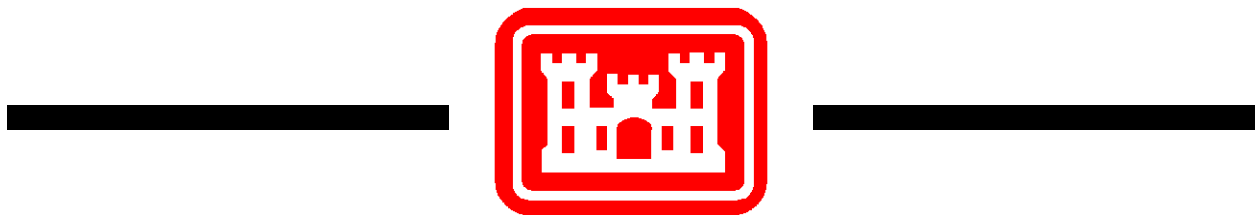


PUBLIC WORKS TECHNICAL BULLETIN 200-1-112
15 DECEMBER 2011

**POROUS CONCRETE LOAD-BEARING
SYSTEM AT FORT HOOD: LESSONS
LEARNED**



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DEPARTMENT OF THE ARMY
U.S. Army Corps of Engineers
441 G Street NW
Washington, DC 20314-1000

CECW-CE

Public Works Technical Bulletin

15 December 2011

No. 200-1-112

FACILITIES ENGINEERING
ENVIRONMENTAL

POROUS CONCRETE LOAD-BEARING SYSTEM AT
FORT HOOD: LESSONS LEARNED

1. Purpose.

a. The purpose of this Public Works Technical Bulletin (PWTB) is to transmit the results of a technology demonstration conducted at Fort Hood, TX. The project's objective was to evaluate the effectiveness of a porous load-bearing system for eliminating standing surface water and reducing stormwater runoff.

b. The study recommended that porous structures intended to capture stormwater from a significant precipitation event be designed and installed to allow sufficient retention time for the stormwater to exfiltrate into the underlying soil.

c. All PWTBs are available electronically (in Adobe® Acrobat® portable document format [PDF]) through the World Wide Web (WWW) at the National Institute of Building Sciences' Whole Building Design Guide webpage, which is accessible through URL:

http://www.wbdg.org/ccb/browse_cat.php?o=31&c=215

2. Applicability. This PWTB applies to all U.S. Army facilities where engineering activities have the responsibility to comply with state and federal stormwater regulations, and wish to implement best management practices (BMP) to achieve compliance.

3. References.

a. Army Regulation (AR) 200-1: Environmental Protection and Enhancement, 13 December 2007.

b. The Clean Water Act (CWA) as amended (Public Law 95-217, 33 U.S.C. 1251 et seq.), 27 December 1977.

c. Title 40, of the Code of Federal Regulations (CFR), Chapter 1, "Environmental Protection Agency," Part 122 (40 CFR 122.1), establishes regulations to implement "EPA Administered Permit Programs: The National Pollutant Discharge Elimination System" (NPDES), revised 1 July 2008.

d. Executive Order (EO) 13514, "Federal Leadership in Environmental, Energy, and Economic Performance," 5 October 2009.

4. Discussion.

a. AR 200-1 requires that Army installations comply with federal environmental regulations, including standards for the management of stormwater, as established by the U.S. Environmental Protection Agency (USEPA) under the authority of the Clean Water Act (CWA).

b. Title 40 CFR, Part 122 defines stormwater discharges from industrial activities and municipal systems as point sources subject to the general and specific requirements for the NPDES Permit Program. The regulatory requirements of each state and municipality pertaining to stormwater are based on this federal regulation, perhaps with additional provisions to address specific needs and conditions of watersheds within a region.

c. EO 13514 requires each federal agency to prepare a Strategic Sustainability Performance Plan (SSPP). The FY 2010 Department of Defense (DoD) SSPP charts the path the DoD will take over the coming decade to improve sustainability across all aspects of the DoD. Goal 2 of DoD's SSPP addresses improved water resources management and storm water management in the reduction of runoff from facilities, thereby reducing the flow of pollutants to bodies of water.

d. The rapid, turbulent flow of stormwater runoff can cause the entrainment of debris, chemicals, sediment, or other pollutants that could adversely affect water quality downstream. These discharges may be covered under general or individual NPDES stormwater discharge permits. Army installations that

conduct industrial activities are typically required to develop and implement stormwater pollution prevention plans. The pollution control methods in these plans are usually the implementation of BMP options by Directorate of Public Works (DPW) personnel to minimize the impact of stormwater discharges and remain compliant with USEPA permit requirements.

