PROTECTING OUR NATURAL RESOURCES

SHOREBLOCK® BD
SHOREBLOCK® SD
SHORELOC™

Concrete Revetment Block
Erosion is the displacement of solids (soil, mud, rock and other particles) by the agents of wind, water or ice, by downward or down-slope movement in response to gravity or by living organisms (in the case of bioerosion).

Erosion is distinguished from weathering, which is the decomposition of rock and particles through processes where no movement is involved, although the two processes may be concurrent.

The most flexible, durable, effective and environmentally-friendly, erosion control method of fighting severe erosion problems.

Erosion is an intrinsic natural process but in many places it is increased by human land use. Poor land use practices include deforestation, overgrazing, unmanaged construction activity and road or trail building.

A certain amount of erosion is natural and, in fact, healthy for the ecosystem. For example, gravels continually move downstream in watercourses. Excessive erosion, however, can cause problems, such as receiving water sedimentation, ecosystem damage and outright loss of soil.

Concrete revetment block can greatly reduce the overall threat created by the erosion process.
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Tidal Canal Flow
Channel Lining
Frequently Asked Questions

Q. What product is appropriate for my application?
A. The Hydraulic Engineering Circular 23 (HEC 23) determines block selection by analyzing the hydraulic conditions with the ACBs permissible shear and calculating the safety factor.

Q. What is maximum velocity a Shoretect™ system can handle?
A. Current Federal design procedures utilize bed shear stress for primary stability analysis. This approach takes into consideration: velocity, depth of flow, and energy slope gradient to determine how much hydraulic energy (bed shear) is incident on the ACBs. Block style and thickness are then selected to provide resistance to the design bed shear with appropriate safety factors based on the individual blocks maximum critical shear value as determined by, full scale, hydraulic flume testing.

Q. What filter fabric is best to use?
A. Overall, woven mono-filaments are preferred over nonwoven geotextiles because of their high hydraulic conductivity and durability. However, in all cases, the soil’s particle size, disbursement and cohesiveness (among other factors) will determine fabric selection. In general, if a fabric exhibits too tight of a weave (or clogs up) sub-structural hydrostatic pressure will build up and force the blocks up and out of the ACB matrix. If the fabric weave is too loose, soil particles will migrate up and through the ACBs causing sub-structural erosion and consequential ACB failure. Most geotextile suppliers can offer assistance, and in some cases, provide fabric selection software to enable proper selection of the fabric.

Q. What are the differences between installing cabled and non-cabled systems?
A. Installation varies depending on the type of system being installed, the accessibility of the project and geometries of the bed slope, side slope and overall configuration of the placement.

Cabled Systems  - Cabled mats are more easily placed in many cases including steep slope and wet applications. Utilization of cabled mats on large projects can significantly enhance speed of installation, a prefabricated 320 sq. ft. cabled mat can be placed at a rate of up to four mats (1,280 sq. ft.) per crane-hour

Non-cabled Positive Interlocking Systems  - Non-cabled mats are the perfect choice for areas where access is limited. This system can be shipped and installed with a minimal amount of machinery. In general, 4” and 6” thick non-cabled block can be installed at a rate of 40 to 90 square feet per man-hour.

Q. Do I need to be concerned about cable deteriorating?
A. Cables are typically sized to carry five (5) times the weight of the particular mat, based on breaking strength many times more than the potential load the cable will see in service after mat placement. Cable deterioration rate will depend on cable material (galvanized steel, polyester, etc.) and the service environment. Except for severe chemical environments, cable deterioration should not adversely affect the long-term system performance.

Q. What is the maximum slope a Shoretect™ system can handle?
A. 2:1 slopes are the preferred limit. However, steeper slopes, up to 1:1, can be designed provided a proper slope stability analysis has been performed. Constructability also becomes an issue on steep (1:1) slopes with vertical elevations over 10’ and will likely necessitate intermat anchoring and cables for placement.
Q. How do you handle upstream and downstream terminations?
A. If the ACB system does not start and end at an existing structure, typically the blocks (and underlying fabric) are tucked into an anchor trench and backfilled and compacted with the appropriate material. In some cases, the “appropriate material” may be: concrete grout, stone, or grouted rip-rap instead of soil. Trench depth is typically 1.5 times the potential depth of scour. If the ACB system starts or ends at an existing structure, a reinforced steel grouted interface treatment is typically used to secure the blocks and insure that hydraulic undermining will not occur.

Q. How do you terminate at the top and toe of a slope?
A. Typically termination at the top of an embankment is achieved by tucking the ACBs (and underlying fabric) into a Top Anchor Trench. Top Anchor Trench depth can range from 12” to 36” deep depending on the specific job characteristics and potential for undermining at the top of the embankment.

