Admixture in Concrete [2]

C 666 Test Method for Resistance of Concrete to Rapid Freezing and Thawing [2]

C 1262 Test Method for Evaluating the Freeze-Thaw Durability of Manufactured Concrete Masonry Units and Related Concrete Units[3]

D 4533 Test Method for Trapezoid Tearing Strength of Geotextiles[5]

D 4632 Test Method for Grab Breaking Load and Elongation of Geotextiles[5]

D 4833 Test Method for Index Puncture Resistance of Geotextiles, Geomembranes, and Related Products[5]

2.2 *Other Documents:*

American Association of State Highway Transportation Officials (AASHTO), 1995, "Standard Specification for Geotextiles," AASHTO Designation M 288, February.

Koerner, R.M., 1998, "Designing With Geotextiles," 4th Edition, Prentice-Hall Publishers, Englewood Cliffs, N.J. p. 761.

3. Terminology

3.1 *Definitions:*

3.1.1 *articulating concrete block (ACB) revetment system, n*—a matrix of interconnected concrete block units sufficient for erosion protection. Units are connected by geometric interlock and/or cables, geotextiles, or geogrids, and typically include a geotextile underlay for subsoil retention.

4. Significance and Use

4.1 An articulating concrete block system is comprised of a matrix of individual concrete blocks placed together to form an erosion-resistant revetment with specific hydraulic performance characteristics. The system includes a filter layer compatible with the subsoil which allows infiltration and exfiltration to occur while providing particle retention. The filter layer may be comprised of a geotextile, properly graded granular media, or both. The blocks within the matrix shall be dense and durable, and the matrix shall be flexible and porous.

4.2 Articulating concrete block systems are used to provide erosion protection to underlying soil materials from the forces of flowing water. The term "articulating," as used in this Standard, implies the ability of individual blocks of the system to conform to changes in subgrade while remaining interconnected by virtue of geometric interlock and/or additional system components such as cables, ropes, geotextiles, or geogrids.

4.3 The definition of articulating concrete block systems

[1] This specification is under the jurisdiction of ASTM Committee D18 on Soil and Rock and is the direct responsibility of Subcommittee D18.25 on Erosion and Sediment Control Technology.

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[2] *Annual Book of ASTM Standards,* Vol 04.02.

[3] *Annual Book of ASTM Standards,* Vol 04.05.

[4] *Annual Book of ASTM Standards,* Vol 04.01.

[5] *Annual Book of ASTM Standards,* Vol 04.09.

does not distinguish between interlocking and non-interlocking block geometries, between cable-tied and non- cable-tied systems, between vegetated and non-vegetated systems or between methods of manufacturing or placement. Furthermore, the definition does not restrict or limit the block size, shape, strength, or longevity; however, guidelines and recommendations regarding these factors are incorporated into this Standard. Block systems are available in either open-cell or closed-cell configurations.

5. Materials and Manufacture

5.1 *Materials Specifications: Cementitious Materials*—Materials shall conform to the following applicable ASTM standards:

Portland Cements	C 150
Blended Cements	C 595
Hydrated Lime Types	C 207
Pozzolans	C 618

5.2 Aggregates shall conform to the following ASTM specifications, except that grading requirements shall not necessarily apply:

Normal Weight	C 33
Light Weight	C 331

5.3 *Physical Properties*—At the time of delivery to the work site, the units shall conform to the physical requirements prescribed in Table 1.

5.3.1 In addition to Table 1, when freeze-thaw durability testing is required, such testing shall be performed in accordance with Test Methods C 67, C 666, or C 1262, at the direction of the Owner. The number of freeze-thaw cycles and the corresponding weight loss criterion for pass-fail determination shall be specified by the Owner along with the test method.

5.4 *Geotextile Filter*—The geotextile filter shall be in compliance with the project specifications, in consideration of its compatibility with the underlying soil subgrade. Minimum strength requirements are provided in Table 2.

5.4.1 *Geotextile*—Subsoil compatibility assessment shall include functional requirements for permeability, particle retention, and resistance to clogging. Physical property requirements for permittivity, aperture size, percent open area, and UV stability should be based on site-specific soil characteristics, site conditions, and construction techniques. Applicable references for conducting compatibility assessments include:

Koemer, R.M., 1998, "Designing With Geotextiles," 4th Edition, Prentice-Hall Publishers, Englewood Cliffs, N.J. p. 761.