e. One best management practice (BMP) that has shown promise at other sites is installing porous load-bearing systems in parking lots and roadways. These systems reduce stormwater runoff by retaining the water below the surface, where it eventually permeates the soil. Environmental personnel at Fort Hood proposed that a study be conducted under the Waste Minimization and Pollution Prevention (WMPP) program managed by the Engineer Research and Development Center - Construction Engineering Research Laboratory (ERDC-CERL) in Champaign, IL. As a result, a study was funded through WMPP to evaluate porous load-bearing systems. The study was conducted in 2005 by MSE Technology Applications, Inc. (MSE), of Butte, MT, the prime contractor for executing the WMPP program.

f. MSE evaluated porous load-bearing system literature and provided that information to environmental personnel with the DPW at Fort Hood. DPW personnel then selected a porous pavement system and modified an existing project in order to install that system in a parking lot. After installation, MSE conducted an elevation survey, ran field permeability tests, and evaluated the effectiveness of this system. Results indicated that the porous concrete appeared to function as expected, because it captured stormwater and eliminated run-off from the surface of the pavement. However, as installed at Fort Hood, the system did not retain the captured stormwater. This was because of a significant elevation drop from one side of the parking lot to the other that allowed the stormwater to exit the system at the lowest elevation. The resulting short detention in the subsurface storage did not allow the stormwater to percolate into the subsoil.

g. MSE also pointed out quality issues with the system's installation. The contractor installing the Ecocrete concrete mixture apparently was inexperienced in mixing the product, which led to the pavement surface being uneven and causing spalling. The study recommended implementing good quality-control measures and monitoring by personnel experienced with the system.

h. Appendix A, "Porous Load-Bearing System Feasibility Study and Demonstration Project," provides further information about the Fort Hood study. Appendix A is the final report submitted by MSE to ERDC-CERL, edited for format and clarity.

i. A glossary of abbreviations is in Appendix B.

j. Appendix C is a list of references cited by the report.

5. Points of Contact.

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APPENDIX A
POROUS LOAD-BEARING SYSTEM FEASIBILITY STUDY
AND DEMONSTRATION PROJECT

Foreword

This project was funded through the Waste Minimization and Pollution Prevention Program (WMPPP) by the U.S. Department of Army, Office of the Assistant Chief of Staff for Installation Management (OACSIM). The WMPP was administered by the U.S. Army Engineer Research and Development Center-Construction Engineering Research Laboratory (ERDC-CERL). The study was conducted by MSE Technology Applications, Inc. (MSE), of Butte, Montana.

The major contributors to this project include:

- Mr. Jay McCloskey, MSE Project Engineer
- Mr. Steve Antonioli, MSE Program Manager
- Mr. Derik Gonzalez, ECOCRETO of Texas, Inc.
- Mr. Randy Doyle, Fort Hood DPW, Environmental Programs Division
- Mr. Gary Gerdes, ERDC-CERL, WMPP Program Manager

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Introduction

Background

Stormwater runoff presents multiple problems for Fort Hood. Due to the vast extent of asphalt and concrete pavement on the installation, very large flows of stormwater runoff follow precipitation events. Suspended solids and petroleum concentrations in the stormwater runoff are near regulatory allowance, restricting Fort Hood's ability to construct new facilities and train for combat. Fort Hood is searching for new technologies and best management practices to deal with stormwater runoff and its associated contaminants. In addition, Fort Hood is continuously searching for cost-effective alternatives to asphalt and concrete around barracks, operations buildings, motor pools, and other facilities.

Environmental personnel at Fort Hood requested that the Waste Minimization and Pollution Prevention (WMPP) Program conduct a study to determine the feasibility of implementing a porous load-bearing system on a parking lot at Fort Hood. The WMPP Program subsequently selected that study for funding, and the study was executed by MSE Technology Application, Inc. (MSE), of Butte, MT. (MSE serves as the prime contractor for the WMPP Program.)

Objective

The project's objective was to evaluate the effectiveness of a porous load-bearing system for eliminating standing surface water and reducing stormwater runoff.

Approach

MSE provided information on various types of porous, load-bearing, pavement systems to Fort Hood to help in the decision process of selecting the most technically and economically suited for installation at Fort Hood. Fort Hood selected the system, the installation site, and the final design of the system. After the porous load-bearing system was installed, MSE performed field tests and evaluated the effectiveness of the system.