Q. How do you anchor the system?
A. Anchoring ACBs can be accomplished by several different methods depending on the design objective. Most common methods utilize galvanized steel helical or duckbill anchors.

Q. What subgrade compaction is required?
A. 95% standard proctor within +/- 3% of optimum moisture content is the normal requirement for fill embankments. Existing compaction of undisturbed soils is sufficient provided they are stable soils and do not exhibit “yielding” of soft areas.

Q. What is the maximum wave height a Shoretect™ System can handle?
A. Opposition to wave attack is primarily based on unit weight. Studies have been conducted by the Federal Highway Administration (FHWA) indicating ACB stability at wave heights of 11’ to 10’ depending on the weight of the block. Typically a 4” (30 to 40 lbs) block can withstand wave attacks of 4’. Special care and consideration should be taken when designing ACB applications for wave attack. Wave attack stability data can be obtained through the FHWA.
Research and Design

For over 30 years, a wide range of research projects have been executed to evaluate the performance of articulating concrete blocks, including the following:

• “Hydraulic Stability of Articulated Concrete Block Revetment Systems During Overtopping Flow.” Colorado State University, 1988-2002


• Standard Test Methods for Sampling and Testing Concrete Masonry Units and Related Units, ASTM C 140-01ae1 ~ ASTM International, 2001

• Design Manual for Articulating Concrete Block Systems ~ Harris County Flood Control District, Houston, Texas, 2001

• Articulated Concrete Block for Erosion Control, TEK 11-9A ~ National Concrete Masonry Association, Herndon, VA, 1999

• Design of Roadside Channels with Flexible Lining ~ Federal Highway Administration Hydraulic Engineering Circular Number 15

• Hydraulic Engineering ~ Federal Highway Administration Hydraulic Engineering Circular Number 23

• RMA-2V Version 4.35 ~ United States Army Corps of Engineers, USACE Waterways Experiment Station, 1997

• HEC-RAS Version 2.2 ~ United States Army Corps of Engineers, USACE Hydrologic Engineering Center, 1998


Design Considerations

Existing and proposed project characteristics combined with the hydraulic design objectives will determine, through a factor of safety analysis, the ACB product that will best serve the project’s erosion control needs. A 1.5 factor of safety is common.

The hydraulic forces which are considered in the design of erosion control projects using this technology are hydraulic lift, drag, and impact. High velocity flows are usually associated with drainage channels, water control structures, dam spillways, and fast flowing rivers. While many of the forces created by water can be readily calculated, particularly uplift and drag, each project application has separate design considerations.

Selecting a Target Factor of Safety

The designer must determine what factor of safety should be used for a particular application. Typically, a minimum allowable factor of safety of 1.2 is used for revetment (bank protection) when the project hydraulic conditions are well known and the installation can be conducted under well-controlled conditions. Higher factors of safety are typically used for protection at bridge piers, abutments, and at channel bends due to the complexity in computing hydraulic conditions at these locations.

The Harris County Flood Control District, Texas (HCFCD) (7) has developed a simple flowchart approach that considers the type of application, uncertainty in the hydraulic and hydrologic models used to calculate design conditions, and consequences of failure to select an appropriate target factor of safety to use when designing an ACB installation. In this approach, the minimum allowable factor of safety for ACB’s at bridge piers is 1.5; this value is then multiplied by two factors, each equal to or greater than 1.0, to account for risk and uncertainty.

System Design Overview

• Determine Type of Application
  • Channel Flow
  • Shore Protection
  • Spillway
  • Retention Basin
  • Wave Attack

• Determine Design Parameters
  • Geometry of Facilities
    • Side Slopes
    • Bed Slopes
  • Hydraulic Parameters
    • Flow Depth
    • Critical Velocity
    • Critical Shear Stress
    • Flow Rates

• Use Appropriate Method of Design and Calculation of Critical Parameters
  • Factor of Safety
  • Pilarczyk
Design Equations for ACB Systems

\[ SF = \frac{(\ell_2/\ell_1)a_0}{\sqrt{1-a_0^2 \cos \beta} + \eta_1 (\ell_2/\ell_1) + \frac{\ell_1 F'_D \cos \delta + \ell_2 F'_L}{\ell_1 w_s}} \]

\[ \beta = \arctan \left( \frac{\cos (\theta_0 + \theta)}{(\ell_2/\ell_3 + 1) \frac{\sqrt{1-a_0^2}}{\eta_0 (\ell_2/\ell_1)} + \sin (\theta_0 + \theta)} \right) \]

\[ \theta = \arctan \left( \frac{\sin \theta_0 \cos \theta_1}{\sin \theta_1 \cos \theta_0} \right) = \arctan \left( \frac{\tan \theta_0}{\tan \theta_1} \right) \]