5.5 *Revetment Cable and Fittings*:

5.5.1 For cabled systems, the revetment cable or rope and fittings shall be designed to provide adequate strength and durability characteristics to facilitate lifting and placing of large mattresses.

5.5.2 Fittings such as sleeves, clamps and stops shall be as required by the manufacturer. Selection of cable or rope and fittings shall be made in a manner that insures a safe design factor for mats being lifted from one or both ends. Consideration shall be taken for the bending of the cables or ropes around hooks or pins during lifting. Revetment cable or rope, splice fittings, sleeves and stops shall be selected so that the cable or rope and all connections result in a minimum factor-of-safety of 5.0 with respect to lifting.

5.5.3 For those systems performance tested with, and that rely on cables, ropes, or other non-concrete components to maintain the block-to-block interconnection, the cables, ropes, and/or non-concrete components shall also meet the design life of the project.

5.6 *Block Production*:

5.6.1 Articulating concrete blocks may be produced at a block plant or onsite using either wet-cast or dry-cast production techniques, provided that the composition and physical characteristics of the furnished units meet the requirements of 5.1-5.3.

5.7 *Matrix Assembly*:

5.7.1 *Non-Cabled System*—Non-cabled articulating concrete block systems are typically palletized, cured, and shipped to the job site. Non-cabled systems may also be assembled on, and/or glued to, a high-strength geotextile fabric which is used to carry the articulated block mattress.

5.7.2 *Cabled System*—Cabled articulating concrete block revetment systems can be assembled into mattresses, typically up to 480 square feet (45 square meters). Whole mat production can occur at the block plant or at the project. The individual blocks are typically placed in their respective matrix positions on a work surface, and the cables or ropes are inserted through the core holes in the block. Once the blocks have been assembled into a mattress, the ends of the cable or rope are secured as necessary based on the characteristics of the system. Wetcast mattresses can be poured with the cables or ropes integral to the blocks both laterally and longitudinally at the time of production. With this method, cable-end sleeves are not necessary.

6. Sampling and Testing

6.1 Manufacturer shall provide test data showing that concrete products manufactured within the previous 24 months of anticipated ACB placement have met the requirements of this Standard.

6.2 Manufacturer shall provide access to lots ready for delivery to the purchaser or his authorized representative for sampling and testing in accordance with the procedures specified in this Standard prior to the commencement of ACB placement.

6.3 For the compressive strength, water absorption, and unit weight (density) determinations, three samples shall be taken

TABLE 1 Physical Requirements

Minimum Compressive Strength, lb/in^2		Maximum Water Absorption, lb/ft^3		Minimum Density (in air), lb/ft^3	
Average of 3 units	Individual Unit	Average of 3 units	Individual Unit	Average of 3 units	Individual Unit
4,000	3,500	9.1	11.7	130	125

NOTE—For units produced by a wet-cast method, tests shall be conducted in accordance with Test Methods C 39 and C 42. For units produced by a dry-cast method, tests shall be conducted in accordance with Test Methods C 140.

TABLE 2 Geotextile Strength Requirements (AASHTO M-288)

Property	ASTM Test Methods	Units	Class 1		Class 2		Class 3	
			Elongation <50%[A]	Elongation >50%[A]	Elongation <50%[A]	Elongation >50%[A]	Elongation <50%[A]	Elongation >50%[A]
Grab Strength	D 4632	lb	315	200	250	160	180	110
Sewn Seam Strength[B]	D 4632	lb	270	180	220	140	160	100
Tear Strength	D 4533	lb	110	80	90[C]	55	70	40
Puncture Strength	D 4833	lb	110	80	90	55	70	40

[A] As measured in accordance with Test Method D 4632.
[B] When seams are required.
[C] The required Minimum Average Roll Value (MARV) tear strength for woven monofilament geotextiles is 55 lb.

NOTE—Required geotextile class for permanent erosion control design is designated below for the indicated application. The severity of installation conditions generally dictates the required geotextile class.
Class 1 is recommended for harsh or severe installation conditions where there is a greater potential for geotextile damage, including irregular sections where repeated mattress lifting, realignment, and replacing is expected, or when vehicular traffic on the installation is anticipated.
Class 2 is recommended for installation conditions where mattress placement in regular, even reaches is expected and little or no vehicular traffic on the installation will occur, or when hand-placing on a graded surface of native soils.
Class 3 is specified for the least severe installation environments, typically hand-placed systems (zero drop height) on a bedding layer of graded sand, road base aggregate, or other select imported material.

from each lot of 50,000 units (i.e., individual blocks) or fraction thereof. Additional samples may be taken at the discretion of the purchaser.