Selection of a Porous Load-bearing System

MSE provided information on potential porous load-bearing systems to replace conventional pavement (e.g., asphalt or

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concrete). Three porous load-bearing systems were identified as potential replacements: (1) Gravelpave2 (Invisible Structures, Inc. n.d.), (2) porous asphalt pavement, and (3) porous concrete. DPW personnel at Fort Hood selected the porous concrete system, specifically Ecocreto™ porous concrete system from Ecocreto of Texas, Inc., because they believed that system would be the most cost effective (Ecocreto of Texas, Inc. n.d.). The remainder of this report refers to the Ecocreto system as "the porous concrete system."

Installation of Porous Concrete System

Fort Hood selected the parking lot of Building 1871 to install the porous concrete system. That lot is part of Fort Hood's renovation project called "Main Street Fort Hood Memorial Park and Historic Sites." Figure A-1 shows the proposed layout of the renovation project. As shown, the parking lot forms a horseshoe shape around Buildings 1871, 44, and 53.

Soil information for the project area was needed to determine permeability of the subsoil, and this information also was required to design water retention and recharge of the porous concrete system. The physical properties of the soil are reported in the Soil Survey of Coryell County, TS (U.S. Dept. of Agriculture [USDA] Soil Conservation Service 1985).

The porous concrete system was installed January-February 2005.

The parking lot was divided into the parking area and traffic road. The porous concrete thickness for the parking area was designed at 4 in., while the road/traffic areas were designed at 6 in. The total area of the parking lot is approximately 39,630 sq ft. Approximately 670 yd of porous concrete were installed. Figure A-2 and Figure A-3 are photographs of the parking lot during installation. Figure A-4 is a photograph of the surface of the porous concrete.

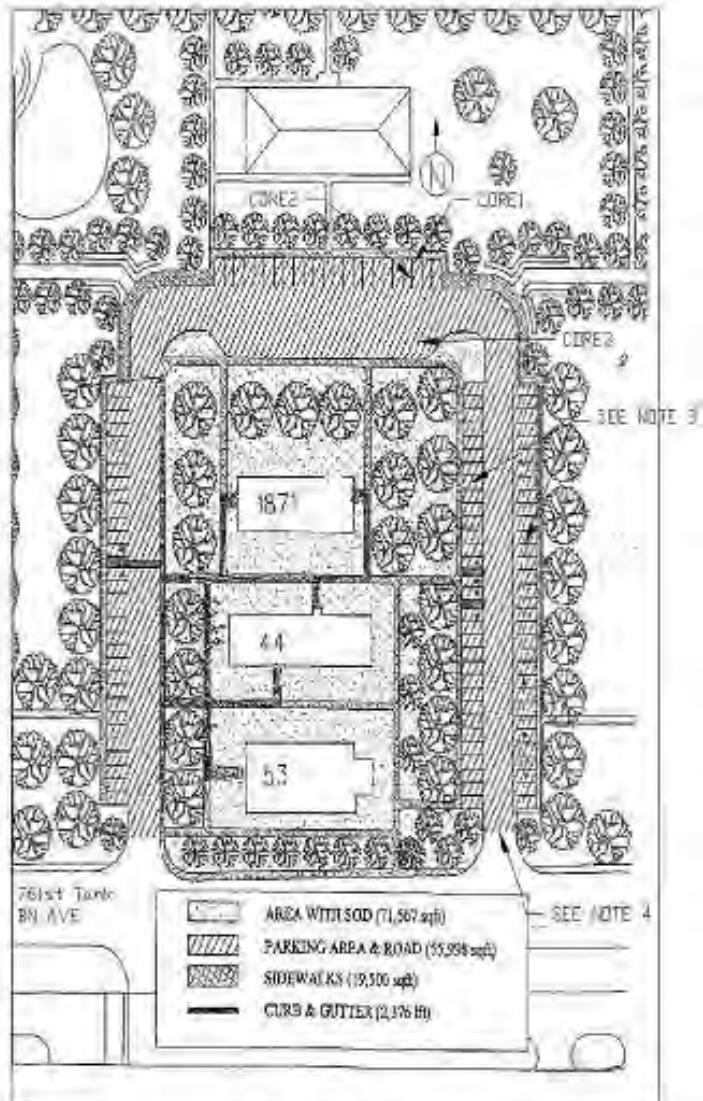


Figure A-1. Proposed layout of the parking lot at Building #1871, Main Street Fort Hood Memorial Park and Historic Sites.



Figure A-2. Workers installing a 1 ½-in. layer of rock for the porous concrete system subsurface.



Figure A-3. Contractors installing the Ecocrete porous concrete system at Fort Hood.