\[ \eta_1 = \left( \frac{\ell_2/\ell_3 + \sin (\theta_0 + \theta + \beta)}{\ell_2/\ell_3 + 1} \right) \eta_0 \]

\[ a_0 = \sqrt{\cos^2 \theta_1 - \sin^2 \theta_0} \]

\[ \delta + \beta + \theta = 90^\circ \text{ or } \pi / 2 \text{ radians} \]

\[ F'_L = F'_D = 0.5 \cdot (\Delta Z) b_p V_{\text{des}}^2 \]

\[ \eta_0 = \frac{\tau_{\text{des}}}{\tau_c} \]

\[ W_s = W \cdot \left( \frac{S_c - 1}{S_c} \right) \]

**Definitions:**
- \( a_0 \) = Projection of WS into sub-grade beneath block
- \( b \) = Block width (ft)
- \( F'_L, F'_D \) = Additional drag & lift forces (lbs)
- \( \ell_x \) = Block moment arms
- \( S_c \) = Specific gravity of concrete (Assume 2.1)
- \( SF \) = Calculated factor of safety
- \( V_{\text{des}} \) = Design velocity (ft/sec)
- \( W \) = Weight of block
- \( W_s \) = Submerged weight of block
- \( \Delta Z \) = Height of block protrusion above ACB Matrix (ft)
- \( \beta \) = Angle of block projection from downward direction once in motion
- \( \delta \) = Angle between drag force and block motion
- \( \eta_0 \) = Stability number for a horizontal surface
- \( \eta_1 \) = Stability number for sloped surface
- \( \theta \) = Angle between side slope projection of WS and the vertical
- \( \theta_0 \) = Channel bed slope (degrees or radians)
- \( \theta_1 \) = Channel bed slope (degrees or radians)

Note - the equations cannot be solved for \( \theta_1 = 0 \) (i.e., division by 0); therefore, a negligible side slope must be entered for the case of \( \theta_1 = 0 \)

- \( \rho \) = Mass density of water (1.94 slugs/ft³)
- \( \tau_c \) = Critical shear stress for block on a horizontal surface (lb/ft²)
- \( \tau_{\text{des}} \) = Design shear stress (lb/ft²)
Selecting a Target Factor of Safety for ACB Systems
(As Published in the Harris County, TX Flood Control District ACB Design Manual)

Step 1: Determine $S_FB$ based on application
$S_FB = (1.2 \text{ to } 2.0)$

Guidance:
- Example Applications
  - Channel bed or bank: 1.2-1.4
  - Bridge pier or abutment: 1.5-1.7
  - Overtopping spillway: 1.8-2.0

Step 2: Determine $X_C$ based on consequence of failure
$X_C = (1.0 \text{ to } 2.0)$

Guidance:
- Consequence of Failure $X_C$
  - Low: 1.0-1.2
  - Medium: 1.3-1.5
  - High: 1.6-1.8
  - Extreme or loss of life: 1.9-2.0

Step 3: Determine $X_M$ based on uncertainty in hydrologic/hydraulic modeling
$X_M = (1.0 \text{ to } 2.0)$

Guidance:
- Type of Modeling Used $X_M$
  - Deterministic (e.g., HEC-RAS, RMA-2V): 1.0-1.3
  - Empirical or Stochastic (e.g., Manning or Rational Equation): 1.4-1.7
  - Estimates: 1.8-2.0

Step 4: Calculate target of safety, $S_FT$ using equation presented below

$S_FT = S_FB X_C X_M$

where
- $S_FT = \text{target factor of safety}$
- $S_FB = \text{base factor of safety}$
- $X_C = \text{multiplier based on consequence of failure}$
- $X_M = \text{multiplier based on model uncertainty}$

Notes:
The intent of this flow chart is to provide a systematic procedure for preselecting a target of safety ($S_FT$) for an ACB system. No simple decision support system can encompass all significant factors that will be encountered in practice; therefore, this flow chart should not replace prudent engineering judgement.

$S_FB$ is a base factor of safety that considers the overall complexity of flow that the ACB system will be expected to. $S_FB$ should reflect erosive flow characteristics that can not be practically modeled, such as complex flow lines and turbulence. $X_C$ is multiplier to incorporate conservatism when the degree of uncertainty in the modeling approach is high, such as the use of a simple model applied to a complex system.

The information contained herein has been compiled by SHORETEC™ and to the best of our knowledge, accurately represents the SHORETEC™ product use in the applications which are illustrated. Final determination of the suitability for the use contemplated and its manner of use are the sole responsibility of the user. Design and analysis shall be performed by a qualified engineer.