6.4 For the compressive strength, water absorption, and unit weight (density) determinations, specimens shall be obtained from the samples and tested in accordance with Test Methods D 39 and D 42 for blocks produced by a wet cast method or in accordance with Test Methods C 140 for blocks produced by a dry-cast method.

6.5 Sample cylinders, cores or coupons shall use a height to thickness ratio of not less than 1:1 nor greater than 2:1 for purposes of compressive strength testing. The minimum thickness (or diameter) shall be 1.5 in. Care shall be taken to achieve square-cut ends and to ensure proper capping prior to testing.

6.6 Samples shall be 100 % solid and shall not contain cable holes or other voids.

6.7 The compressive strength of the sample shall be considered to be the net area compressive strength of the full size unit, as corrected for the height to thickness ratio of the sample in accordance with Test Methods C 140.

7. Compliance

7.1 In the event that a sample fails to conform to the specified requirements, the manufacturer may sort the shipment and test new units, selected at random by the purchaser from the retained lot. If the second set of tests also fails to conform to the specified requirements, the entire lot may be rejected.

NOTE 1—Unless otherwise specified in the purchase order, the cost of tests is typically borne as follows: (*1*) if the results of the tests show that the units do not conform to the requirements of this Standard, the cost is typically borne by the seller; (*2*) if the results of the tests show that the units conform to the requirements of this Standard, the cost is typically borne by the purchaser.

8. Quality Assurance

8.1 All units shall be sound and free of defects that would interfere with proper placement or that would impair the strength or longevity of the installation.

8.2 Minor cracks incidental to the usual method of manufacture, or chipping that results from customary methods of handling in shipping, delivery and placement shall not be deemed grounds for rejection provided the requirements of 8.1 are met.

9. Keywords

9.1 articulating concrete block (ACB) revetment systems; channel; channel stability; erosion; erosion control; open-channel flow; revetments

Utilidad del Software Hec-Ras.

Los códigos y documentación del Hec-Ras son un software de dominio público creado por el Centro de Ingeniería Hidrológica del Cuerpo de Ingenieros del Ejército de los Estados Unidos. El programa fue creado a costas del Gobierno de los Estados Unidos. Se puede encontrar para su utilización en la página www.hec.usace.army.mil.

El Centro de Ingeniería Hidrológica no provee de soporte técnico a personas fuera del Cuerpo de Ingenieros del Ejército de Estados Unidos, para lo cual existen organizaciones que ofrecen documentación, soporte y servicio por un costo. Sin embargo el centro responderá a errores del programa.

El programa permite al usuario simular el flujo estable en una dimensión, cálculos de flujo inestable, modelados y cálculos utilizando la computadora de transporte de sedimentos y de temperatura de agua.

Componentes de un análisis de río.

1. Perfiles de la superficie de agua en flujo estable.

Este componente del sistema de modelado es intencionado para el cálculo de perfiles de la superficie de agua para el flujo estable gradualmente variado. El sistema puede manejar una completa red de canales, sistemas dendríticos, o un tramo de río. El componente de flujo estable es capaz de modelar perfiles de superficie de agua para flujo sub crítico, super crítico y mixto.

El proceso computacional básico es basado en la solución de la ecuación de la energía en una dimensión. Las pérdidas de energías se evalúan por fricción, expansión y contracción. La ecuación de momento es utilizada para situaciones donde el perfil de la superficie de agua es rápidamente variado. Estas situaciones incluyen el cálculo para un régimen de flujo mixto, hidráulica de puentes y evaluación de los perfiles en las confluencias del río.

El efecto de varias obstrucciones tales como puentes, alcantarillas, diques, presas y otras estructuras que en las en el simples crecidas deben de ser consideradas en los cálculos. El sistema de flujo estable está diseñado para aplicar en el manejo del las crecidas y estudios de seguridad de crecidas para evaluar el crecimiento del nivel del agua. También posee capacidades para evaluar el cambio en el perfil de la superficie de agua debido a modificaciones en el cana

Características especiales de los componentes de flujo variable incluyen: análisis múltiples de los planes, calculo múltiple de perfiles, múltiples análisis de puentes o alcantarillas. Análisis del esfuerzo abrasivo generado por el agua en los puentes. Optimización de la división de flujos y diseño y análisis para canales estables.