Figure A-4. The Ecocrete porous concrete finished surface.

Evaluation of the Porous Concrete System Installation

Following installation of the porous concrete, MSE was directed by Fort Hood to develop a strategy to evaluate the porous concrete system to include an elevation survey, coring the pavement and gravel layers, and permeability testing. (Note that normally, permeability testing of the underlying soil would be conducted prior to system design and construction.) A field permeability testing strategy was selected by MSE and approved by Fort Hood. During February 2005, MSE performed an elevation survey and evaluated the system.

Elevation Survey

Prior to installing test ports for the field permeability tests, MSE completed an elevation survey of the project area. This survey showed that the elevation at the parking lot entrance from 761st Tank BN Ave. is 101.64 ft, and the elevation at the parking lot exit is 97.42 ft, which represents an elevation drop of more than 4.0 ft. This is a significant finding because that much slope would be expected to diminish the ability of the porous concrete system to retain stormwater.

Field Permeability Testing

A modified National Center for Asphalt Technology (NCAT) permeability test was used to determine permeability of the porous pavement. The testing required installation of sample ports in the porous pavement, and fabrication of a water feed apparatus to measure the flow of water through the ports.

The sample ports were installed using a 6-in. hole saw to cut through the porous concrete (Fig A-5). A 6-in., schedule 10 steel pipe was driven through the washed gravel and into the native soil. The top of the sample port was level with the porous concrete surface. The removed porous concrete plug was then replaced and sealed around the top where it touches the sample pipe. Sample ports were planned for installation at the three locations identified on the site layout (see Figure A-1: CORE 1, CORE 2, and CORE 3).



Figure A-5. Hole saw used for drilling a sample port.

MSE had minimal success in installing a sample port at all three locations. It was not possible to install the sample pipe below the porous concrete without disrupting the crushed rock fill below it. In an attempt to determine the permeability of an

undisturbed crushed rock layer, Site 1 was only cored through the layer of porous concrete. Sites 2 and 3 were core-drilled completely to the geotextile fabric. A sample pipe was placed in Site 1 down to the crushed rock layer. The core from Site 2 was completely removed and a sample pipe was placed in the hole to form an apparent seal with the geotextile fabric and clay soil (it was not possible to verify this seal). This hole was intended to determine the permeability of the fabric liner and underlying soil. Site 3 was used to approximate the combined permeability of the concrete and rock layers. The cylindrical pavement core was left in the hole after being cut out with the hole-saw tool. The hole saw left a circle-shaped gap between the core and the surrounding pavement that allowed a sample pipe to be forced into the hole, putting the core inside the pipe. Figure A-6 is a photograph of the core taken from sample Site 2. Some gravel removed from a sample port (Figure A-7) indicated that the crushed rock had not been completely washed. This meant it had some tendency to absorb water and become sticky, which is not ideal for best drainage.



Figure A-6. Core sample from Site 2.



Figure A-7. Poorly washed gravel removed from a sample port.

A permeability measuring device similar to a NCAT device was fabricated, and consisted of conjoined segments of piping with sequentially decreasing cross sections. This device was placed over the embedded steel pipe in the core holes. During testing, the conjoined pipe segments are filled with water to the top using a funnel at a steady rate. Permeability is determined by the rate at which the water level drops within a pipe segment. The most suitable pipe segment for determining permeability is selected based on how fast the water level drops.

Permeability testing was attempted at Site 1, but as expected, the rock layer was so permeable that the water level dropped too fast for measurement. Data was taken for permeability with Site 2 for the geotextile fabric and clay layer. The permeability rate was measured from 38 to 59 cu. in. of water per minute over a series of five consecutive tests. The disruption to the rock layer in Site 3 was significant enough to produce data that were flawed and not considered.

Based on the core samples, the actual installation could be characterized as consisting of a 1½-in. crushed, washed rock layer approximately 14 in. deep and approximately 5 in. of Ecocreto for parking areas (Figure A-6). The main driveways consist of approximately 8 in. of crushed 1½-in. washed rock and 7 in. of Ecocreto. Both areas have a heavy geotextile mat under the crushed rock.

Observations and Lessons Learned

Personal observations were the most valuable for the evaluation of the porous concrete system. Following are observations that were made after the system was installed.

- (1) The majority of the concrete surface of the parking lot was spalling (flaking and chipping) at the time of inspection. Also, the surface was roughly graded and had non-uniform color; this indicates improper handling, placement, curing, and finishing of the surface.