2. Simulación del flujo inestable.

Este componente del sistema de modelado HEC-RAS es capaz de simular flujo inestable en una dimensión a través de una red de canales abiertos. La ecuación utilizada para resolver la simulación para flujo inestable fue adaptada de la del modelo UNET del Dr. Robert L. Barkaus.

El modelo puede desempeñar flujo régimen mixto de flujo para los cálculos de flujo inestable (subcrítico, supercrítico, saltos hidráulicos).

El cálculo hidráulico para secciones transversales, puentes, alcantarillas, y otras estructuras hidráulicas que fue desarrollada para los componentes del flujo estable fueron también adaptados para el modulo de flujo inestable.

Características especiales incluidas para los componentes del flujo inestable son: análisis del diques, estaciones de bombeo, operaciones de navegación del dique, y sistemas de tubo con presión.

Almacenamiento y administración de información.

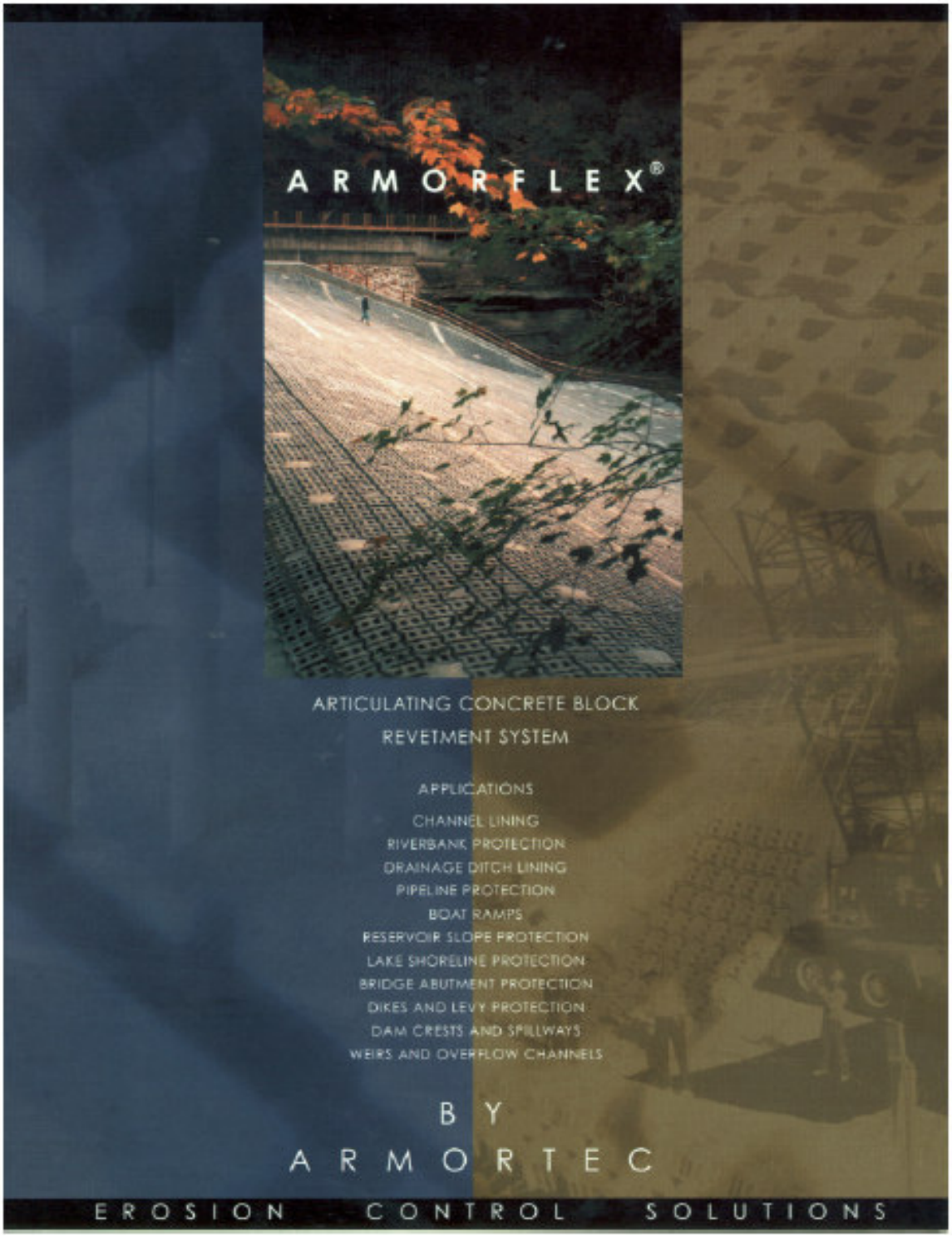
El almacenamiento de información se hace por medio de los archivos Flat. El usuario introduce la información en los archivos flan en categorías separadas como proyecto, plan, geometría, flujo estable, flujo inestable. La información output se almacena predominantemente en archivos binarios separados. La información puede ser transferida para otros programas utilizando el HEC-DSS.

La administración del a información se va realizando mediante la interfase del usuario. El modelo requiere que se introduzca un nombre de archivo simple para que se desarrolle el proyecto. Luego de que el nombre del proyecto esta determinado los demás archivos se crean y almacenan automáticamente según la interfase que se requiera. La interfase provee la opción de cambiar nombre, borrar o mover el archivo.

Gráficos y reportes

Los gráficos incluyen ploteos en planos de coordenadas x, y de esquemas de los sistemas del río, secciones transversales, perfiles, curvas promedios y muchas otras variables hidráulicas. Un ploteo tres dimensiones de las múltiples secciones transversales también es disponible. La información obtenida con el programa se presenta en tablas las cuales el usuario puede seleccionar si las desea pre-definida o desarrolla sus propias tablas. Todos los gráficos y la información tabulada se puede mostrar en la pantalla y ser enviada a una impresora o copiar a través de Windows a una programa como Microsoft Excell o Microsoft Word.

DETALLES DEL PRODUCTO ARMOFLEX



ArmorFlex is a flexible, interlocking matrix of concrete blocks of uniform size, shape and weight connected by a series of cables which pass longitudinally through preformed ducts in each block. ArmorFlex is installed over site specific filter fabric on a prepared surface. ArmorFlex revetment systems combine the favorable aspects of lightweight blankets and meshes, such as porosity, flexibility, vegetation encouragement and habitat enhancement with nonerodible, self-weight and high tractive force resistance of a rigid lining.

ArmorFlex has proven to be an aesthetic and functional alternative to dumped stone riprap, gabions, structural concrete and other heavy-duty, durable erosion protection systems. ArmorFlex is easy to install, therefore, can dramatically reduce overall project costs. More specifically, when compared to other systems, life-cycle costs have been reduced because ArmorFlex is a permanent system and saves on subsequent maintenance expenses.

FEATURES

- STABILITY
- FLEXIBILITY
- PERFORMANCE
- VEGETATION
- PERMEABILITY
- EASY TO INSTALL
- COST EFFECTIVE

BLOCK STYLES

When placed on a site specific filter fabric, the permeability of the revetment system relieves hydrostatic pressure in the subgrade. The system's capability for soil retention prevents leaching of subsoils throughout the installation.

FLEXIBILITY

ArmorFlex blocks are interconnected by flexible cables, providing articulation between adjacent blocks. Block walls are designed with beveled side walls to allow for flexibility in all directions.