It was reported at Fort Hood that the installing contractor experienced many different problems associated with mixing and placing the Ecocreto. Apparently, there were no quality-control tests performed on the fresh concrete before or after the Ecocreto mixture was added. Subsequent discussions with Ecocreto and Fort Hood personnel indicated the contractor had numerous problems controlling the mixture prior to placement. It was also reported that the contractor attempted to slow the reaction of the mix by placing ice in it or by adding unmeasured quantities of water to the mix on site. The addition of water can be permitted after slump tests are performed; however, a final slump test should be performed to verify the slump prior to adding the Ecocreto admixture. The Ecocreto representative also stated that the contractor had sprayed the surface with water in an attempt to cure it. This action was more than likely the cause of the spalling because washing would remove cement fines, resulting in inadequate binding of the aggregate. The rough grade of the surface was probably a result of the mixture setting too fast and poor handling of the materials. Care should be taken to avoid these problems with future installations of this system.

- (2) A light rainfall occurred during the night of 1 March 2005, and the porous pavement installation was inspected the following morning. Ponding was not observed on the parking lot surface, which could have meant the concrete surface was indeed porous. However, water was observed exiting from the parking lot at the southeast driveway (Figure A-8). Water then flowed east along the curb until it reached a storm drain approximately 150 yd from the parking lot. This observation indicated the system did not retain water as desired.



Figure A-8. Water seeping from the southeast end of the parking lot.

- (3) An evaluation of the parking lot layout determined that there was no need to place the porous concrete in all areas. Placement of porous concrete in select areas, with road crowning and standard asphalt in the other areas, could have provided acceptable drainage. In addition, proper grading and placement of the porous sections could have reduced the overall cost of the parking lot installation.

The initial intent of the project was to implement a porous system that would be designed with the capacity to retain water from a significant precipitation event with subsequent infiltration of runoff into the native soil. The Ecocrete representative indicated that there is a pore space volume of 40%-46% in the sub-base material (crushed washed rock). This is supported by inspection of the subgrade after removal of the core samples. However, this pore space was not being used to retain water, which was evident by the volume of water observed flowing from the parking lot. With the elevation drop of 4 ft from the entrance at the northeast corner to the exit at the southeast corner, the porous concrete structure appeared to be operating as a subsurface drain channel for the water captured by the parking lot rather than for storage.

Recommendations

It is recommended that future porous concrete systems be designed and installed to ensure the capture of stormwater from a significant precipitation event and to allow enough retention time for the stormwater to exfiltrate to the underlying soil.

Designers should verify the infiltration capacity of the soil prior to site selection and construction of a porous pavement system. Engineers should confirm that the slope of the underlying soil is such that water will be retained until infiltration occurs.

DPW should work with the porous pavement system vendor to insure that installation is done properly and that necessary QA/QC is in place during installation.

APPENDIX B
ACRONYMS AND ABBREVIATIONS

Term	Spellout
AR	Army Regulation
BMP	best management practice
CERL	Construction Engineering Research Laboratory
CFR	Code of the Federal Regulations
CS	Carbon Steel
CWA	Clean Water Act
DA	Department of the Army
DOD	Department of Defense
DPW	Directorate of Public Works
EPA	Environmental Protection Agency; also USEPA
ERDC	Engineer Research and Development Center
HQUSACE	Headquarters, U.S. Army Corps of Engineers
MSE	MSE Technology Applications, Inc.
NCAT	National Center for Asphalt Technology
NOV	Notice of Violation
NPDES	National Pollutant Discharge Elimination System
OACSIM	Office of the Assistant Chief of Staff for Installation Management
POC	point of contact
PWTB	Public Works Technical Bulletin
SIS	Specialized Information Services
SSPP	Strategic Sustainability Performance Plan
TN	Technical Note
USDA	U.S. Department of Agriculture
USEPA	U.S. Environmental Protection Agency
WMPP	Waste Minimization and Pollution Prevention

APPENDIX C
REFERENCES

Ecocreto™ of Texas, Inc. n.d. Product information on Ecocreto™ porous pavement system. Available at:
<http://www.ecocreto.com> (accessed Mar. 2004, confirmed Feb. 2010).

Invisible Structures, Inc. n.d. Product information for Gravelpave2. Available at:
<http://www.invisiblestructures.com/gravelpave2.html>
(accessed Mar. 2004, confirmed Feb. 2010).

U.S. Dept. of Agriculture, Soil Conservation Service. 1985. *Soil survey of Coryell County, Texas*. Available at:
<http://soildatamart.nrcs.usda.gov/Manuscripts/TX099/0/corye11.pdf> (accessed Feb. 2010).

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