CONCRETE BLOCK "S" CLASS

Example: from chart right

Class 30S
Open Cell
Block Weight 31-36 lbs.
Open Area 20%

STANDARD CLASS CONCRETE BLOCK

Example: from chart right

Class 40
Open Cell
Block Weight 62-71 lbs.
Open Area 20%

CONCRETE BLOCK "L" CLASS

Example: from chart right

Class 40L
Closed Cell
Block Weight 90-106 lbs.
Open Area 20%

ARMORFLEX BLOCK SPECIFICATIONS

Concrete Block Class	Open/ Closed Cell	Nominal Dimensions			Gross Area/ (sq. ft.)	Block Weight		Open Area %
		L	W	H		lbs.	lbs./sq. ft.	
30s	Open	13.0	11.8	4.75	0.98	31-36	32-37	20
50s	Open	13.0	11.8	6.00	0.98	45-52	45-53	20
40	Open	17.4	15.5	4.75	1.77	62-71	35-40	20
50	Open	17.4	15.5	6.00	1.77	81-94	46-53	20
60	Open	17.4	15.5	7.50	1.77	99-113	56-64	20
70	Open	17.4	15.5	9.00	1.77	120-136	68-78	20
40L	Open	17.4	23.6	4.75	2.58	90-106	35-41	20
50L	Open	17.4	23.6	6.00	2.58	116-134	45-52	20
60L	Open	17.4	23.6	7.50	2.58	144-168	56-65	20
70L	Open	17.4	23.6	9.00	2.58	173-201	67-78	20
45s	Closed	13.0	11.8	4.75	0.98	39-45	40-45	10
55s	Closed	13.0	11.8	6.00	0.98	53-61	54-62	10
45	Closed	17.4	15.5	4.75	1.77	78-89	43-50	10
55	Closed	17.4	15.5	6.00	1.77	94-108	53-61	10
75	Closed	17.4	15.5	7.50	1.77	120-138	68-78	10
95	Closed	17.4	15.5	9.00	1.77	145-167	82-94	10
45L	Closed	17.4	23.6	4.75	2.58	108-126	42-49	10
55L	Closed	17.4	23.6	6.00	2.58	139-163	54-63	10
75L	Closed	17.4	23.6	7.50	2.58	173-201	67-78	10
95L	Closed	17.4	23.6	9.00	2.58	209-243	81-94	10

MINIMUM PHYSICAL REQUIREMENTS

- Compressive Strength of 4,000 psi
- Max. Absorption of 12 lbs / ft^3
- Specific wt. of 130 - 150 lbs /ft^3

RESEARCH AND DESIGN

Since 1980, ArmorTec has initiated and participated in a wide range of research projects to evaluate the performance of ArmorFlex, including the following:

- Tetratech model tests - California, U.S.A.
- Wave Attack Tests, Report No. M1910 - Delft Hydraulics Laboratory, 1982
- "Large-Scale model study of ArmorFlex slope protection" Tekmarine, Inc., May, 1984
- "Design for Reinforced Grass Waterways," - CIRIA Report 116, 1987
- "Minimizing Embankment Damage During Overtopping Flows," FHWA Report RD-88-181 prepared by Simons, Li and Associates, Inc, November 1988
- "Hydraulic Stability of Articulated Concrete Block Revetment Systems During Overtopping Flow," FHWA Report RD-89-199 prepared by Simons, Li and Associates, Inc., July 1989
- ArmorFlex Overtopping Test, prepared by Ayers Associates, Inc.

RESEARCH PROVEN PERFORMANCE

Armortec has carried out extensive research into wave and open channel flow conditions on ArmorFlex in the United Sates and the Netherlands. Design manuals and computer programs are available to assist in the proper ArmorFlex block selection for your hydraulic conditions. Design recommendations can thus be made on the basis of specific research data and sound engineering principles.

w. | delft hydraulics Dam Overtopping Tests

ARMORFLEX INSTALLATION

- ArmorFlex arrives on-site as a system of factory-assembled mats. ArmorFlex is placed on a site specific geotextile which has been placed on a prepared subgrade using conventional construction equipment.
- Mats are supplied on 42-foot trailers, up to 1600 square feet per truck.
- Mats can be handled with a spreader bar which is provided by Armortec with the initial load.
- Permanent anchorage can be achieved by connecting the mat cables to patented anchors such as "Helix" or "Duckbill".
- Mats subject to wave attack should be blinded with a sand/gravel mixture. Above normal waterline mats may be topsoiled and seeded to give a "green" effect.
- Proper toe trench requires a minimum of 2 rows of block buried below predicated soil depth.
- Mats subject to wave attack are required to have a bedding layer of crushed stone or gravel.


SITE PREPARATION


DELIVERY & UNLOADING


INSTALLING & LIFTING DEVICE


BACKFILL & VEGETATION

OTHER ARMORTEC BROCHURES

ARMORLOC · A-JACKS COASTAL

A-JACKS STREAMBANK & SCOUR · ARMORTEC MULTI-PRODUCT

ARMORFLEX HAND PLACED · ARMORWEDGE

ARMORFLEX OS · DITCHLOK

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AUTHORIZED AGENT

Detalle del proceso constructivo.

1. Conformación del talud:

2. Traslado interno de las mantas:

3. Colocación del geotextil:

4. Colocación de la manta de los bloques articulados de concreto:

5. Instalación terminada: