P-005-2013 (Consultant)

M E M O R A N D U M

TO: Mark Hite, P.E.
Director
Division of Structural Design

FROM: Bart Asher, P.E., L.S.
TEBM, Geotechnical Branch

BY: Daryl J. Greer, P.E.
Geotechnical Branch

DATE: August 19, 2013

SUBJECT: **Garrard/Mercer Counties**
FD52 040 0152 000-001
FD52 084 0152 018-019
BRO 5129 (012)
MARS No. 8469001D
KY 152 Bridge and Approaches over Herrington Lake
Item No. 7-1116.00
Geotechnical Engineering Overview Report

The geotechnical engineering overview report for the subject project has been completed by Florence & Hutcheson, Inc. We have reviewed and concur with the recommendations as presented in this report.

A copy of the report is attached. If you have any questions, please contact this office at 502-564-2374.

Attachments

cc: K. Sandefur
W. McKinney
R. Powell
B. Nunley
M. Simpson
K. Caudill
L. Hammer
R. Thomas
D. Byers (WMB)
M. Litkenhus (Stantec)

Geotechnical Overview Report

KY 152 over Herrington Lake
Garrard and Mercer Counties, Kentucky

Stantec Consulting Services Inc.
One Team. Infinite Solutions
1409 North Forbes Road
Lexington, KY 40511-2050
Tel: (859) 422-3000 • Fax: (859) 422-3100
www.stantec.com

Prepared for:
WMB, Inc.
Lexington, Kentucky

August 14, 2013

Stantec Consulting Services Inc.
1409 North Forbes Road
Lexington, KY 40511-2050
Tel: (859) 422-3000
Fax: (859) 422-3100

August 14, 2013

rpt_001_175562020

Mr. Charlie Raymer, PE
WMB, Inc.
1950 Haggard Court
Lexington, Kentucky 40505

Re: Geotechnical Overview Report
KY 152 over Herrington Lake
Garrard and Mercer Counties, Kentucky

Dear Mr. Raymer:

Stantec Consulting Services Inc. (Stantec) is pleased to submit this geotechnical overview for the proposed replacement of KY 152 bridge over Herrington Lake in Garrard and Mercer Counties. The overview is based upon research of available published data, rockcore borings and laboratory testing completed by Stantec.

WMB Inc. provided Stantec with preliminary boring locations for the proposed bridge. The scope of work performed and results of the overview are presented in the accompanying attachment. Stantec appreciates having the opportunity to provide these engineering services and would be happy to answer any questions and further assist you concerning this project.

Sincerely,

STANTEC CONSULTING SERVICES INC.

Benjamin A. Halada, PE
Project Engineer

Adam A. Crace, PE
Project Manager

Mark A. Litkenhus, PE
Senior Principal

/rws

Geotechnical Overview Report

KY 152 over Herrington Lake Garrard and Mercer Counties, Kentucky

Prepared for:
WMB, Inc.
Lexington, Kentucky

August 14, 2013

Geotechnical Overview Report

KY 152 over Herrington Lake
Garrard and Mercer Counties, Kentucky

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Geotechnical Overview Report
KY 152 over Herrington Lake
Garrard and Mercer Counties, Kentucky

1. Introduction

The Kentucky Transportation Cabinet (KYTC) is planning to replace the Kennedy Bridge, KY 152, over Herrington Lake. The existing bridge has been in service since 1933 and is currently operating under a reduced service load of 15 tons. It is proposed that a new bridge will be constructed just downstream of the existing bridge. This overview report discusses the geotechnical considerations of this project.

Since the completion of the existing bridge in 1924, the pier nearest the Mercer County side risen vertically approximately 30 inches and tilted upstream and toward Mercer County about 12 inches. The cause of this movement has never been determined. Existing bridge plans do not provide any geotechnical information at the location of this pier and no exploration has been attempted because of the difficulty associated with drilling in water depths of around 200 feet.

2. Scope of Work

The scope of work for this study consisted of performing a geotechnical overview for the proposed bridge based upon research of available published data, drilling two exploratory borings on the western approach and Stantec Consulting Services Inc. (Stantec) experience with bridge foundations and construction within the region. General geotechnical and geologic characteristics of the study area have been identified and are discussed in this report. Stantec personnel, using a variety of resources, performed a literature search that included reviews of the following:

- Available topographic and geologic mapping of the project area published by the United States Geological Survey (USGS) and the Kentucky Geological Survey (KGS);

- The Geologic Map of Kentucky, published by the USGS and the KGS (1988);

- KYTC Geotechnical Data, published by the KGS and KYTC, http://kgs.uky.edu/kgsmap/kytcLinks.asp;

- Physiographic Regions, published by KGS, http://kgs.uky.edu/kgsweb; and

- Plans of the existing KY 152 Kennedy Bridge over Herrington Lake.

- A Data Needs Analysis Study – Item 7-116.00 Bridge Replacement on Herrington Lake, KY 152 at Mercer / Garrard County line, Prepared By: Division of Planning & District 7 KYTC, June 6, 2011

Stantec completed two rock core borings at the proposed location of the Mercer County side abutment. Boring B-1 was drilled vertically and extended approximately 320 feet into bedrock. Boring B-2 was drilled at a 35 degree angle from vertical in a southwestern direction and extended approximately 57 feet (on the angle) into bedrock. Once the drilling work was completed, the rock core was returned to Stantec's lab where unconfined compressive testing was performed on nineteen selected samples from B-1. Drafted boring logs for borings B-1 and B-2 are presented in Appendix A.

3. Physiographic and Stratigraphic Setting

3.1. Topography and Drainage

The proposed bridge location is in Central Kentucky, situated on the northern portion of the Bryantsville (1971) USGS 7.5-minute topographic quadrangle map. The study area is situated within the Bluegrass Physiographic Region of Kentucky. The Bluegrass Region is characterized by gently rolling hills with rich fertile soils. Weathering of the underlying limestone bedrock has produced caves, sinkholes and springs. The proposed bridge is located close to the Kentucky River Palisades, which formed when the Kentucky River and its tributaries cut through the limestone bedrock to form high cliffs and steep gorges within the study area. The limits of each Region are detailed in Figure 1.

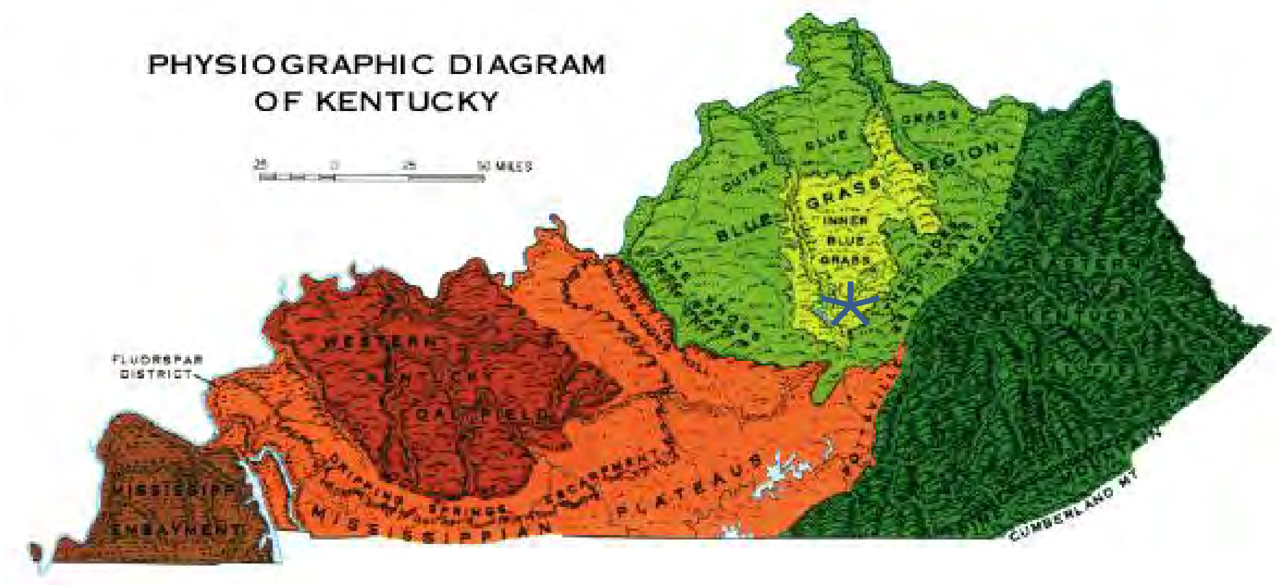


Figure 1. Physiographic Region Overview

Surface drainage within the project area is directed into Herrington Lake (Dix River) and then proceeds from the lake to the Kentucky River.

3.2. Stratigraphy

Based on the corresponding Bryantsville (1971) USGS Quadrangle, the approaches to the project area is primarily underlain by residual clayey and silty soils. The proposed bridge location is underlain by limestone and possibly dolomite bedrock of the Middle Ordovician age. According to the USGS Quadrangle, the limestones are predominantly light gray to gray, micro-crystalline to fine grained, thin to medium bedded, with shale stringers. The dolomite is described as light-gray to gray, micro-crystalline grained and thick bedded.

3.3. Faulting in the Area

Based on USGS Geologic mapping, several unnamed faults are present within approximately one mile of the proposed bridge location. The unnamed faults fall to the north, southwest and south of the bridge location. The Kentucky River Fault Zone is also located near the bridge location. At the closest point, the Kentucky River Fault Zone is approximately 3.25 miles to the southeast of the bridge location. None of these faults are known to have been active within recent history.

3.4. Soils Materials

Residual soils are the predominate soil type within the approach areas of the bridge. Soil descriptions contained herein are based upon SCS soil surveys and on Stantec's knowledge of the study area. Soils can become very thin to very deep in karst areas within a relatively short distance. Overburden material encountered within borings B-1 and B-2 consisted of approximately 1 foot of topsoil followed by clay to the top of rock. The clay is described as red brown to brown in color, medium stiff in terms of stiffness and moist in terms of natural moisture content. The overburden materials were not sampled as part of the completed borings.

3.5. Bedrock

Bedrock encountered in Borings B-1 and B-2 correlate well with the published USGS Quadrangle. Boring B-1 consisted of limestone that can be described as light gray to gray, micro-crystalline to fine grained, thin to medium bedded with shale stringers and some weathered zones. With the exception of a shale layer from 759.4 feet to 751.8 feet, B-1 consisted of the above described limestone. The shale layer can be described as light brown to dark brown, with some limestone streaks, little weathering and some water staining. B-2 did not encounter the shale layer that B-1 encountered. The limestone in B-2 matches the description of the limestone in B-1.

Boring B-1 was drilled vertically from the top of ground at elevation 786.0 feet to an elevation of 460.3 feet in order to obtain rock samples from below the estimated bearing elevation of the lake piers without performing barge work. Rock core from B-1 is being utilized to provide preliminary bearing information at the lake pier locations. Boring B-2 was drilled at a 35 degree angle from vertical to an elevation of 731.1 feet. B-2 was drilled at an angle to try to intercept any bedding planes, fractures and joints in the bedrock that may be present behind the abutment. Photographs of the rock core from B-1 and B-2 can be seen in Appendix B.

For the existing Mercer County side pier, the top of the footing is estimated to be at elevation 561.9 feet and the bottom of the footing is estimated to be at 551.5 feet. Bedrock from B-1 at this elevation is consistent with the description of the limestone encountered in the boring.

3.6. Regional Seismicity

Seismicity within the Commonwealth of Kentucky varies widely depending on location. The western portion of the state is dominated by the New Madrid and Wabash Valley source zones. In general, these zones are fairly active with many documented historical seismic events. Central and eastern portions of the state experience less frequent earthquakes because the source zones are quite distant from these areas. To assist designers in the Commonwealth of Kentucky, the KYTC began a research project in conjunction with the University of Kentucky and the Kentucky Transportation Center (KTC) in 1996. The products of this effort are documents in the publication "Source Zones, Recurrence Rates, and Time Histories for Earthquakes Affecting Kentucky", Research Report KTC-96-4, by Ron Street, et al., (1996). This document and other information available from the Kentucky Geological Survey (KGS) were reviewed in relation to the proposed bridge location.

An Earthquake Epicenters and Magnitudes Map for the Central and Eastern United States from 1568 to 1987 are presented in Figure 2. This map indicates that the proposed bridge would be minimally affected by earthquake events, particularly the New Madrid Seismic Zone (NMSZ). The NMSZ lies within the Central Mississippi Valley, extending from northeast Arkansas, southeast Missouri, western Tennessee, western Kentucky, and southern Illinois. The NMSZ is the most seismically active region in the United States east of the Rocky Mountains.

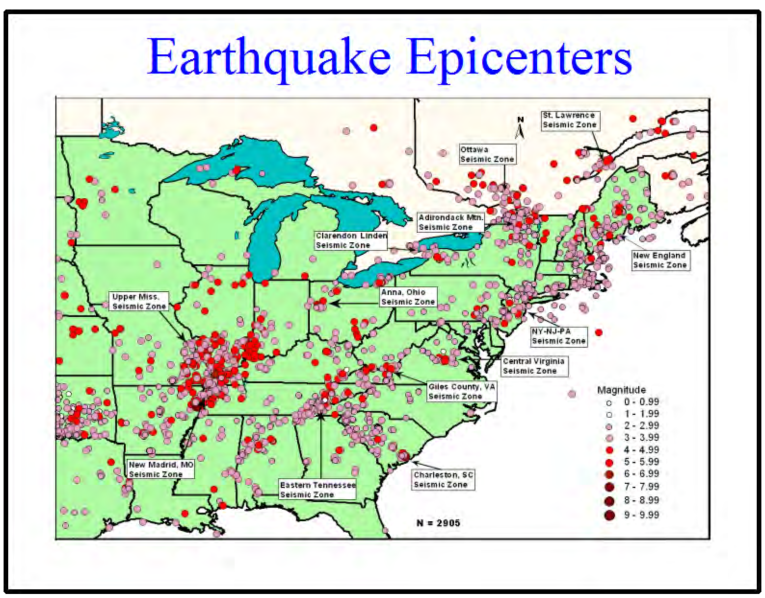


Figure 2. Earthquake Epicenters and Magnitudes in the Central and Eastern United States from 1568 - 1987

The KTC-96-4 research report indicated that a Central Kentucky earthquake event occurred on February 28, 1854 and assigned a Modified Mercalli intensity of V. The most severe effects of that earthquake were reported in Lebanon, where dishes and windows rattled. The earthquake was felt at numerous other locations in Kentucky including Bardstown and Harrodsburg.

3.7. Literature Research

Stantec performed a literature review in an effort to identify information associated with the foundation for the existing bridge. The Kentucky Historical Registry was contacted and forwarded Stantec to the KYTC Structures Division for bridge plans. In addition, Stantec contacted several individuals associated with Kentucky Utilities (KU) to see if there were any plans stored in their plan vaults. Stantec was able to find original plans for the bridge that show the deep water piers were proposed to be a traditional two column concrete pier. However, the piers ended up being constructed as hollow oval shaped piers by a chimney construction company. The piers were constructed and then the lake was impounded. The movement of the Mercer County side pier was observed and measured several years after the lake was impounded. The plans that were recovered are included in Appendix E. However, there was no data associated with the foundations. Therefore, it was concluded that some initial geotechnical drilling would need to be performed to aid the design team with preliminary foundation recommendations.

4. Geotechnical Considerations

4.1. General

Based on project plans provided to Stantec, it is anticipated that there will be relatively few new cuts or fills required as part of the roadway improvements leading to the bridge approaches. However, it does appear that approaches to the proposed bridge will need to be reworked / realigned to meet current roadway standards. The revisions to the approaches will include lengthening ramps and changing horizontal / vertical alignments. As the approaches are reworked, the Project Team should consider the geotechnical considerations that are included in Section 4.

The proposed replacement bridge will be located directly downstream of the existing KY 152 Kennedy Bridge. Project plans show this bridge be a 3-span bridge with an overall length of approximately 802 feet. Abutments will be founded on the Mercer and Garrard County sides of the lake. In addition, two piers will support the bridge from the middle of the span and from a pier located upslope from the water line on the east side of the bridge.

Due to the water depth of around 200 feet, a geotechnical exploration and construction will be difficult, complex and expensive. An anchoring system will need to be installed to help position the floating equipment and prevent it from moving during drilling and construction. The installation of this system will most likely involve the use of divers. The existing bridge piers should not be used as part of the anchoring system.

4.2. Cut Slope Considerations

One cut slope is planned at the east approach to the bridge. Cut slopes in this area may encounter the Tyrone Limestone depending on the thickness of the overlying soil layer. Design plans show this cut to be on the order of 20 feet in height. Shallow cuts in bedrock may be best handled on 2H:1V slopes, covered with a soil layer and vegetated.

4.3. Embankment Considerations

Embankments constructed of durable rock materials generally exhibit adequate stability at 2H:1V slope configurations. However, flatter embankment slopes may be required for embankments greater than 20 feet in height. Since most of the improvements will be focused at the approaches to the proposed bridge, it is anticipated the embankments will be constructed from borrow and offsite sources.

4.4. Erosion

Erosional issues should be minimal due to the relative shallow depth of bedrock encountered in the borings advanced within the area.

4.5. Karst Activity in the Area

Karst activity exists within the Bluegrass Physiographic Region of Central Kentucky. USGS Quadrangle maps do not show the locations of any known karstic features. Undiscovered karstic features may be present in the project area. No karstic features were observed by Stantec at the Mercer County side abutment while drilling borings B-1 and B-2. However, the voids encountered within the upper 5 feet of bedrock in B-1 and the upper 20 feet of bedrock in B-2 could be an indication of karst activity. A detailed study should be undertaken to locate any karstic features that may be present within the final approach alignment.

On March 28, 2012, Stantec personnel performed a field reconnaissance to look at fracture and joint patterns in the rock near the proposed Mercer County side abutment. In addition, Stantec observed the area around the existing bridge for any signs of what may have caused Pier No. 2 to rise when the lake was impounded. It was concluded that there were no visible signs that would have assisted in the initial movement of Pier No. 2.

4.6. Fractures and Joints

B-2 was drilled at an angle to try to intercept any joints, fractures and bedding planes in the bedrock that may be present behind the proposed abutment. Review of the rock core from this boring does not indicate the presence of joints, fractures or bedding planes behind the proposed abutment location. Locating any unknown features is crucial to determining where the abutment can be placed. Additionally, photographs taken from Herrington Lake by Stantec personnel on March 28, 2012 do not show any abnormalities in the rock face under where the abutment would be founded. The jointing / bedding of the rock core recovered from the borings showed that the joints between the bedding plains was generally intact, with the exception of the upper 40 feet in B-1 and the upper 37 feet in B-2. Water staining was only present around the voids encountered near the top of bedrock in each boring. Refer to Appendix C for photographs from the March 28, 2012 site visit.

4.7. Preliminary Foundation Analysis

Stantec performed a Rock Mass Rating (RMR) for the bedrock encountered in the exploratory borings. The bedrock was divided into two layers for the purpose of estimating bearing strengths. Table 1 summarizes the RMR for the two bedrock layers.

Table 1. Summary of Rock Mass Rating

Layer	Elevation (ft)	Unconfined Compressive Strength (ksf)	Rock Mass Rating
One	779.5 – 720.5	1,425	67
Two	720.5 – 460.3	2,850	76

*Using Table 10.4.6.4-1 from 2012 Edition of AASHTO LRFD Bridge Design Specifications.

Layer One represents the bearing zone for the bridge abutments. Layer Two represents the bearing zone of the lake piers. Unconfined compressive strength testing data is presented in Appendix D.

4.7.1. Drilled Shafts

Stantec estimated allowable bearing capacities for the strength limit state by deriving nominal end bearing and side resistance of drilled shafts in bedrock based on the results of the drilling, sampling, and laboratory testing programs conducted. The methodology used to calculate the nominal end bearing (q_p) and side resistance (q_s) of drilled shafts in bedrock is presented in the 2012 Edition of the AASHTO LRFD Bridge Design Specifications, Section 10.8.3.5.4. Using the referenced procedures and design unconfined compressive strengths of 3,500 psi for concrete, the nominal end bearing resistance (q_p) and the nominal side resistance (q_s) are presented in the following table based on the different rock stratigraphy. Table 2 presents end bearing and friction parameters for drilled shafts.

Table 2. Drilled Shaft Parameters

Layer	Rock Mass Rating	Maximum Side Friction (ksf)*	Maximum End Bearing (ksf)
One	67	21	575
Two	76	21	2386

* The maximum side friction was limited by the strength of the concrete.

4.7.2. Spread Footings

Based upon the information derived from drilling, sampling, and laboratory testing operations conducted for the rock core, Stantec derived nominal bearing capacity estimates for the two bedrock layers. Section 10.6.3.2 of the 2012 Edition of the AASHTO LRFD Bridge Design Specifications provides recommendations for the development of nominal bearing capacity (q_n) using semi-empirical or analytical procedures. Stantec derived the nominal bearing capacity of the bedrock using the methods and procedures outlined in “Hoek-Brown Failure Criterion – 2002 Edition” by Hoek, Carranza Torres, and Corkum. The computer program RocLab version 1.031, developed by RocScience, Inc., was used to derive the bearing capacity of the bedrock mass based on the unconfined compressive strength of intact rock samples, and visual assessments of rock samples obtained from coring operations.

This project will be designed using the Load and Resistance Factor Design (LRFD) methodology. LRFD is a design approach in which applicable failure and serviceability conditions can be evaluated considering the uncertainties associated with loads and materials resistances. This design methodology incorporates the use of load factors and resistance factors to account for uncertainty in applied loads and load resistance of structure elements separately in contrast to the Factor of Safety traditionally applied only to the resistances in Allowable Stress Design (ASD) methodology. Selection of the resistance factors account for the type of loading (axial compression versus uplift) and the variability and reliability of models or methodologies used to determine nominal resistance (R_n) capacities. Table 10.5.5.2.2-1 in the 2012 Edition of the AASHTO LRFD Bridge Design Specifications recommends a resistance factor (φ_b) of 0.45 for shallow foundations bearing on rock. Table 3 presents parameters for spread footings.

Table 3. Spread Footing Parameters

Layer	Rock Mass Rating	Factored Bearing Capacity (ksf)
One	67	375
Two	76	750

For the Mercer Counter side abutment, since no abnormalities were found in boring B-2, the beginning of the bridge (center of abutment) should be set approximately 70 back from the vertical face of the rock wall. This will be about 35 feet from the top of the sloped portion of the rock wall to the beginning of the bridge. This space will provide a construction area and account for any abnormalities not encountered in the exploratory borings.

4.8. Seismic Concerns

The seismic hazard at a bridge site shall be characterized by the acceleration response spectrum for the site and the site factors for the relevant site class. A comprehensive geotechnical investigation would be required to determine the site class. The 2012 AASHTO LRFD Bridge Design Specifications provides guidelines for selecting a seismic performance category and a soil profile type for bridge sites. This information establishes the elastic seismic response coefficient and spectrum for use in further structural design and analyses. Refer to Section 3.10.2 of the referenced AASHTO publication for specifications.

5. Recommendations

5.1. The Mercer County side abutment foundations should be founded below the voids and shale layer encountered in borings B-1 and B-2. This elevation is estimated to be approximately 750.0 feet.

5.2. The spread footing for the Mercer County side abutment should be set 70 feet from the face of the vertical rock wall.

5.3. A comprehensive geotechnical investigation should be performed for the bridge and roadway.

5.4. Geotechnical rock core borings should be performed at the lake pier locations and unconfined compression testing of the rock core should be performed. It should be noted that performing rock core borings from floating equipment will be expensive, challenging and time consuming due to water depths around 200 feet. An anchoring system will need to be installed to keep the floating equipment in position. The existing bridge pier should not be used as part of this anchoring system.

5.5. A detailed study should be undertaken to locate any karstic features that may be present within the final approach alignment.

Appendix A

Project Location and Drafted Boring Log

BORING LOCATION TABLE			
BORING NO.	NOTHING	EASTING	ELEVATION
1	3,796,696.67	5,223,394.85	786.0
2	3,796,642.18	5,223,363.06	786.6

LEGEND

Rock Core

Direction of Angled Boring

SCALE: 1" = 50'

0' 50' 100' 200'

Sheet 1 of 2

FILE NAME: V:\1755\ACTIVE\175562020\GEOTECHNICAL\DRAWING\SHEET_FILES\62020B-101-BL1.DGN

USER: pbond
DATE PLOTTED: June 18, 2013

E-SHEET NAME:

MicroStation v8.11.7.443

REVISION	DATE
DATE:	CHECKED BY
DESIGNED BY:	
DETAILED BY: PJB	

Commonwealth of Kentucky
DEPARTMENT OF HIGHWAYS

COUNTY
MERCER

ROUTE	CROSSING
KY 152	HERRINGTON LAKE

BORING LAYOUT

PREPARED BY
Stantec

SHEET NO.
DRAWING NO.

ITEM NUMBER
7-1116.00

NOTES:

1. This sheet presents geotechnical data and recommendations. Refer to project plans, profiles, and cross sections for final alignment and grade.
2. Surface elevations are referenced to Mean Sea Level.

SCALE: 1" = 10'
(Vertical Only)

Sheet 2 of 2

REVISION	DATE
DATE:	CHECKED BY
DESIGNED BY:	
DETAILED BY: PJB	

Commonwealth of Kentucky
DEPARTMENT OF HIGHWAYS

COUNTY
MERCER

ROUTE	CROSSING
KY 152	HERRINGTON LAKE

LOGS OF BORING

PREPARED BY
Stantec

SHEET NO.
DRAWING NO.

ITEM NUMBER
7-1116.00

FILE NAME: V:\1755\ACTIVE\175562020\GEOTECHNICAL\DRAWING\SHEET_FILES\62020B-301-B01.DGN
USER: tjohnson
DATE PLOTTED: August 13, 2013
E-SHEET NAME:
MicroStation v8.11.7.443

Appendix B

Rock Core Photographs

B-1


Mercer County, KY
KY 152 over Herrington Lake
175562020 B-1
CID:
Structure: S-038-2012
Surface Elevation: [redacted] 786.58
Depth 6.5'-23.0'
Box 1 of
Runs 1-2
6.5'
RUN 1 - 6.5'-15.0'
15.0
23.0'
03/12/2013

Mercer County, KY
KY 152 over Herrington Lake
175562020 B-1
CID:
Structure: S-038-2012
Surface Elevation: 786.58'
Depth 23.0' to 37.6'
Box 2 of
23.0'
RUN 2: 15.0'-25.0'
RUN 3: 25.0'-35.0'
25.0
35.0
RUN 4: 35.0'-45.0'
37.6'
03/12/2013


Mercer County, KY
KY 152 over Herrington Lake
175562020 B-1
[redacted] Item #: 7-1116.00
Structure: S-038-2012
Surface Elevation: 786.58'
Depth: 37.6' to 51.3'
Box: 3 of
RUNS: 4-5
37.6'
Run 4: 35.0' - 45.0'
Run 4
Run 4
Run 4-5
45.0'
Run 5
51.3'
RUN 5: 45.0' - 55.0'
03/13/2013


Mercer County KY
KY 152 over Herrington Lake
175562020 B-1
Item #: 7-1116.00
Structure: S-038-2012
Surface Elevation: 786.58
Depth: 51.3' to 65.0'
Box 4 of
RUNS: 5 - 6
Run 5: 45.0' - 55.0'
51.3'
55.0'
RUN 6: 55.0' - 65.0'
65.0'
Run 5
Run 6
03/13/2013


Mercer County, KY
KY 152 over Herrington Lake
175562020 B-1
Item #: 7-1116.00
Structure: S-038-2012
Surface Elevation: 786.58'
Depth: 65.0' to 78.6'
Box: 5 of
RUNS: 7 - 8
65.0'
RUN 7: 65.0' - 75.0'
RUN 7
RUN 7
RUN 7
RUN 8
RUN 8: 75.0' - 85.0'
Mech Break
78.6'
03/13/2013


Mercer County, KY
KY 152 over Herrington Lake
175562020 B-1
Item #: 7-1116.00
Structure: S-038-2012
Surface Elevation: 786.58'
Depth: 78.6' to 92.6'
Box: 6 of
RUNS: 8 - 9
78.6' Mech Break
RUN 8: 75.0' - [redacted] 84.5'
RUN 8
RUN 8
84.5'
RUN 9
RUN 9
RUN 9: 84.5' - 95.0'
92.6'
03/13/2013


Mercer County KY
KY 152 over Herrington Lake
175562020 B-1
Item #: 7-1116.00
Structure: S-038-2012
Surface Elevation: 786.58'
Depth: 92.6' to 107.9'
Box: 7 of
RUNS: 9 - 11
92.6'
RUN 9: 84.5'-95.0'
95.0'
RUN 10: 95.0'-105.0'
RUN 11: 105.0'-115.0'
105.0'
107.9'
03/13/2013

Mercer County, KY
KY 152 over Herrington Lake
175562020 B-1
Item #: 7-1116.00
Structure: S-038-2012
Surface Elevation: 786.58'
Depth: 107.9' to 121.8'
Box: 8 of
Runs: 11 - 12
107.9'
RUN 11: 105.0' - 115.0'
RUN 11
RUN 11
115.0'
RUN 12
RUN 12
RUN 12: 115.0' - 125.0'
121.8'
03/13/2013


Mercer County, KY
KY 152 over Herrington Lake
175562020 B-1
Item #: 7-1116.00
Structure: 5-038-2012
Surface Elevation: 786.58'
Depth: 121.8' to 135.0'
Box: 9 of
RUNS: 12 – 13
121.8'
RUN 12: 115.0'-125.0'
RUN 12
RUN 13
RUN 13
RUN 13
125.0'
135.0'
RUN 13: 125.0'-135.0'
03/13/2013

Mercer Canty, KY
KY 152 over Herrington Lake
175562020 B-1
Item #: 7-1116.00
Structure: 5-038-2012
Surface Elevation: 786.58'
Depth: 135.0' to 150.0'
Box: 10 of
RUNS: 14 - 15
135.0'
RUN 14: 135.0' - 145.0'
145.0'
150.0'
RUN 15: 145.0' - 150.0'
03/13/2013


Mercer County KY
KY 152 over Herrington Lake
175562020 B-1
Item #: 7-1116.00
Structure: S-038-2012
Surface Elevation: 766.58'
Depth: 150.0' to 165.0'
Box: 11 of
RUNS: 16 - 17
RUN 16: 150.0' - 155.0'
155.0'
165.0'
RUN 17: 155.0' - 165.0'
03/13/2013


Mercer County, KY
KY 152 over Herrington Lake
175562020 B-1
Item #: 7-1116.00
Structure: S-038-2012
Surface Elevation: 786.58'
Depth: 165.0' to 179.9'
Box: 12 of
RUNS: 18 - 19
165.0'
RUN 18: 165.0' - 175.0'
RUN 18
RUN 18
RUN 18
175.0'
RUN 19
179.9'
RUN 19: 175.0' - 185.0'
03/13/2013


Mercer County, KY
KY 152 over Herrington Lake
175562020 B-1
Item #: 7-1116.00
Structure: S-038-2012
Surface Elevation: 786.58'
Depth: 179.9' to 193.2'
Box: 13 of
RUNS: 19 - 21
179.9'
RUN 19: 175.0' - 185.0'
185.0'
190.0'
RUN 20: 185.0' - 190.0'
RUN 21: 190.0' - 195.0'
193.2'
03/13/2013


Mercer County, KY
KY 152 over Herrington Lake
175562020 B-1
Item #: 7-1116.00
Structure: S-038-2012
Surface Elevation: 786.58'
Depth: 193.2' to 207.9'
Box: 14 of
RUNS: 21 - 23
193.2'
RUN 21: 190.0'-195.0'
RUN 22: 195.0'-205.0'
RUN 21
RUN 22
RUN 22
205.0'
RUN 23: 205.0'-215.0'
207.9'
03/13/2013


Mercer County, KY
KY 152 over Herrington Lake
175562020 B-1
Item #: 7-1116.00
Structure: S-038-2012
Surface Elevation: 786.58'
Depth: 207.9' to 222.2'
Box: 15 of
RUNS: 23 – 24
207.9'
RUN 23: 205.0' – 215.0'
RUN 23
RUN 23
215.0'
RUN 24
RUN 24
RUN 24: 215.0' – 225.0'
222.2'
03/13/2013


Mercer County, KY
KY 152 over Herrington Lake
175562020 B-1
Item #: 7-1116.00
Structure: S-038-2012
Surface Elevation: 786.58'
Depth: 222.2' to 235.0'
Box: 16 of
RUNS: 24 - 25
222.2'
RUN 24: 215.0' - 225.0'
RUN 24
RUN 25
225.0'
RUN 25: 225.0' - 235.0'
235.0'
03/13/2013


Mercer County, KY
KY 152 over Herrington Lake
175562020 B-1
Item #: 7-1116.00
Structure: 5-038-2012
Surface Elevation: 786.58'
Depth: 235.0' to 249.6'
Box: 17 of
RUNS 26 - 27
235.0'
RUN 26: 235.0'-245.0'
RUN 26
RUN 26
RUN 26
245.0'
RUN 27
RUN 27: 245.0'-255.0'
249.6'
03/13/2013


Mercer County, KY
KY 152 over Herrington Lake
175562020 B-1
Item #: 7-1116.00
Structure: S-038-2012
Surface Elevation: 786.58'
Depth: 249.6' to 263.7'
Box: 18 of
RUNS: 27 - 28
249.6'
RUN 27: 245.0' - 255.0'
RUN 27
RUN 27
255.0'
RUN 28
RUN 28
263.7'
RUN 28: 255.0' - 265.0'
03/13/2013


Mercer County, KY
KY 152 over Herrington Lake
175562020 B-1
Item #: 7-1116.00
Structure: S-038-2012
Surface Elevation: 786.58'
Depth: 263.7' to 278.0'
Box: 19 of
RUNS: 28 - 30
263.7'
RUN #28: 255.0'-265.0'
RUN 29: 265.0'-275.0'
RUN 30: 275.0'-285.0'
278.0'
03/15/2013


Mercer County, KY
KY 152 over Herrington Lake
175562020 B-1
Item #: 7-1116.00
Structure: S-038-2012
Surface Elevation: 786.58'
Depth: 278.0' to 292.2'
Box: 20 of
RUNS: 30 - 32
278.0'
RUN 30: 275.0' - 285.0'
RUN 30
RUN 30
285.0'
RUN 31
RUN 32
290.7'
RUN 31: 285.0' - 290.7'
RUN 32: 290.7' - 298.8'
292.2'
03/15/2013

Mercer County, KY
KY 152 over Herrington Lake
175562020 B-1
Item #: 7-1116.00
Structure: 5-038-2012
Surface Elevation: 786.58'
Depth: 292.2' to 306.3'
Box: 21 of
RUNS: 32 - 33
292.2'
RUN 32: 290.7' - 298.8'
RUN 32
RUN 32
298.8'
RUN 33
RUN 33
306.3
RUN 33: 298.8' - 309.0'
03/15/2013


Mercer County, KY
KY 152 over Herrington Lake
175562020 B-1
Item #: 7-1116.00
Structure: S-038-2012
Surface Elevation: 786.58'
Depth: 306.3' to 320.6'
Box: 22 of 23
RUNS: 33 - 35
1F
2F
3F
306.3'
RUN 33: 298.8' - 309.0'
RUN 33
309.0'
RUN 34
RUN 34
RUN 34
319.0'
RUN 34: 309.0' - 319.0'
RUN 35: 319.0' - 325.7'
320.6
03/15/2013


Mercer County, KY
KY 152 over Herrington Lake
175562020 B-1
Item #: 7-1116.00
Structure: S-038-2012
Surface Elevation: 786.58'
Depth: 320.6' to 325.7'
Box: 23 of 23
RUNS: 35 - 35
320.6'
RUN 35: 319.0' - 325.7'
RUN35
RUN 35
325.7'
03/15/2013

B-2

Drilled 35 degrees from Vertical


Mercer County, KY
KY 152 over Herrington Lake
175562020 B-2
Item #: 7-1116.00
Structure: S-038-2012
Surface Elevation: 786.58'
Depth: 5.4' to 25.4'
Box: 1 of
RUNS: 1 - 3
Run 1: 5.4' - 12.5'
12.5'
20.0'
RUN 2: 12.5' - 20.0'
RUN 3: 20.0' - 27.5'
25.4'
03/18/2013


Mercer County, KY
KY 152 over Herrington Lake
175562020 B-2
Item #: 7-1116.00
Structure: 5-038-2012
Surface Elevation: 786.58'
Depth: 25.4' to 41.9
Box: 2 of
RUNS: 3 - 5
25.4'
RUN 3: 20.0'-27.5'
RUN 4: 27.5'-32.5'
27.5'
32.5'
Mech Breaks
2.5' Void
34.0'-36.5'
RUN 5: 32.5'-42.5'
41.9'
03/19/2013


Mercer County, KY
KY 152 over Herrington Lake
175562020 B-2
Item #: 7-1116.00
Structure: 5-038-2012
Surface Elevation: 786.58'
Depth: 41.9' to 56.0'
Box: 3 of
RUNS: 5 - 8
41.9'
RUN 6: 42.5' - 50.2'
RUN 7: 50.2' - 52.7'
50.2'
52.7'
56.0'
Run 8: 52.7' - 62.7'
03/19/2013


Mercer County, KY
KY 152 over Herrington Lake
175562020 B-2
Item #: 7-1116.00
Structure: S-038-2012
Surface Elevation: 786.58'
Depth: 56.0' to 67.7'
Box: 4 of 4
RUNS: 8 - 9
56.0'
RUN 8: 52.7' - 62.7'
62.7'
67.7'
RUN 9: 62.7' - 67.7'
03/19/2013

Appendix C

Herrington Lake Photographs


03/12/2007


03/12/2007


03/12/2007


03/12/2007


03/12/2007


03/12/2007


03/12/2007


03/12/2007


03/12/2007


03/12/2007

Appendix D

Laboratory Testing Results

Stantec

Unconfined Compressive Strength Of Intact Rock Core

KM 64-523-02

Project Name	KY 152 Item 7-1116.00	Project Number	175562020
Lithology	Limestone, gray, moderately hard	Lab ID	UCR-1
Hole Number	B-1 #1 — Depth (ft) 63.5'-63.9'	Date Received	03-26-2013

Temperature (^oC)	22.8	Moisture Condition	As received, moist	Date Tested	04-28-2013
Side Planeness	Pass	Height (in)	4.835	Wet Unit Weight (pcf)	168.4
Perpendicularity	Pass	Diameter (in)	1.980	Dry Unit Weight (pcf)	168.3
End Planeness	Pass	Area (in^2)	3.078	Moisture Content[1] (%)	0.1
		Height/Diameter Ratio	2.442	Weight (lb)	1.451

Loading Rate (lbf/sec)	149
Peak Load (lbf)	76381
Failure Type	Undetermined
Compressive Strength (psi)	24810
Compressive Strength (psf)	3572640
Compressive Strength (tsf)	1787

Failure Sketches

N/A

Comments

Alternate Compressive Strength Calculation[2]
(Where Height/Diameter Ratio < 2)

Correction Coefficient	N/A
Corrected Compressive Strength (psi)	N/A
Corrected Compressive Strength (psf)	N/A
Corrected Compressive Strength (tsf)	N/A

[1] Post testing moisture content determination was performed as per ASTM D 2216, where as much of the whole specimen as available after compression testing was used in moisture content testing. Method B.

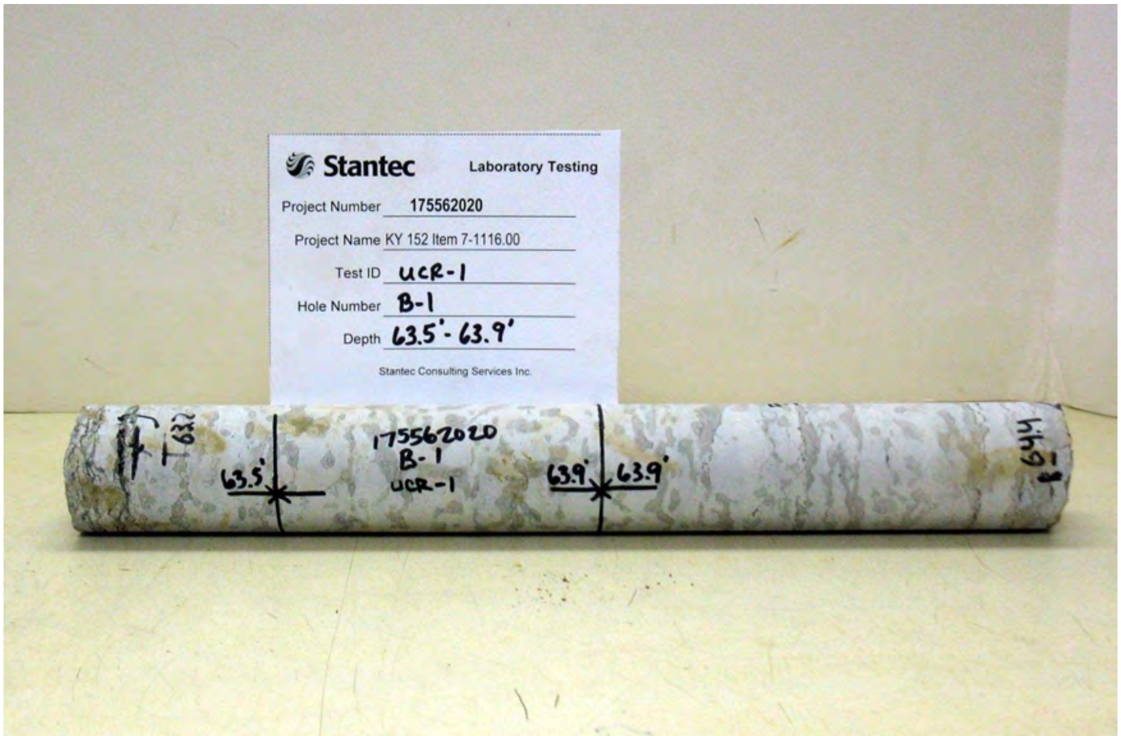
[2] The alternate compressive strength calculation is presented when the height to diameter ratio is less than 2, as per KM 64-523-02.

Reviewed By JW

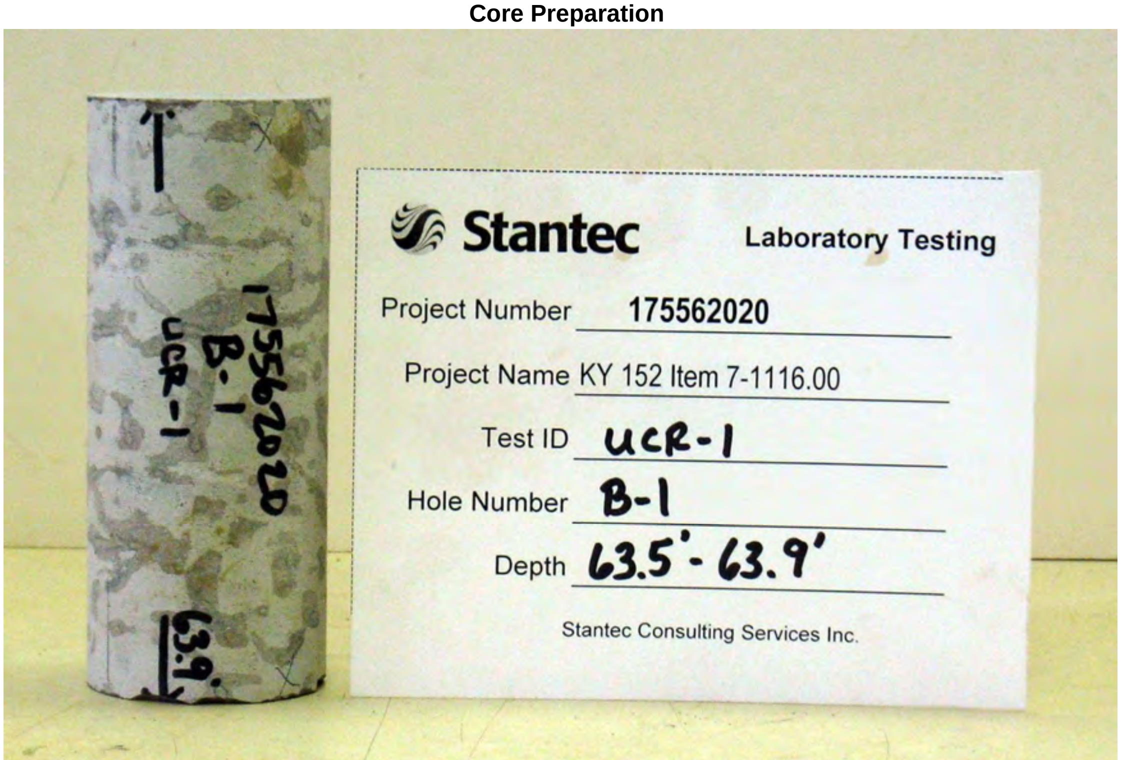
Photo Report

Project Name	KY 152 Item 7-1116.00	Project Number	175562020
Lithology	Limestone, gray, moderately hard	Lab ID	UCR-1
Hole Number	B-1 #1	Depth (ft)	63.5'-63.9'
Test Type	Unconfined compressive strength		

As Received



Core Preparation

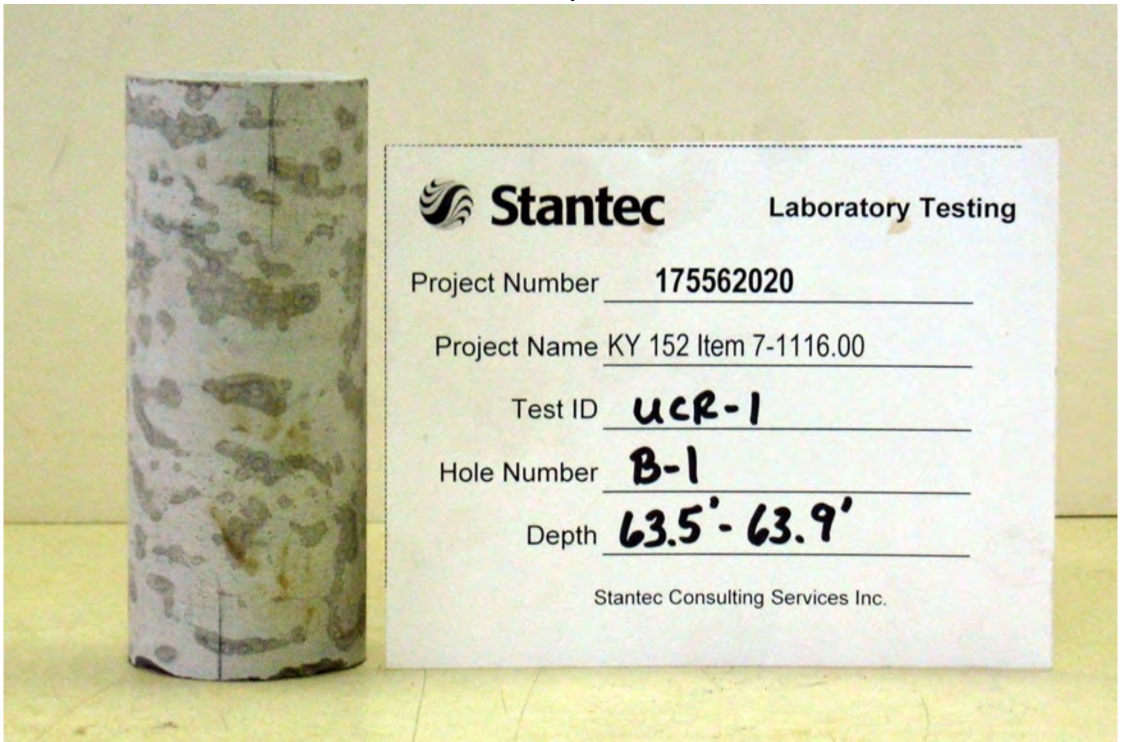


Stantec

Photo Report

Project Name	KY 152 Item 7-1116.00	Project Number	175562020
Lithology	Limestone, gray, moderately hard	Lab ID	UCR-1
Hole Number	B-1 #1	Depth (ft)	63.5'-63.9'
Test Type	Unconfined compressive strength		

Core Preparation



Post Test

Stantec

Unconfined Compressive Strength Of Intact Rock Core

KM 64-523-02

Project Name	KY 152 Item 7-1116.00	Project Number	175562020
Lithology	Limestone, gray, moderately hard	Lab ID	UCR-2
Hole Number	B-1 #2 Depth (ft) 50.7'-51.1'	Date Received	03-26-2013

Temperature (^oC)	23.1	Moisture Condition	As received, moist	Date Tested	04-28-2013

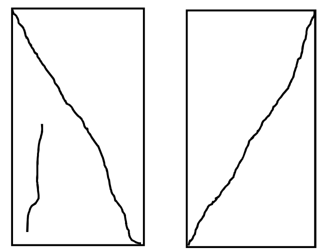
Side Planeness	Pass	Height (in)	4.775	Wet Unit Weight (pcf)	168.2
Perpendicularity	Pass	Diameter (in)	1.975	Dry Unit Weight (pcf)	168.0
End Planeness	Pass	Area (in^2)	3.065	Moisture Content[1] (%)	0.1
		Height/Diameter Ratio	2.417	Weight (lb)	1.424

Loading Rate (lbf/sec) 143
Peak Load (lbf) 57468

Failure Type Shear

Compressive Strength (psi) 18750
Compressive Strength (psf) 2700000
Compressive Strength (tsf) 1350

Failure Sketches



Comments

Alternate Compressive Strength Calculation[2]
(Where Height/Diameter Ratio < 2)

Correction Coefficient N/A

Corrected Compressive Strength (psi) N/A
Corrected Compressive Strength (psf) N/A
Corrected Compressive Strength (tsf) N/A

[1] Post testing moisture content determination was performed as per ASTM D 2216, where as much of the whole specimen as available after compression testing was used in moisture content testing. Method B.

[2] The alternate compressive strength calculation is presented when the height to diameter ratio is less than 2, as per KM 64-523-02.

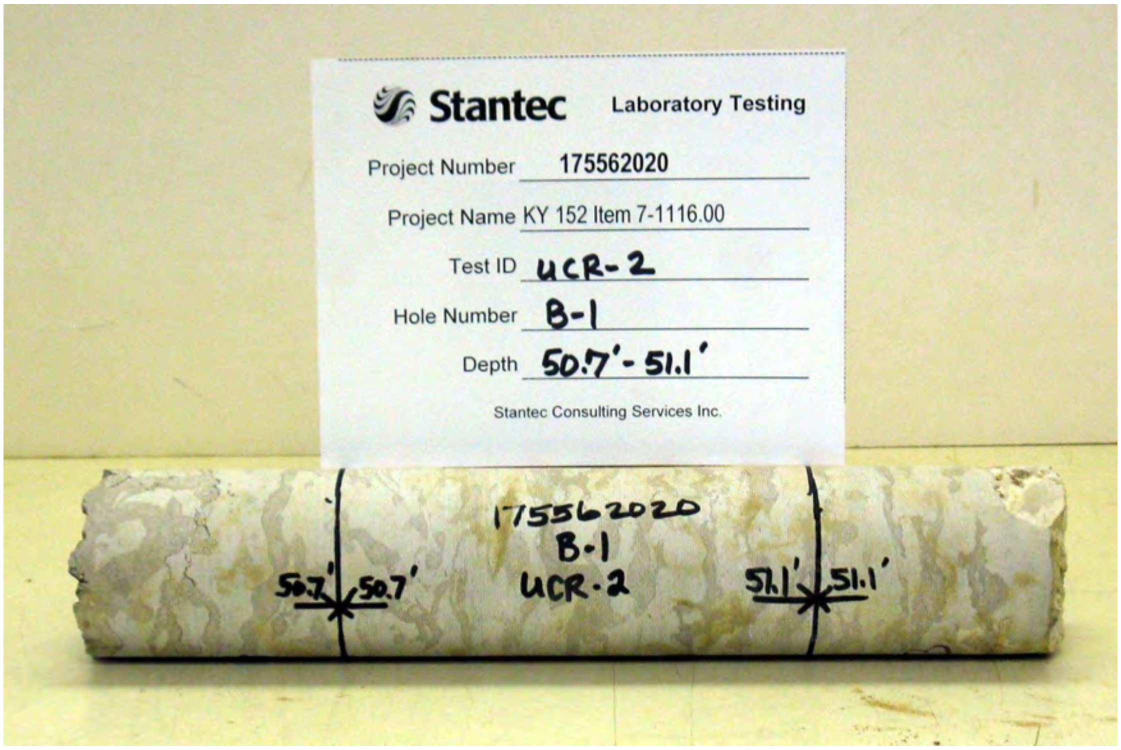
Reviewed By JW

Stantec

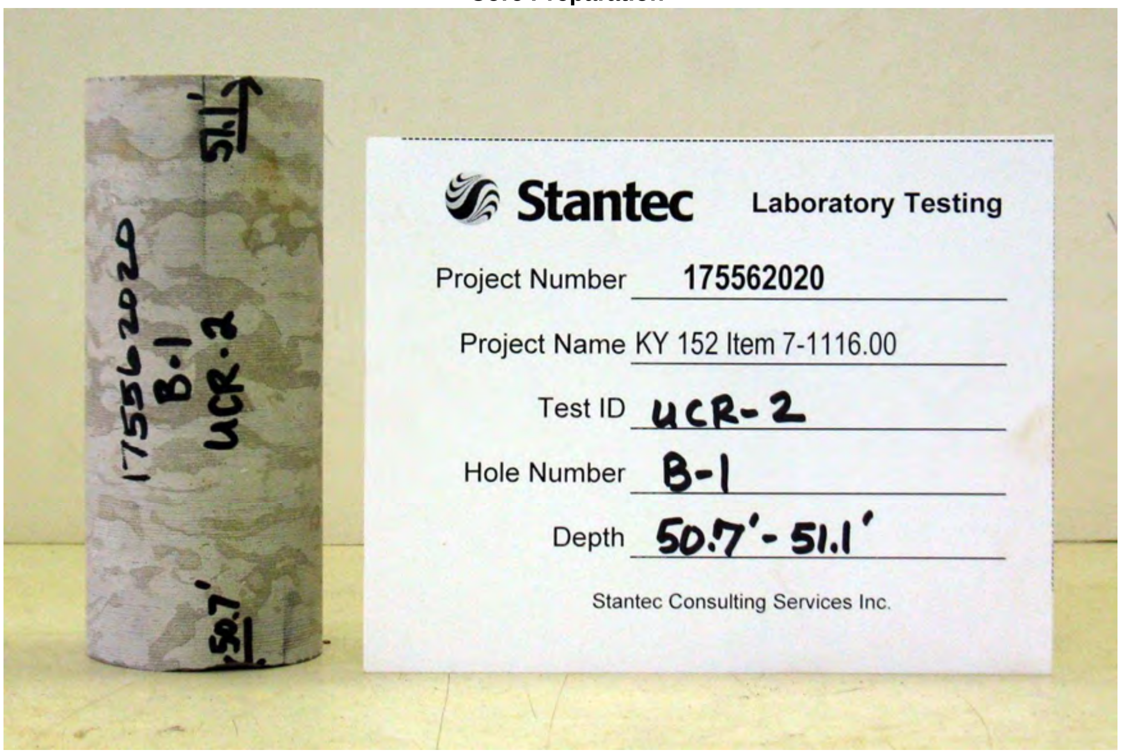
Photo Report

Project Name	KY 152 Item 7-1116.00	Project Number	175562020
Lithology	Limestone, gray, moderately hard	Lab ID	UCR-2
Hole Number	B-1 #2	Depth (ft)	50.7'-51.1'
Test Type	Unconfined compressive strength		

As Received



Core Preparation



Stantec

Photo Report

Project Name KY 152 Item 7-1116.00 | Project Number 175562020
Lithology Limestone, gray, moderately hard | Lab ID UCR-2
Hole Number B-1 #2 | Depth (ft) 50.7'-51.1'
Test Type Unconfined compressive strength

Core Preparation

Post Test

Stantec

Photo Report

Project Name KY 152 Item 7-1116.00
Lithology Limestone, gray, moderately hard
Hole Number B-1 #2 Depth (ft) 50.7'-51.1'
Test Type Unconfined compressive strength

Project Number 175562020
Lab ID UCR-2

Post Test

Stantec

Unconfined Compressive Strength Of Intact Rock Core

KM 64-523-02

Project Name	KY 152 Item 7-1116.00			Project Number	175562020
Lithology	Limestone, gray, moderately hard, shale stringers			Lab ID	UCR-3
Hole Number	B-1 #3	Depth (ft)	40.3'-40.7'	Date Received	03-26-2013
Temperature (^oC)	23.2	Moisture Condition	As received, moist	Date Tested	04-28-2013
Side Planeness	Pass	Height (in)	4.473	Wet Unit Weight (pcf)	167.0
Perpendicularity	Pass	Diameter (in)	1.976	Dry Unit Weight (pcf)	166.8
End Planeness	Pass	Area (in^2)	3.066	Moisture Content[1] (%)	0.1
		Height/Diameter Ratio	2.264	Weight (lb)	1.325

Loading Rate (lbf/sec) 151

Peak Load (lbf) 26242

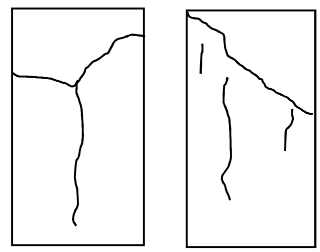
Failure Type Undetermined

Compressive Strength (psi) 8560

Compressive Strength (psf) 1232640

Compressive Strength (tsf) 616

Failure Sketches



Comments

Alternate Compressive Strength Calculation[2]
(Where Height/Diameter Ratio < 2)

Correction Coefficient N/A

Corrected Compressive Strength (psi) N/A

Corrected Compressive Strength (psf) N/A

Corrected Compressive Strength (tsf) N/A

[1] Post testing moisture content determination was performed as per ASTM D 2216, where as much of the whole specimen as available after compression testing was used in moisture content testing. Method B.

[2] The alternate compressive strength calculation is presented when the height to diameter ratio is less than 2, as per KM 64-523-02.

Reviewed By JW

Form: tmp_ucr_km_input.xlsm
Preparation Date: 12-1999
Revision Date: 01-2008

Stantec Consulting Services Inc.
Lexington, Kentucky

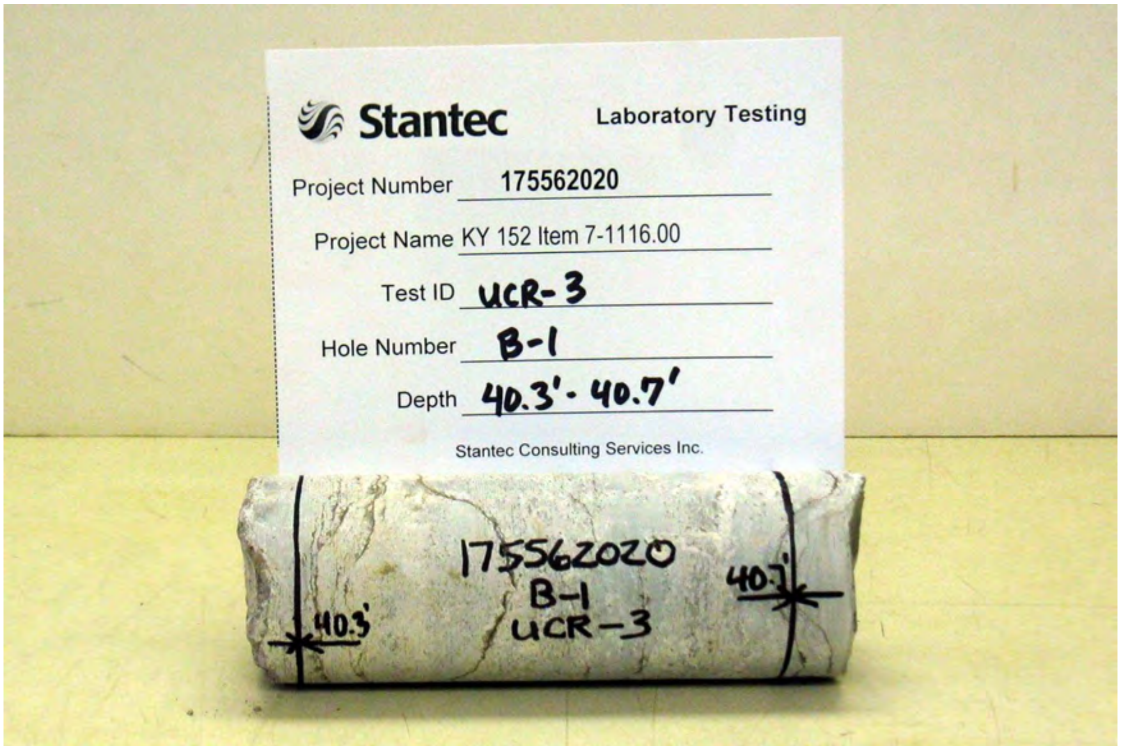
Laboratory Document
Prepared By: JW
Approved By: TLK

Stantec

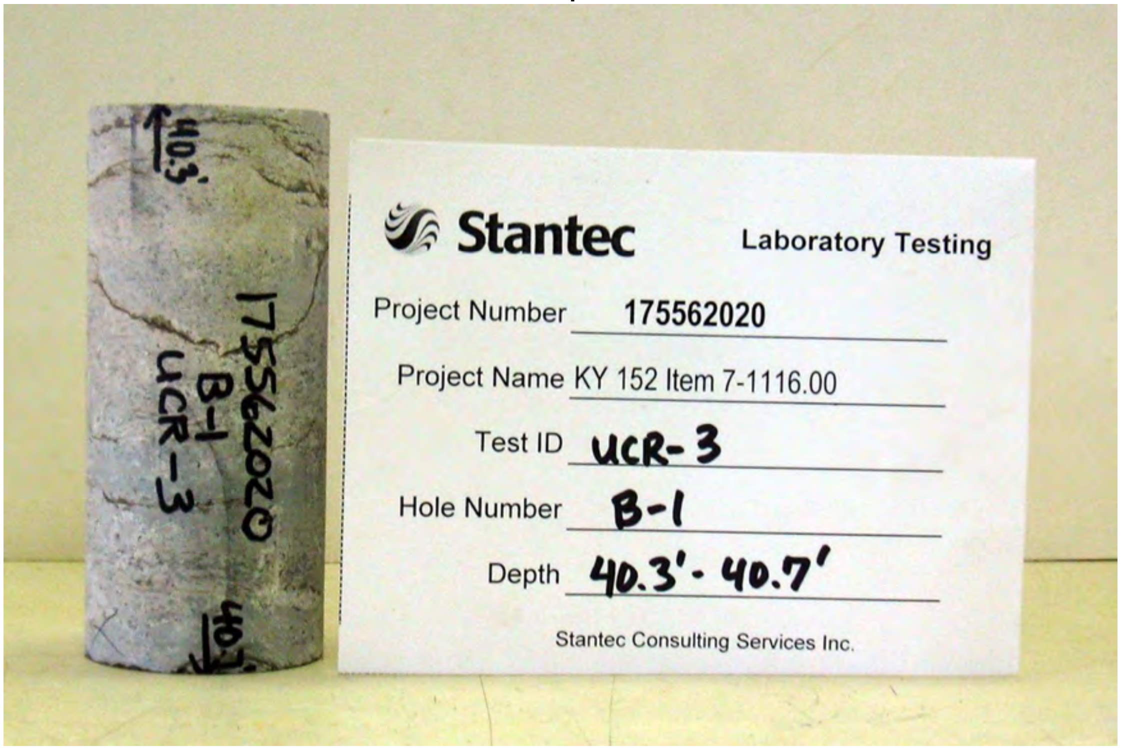
Photo Report

Project Name	KY 152 Item 7-1116.00	Project Number	175562020
Lithology	Limestone, gray, moderately hard, shale stringers	Lab ID	UCR-3
Hole Number	B-1 #3 Depth (ft) 40.3'-40.7'		
Test Type	Unconfined compressive strength		

As Received



Core Preparation

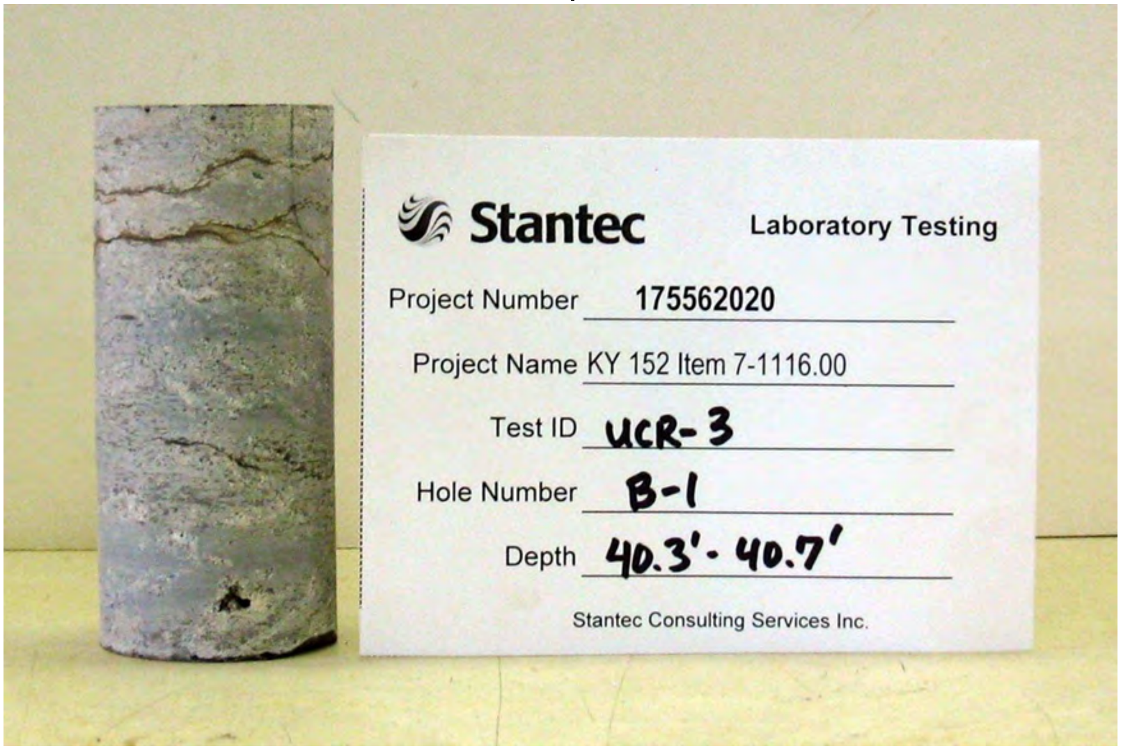


Stantec

Photo Report

Project Name	KY 152 Item 7-1116.00	Project Number	175562020
Lithology	Limestone, gray, moderately hard, shale stringers	Lab ID	UCR-3
Hole Number	B-1 #3	Depth (ft)	40.3'-40.7'
Test Type	Unconfined compressive strength		

Core Preparation



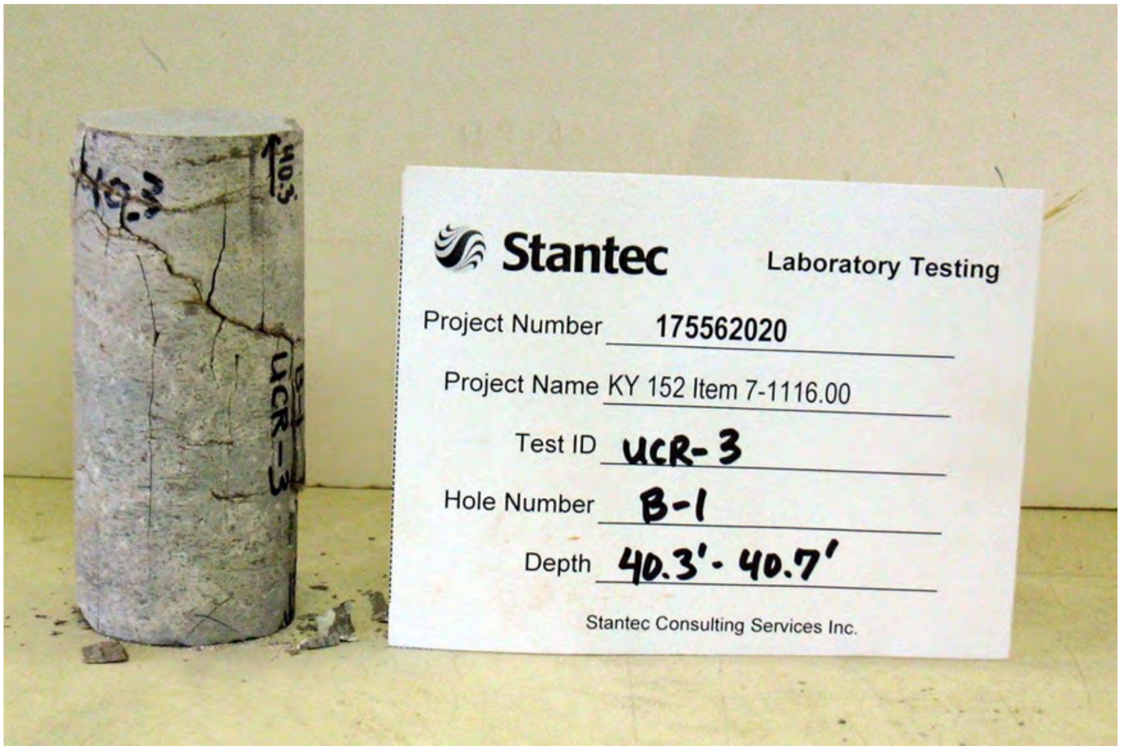
Post Test

Stantec

Photo Report

Project Name	KY 152 Item 7-1116.00	Project Number	175562020
Lithology	Limestone, gray, moderately hard, shale stringers	Lab ID	UCR-3
Hole Number	B-1 #3 Depth (ft) 40.3'-40.7'		
Test Type	Unconfined compressive strength		

Post Test



Stantec

Unconfined Compressive Strength Of Intact Rock Core

KM 64-523-02

Project Name KY 152 Item 7-1116.00 | Project Number 175562020
Lithology Dolomite, gray, moderately hard | Lab ID UCR-4
Hole Number B-1 #4 | Depth (ft) 31.1'-31.5' | Date Received 03-26-2013

Temperature (^oC) 23.2 | Moisture Condition As received, moist | Date Tested 04-28-2013

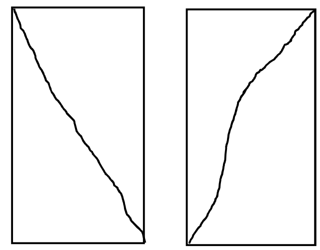
Side Planeness	Pass	Height (in)	4.800	Wet Unit Weight (pcf)	162.5
Perpendicularity	Pass	Diameter (in)	1.977	Dry Unit Weight (pcf)	158.3
End Planeness	Pass	Area (in^2)	3.069	Moisture Content[1] (%)	2.7
		Height/Diameter Ratio	2.428	Weight (lb)	1.386

Loading Rate (lbf/sec) 141
Peak Load (lbf) 10518

Failure Type Shear

Compressive Strength (psi) 3430
Compressive Strength (psf) 493920
Compressive Strength (tsf) 247

Failure Sketches



Comments Specimen failed prior to expected minimum compressive load.

Alternate Compressive Strength Calculation[2]
(Where Height/Diameter Ratio < 2)

Correction Coefficient N/A

Corrected Compressive Strength (psi) N/A
Corrected Compressive Strength (psf) N/A
Corrected Compressive Strength (tsf) N/A

[1] Post testing moisture content determination was performed as per ASTM D 2216, where as much of the whole specimen as available after compression testing was used in moisture content testing. Method B.

[2] The alternate compressive strength calculation is presented when the height to diameter ratio is less than 2, as per KM 64-523-02.

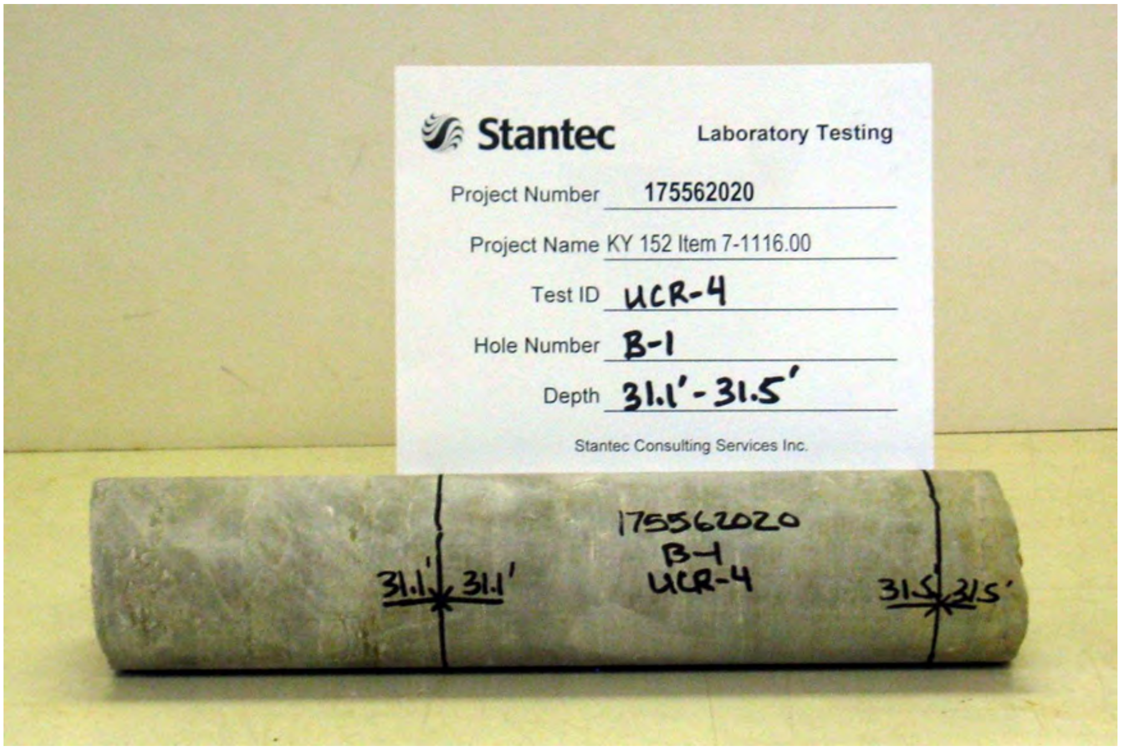
Reviewed By JW

Stantec

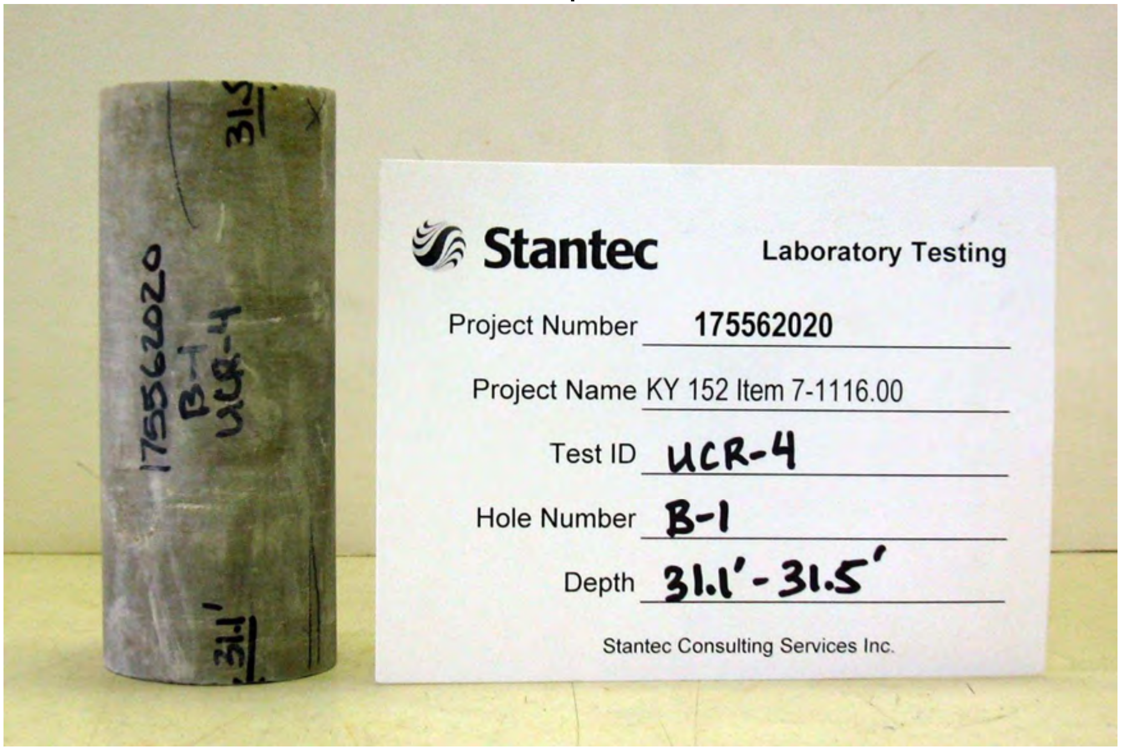
Photo Report

Project Name	KY 152 Item 7-1116.00	Project Number	175562020
Lithology	Dolomite, gray, moderately hard	Lab ID	UCR-4
Hole Number	B-1 #4 Depth (ft) 31.1'-31.5'		
Test Type	Unconfined compressive strength		

As Received



Core Preparation



Stantec

Photo Report

Project Name KY 152 Item 7-1116.00

Lithology Dolomite, gray, moderately hard

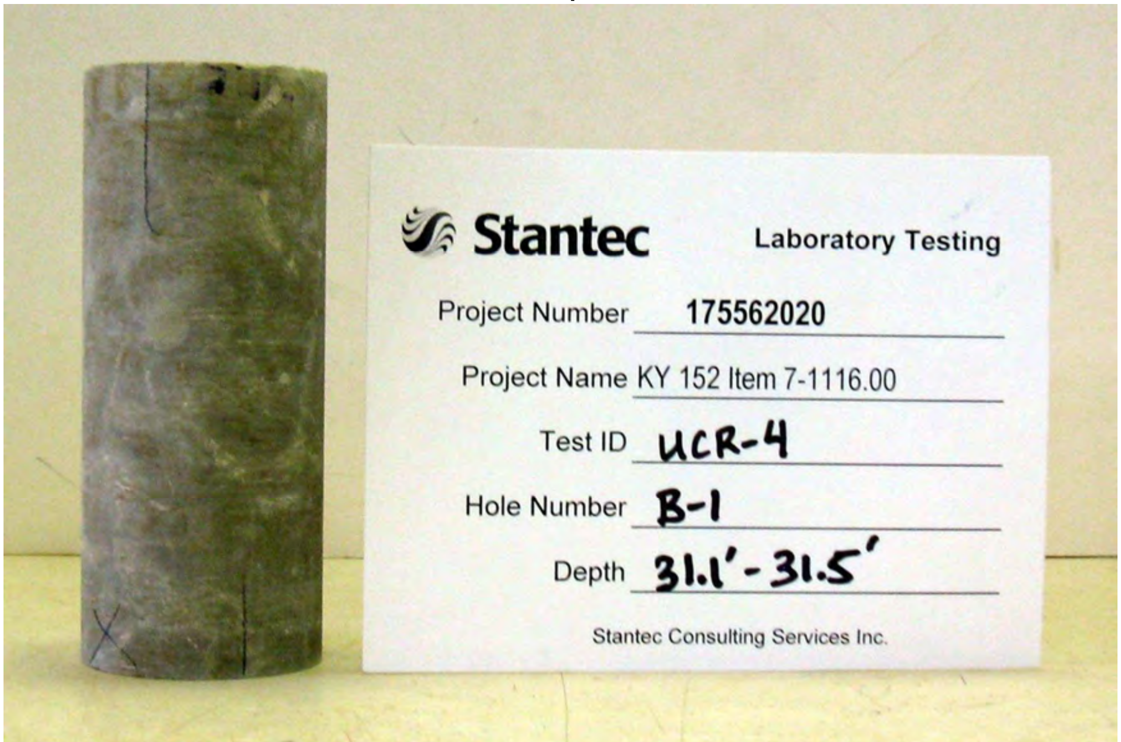
Hole Number B-1 #4 Depth (ft) 31.1'-31.5'

Test Type Unconfined compressive strength

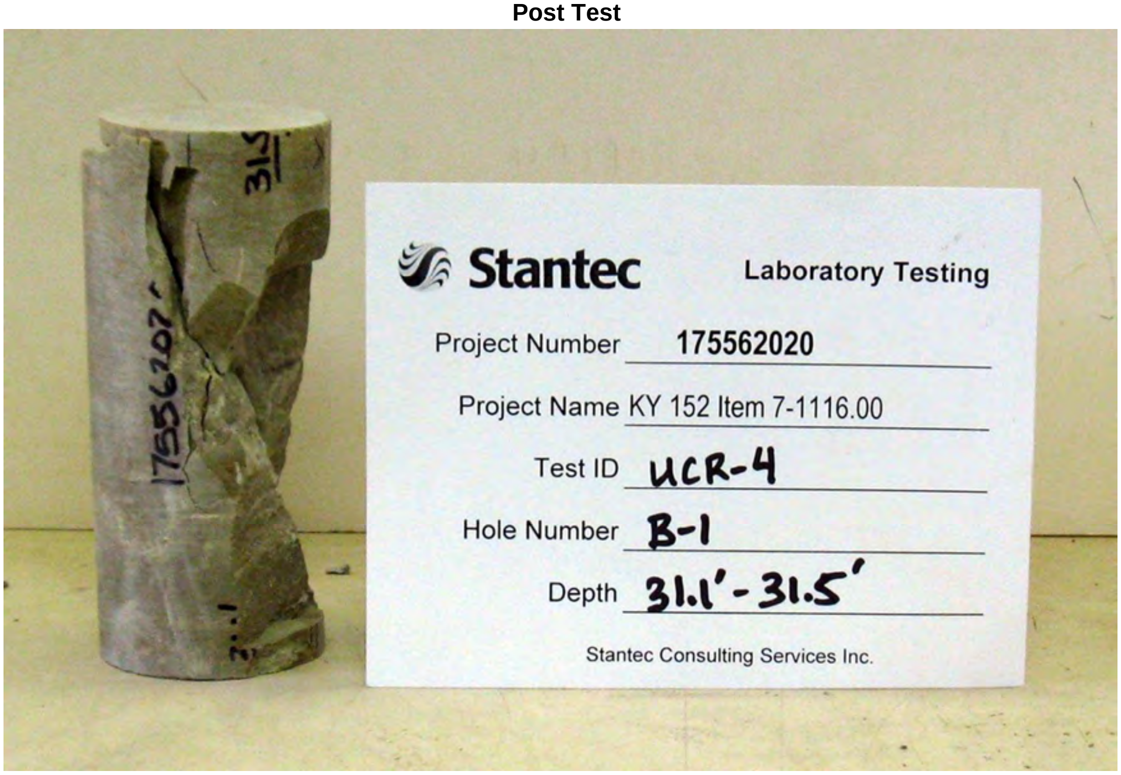
Project Number 175562020

Lab ID UCR-4

Core Preparation



Post Test



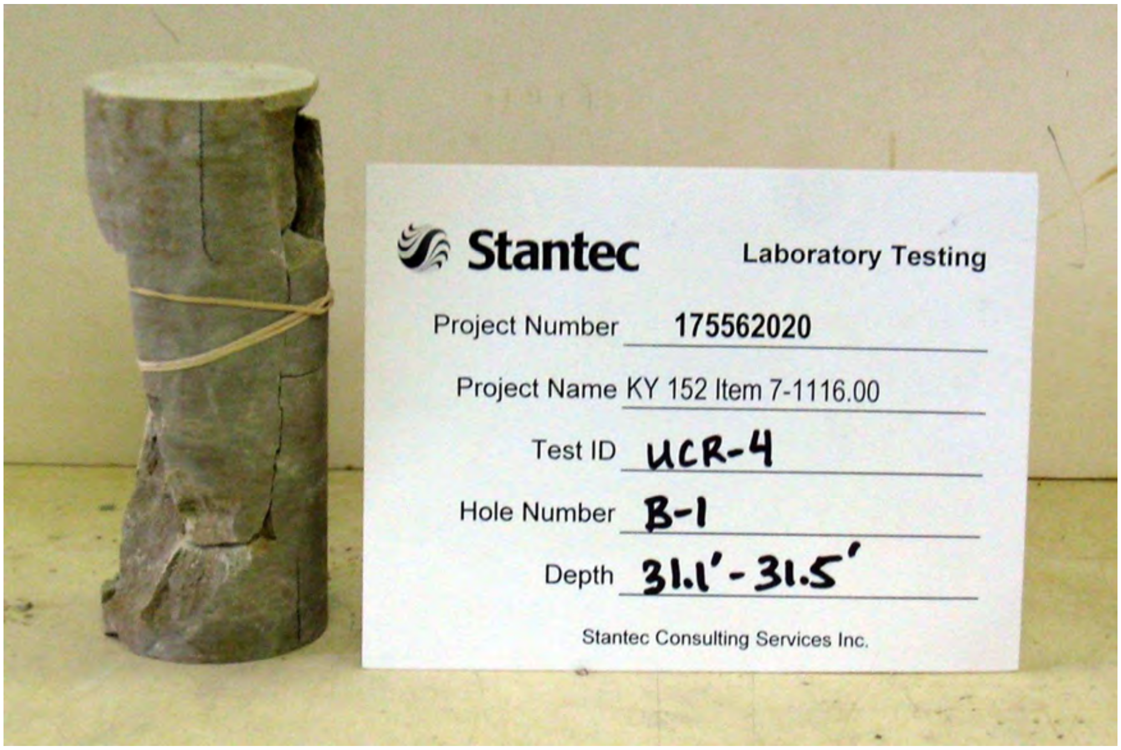
Stantec

Photo Report

Project Name KY 152 Item 7-1116.00
Lithology Dolomite, gray, moderately hard
Hole Number B-1 #4 Depth (ft) 31.1'-31.5'
Test Type Unconfined compressive strength

Project Number 175562020
Lab ID UCR-4

Post Test



Stantec

Unconfined Compressive Strength
Of Intact Rock Core
KM 64-523-02

Project Name	KY 152 Item 7-1116.00	Project Number	175562020
Lithology	Limestone, gray, moderately hard	Lab ID	UCR-5
Hole Number	B-1 #5 — Depth (ft) 20.0'-20.5'	Date Received	03-26-2013

Temperature (^oC)	23.3	Moisture Condition	As received, moist	Date Tested	04-28-2013
Side Planeness	Pass	Height (in)	4.795	Wet Unit Weight (pcf)	168.2
Perpendicularity	Pass	Diameter (in)	1.980	Dry Unit Weight (pcf)	167.7
End Planeness	Pass	Area (in^2)	3.078	Moisture Content[1] (%)	0.3
		Height/Diameter Ratio	2.422	Weight (lb)	1.436

Loading Rate (lbf/sec)	146
Peak Load (lbf)	54124
Failure Type	Undetermined
Compressive Strength (psi)	17580
Compressive Strength (psf)	2531520
Compressive Strength (tsf)	1266

Failure Sketches

N/A

Comments

Alternate Compressive Strength Calculation[2]
(Where Height/Diameter Ratio < 2)

Correction Coefficient	N/A
Corrected Compressive Strength (psi)	N/A
Corrected Compressive Strength (psf)	N/A
Corrected Compressive Strength (tsf)	N/A

[1] Post testing moisture content determination was performed as per ASTM D 2216, where as much of the whole specimen as available after compression testing was used in moisture content testing. Method B.

[2] The alternate compressive strength calculation is presented when the height to diameter ratio is less than 2, as per KM 64-523-02.

Reviewed By JW

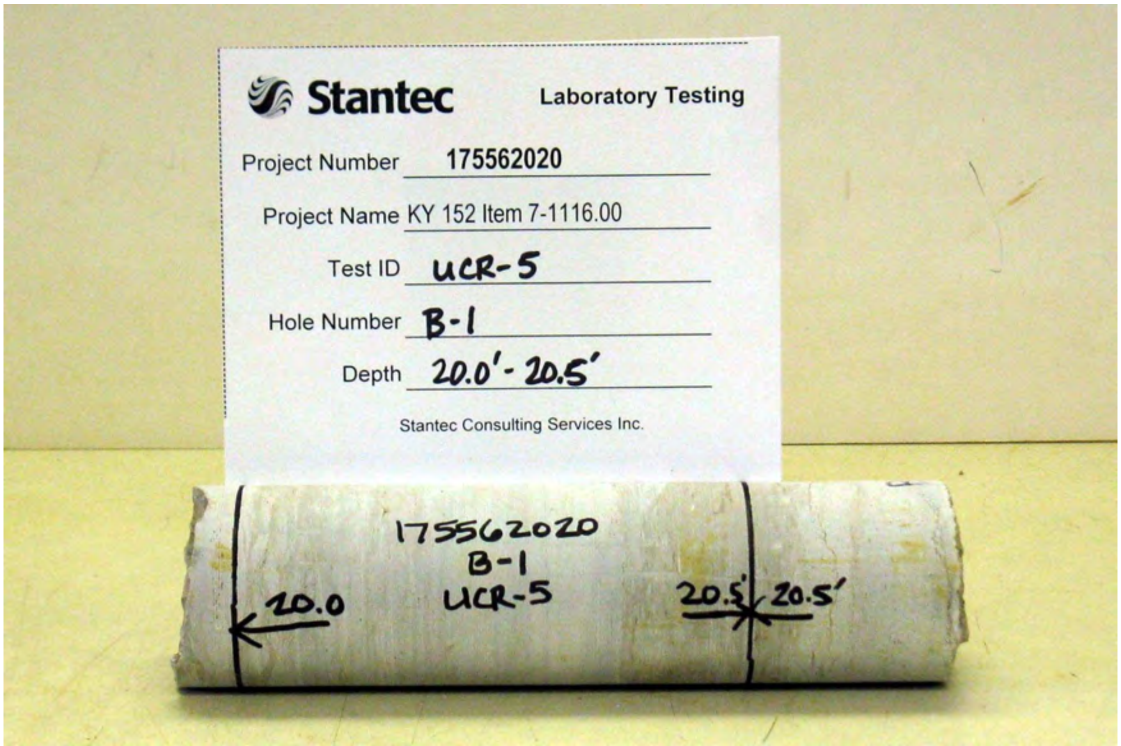
Stantec

Photo Report

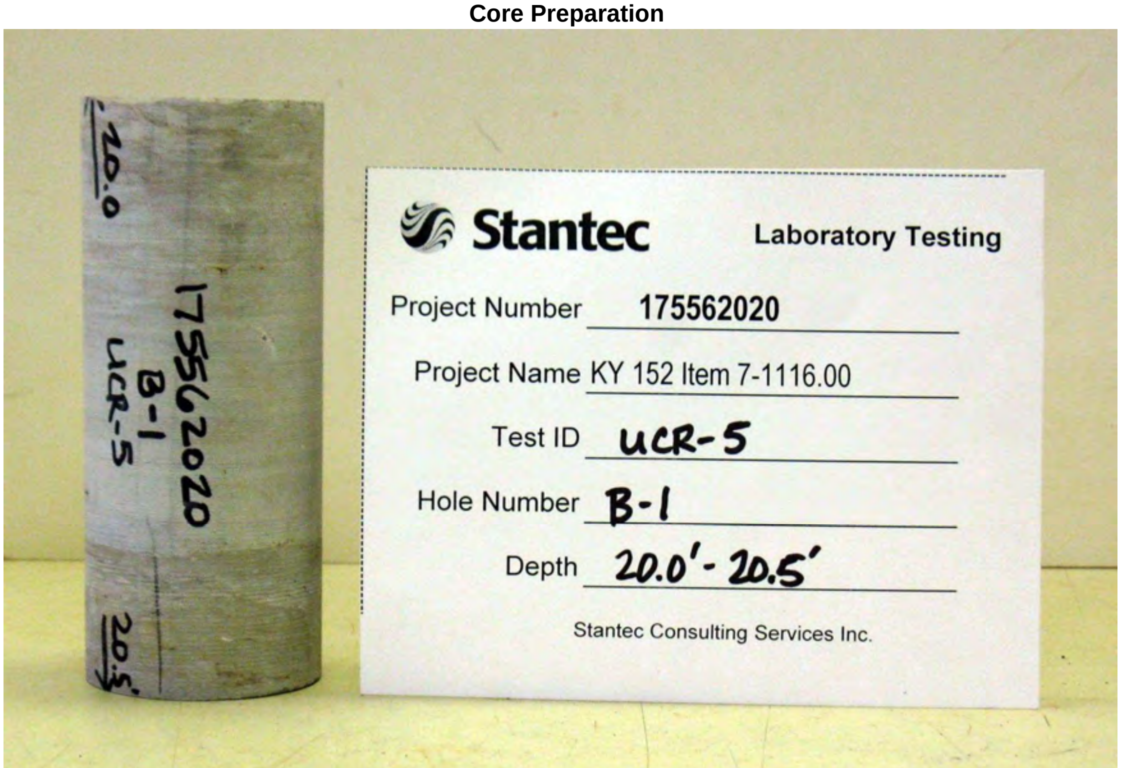
Project Name KY 152 Item 7-1116.00
Lithology Limestone, gray, moderately hard
Hole Number B-1 #5 Depth (ft) 20.0'-20.5'
Test Type Unconfined compressive strength

Project Number 175562020
Lab ID UCR-5

As Received



Core Preparation



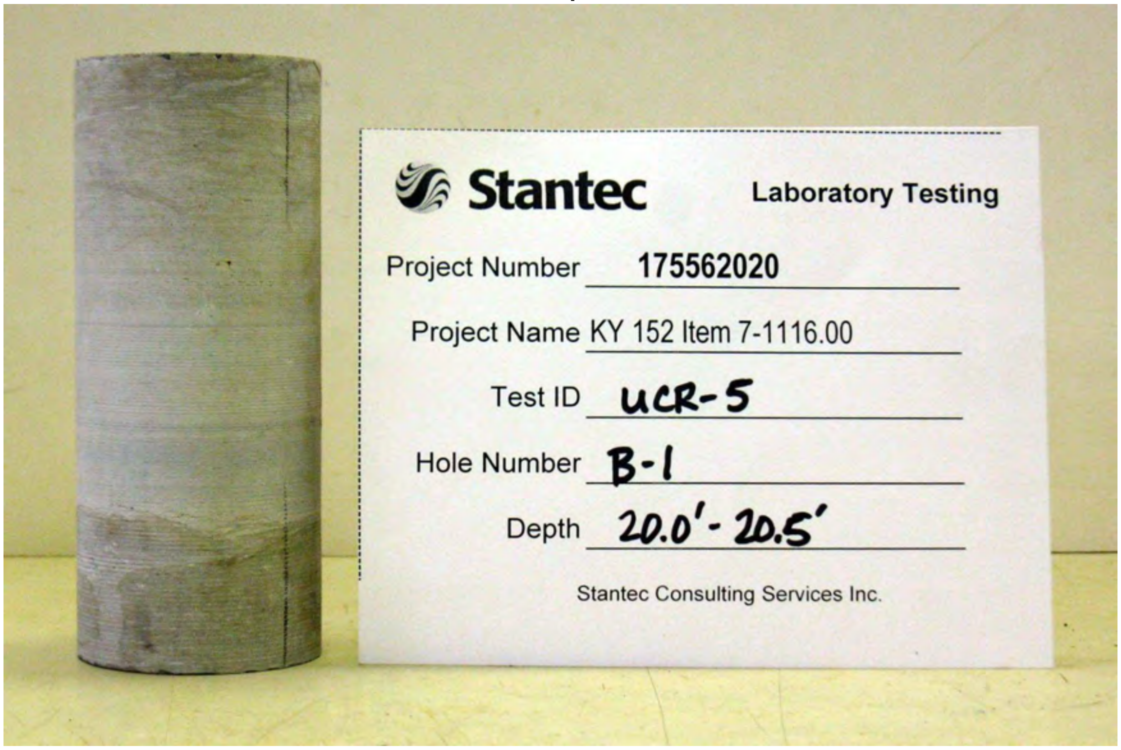
Stantec

Photo Report

Project Name KY 152 Item 7-1116.00
Lithology Limestone, gray, moderately hard
Hole Number B-1 #5 Depth (ft) 20.0'-20.5'
Test Type Unconfined compressive strength

Project Number 175562020
Lab ID UCR-5

Core Preparation



Post Test

Stantec

Photo Report

Project Name	KY 152 Item 7-1116.00	Project Number	175562020
Lithology	Limestone, gray, moderately hard	Lab ID	UCR-5
Hole Number	B-1 #5	Depth (ft)	20.0'-20.5'
Test Type	Unconfined compressive strength		

Post Test

Stantec

Unconfined Compressive Strength Of Intact Rock Core

KM 64-523-02

Project Name	KY 152 Item 7-1116.00	Project Number	175562020
Lithology	Limestone, gray, moderately hard, shale stringers	Lab ID	UCR-6
Hole Number	B-1 #6 Depth (ft) 251.5'-251.9'	Date Received	03-26-2013

Temperature (^oC) 23.3 Moisture Condition As received, moist Date Tested 04-28-2013

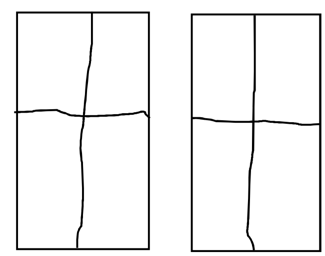
Side Planeness	Pass	Height (in)	4.552	Wet Unit Weight (pcf)	167.0
Perpendicularity	Pass	Diameter (in)	1.977	Dry Unit Weight (pcf)	166.0
End Planeness	Pass	Area (in^2)	3.071	Moisture Content[1] (%)	0.6
		Height/Diameter Ratio	2.302	Weight (lb)	1.351

Loading Rate (lbf/sec) 152
Peak Load (lbf) 61352

Failure Type Columnar

Compressive Strength (psi) 19980
Compressive Strength (psf) 2877120
Compressive Strength (tsf) 1439

Failure Sketches



Comments

Alternate Compressive Strength Calculation[2]
(Where Height/Diameter Ratio < 2)

Correction Coefficient N/A

Corrected Compressive Strength (psi) N/A
Corrected Compressive Strength (psf) N/A
Corrected Compressive Strength (tsf) N/A

[1] Post testing moisture content determination was performed as per ASTM D 2216, where as much of the whole specimen as available after compression testing was used in moisture content testing. Method B.

[2] The alternate compressive strength calculation is presented when the height to diameter ratio is less than 2, as per KM 64-523-02.

Reviewed By JW

Stantec

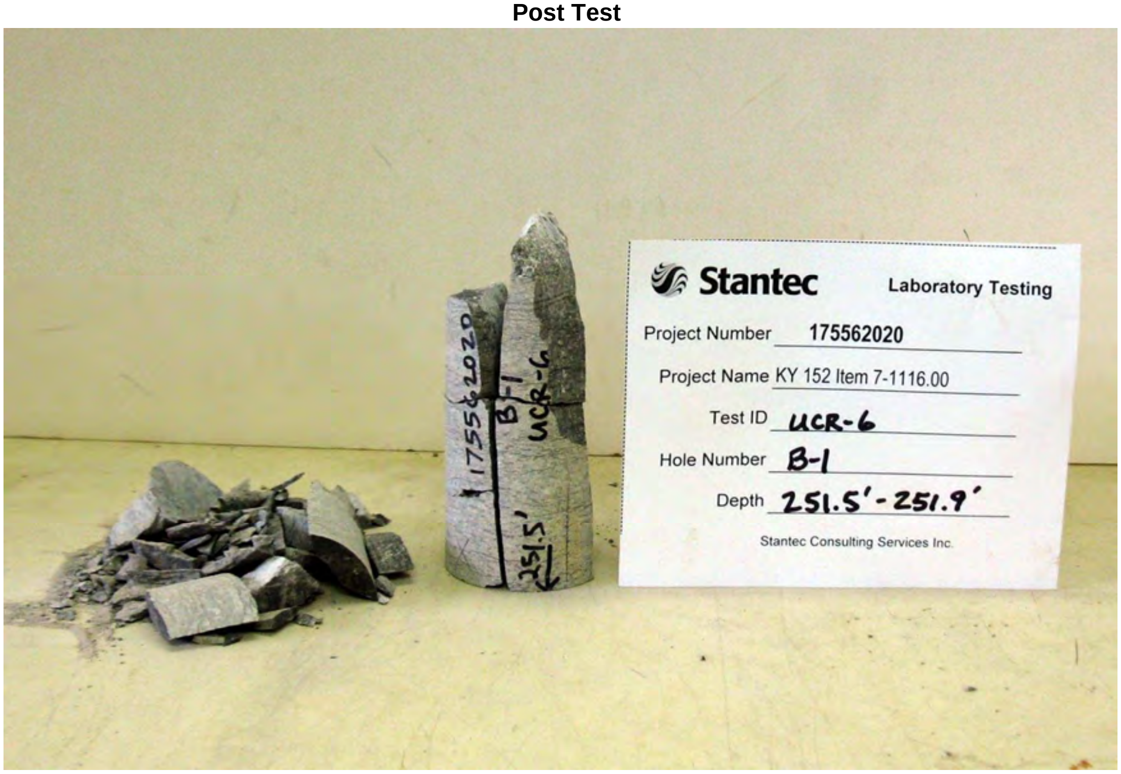
Photo Report

Project Name KY 152 Item 7-1116.00
Lithology Limestone, gray, moderately hard, shale stringers
Hole Number B-1 #6 Depth (ft) 251.5'-251.9'
Test Type Unconfined compressive strength

Project Number 175562020
Lab ID UCR-6

As Received

Post Test



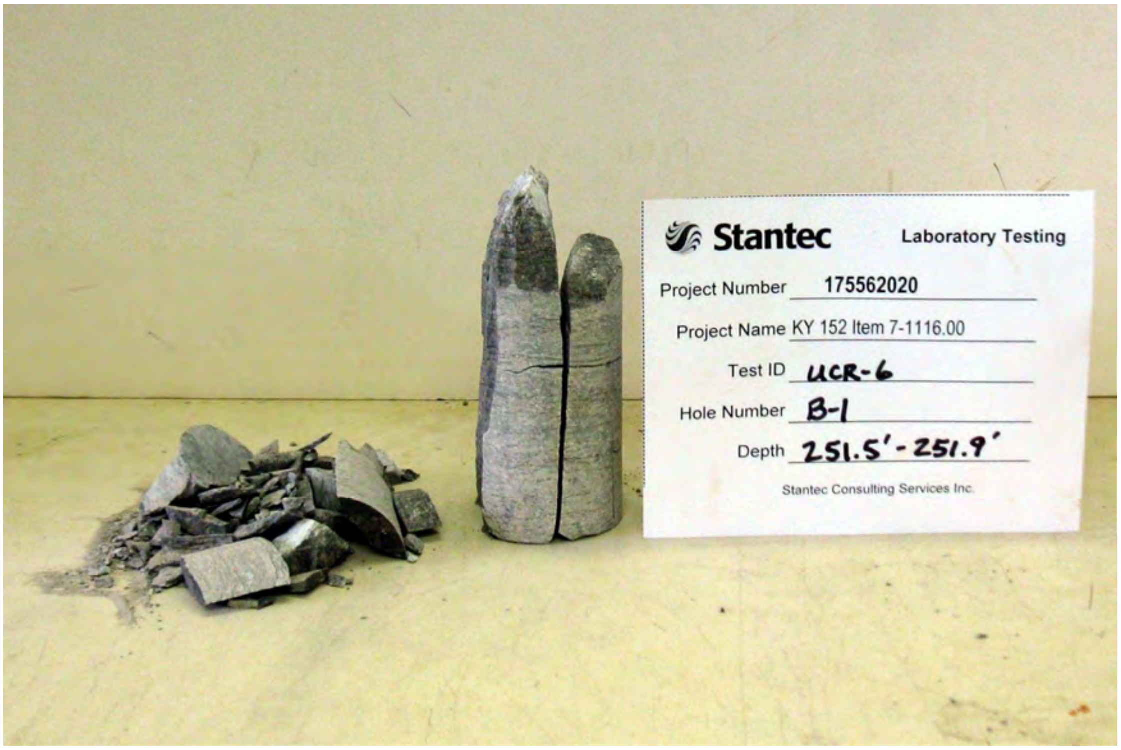
Stantec

Photo Report

Project Name KY 152 Item 7-1116.00
Lithology Limestone, gray, moderately hard, shale stringers
Hole Number B-1 #6 Depth (ft) 251.5'-251.9'
Test Type Unconfined compressive strength

Project Number 175562020
Lab ID UCR-6

Post Test



Stantec

Unconfined Compressive Strength Of Intact Rock Core
KM 64-523-02

Project Name: KY 152 Item 7-1116.00
Project Number: 175562020
Lithology: Limestone, gray, moderately hard, shale stringers
Lab ID: UCR-7
Hole Number: B-1 #7
Depth (ft): 260.8'-261.2'
Date Received: 03-26-2013

Temperature (^{o}C): 23.4
Moisture Condition: As received, moist
Date Tested: 04-28-2013

Side Planeness	Pass	Height (in)	4.663	Wet Unit Weight (pcf)	168.6
Perpendicularity	Pass	Diameter (in)	1.978	Dry Unit Weight (pcf)	168.4
End Planeness	Pass	Area (in^2)	3.072	Moisture Content[1] (%)	0.1
		Height/Diameter Ratio	2.358	Weight (lb)	1.397

Loading Rate (lbf/sec): 150
Peak Load (lbf): 67762

Failure Type: Undetermined

Compressive Strength (psi): 22060
Compressive Strength (psf): 3176640
Compressive Strength (tsf): 1588

Failure Sketches

N/A

Comments:

Alternate Compressive Strength Calculation[2]
(Where Height/Diameter Ratio < 2)

Correction Coefficient: N/A

Corrected Compressive Strength (psi): N/A
Corrected Compressive Strength (psf): N/A
Corrected Compressive Strength (tsf): N/A

[1] Post testing moisture content determination was performed as per ASTM D 2216, where as much of the whole specimen as available after compression testing was used in moisture content testing. Method B.

[2] The alternate compressive strength calculation is presented when the height to diameter ratio is less than 2, as per KM 64-523-02.

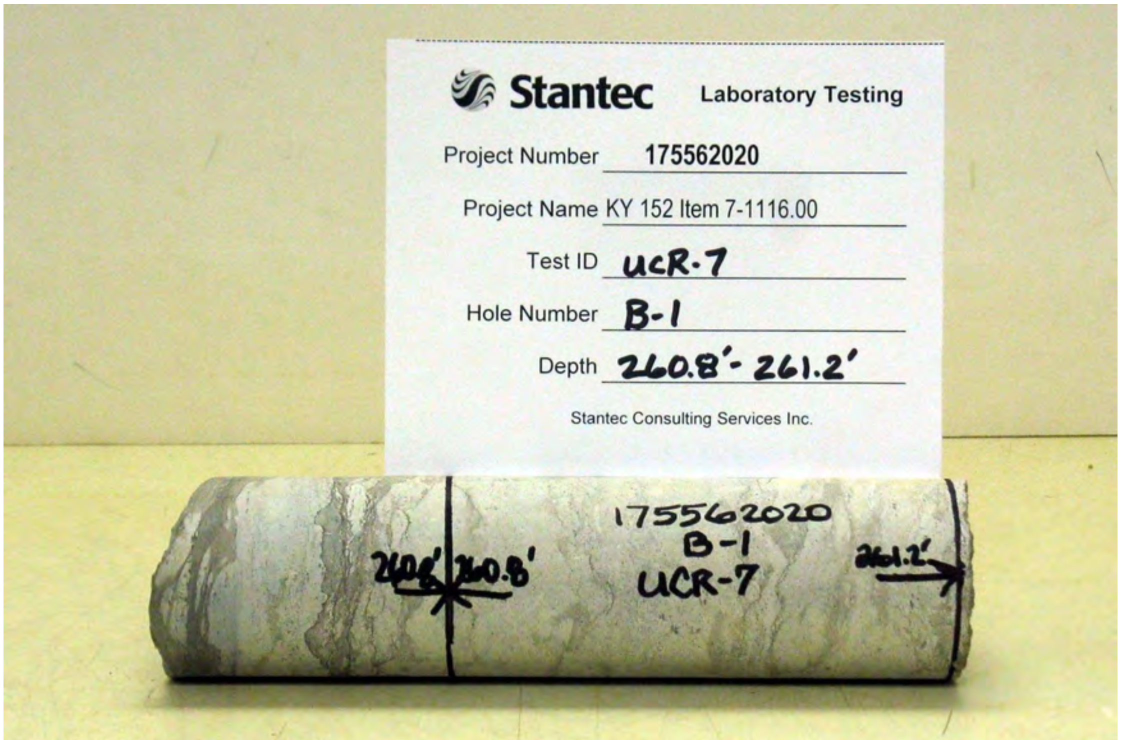
Reviewed By: JW

Stantec

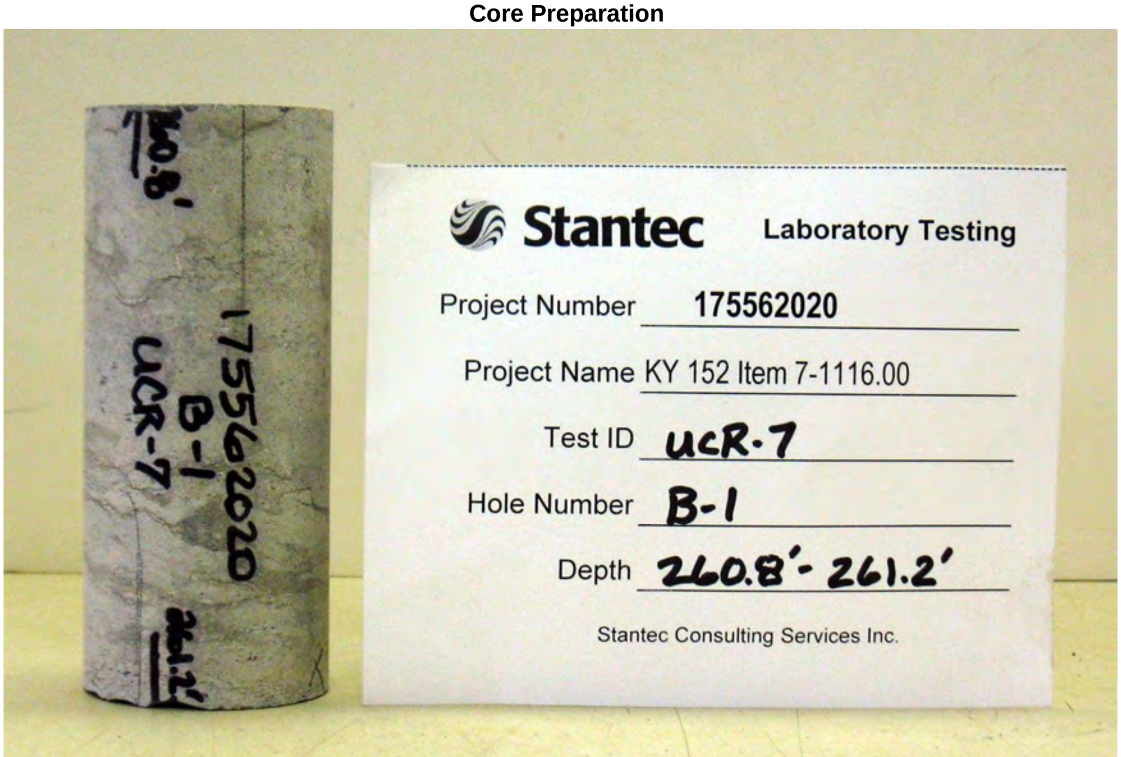
Photo Report

Project Name	KY 152 Item 7-1116.00	Project Number	175562020
Lithology	Limestone, gray, moderately hard, shale stringers	Lab ID	UCR-7
Hole Number	B-1 #7	Depth (ft)	260.8'-261.2'
Test Type	Unconfined compressive strength		

As Received



Core Preparation

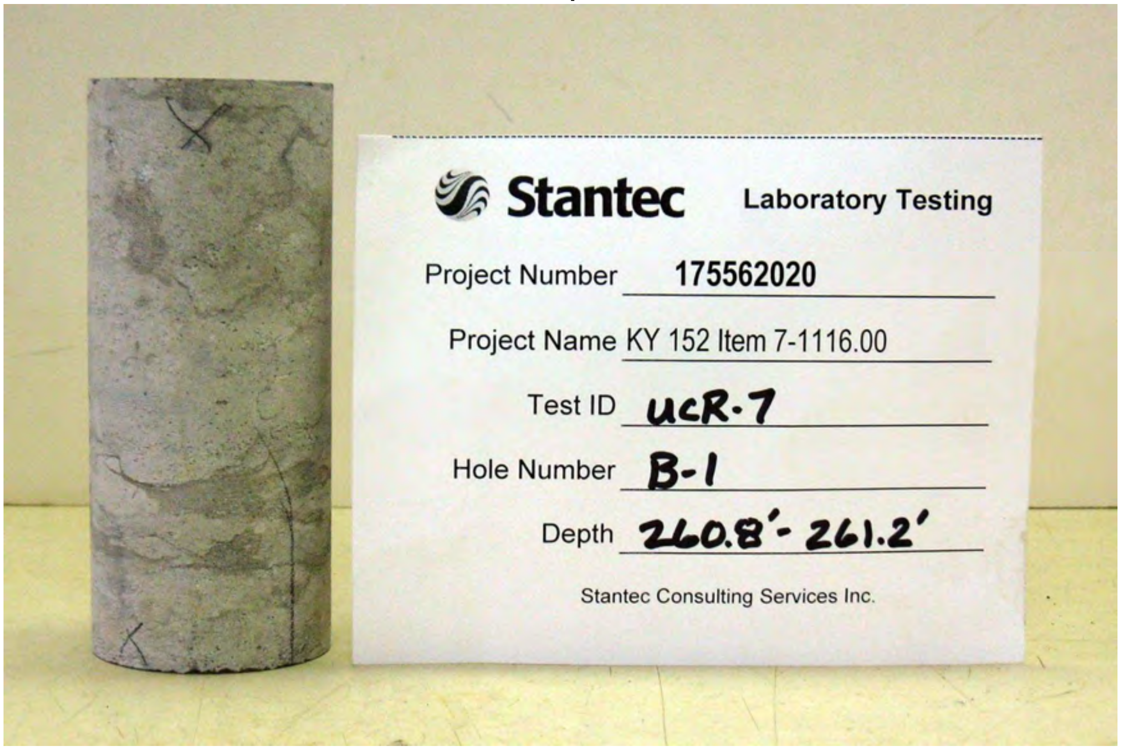


Stantec

Photo Report

Project Name	KY 152 Item 7-1116.00	Project Number	175562020
Lithology	Limestone, gray, moderately hard, shale stringers	Lab ID	UCR-7
Hole Number	B-1 #7 Depth (ft) 260.8'-261.2'		
Test Type	Unconfined compressive strength		

Core Preparation



Post Test

Stantec

Photo Report

Project Name KY 152 Item 7-1116.00
Lithology Limestone, gray, moderately hard, shale stringers
Hole Number B-1 #7 Depth (ft) 260.8'-261.2'
Test Type Unconfined compressive strength

Project Number 175562020
Lab ID UCR-7

Post Test

Stantec

Unconfined Compressive Strength Of Intact Rock Core

KM 64-523-02

Project Name KY 152 Item 7-1116.00

Project Number 175562020

Lithology Limestone, gray, moderately hard, shale stringers

Lab ID UCR-8

Hole Number B-1 #8

Depth (ft) 270.5'-270.9'

Date Received 03-26-2013

Temperature (°C) 23.5

Moisture Condition As received, moist

Date Tested 04-28-2013

Side Planeness	Pass	Height (in)	4.760	Wet Unit Weight (pcf)	168.8
Perpendicularity	Pass	Diameter (in)	1.979	Dry Unit Weight (pcf)	168.6
End Planeness	Pass	Area (in^2)	3.076	Moisture Content[1] (%)	0.1
		Height/Diameter Ratio	2.405	Weight (lb)	1.430

Loading Rate (lbf/sec) 148

Peak Load (lbf) 78993

Failure Type Undetermined

Compressive Strength (psi) 25680

Compressive Strength (psf) 3697920

Compressive Strength (tsf) 1849

Failure Sketches

N/A

Comments

Alternate Compressive Strength Calculation[2]
(Where Height/Diameter Ratio < 2)

Correction Coefficient N/A

Corrected Compressive Strength (psi) N/A

Corrected Compressive Strength (psf) N/A

Corrected Compressive Strength (tsf) N/A

[1] Post testing moisture content determination was performed as per ASTM D 2216, where as much of the whole specimen as available after compression testing was used in moisture content testing. Method B.

[2] The alternate compressive strength calculation is presented when the height to diameter ratio is less than 2, as per KM 64-523-02.

Reviewed By JW

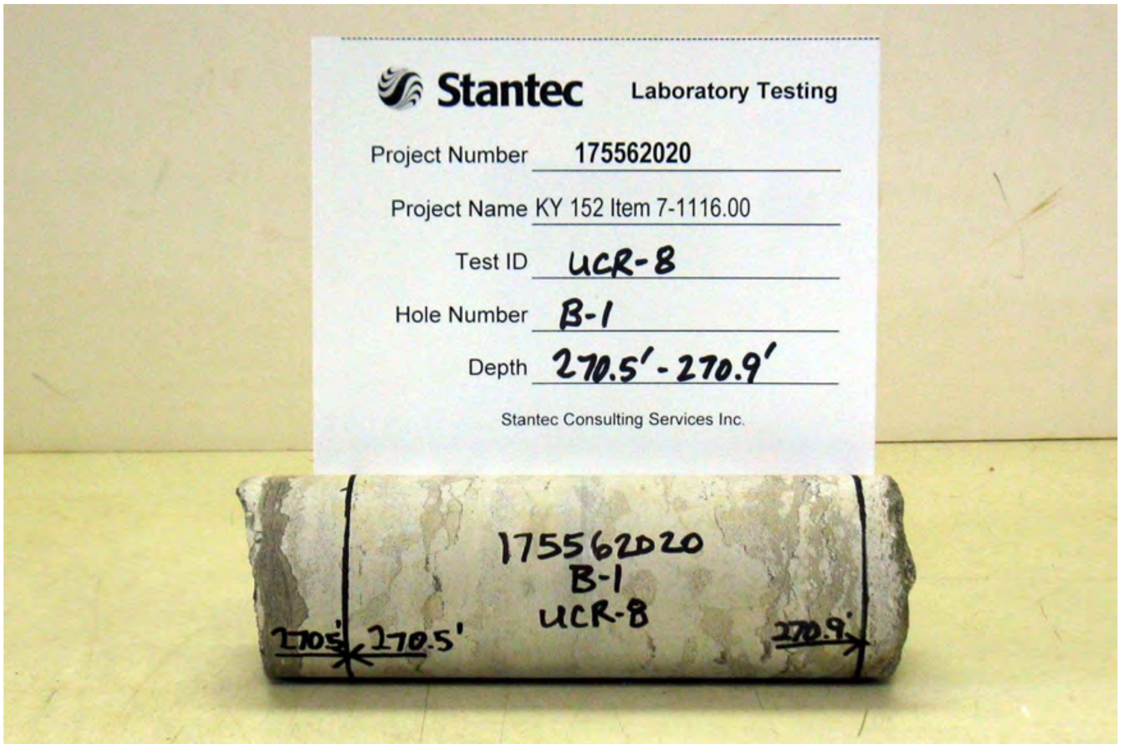
Stantec

Photo Report

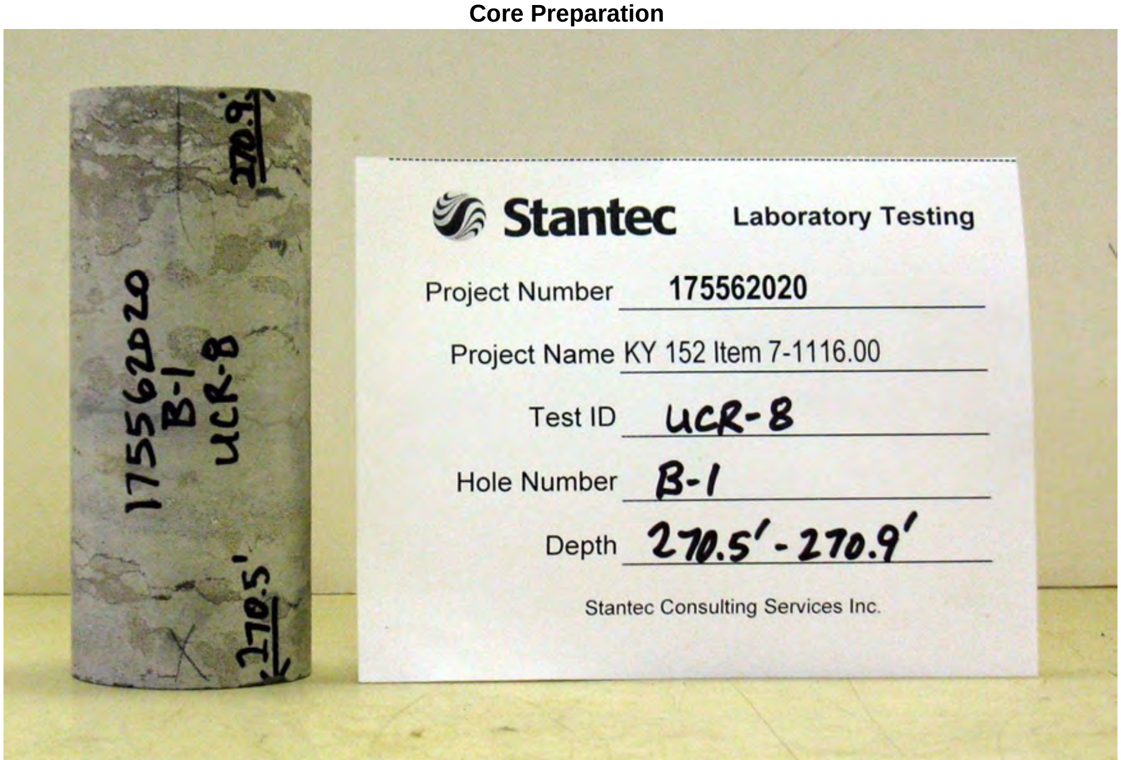
Project Name KY 152 Item 7-1116.00
Lithology Limestone, gray, moderately hard, shale stringers
Hole Number B-1 #8 Depth (ft) 270.5'-270.9'
Test Type Unconfined compressive strength

Project Number 175562020
Lab ID UCR-8

As Received



Core Preparation

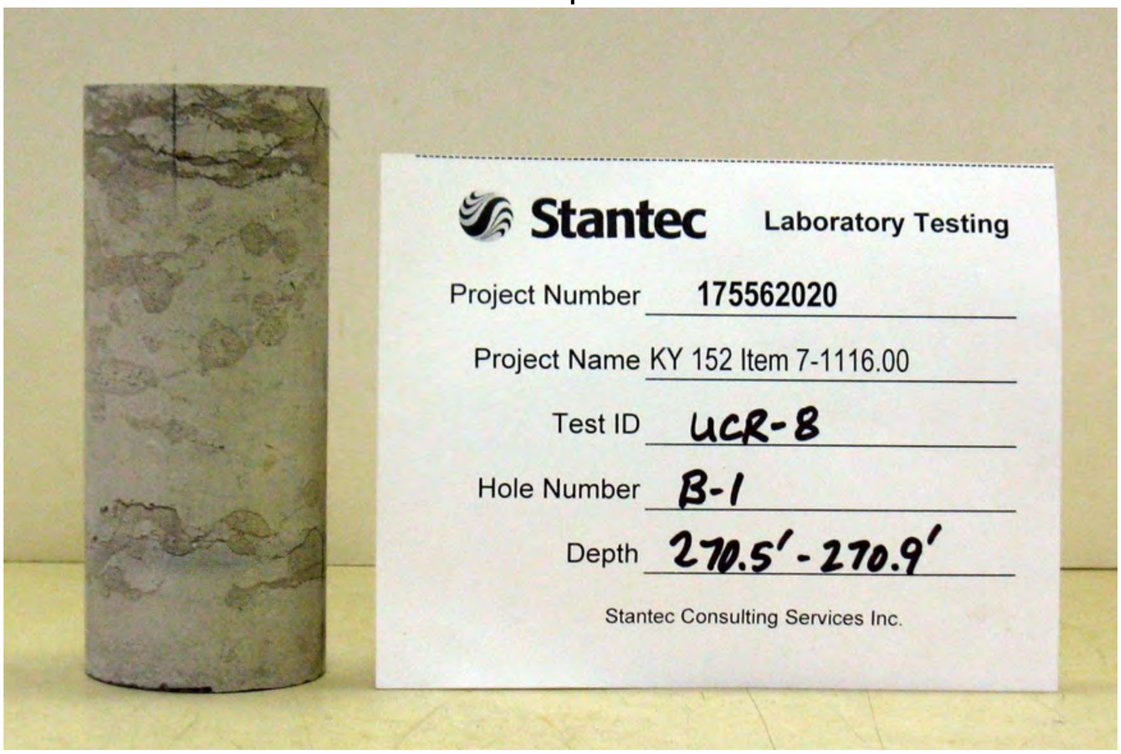


Stantec

Photo Report

Project Name	KY 152 Item 7-1116.00	Project Number	175562020
Lithology	Limestone, gray, moderately hard, shale stringers	Lab ID	UCR-8
Hole Number	B-1 #8 Depth (ft) 270.5'-270.9'		
Test Type	Unconfined compressive strength		

Core Preparation



Post Test

Stantec

Photo Report

Project Name KY 152 Item 7-1116.00
Lithology Limestone, gray, moderately hard, shale stringers
Hole Number B-1 #8 Depth (ft) 270.5'-270.9'
Test Type Unconfined compressive strength

Project Number 175562020
Lab ID UCR-8

Post Test

Stantec

Unconfined Compressive Strength Of Intact Rock Core

KM 64-523-02

Project Name: KY 152 Item 7-1116.00
Project Number: 175562020
Lithology: Limestone, gray, moderately hard, shale stringers
Lab ID: UCR-9
Hole Number: B-1 #9
Depth (ft): 280.9'-281.3'
Date Received: 03-26-2013

Temperature (^oC): 23.6
Moisture Condition: As received, moist
Date Tested: 04-28-2013

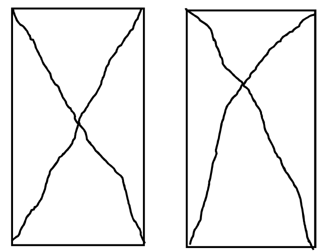
Side Planeness	Pass	Height (in)	4.896	Wet Unit Weight (pcf)	163.0
Perpendicularity	Pass	Diameter (in)	1.980	Dry Unit Weight (pcf)	161.9
End Planeness	Pass	Area (in^2)	3.080	Moisture Content[1] (%)	0.7
		Height/Diameter Ratio	2.472	Weight (lb)	1.423

Loading Rate (lbf/sec): 152
Peak Load (lbf): 47090

Failure Type: Cone

Compressive Strength (psi): 15290
Compressive Strength (psf): 2201760
Compressive Strength (tsf): 1101

Failure Sketches



Comments:

Alternate Compressive Strength Calculation[2]
(Where Height/Diameter Ratio < 2)

Correction Coefficient: N/A

Corrected Compressive Strength (psi): N/A
Corrected Compressive Strength (psf): N/A
Corrected Compressive Strength (tsf): N/A

[1] Post testing moisture content determination was performed as per ASTM D 2216, where as much of the whole specimen as available after compression testing was used in moisture content testing. Method B.

[2] The alternate compressive strength calculation is presented when the height to diameter ratio is less than 2, as per KM 64-523-02.

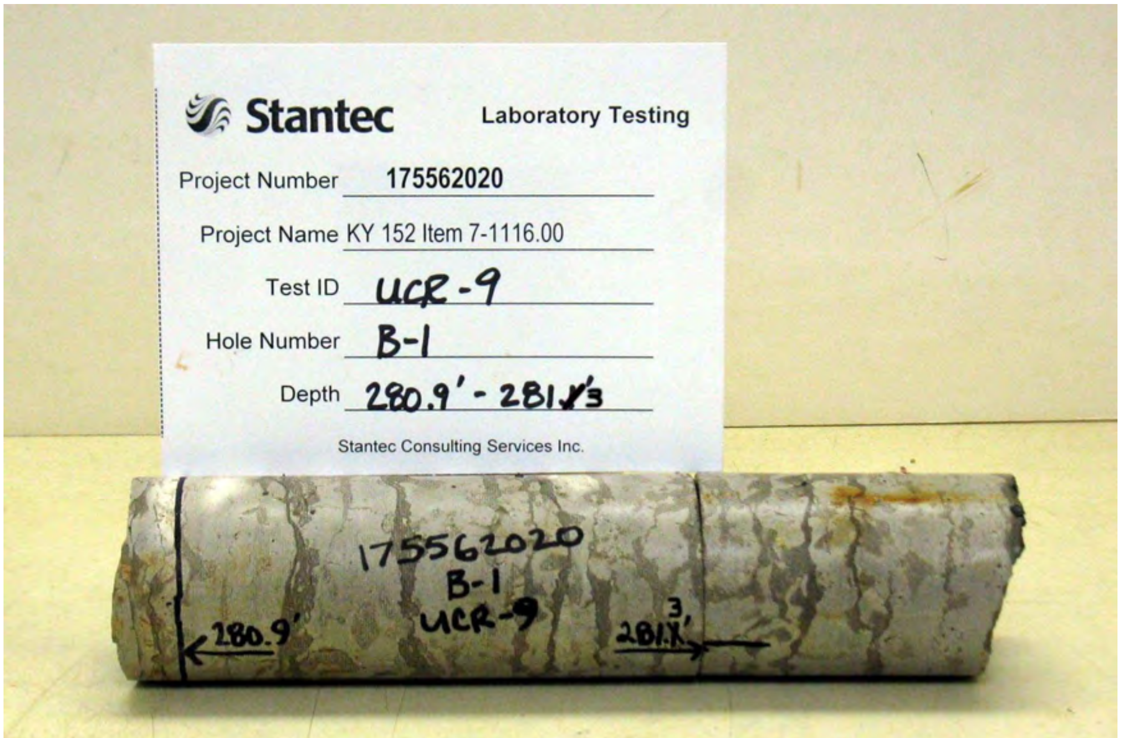
Reviewed By: JW

Stantec

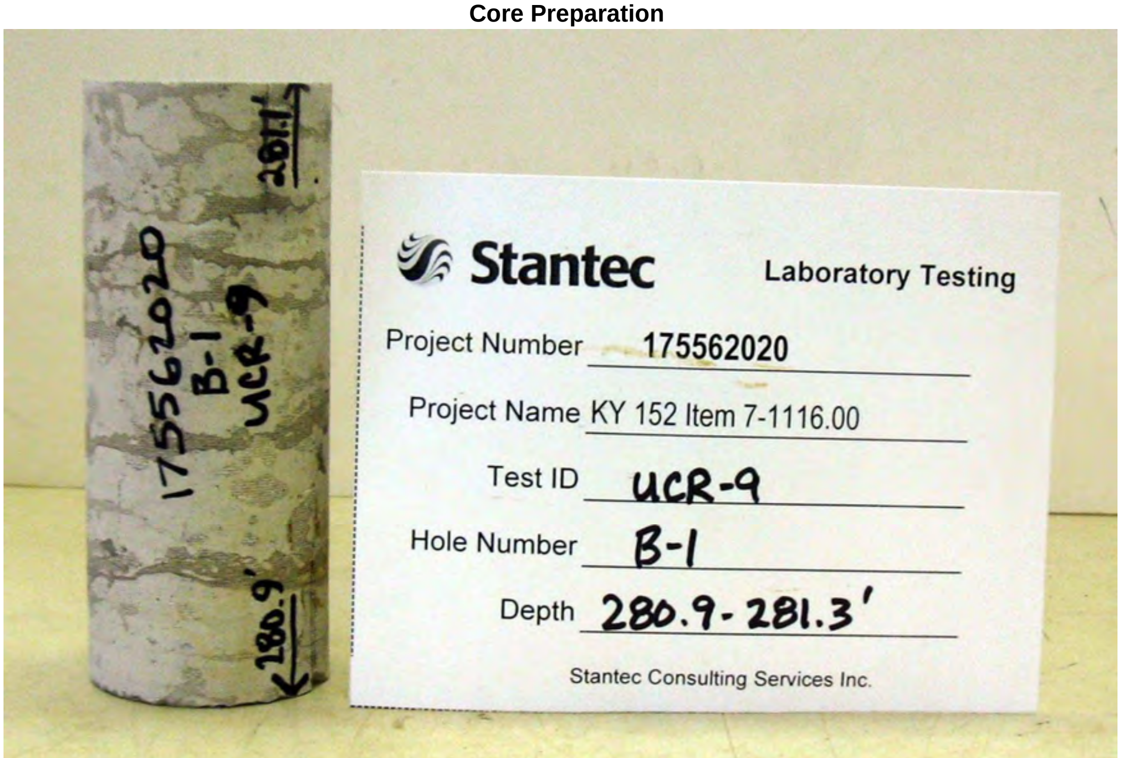
Photo Report

Project Name	KY 152 Item 7-1116.00	Project Number	175562020
Lithology	Limestone, gray, moderately hard, shale stringers	Lab ID	UCR-9
Hole Number	B-1 #9	Depth (ft)	280.9'-281.3'
Test Type	Unconfined compressive strength		

As Received



Core Preparation

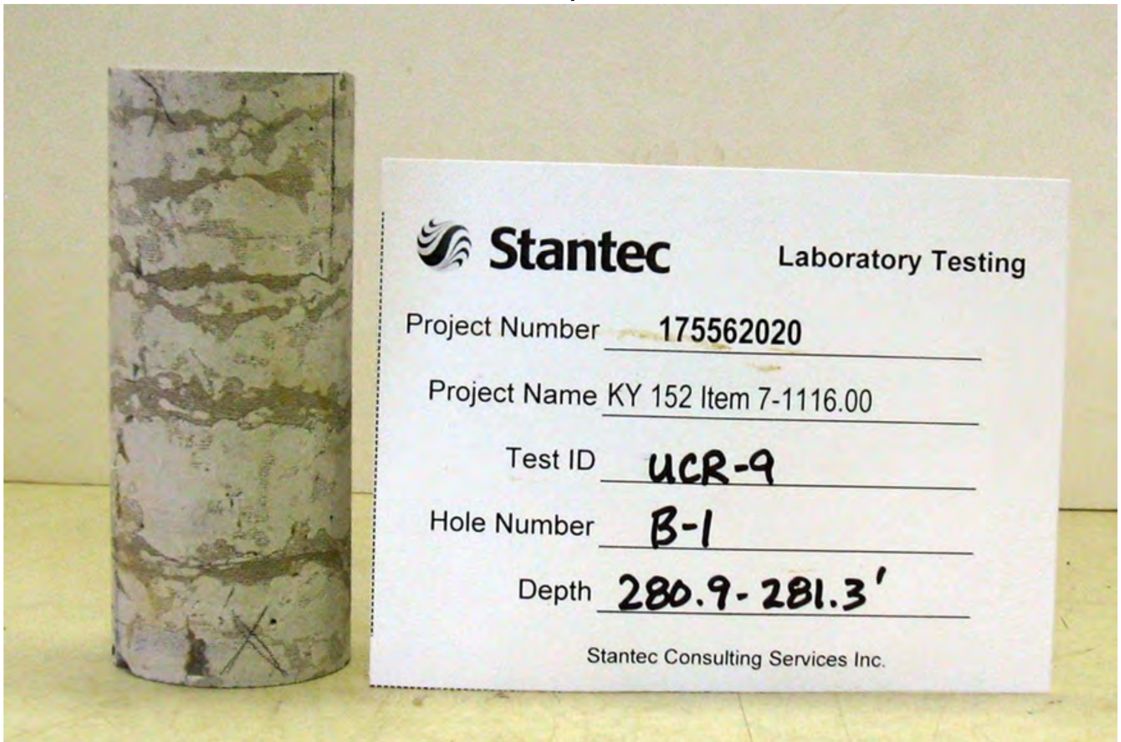


Stantec

Photo Report

Project Name	KY 152 Item 7-1116.00	Project Number	175562020
Lithology	Limestone, gray, moderately hard, shale stringers	Lab ID	UCR-9
Hole Number	B-1 #9 Depth (ft) 280.9'-281.3'		
Test Type	Unconfined compressive strength		

Core Preparation



Post Test

Stantec

Photo Report

Project Name	KY 152 Item 7-1116.00	Project Number	175562020
Lithology	Limestone, gray, moderately hard, shale stringers	Lab ID	UCR-9
Hole Number	B-1 #9 Depth (ft) 280.9'-281.3'		
Test Type	Unconfined compressive strength		

Post Test

Stantec

Unconfined Compressive Strength Of Intact Rock Core

KM 64-523-02

Project Name KY 152 Item 7-1116.00 Project Number 175562020

Lithology Limestone, gray, moderately hard, shale stringers Lab ID UCR-10

Hole Number B-1 #10 Depth (ft) 290.8'-291.2' Date Received 03-26-2013

Temperature (^oC) 23.6 Moisture Condition As received, moist Date Tested 04-28-2013

Side Planeness	Pass	Height (in)	4.762	Wet Unit Weight (pcf)	165.0
Perpendicularity	Pass	Diameter (in)	1.979	Dry Unit Weight (pcf)	163.3
End Planeness	Pass	Area (in^2)	3.077	Moisture Content[1] (%)	1.0
		Height/Diameter Ratio	2.406	Weight (lb)	1.399

Loading Rate (lbf/sec) 149

Peak Load (lbf) 55377

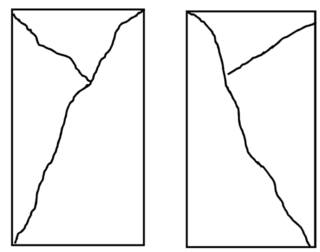
Failure Type Cone and Shear

Compressive Strength (psi) 18000

Compressive Strength (psf) 2592000

Compressive Strength (tsf) 1296

Failure Sketches



Comments

Alternate Compressive Strength Calculation[2]

(Where Height/Diameter Ratio < 2)

Correction Coefficient N/A

Corrected Compressive Strength (psi) N/A

Corrected Compressive Strength (psf) N/A

Corrected Compressive Strength (tsf) N/A

[1] Post testing moisture content determination was performed as per ASTM D 2216, where as much of the whole specimen as available after compression testing was used in moisture content testing. Method B.

[2] The alternate compressive strength calculation is presented when the height to diameter ratio is less than 2, as per KM 64-523-02.

Reviewed By JW

Form: tmp_ucr_km_input.xlsm
Preparation Date: 12-1999
Revision Date: 01-2008

Stantec Consulting Services Inc.
Lexington, Kentucky

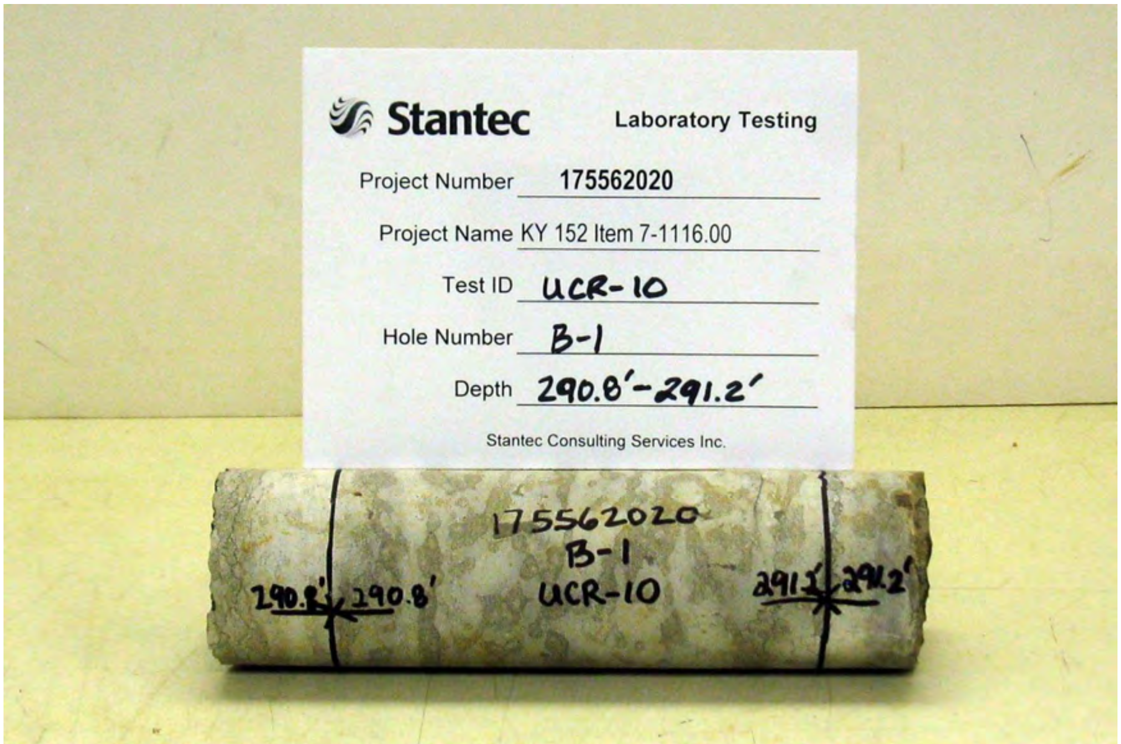
Laboratory Document
Prepared By: JW
Approved By: TLK

Stantec

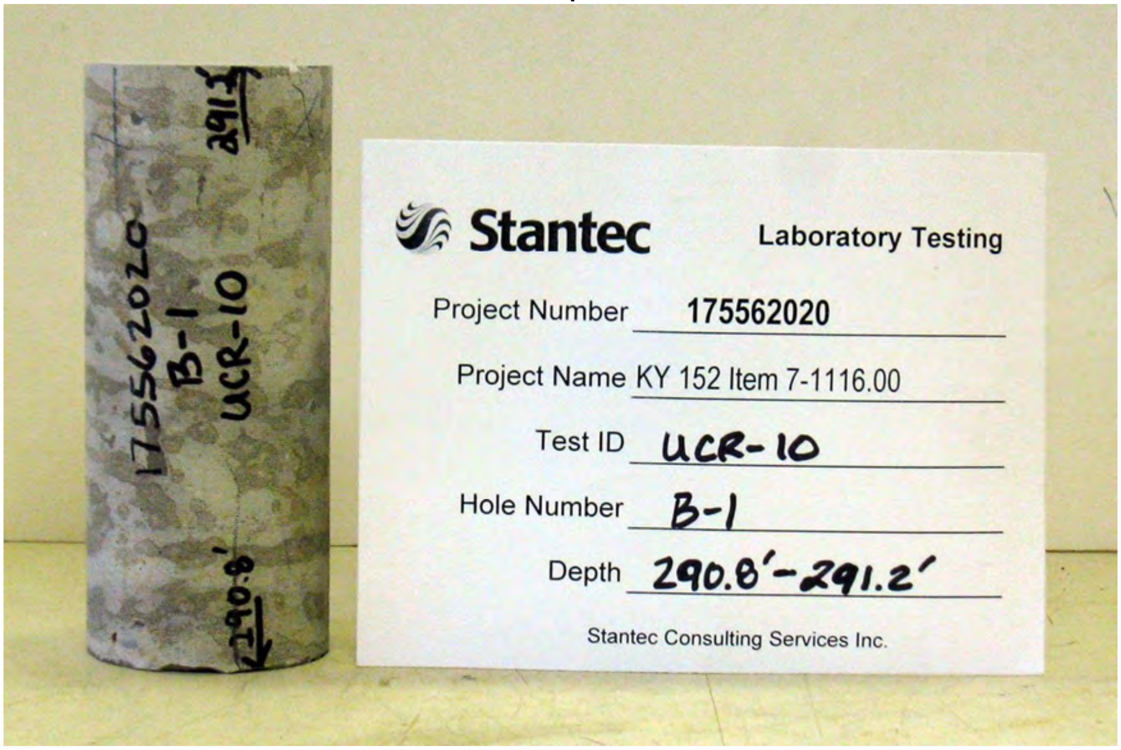
Photo Report

Project Name KY 152 Item 7-1116.00
Project Number 175562020
Lithology Limestone, gray, moderately hard, shale stringers
Lab ID UCR-10
Hole Number B-1 #10
Depth (ft) 290.8'-291.2'
Test Type Unconfined compressive strength

As Received



Core Preparation

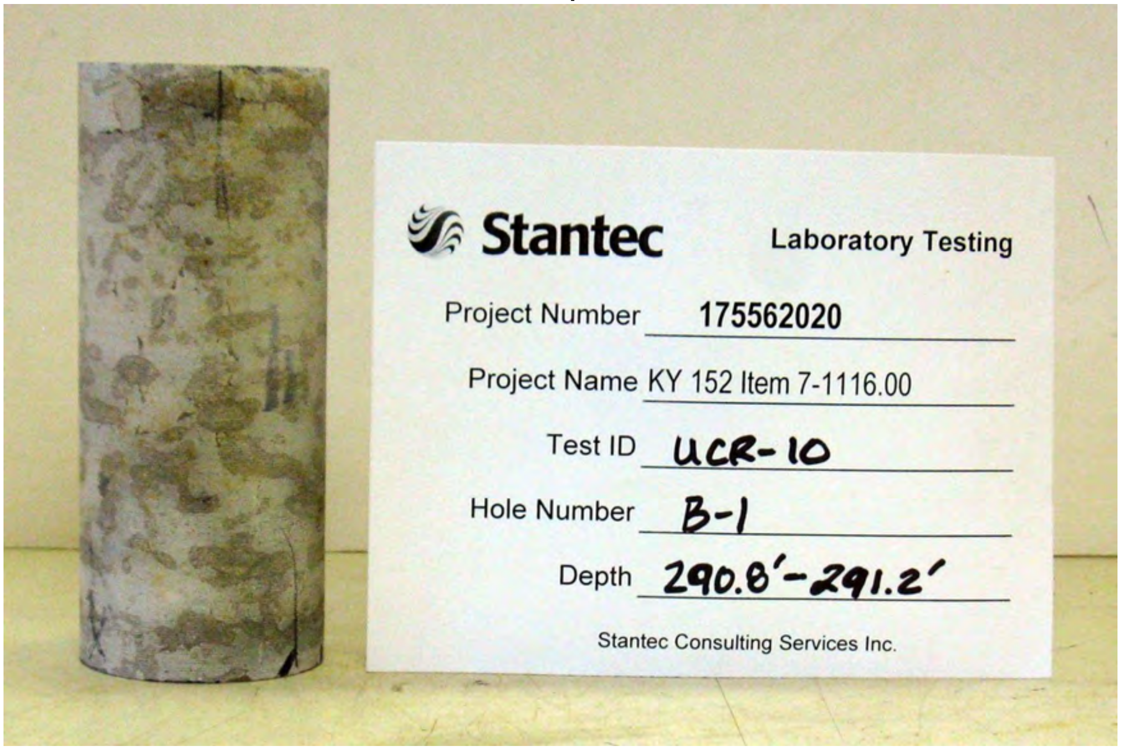


Stantec

Photo Report

Project Name	KY 152 Item 7-1116.00	Project Number	175562020
Lithology	Limestone, gray, moderately hard, shale stringers	Lab ID	UCR-10
Hole Number	B-1 #10 Depth (ft) 290.8'-291.2'		
Test Type	Unconfined compressive strength		

Core Preparation



Post Test

Stantec

Photo Report

Project Name KY 152 Item 7-1116.00
Lithology Limestone, gray, moderately hard, shale stringers
Hole Number B-1 #10 Depth (ft) 290.8'-291.2'
Test Type Unconfined compressive strength

Project Number 175562020
Lab ID UCR-10

Post Test

Stantec

Unconfined Compressive Strength Of Intact Rock Core

KM 64-523-02

Project Name KY 152 Item 7-1116.00 | Project Number 175562020
Lithology Limestone, gray, moderately hard, shale stringers | Lab ID UCR-11
Hole Number B-1 #11 | Depth (ft) 301.6'-302.0' | Date Received 03-26-2013

Temperature (^oC) 23.7 | Moisture Condition As received, moist | Date Tested 04-28-2013

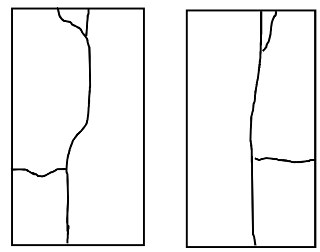
Side Planeness	Pass	Height (in)	4.625	Wet Unit Weight (pcf)	167.9
Perpendicularity	Pass	Diameter (in)	1.981	Dry Unit Weight (pcf)	167.7
End Planeness	Pass	Area (in^2)	3.082	Moisture Content[1] (%)	0.1
		Height/Diameter Ratio	2.335	Weight (lb)	1.385

Loading Rate (lbf/sec) 154
Peak Load (lbf) 60025

Failure Type Undetermined

Compressive Strength (psi) 19470
Compressive Strength (psf) 2803680
Compressive Strength (tsf) 1402

Failure Sketches



Comments

Alternate Compressive Strength Calculation[2]
(Where Height/Diameter Ratio < 2)

Correction Coefficient N/A

Corrected Compressive Strength (psi) N/A
Corrected Compressive Strength (psf) N/A
Corrected Compressive Strength (tsf) N/A

[1] Post testing moisture content determination was performed as per ASTM D 2216, where as much of the whole specimen as available after compression testing was used in moisture content testing. Method B.

[2] The alternate compressive strength calculation is presented when the height to diameter ratio is less than 2, as per KM 64-523-02.

Reviewed By JW

Form: tmp_ucr_km_input.xlsm
Preparation Date: 12-1999
Revision Date: 01-2008

Stantec Consulting Services Inc.
Lexington, Kentucky

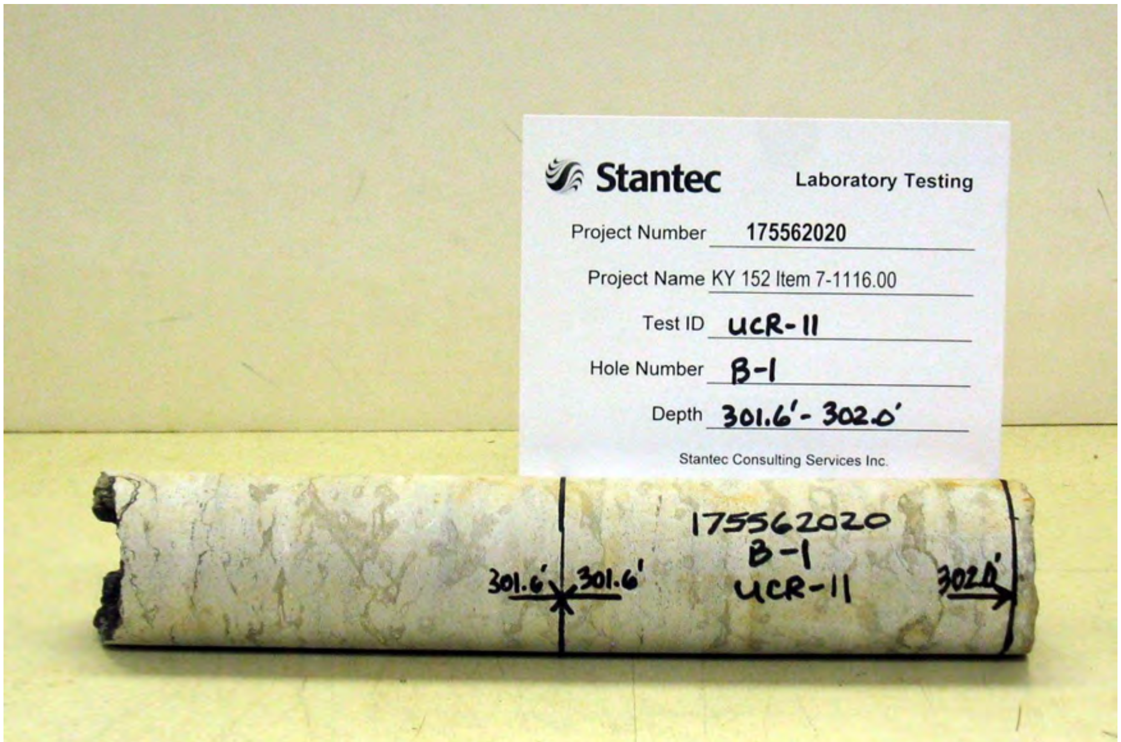
Laboratory Document
Prepared By: JW
Approved By: TLK

Stantec

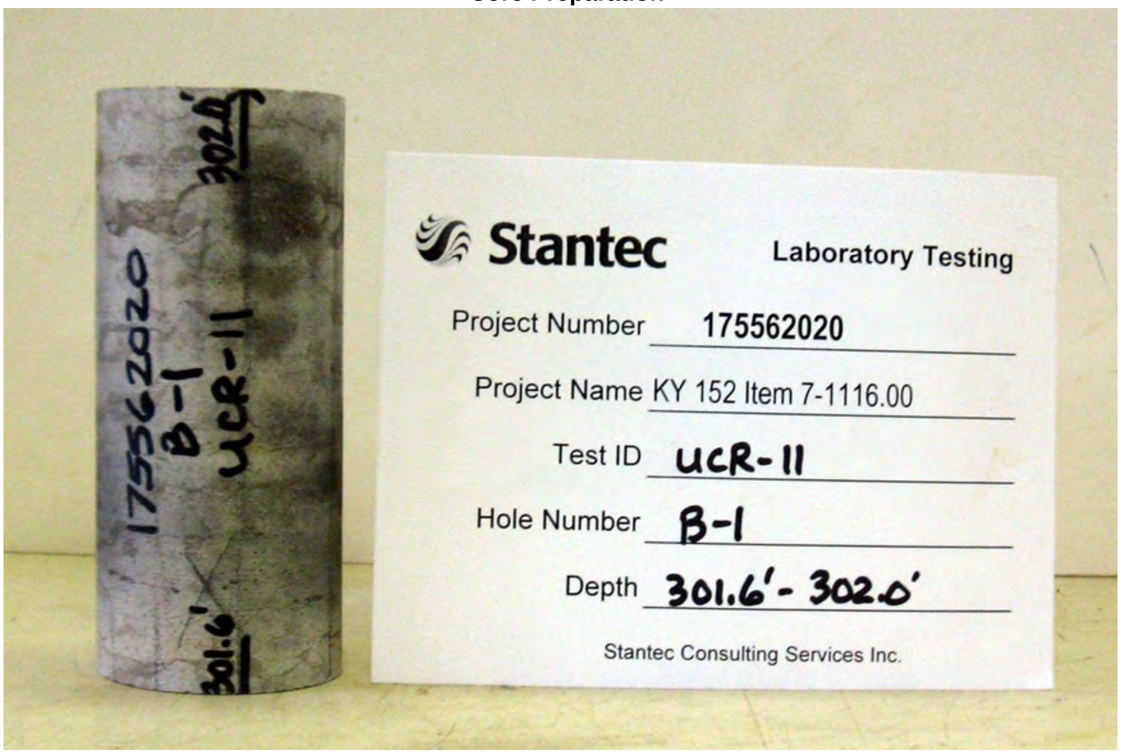
Photo Report

Project Name	KY 152 Item 7-1116.00	Project Number	175562020
Lithology	Limestone, gray, moderately hard, shale stringers	Lab ID	UCR-11
Hole Number	B-1 #11 Depth (ft) 301.6'-302.0'		
Test Type	Unconfined compressive strength		

As Received



Core Preparation

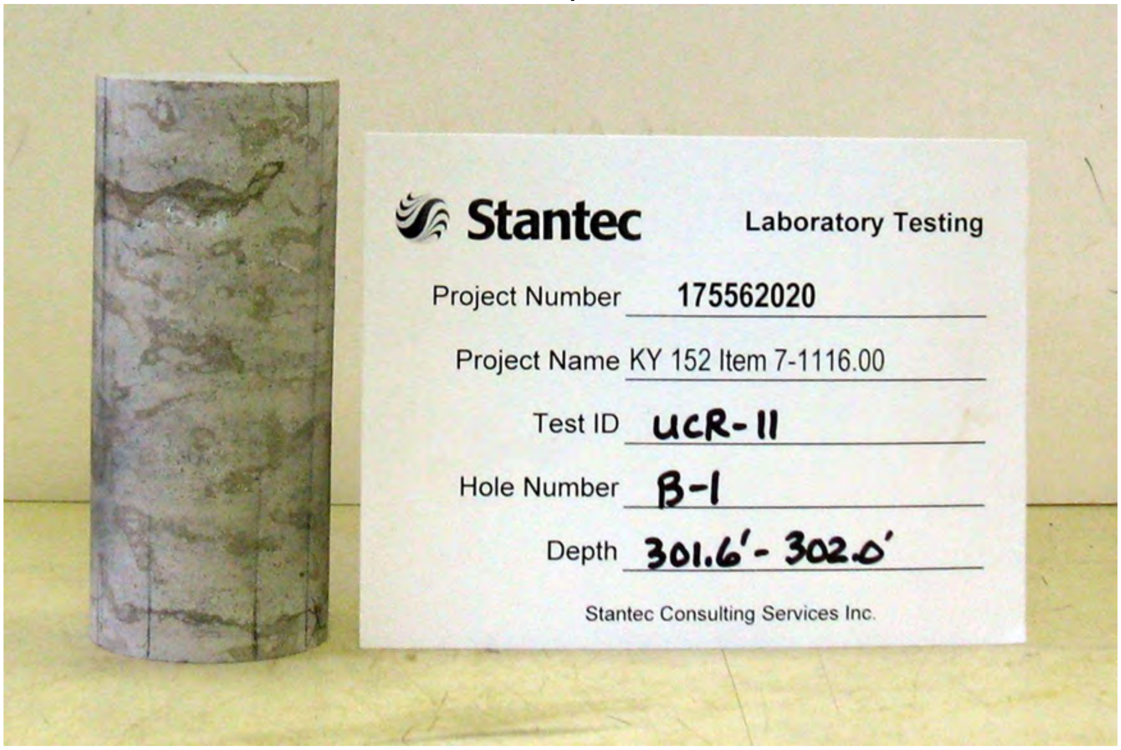


Stantec

Photo Report

Project Name	KY 152 Item 7-1116.00	Project Number	175562020
Lithology	Limestone, gray, moderately hard, shale stringers	Lab ID	UCR-11
Hole Number	B-1 #11 Depth (ft) 301.6'-302.0'		
Test Type	Unconfined compressive strength		

Core Preparation



Post Test

Stantec

Photo Report

Project Name	KY 152 Item 7-1116.00	Project Number	175562020
Lithology	Limestone, gray, moderately hard, shale stringers	Lab ID	UCR-11
Hole Number	B-1 #11	Depth (ft)	301.6'-302.0'
Test Type	Unconfined compressive strength		

Post Test

Stantec

Unconfined Compressive Strength Of Intact Rock Core

KM 64-523-02

Project Name KY 152 Item 7-1116.00
Project Number 175562020
Lithology Limestone, gray, moderately hard, shale stringers
Lab ID UCR-12
Hole Number B-1 #12
Depth (ft) 311.0'-311.4'
Date Received 03-26-2013

Temperature (^{o}C) 23.7
Moisture Condition As received, moist
Date Tested 04-28-2013

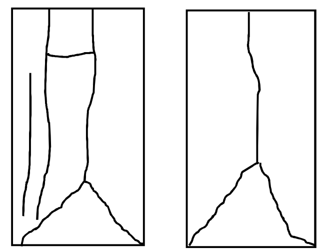
Side Planeness	Pass	Height (in)	4.754	Wet Unit Weight (pcf)	169.3
Perpendicularity	Pass	Diameter (in)	1.981	Dry Unit Weight (pcf)	169.1
End Planeness	Pass	Area (in^2)	3.083	Moisture Content[1] (%)	0.1
		Height/Diameter Ratio	2.399	Weight (lb)	1.436

Loading Rate (lbf/sec) 155
Peak Load (lbf) 54906

Failure Type Cone and Split

Compressive Strength (psi) 17810
Compressive Strength (psf) 2564640
Compressive Strength (tsf) 1282

Failure Sketches



Comments

Alternate Compressive Strength Calculation[2]
(Where Height/Diameter Ratio < 2)

Correction Coefficient N/A

Corrected Compressive Strength (psi) N/A
Corrected Compressive Strength (psf) N/A
Corrected Compressive Strength (tsf) N/A

[1] Post testing moisture content determination was performed as per ASTM D 2216, where as much of the whole specimen as available after compression testing was used in moisture content testing. Method B.

[2] The alternate compressive strength calculation is presented when the height to diameter ratio is less than 2, as per KM 64-523-02.

Reviewed By JW

Form: tmp_ucr_km_input.xlsm
Preparation Date: 12-1999
Revision Date: 01-2008

Stantec Consulting Services Inc.
Lexington, Kentucky

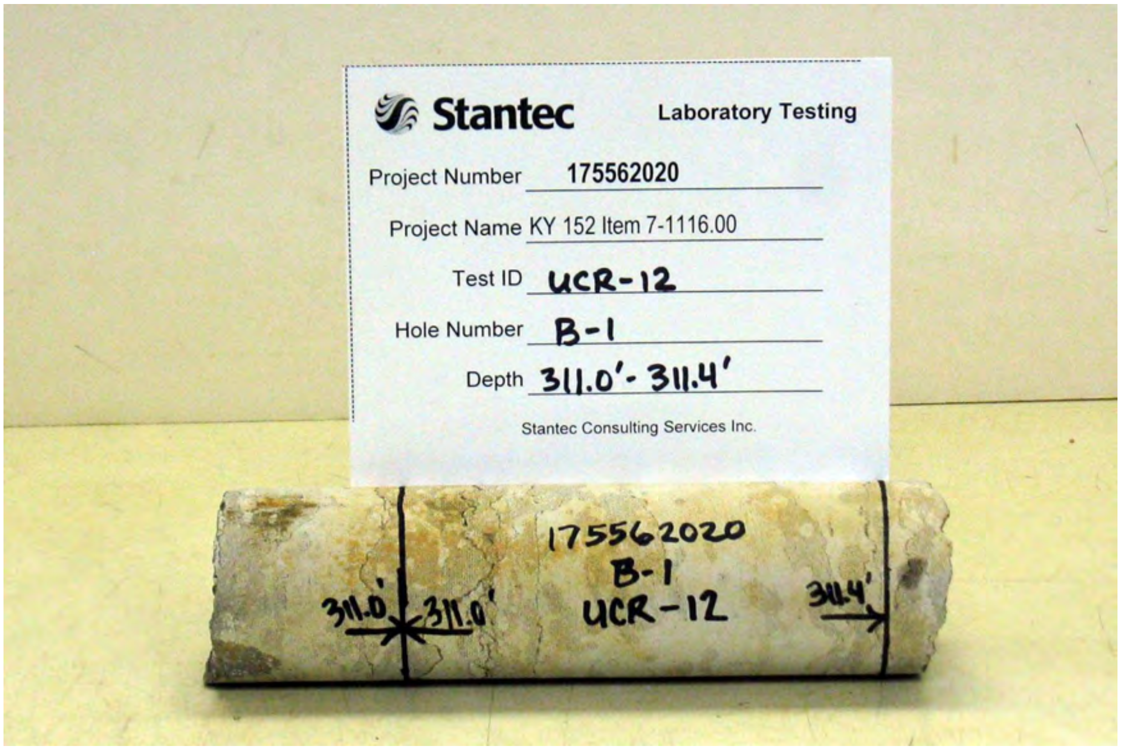
Laboratory Document
Prepared By: JW
Approved By: TLK

Stantec

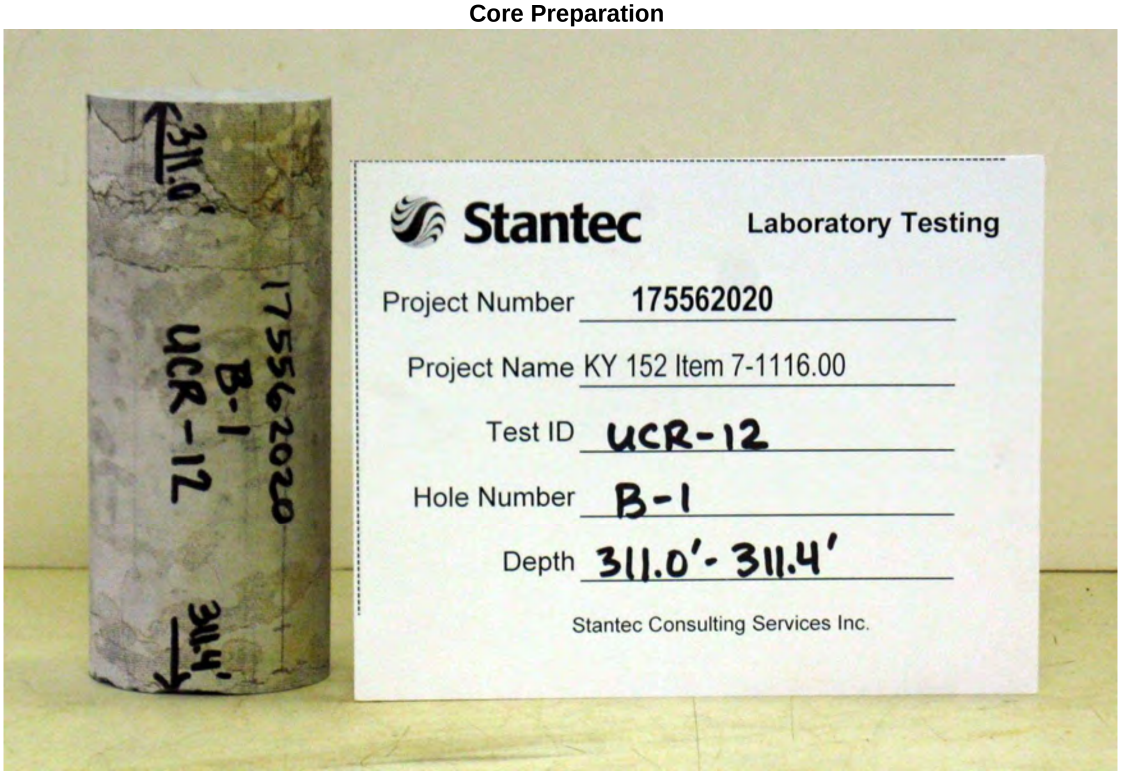
Photo Report

Project Name KY 152 Item 7-1116.00
Project Number 175562020
Lithology Limestone, gray, moderately hard, shale stringers
Lab ID UCR-12
Hole Number B-1 #12 Depth (ft) 311.0'-311.4'
Test Type Unconfined compressive strength

As Received



Core Preparation



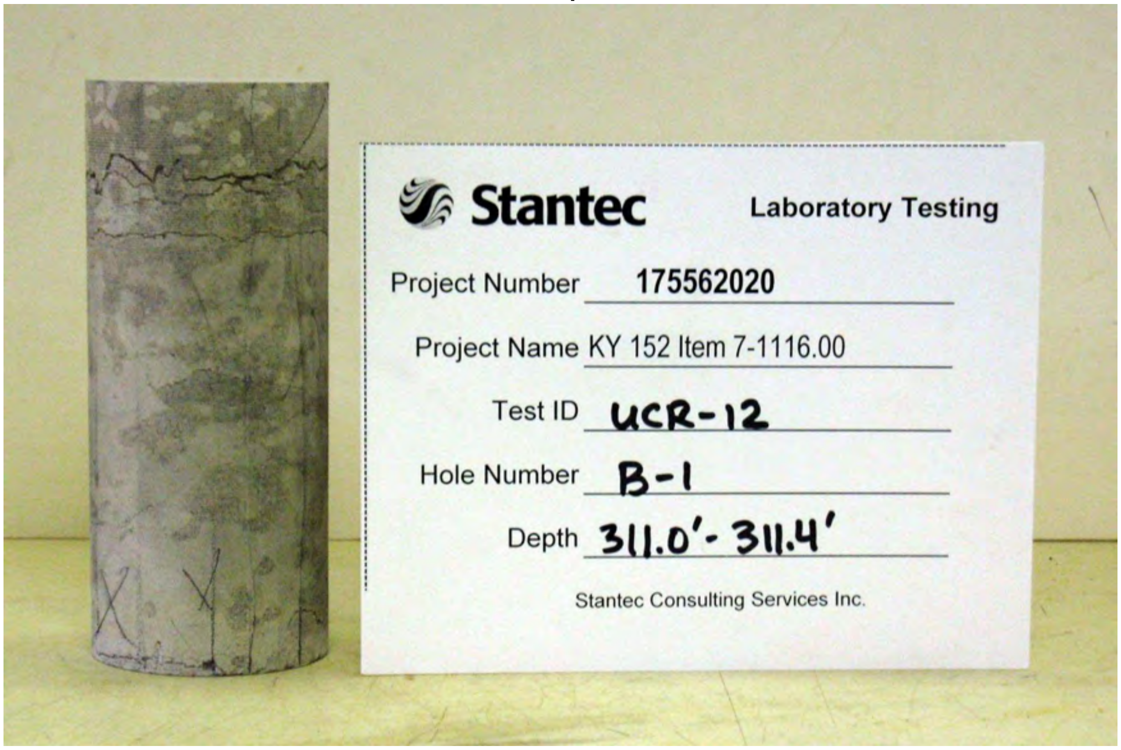
Stantec

Photo Report

Project Name KY 152 Item 7-1116.00
Lithology Limestone, gray, moderately hard, shale stringers
Hole Number B-1 #12 Depth (ft) 311.0'-311.4'
Test Type Unconfined compressive strength

Project Number 175562020
Lab ID UCR-12

Core Preparation



Post Test

Stantec

Photo Report

Project Name KY 152 Item 7-1116.00
Lithology Limestone, gray, moderately hard, shale stringers
Hole Number B-1 #12 Depth (ft) 311.0'-311.4'
Test Type Unconfined compressive strength

Project Number 175562020
Lab ID UCR-12

Post Test

Stantec

Unconfined Compressive Strength
Of Intact Rock Core
KM 64-523-02

Project Name	KY 152 Item 7-1116.00	Project Number	175562020
Lithology	Limestone, gray, moderately hard, shale stringers	Lab ID	UCR-13
Hole Number	B-1 #13	Depth (ft)	321.0'-321.4'
Date Received	03-26-2013		
Temperature (^{o}C)	23.7	Moisture Condition	As received, moist
Date Tested	04-28-2013		

Side Planeness	Pass	Height (in)	4.752	Wet Unit Weight (pcf)	169.8
Perpendicularity	Pass	Diameter (in)	1.980	Dry Unit Weight (pcf)	169.6
End Planeness	Pass	Area (in^2)	3.079	Moisture Content[1] (%)	0.1
		Height/Diameter Ratio	2.400	Weight (lb)	1.437

Loading Rate (lbf/sec)	152
Peak Load (lbf)	75566
Failure Type	Undetermined
Compressive Strength (psi)	24540
Compressive Strength (psf)	3533760
Compressive Strength (tsf)	1767

Failure Sketches

N/A

Comments ______________________

Alternate Compressive Strength Calculation[2]
(Where Height/Diameter Ratio < 2)

Correction Coefficient	N/A
Corrected Compressive Strength (psi)	N/A
Corrected Compressive Strength (psf)	N/A
Corrected Compressive Strength (tsf)	N/A

[1] Post testing moisture content determination was performed as per ASTM D 2216, where as much of the whole specimen as available after compression testing was used in moisture content testing. Method B.

[2] The alternate compressive strength calculation is presented when the height to diameter ratio is less than 2, as per KM 64-523-02.

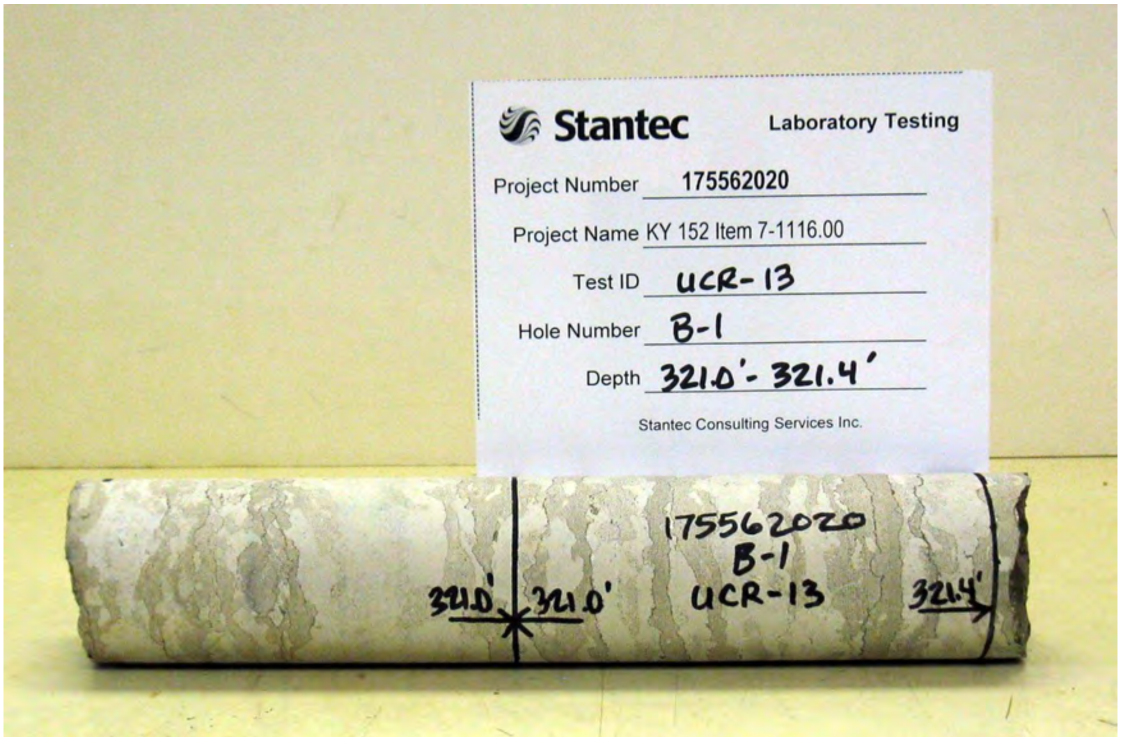
Reviewed By ____

Stantec

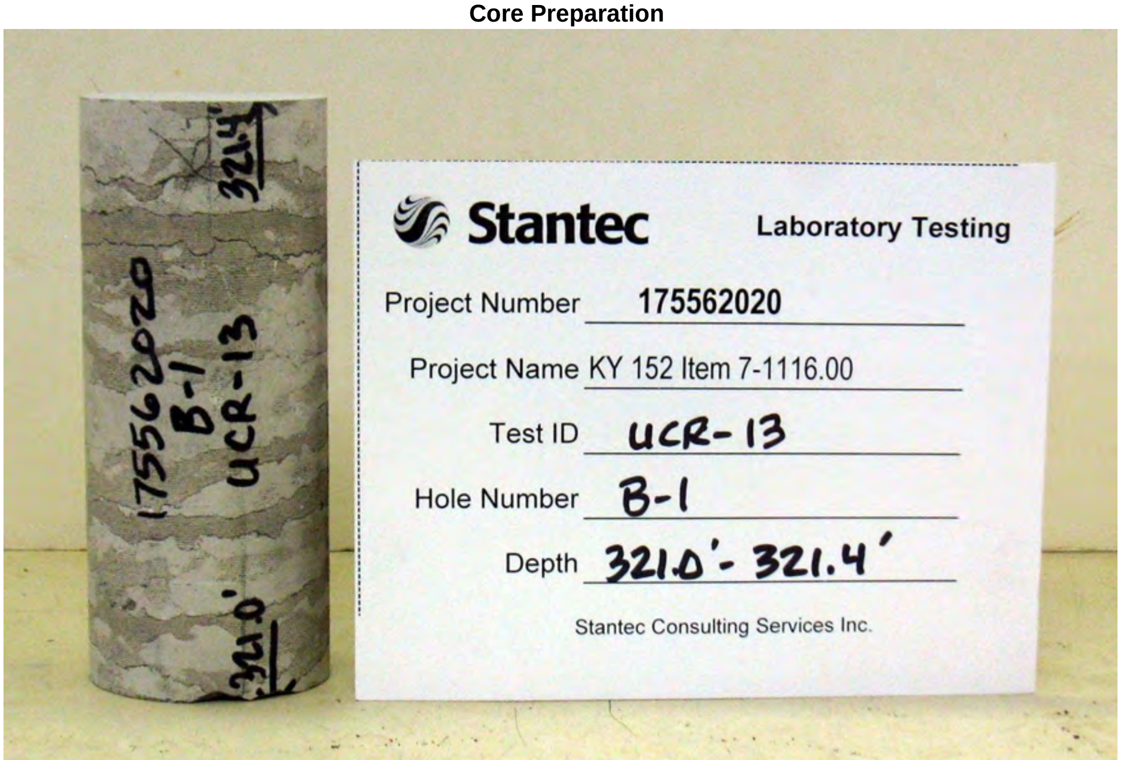
Photo Report

Project Name	KY 152 Item 7-1116.00	Project Number	175562020
Lithology	Limestone, gray, moderately hard, shale stringers	Lab ID	UCR-13
Hole Number	B-1 #13 Depth (ft) 321.0'-321.4'		
Test Type	Unconfined compressive strength		

As Received



Core Preparation

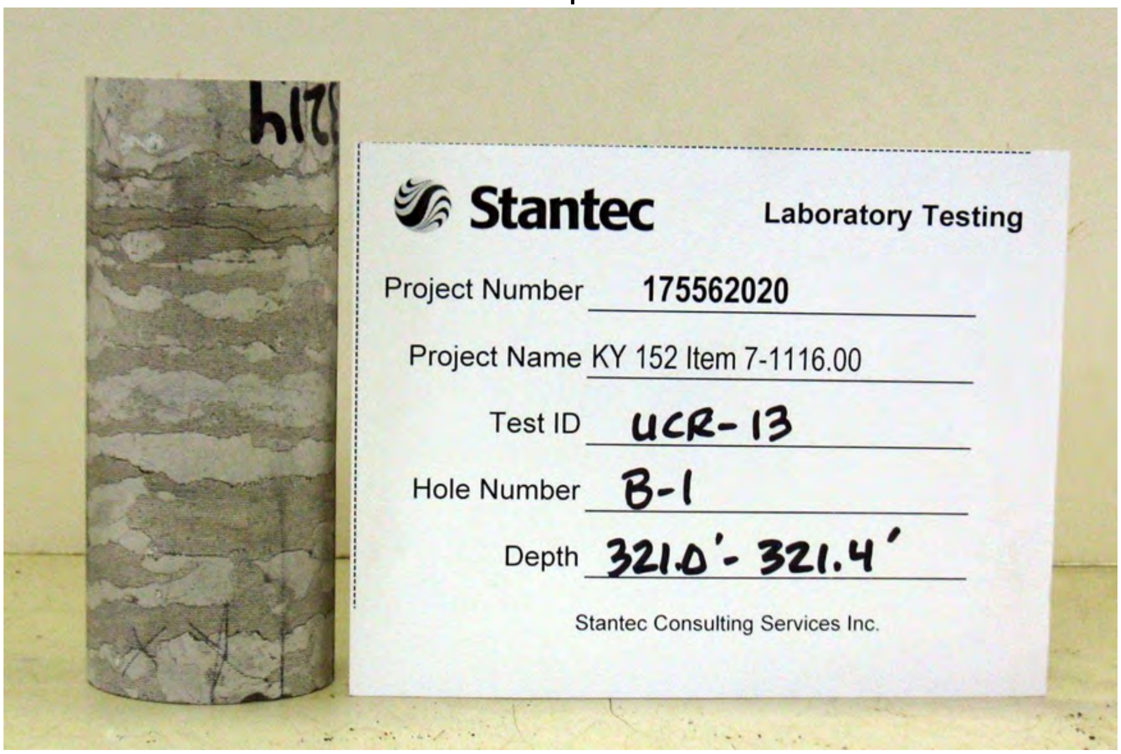


Stantec

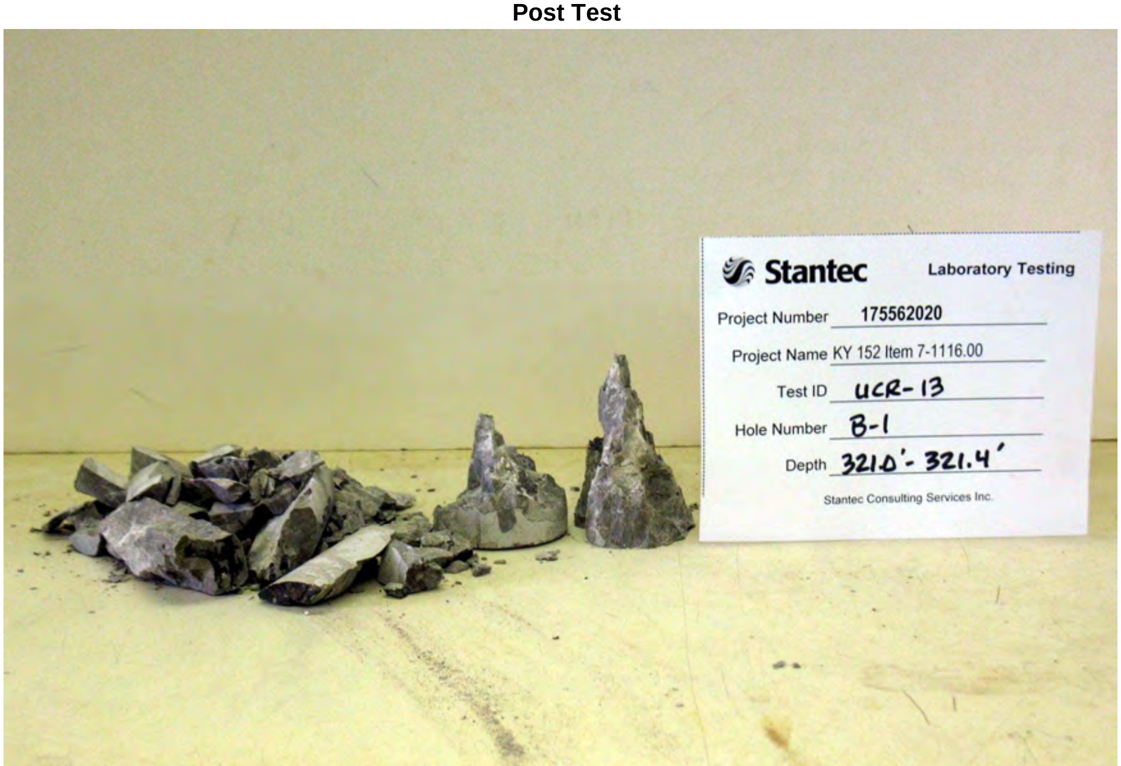
Photo Report

Project Name	KY 152 Item 7-1116.00	Project Number	175562020
Lithology	Limestone, gray, moderately hard, shale stringers	Lab ID	UCR-13
Hole Number	B-1 #13 Depth (ft) 321.0'-321.4'		
Test Type	Unconfined compressive strength		

Core Preparation



Post Test



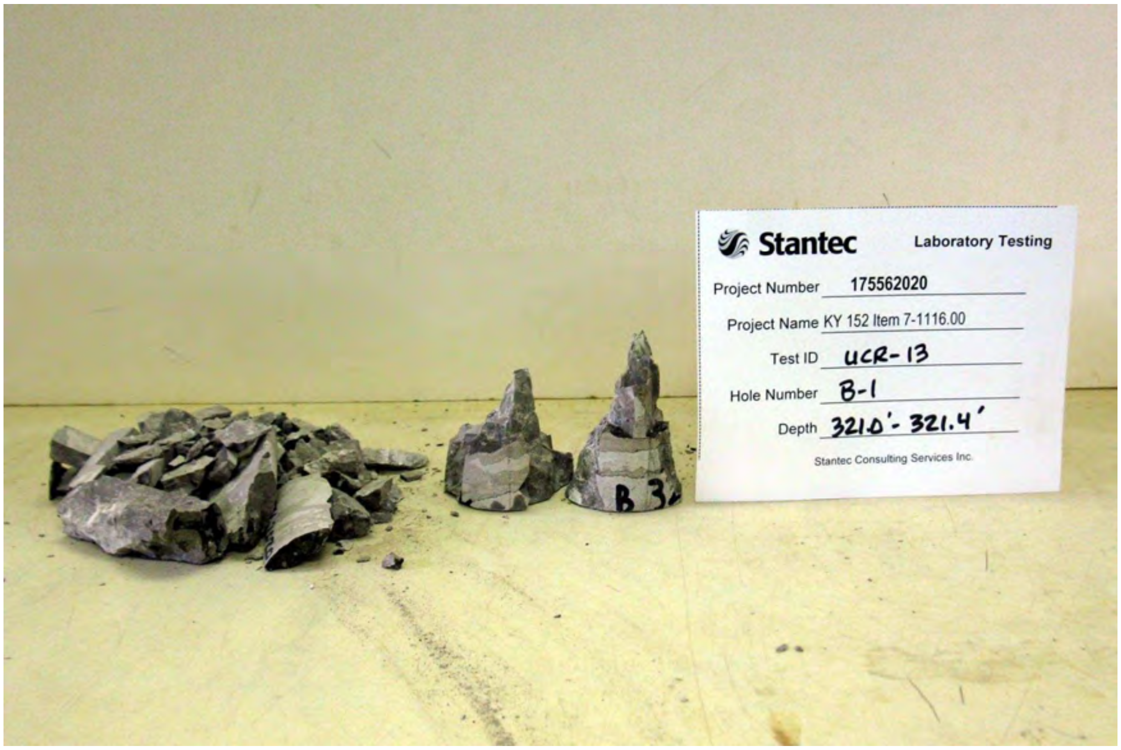
Stantec

Photo Report

Project Name KY 152 Item 7-1116.00
Lithology Limestone, gray, moderately hard, shale stringers
Hole Number B-1 #13 Depth (ft) 321.0'-321.4'
Test Type Unconfined compressive strength

Project Number 175562020
Lab ID UCR-13

Post Test



Stantec

Unconfined Compressive Strength Of Intact Rock Core

KM 64-523-02

Project Name	KY 152 Item 7-1116.00
Project Number	175562020
Lithology	Limestone, gray, moderately hard
Lab ID	UCR-14
Hole Number	B-1 #14
Depth (ft)	195.6'-196.4'
Date Received	03-26-2013
Temperature (^{o}C)	23.8
Moisture Condition	As received, moist
Date Tested	04-28-2013

Side Planeness	Pass	Height (in)	4.805	Wet Unit Weight (pcf)	168.3
Perpendicularity	Pass	Diameter (in)	1.981	Dry Unit Weight (pcf)	167.8
End Planeness	Pass	Area (in^2)	3.081	Moisture Content[1] (%)	0.3
		Height/Diameter Ratio	2.426	Weight (lb)	1.442

Loading Rate (lbf/sec)	154
Peak Load (lbf)	94323
Failure Type	Undetermined
Compressive Strength (psi)	30610
Compressive Strength (psf)	4407840
Compressive Strength (tsf)	2204

Failure Sketches

N/A

Comments

Alternate Compressive Strength Calculation[2]
(Where Height/Diameter Ratio < 2)

Correction Coefficient	N/A
Corrected Compressive Strength (psi)	N/A
Corrected Compressive Strength (psf)	N/A
Corrected Compressive Strength (tsf)	N/A

[1] Post testing moisture content determination was performed as per ASTM D 2216, where as much of the whole specimen as available after compression testing was used in moisture content testing. Method B.

[2] The alternate compressive strength calculation is presented when the height to diameter ratio is less than 2, as per KM 64-523-02.

Reviewed By JW

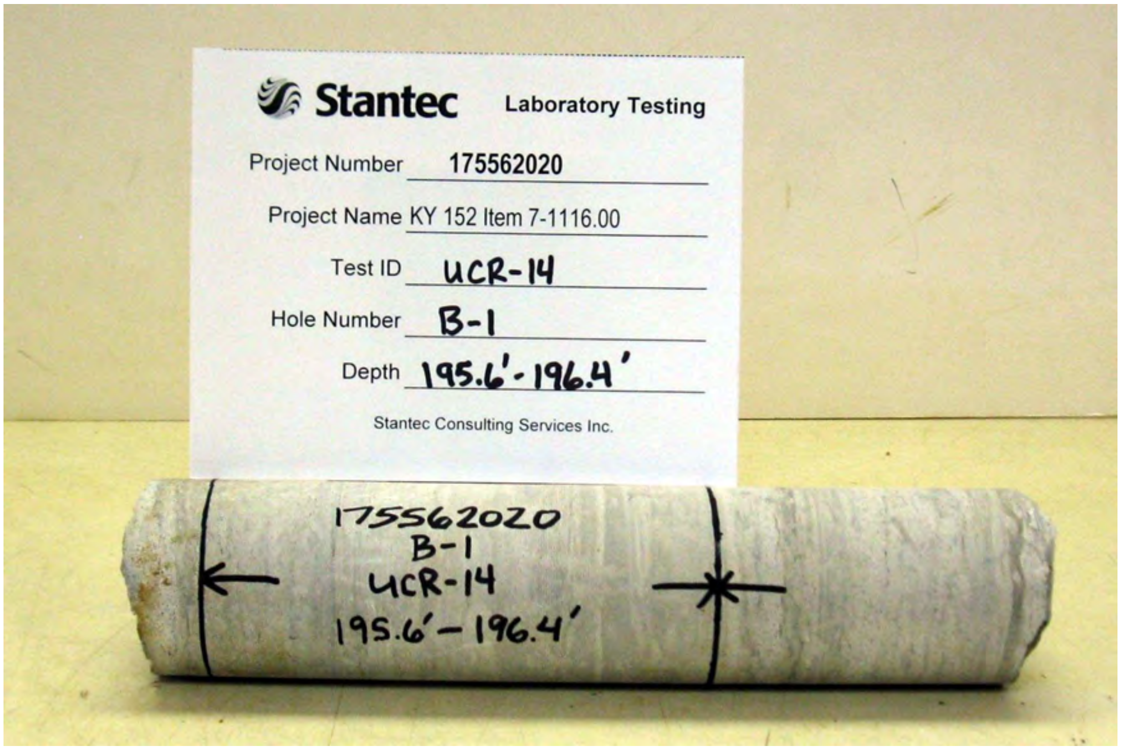
Stantec

Photo Report

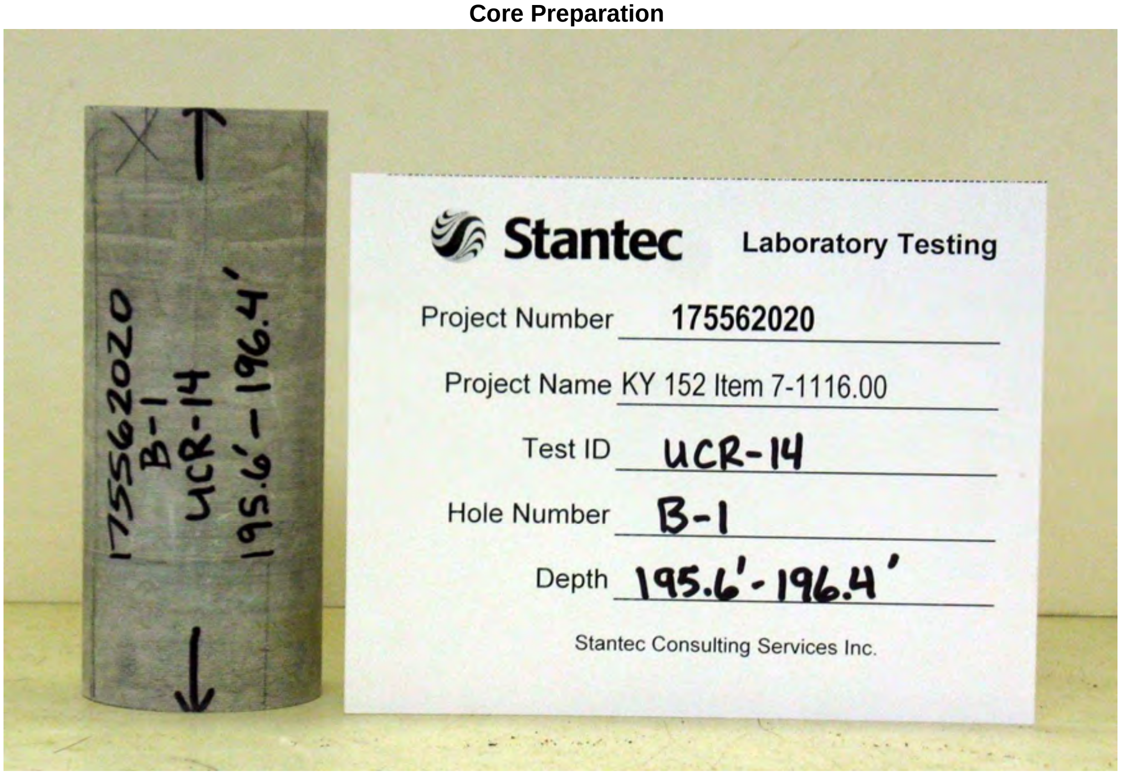
Project Name KY 152 Item 7-1116.00
Lithology Limestone, gray, moderately hard
Hole Number B-1 #14 Depth (ft) 195.6'-196.4'
Test Type Unconfined compressive strength

Project Number 175562020
Lab ID UCR-14

As Received



Core Preparation

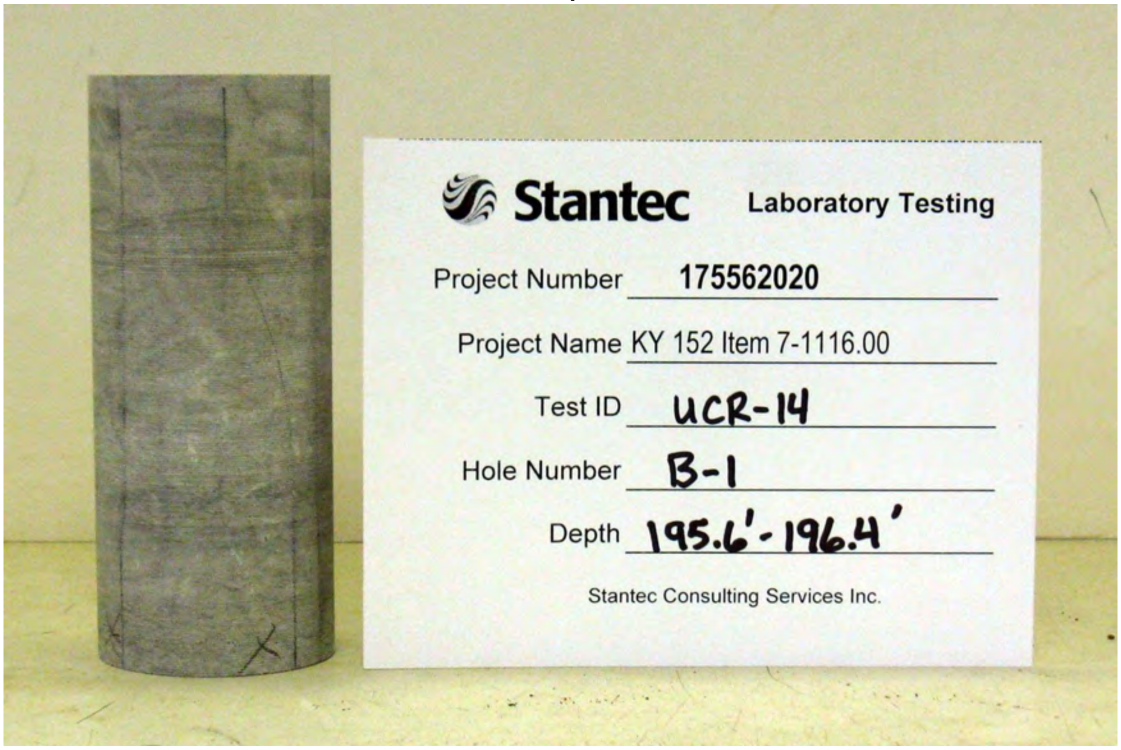


Stantec

Photo Report

Project Name	KY 152 Item 7-1116.00	Project Number	175562020
Lithology	Limestone, gray, moderately hard	Lab ID	UCR-14
Hole Number	B-1 #14	Depth (ft)	195.6'-196.4'
Test Type	Unconfined compressive strength		

Core Preparation



Post Test

Photo Report

Project Name	KY 152 Item 7-1116.00	Project Number	175562020
Lithology	Limestone, gray, moderately hard	Lab ID	UCR-14
Hole Number	B-1 #14	Depth (ft)	195.6'-196.4'
Test Type	Unconfined compressive strength		

Post Test

Stantec

Unconfined Compressive Strength Of Intact Rock Core

KM 64-523-02

Project Name: KY 152 Item 7-1116.00
Project Number: 175562020
Lithology: Limestone, gray, moderately hard, shale stringers
Lab ID: UCR-15
Hole Number: B-1 #15
Depth (ft): 205.0'-205.8'
Date Received: 03-26-2013

Temperature (^oC): 23.8
Moisture Condition: As received, moist
Date Tested: 04-28-2013

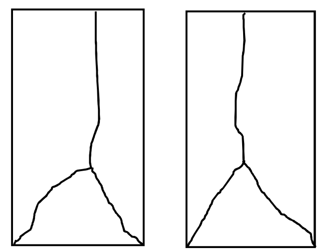
Side Planeness	Pass	Height (in)	4.661	Wet Unit Weight (pcf)	166.8
Perpendicularity	Pass	Diameter (in)	1.979	Dry Unit Weight (pcf)	166.4
End Planeness	Pass	Area (in^2)	3.076	Moisture Content[1] (%)	0.2
		Height/Diameter Ratio	2.355	Weight (lb)	1.383

Loading Rate (lbf/sec): 153
Peak Load (lbf): 86325

Failure Type: Cone and Split

Compressive Strength (psi): 28060
Compressive Strength (psf): 4040640
Compressive Strength (tsf): 2021

Failure Sketches



Comments:

Alternate Compressive Strength Calculation[2]
(Where Height/Diameter Ratio < 2)

Correction Coefficient: N/A

Corrected Compressive Strength (psi): N/A
Corrected Compressive Strength (psf): N/A
Corrected Compressive Strength (tsf): N/A

[1] Post testing moisture content determination was performed as per ASTM D 2216, where as much of the whole specimen as available after compression testing was used in moisture content testing. Method B.

[2] The alternate compressive strength calculation is presented when the height to diameter ratio is less than 2, as per KM 64-523-02.

Reviewed By: JW

Form: tmp_ucr_km_input.xlsm
Preparation Date: 12-1999
Revision Date: 01-2008

Stantec Consulting Services Inc.
Lexington, Kentucky

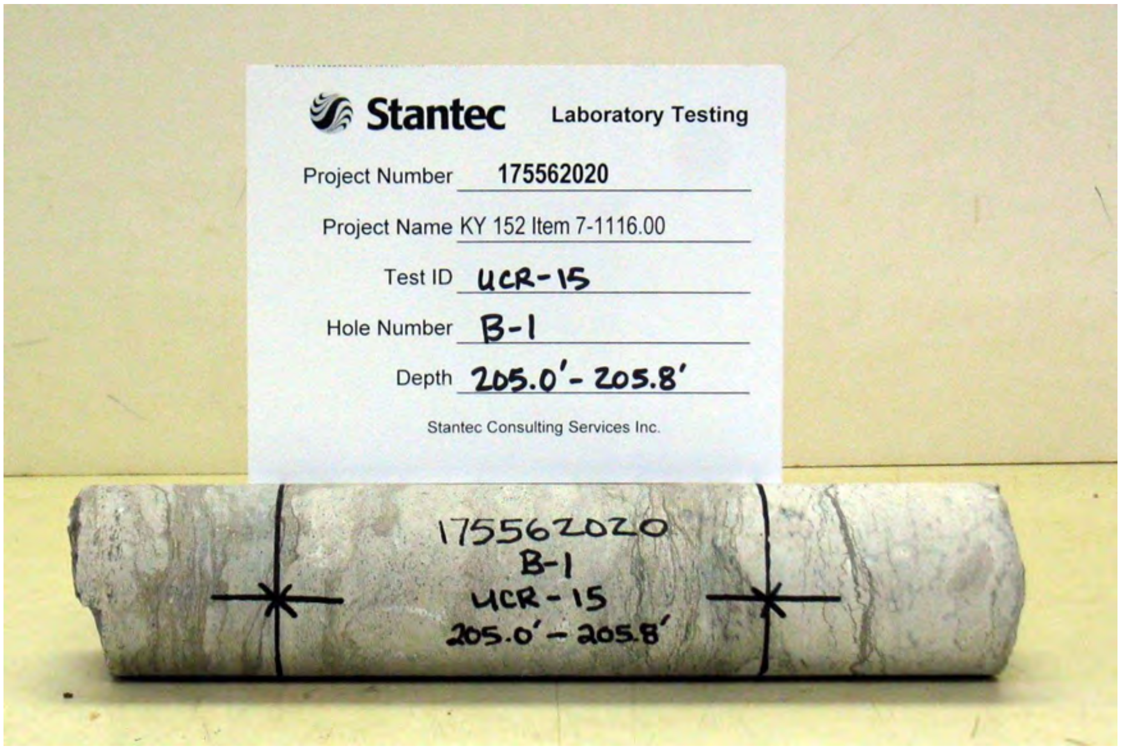
Laboratory Document
Prepared By: JW
Approved By: TLK

Stantec

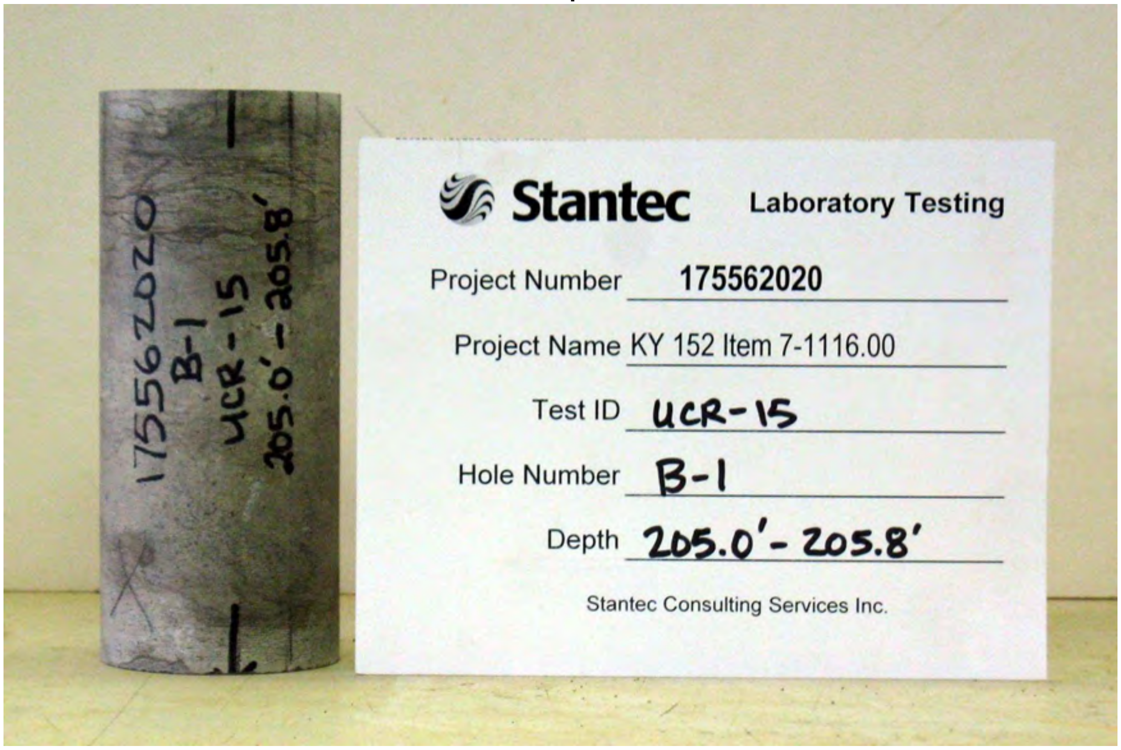
Photo Report

Project Name	KY 152 Item 7-1116.00	Project Number	175562020
Lithology	Limestone, gray, moderately hard, shale stringers	Lab ID	UCR-15
Hole Number	B-1 #15 Depth (ft) 205.0'-205.8'		
Test Type	Unconfined compressive strength		

As Received



Core Preparation

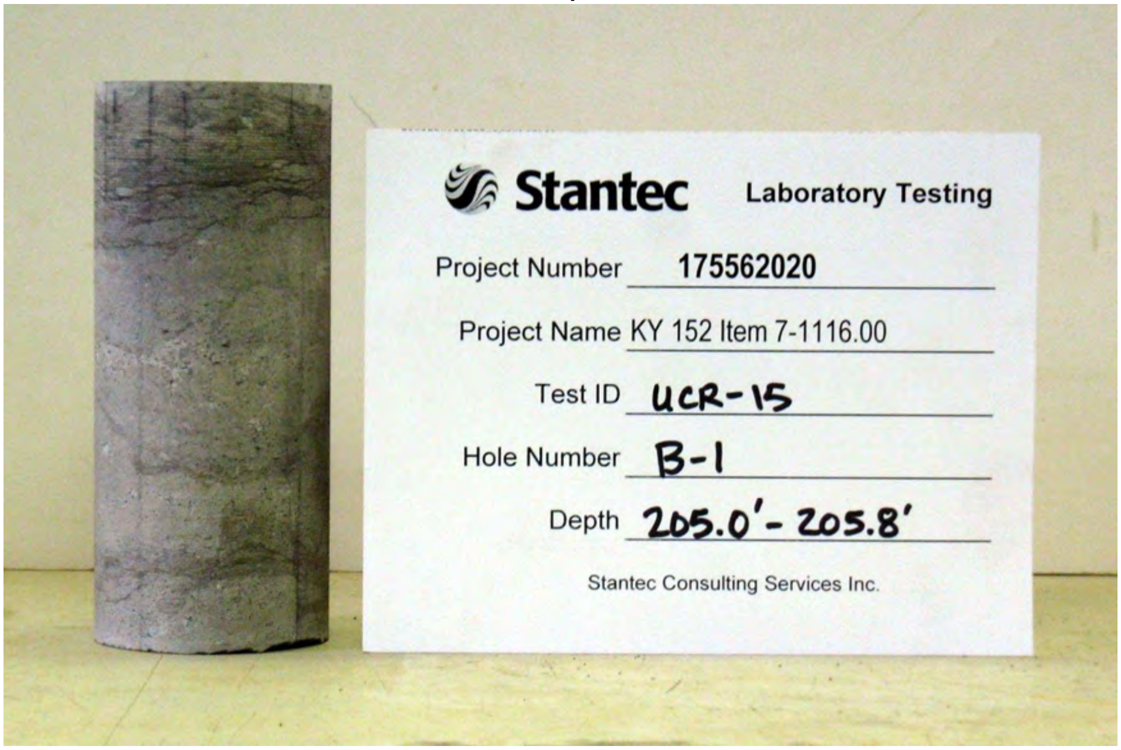


Stantec

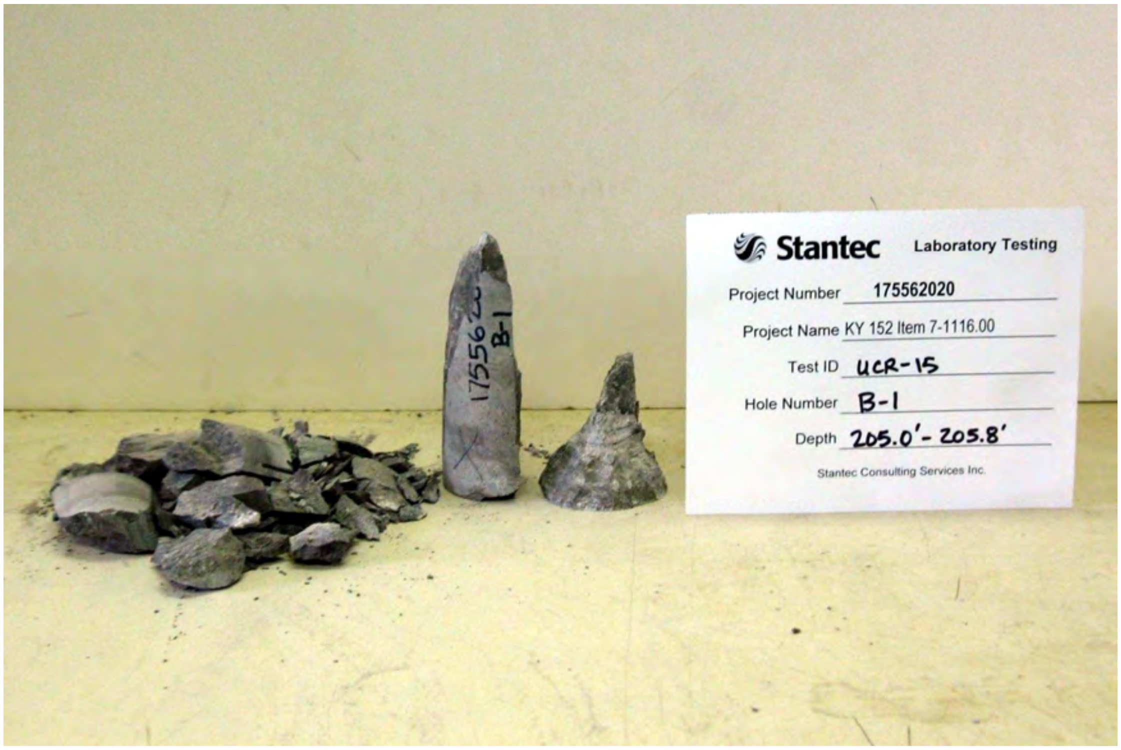
Photo Report

Project Name	KY 152 Item 7-1116.00	Project Number	175562020
Lithology	Limestone, gray, moderately hard, shale stringers	Lab ID	UCR-15
Hole Number	B-1 #15 Depth (ft) 205.0'-205.8'		
Test Type	Unconfined compressive strength		

Core Preparation



Post Test



Stantec

Photo Report

Project Name	KY 152 Item 7-1116.00	Project Number	175562020
Lithology	Limestone, gray, moderately hard, shale stringers	Lab ID	UCR-15
Hole Number	B-1 #15 Depth (ft) 205.0'-205.8'		
Test Type	Unconfined compressive strength		

Post Test

Stantec

Unconfined Compressive Strength Of Intact Rock Core

KM 64-523-02

Project Name: KY 152 Item 7-1116.00
Project Number: 175562020
Lithology: Limestone, gray, moderately hard, shale stringers
Lab ID: UCR-16
Hole Number: B-1 #16
Depth (ft): 212.7'-213.4'
Date Received: 03-26-2013

Temperature (^oC): 23.9
Moisture Condition: As received, moist
Date Tested: 04-28-2013

Side Planeness	Pass	Height (in)	4.410	Wet Unit Weight (pcf)	167.1
Perpendicularity	Pass	Diameter (in)	1.980	Dry Unit Weight (pcf)	166.9
End Planeness	Pass	Area (in^2)	3.080	Moisture Content[1] (%)	0.1
		Height/Diameter Ratio	2.227	Weight (lb)	1.313

Loading Rate (lbf/sec): 148
Peak Load (lbf): 69674

Failure Type: Undetermined

Compressive Strength (psi): 22620
Compressive Strength (psf): 3257280
Compressive Strength (tsf): 1629

Failure Sketches

N/A

Comments:

Alternate Compressive Strength Calculation[2]
(Where Height/Diameter Ratio < 2)

Correction Coefficient: N/A

Corrected Compressive Strength (psi): N/A
Corrected Compressive Strength (psf): N/A
Corrected Compressive Strength (tsf): N/A

[1] Post testing moisture content determination was performed as per ASTM D 2216, where as much of the whole specimen as available after compression testing was used in moisture content testing. Method B.

[2] The alternate compressive strength calculation is presented when the height to diameter ratio is less than 2, as per KM 64-523-02.

Reviewed By: JW

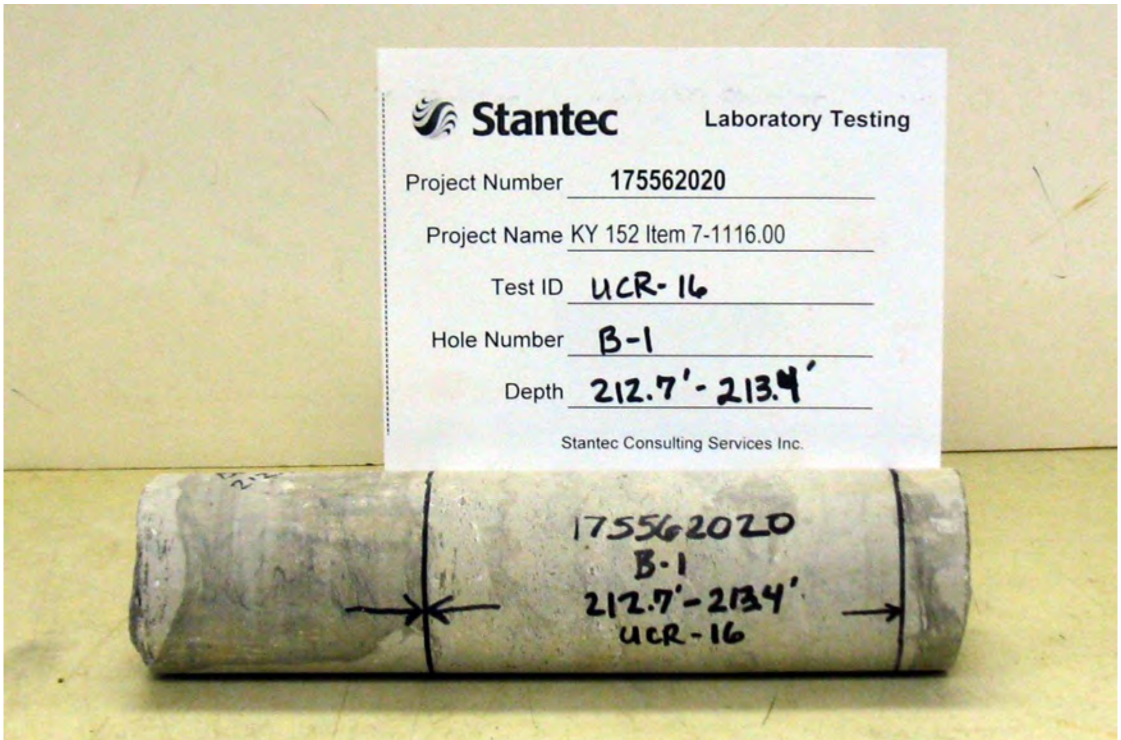
Stantec

Photo Report

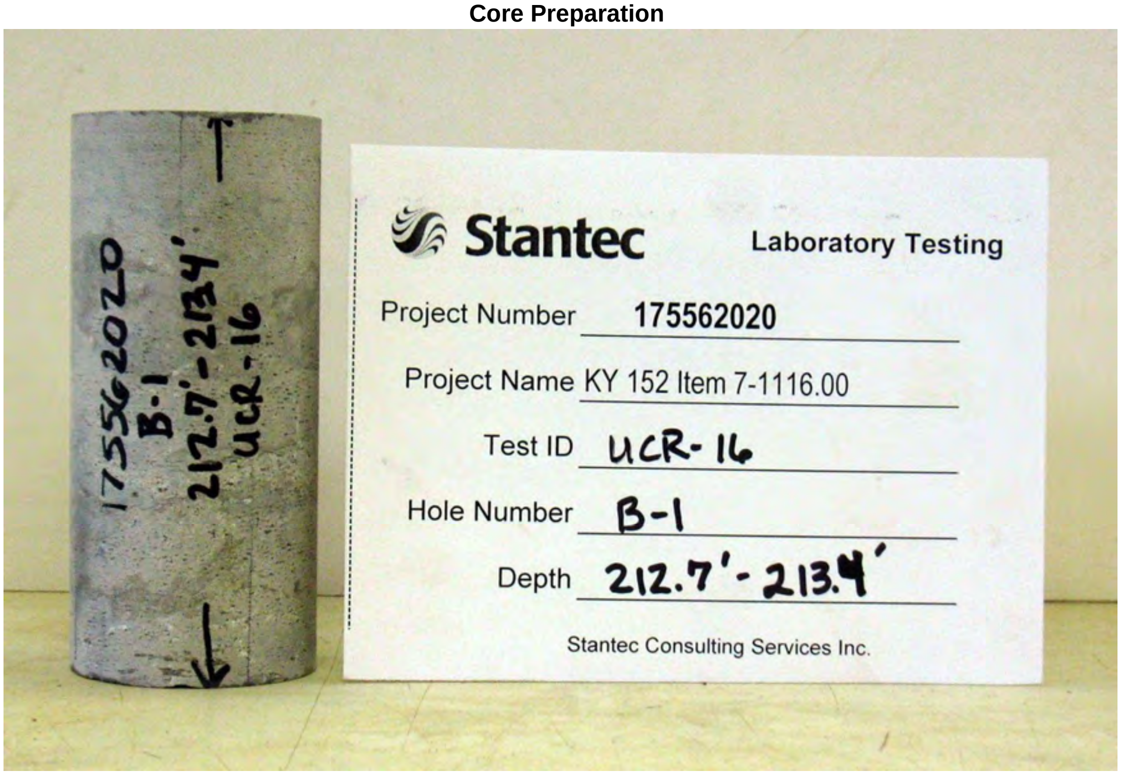
Project Name KY 152 Item 7-1116.00
Lithology Limestone, gray, moderately hard, shale stringers
Hole Number B-1 #16 Depth (ft) 212.7'-213.4'
Test Type Unconfined compressive strength

Project Number 175562020
Lab ID UCR-16

As Received



Core Preparation



Stantec

Photo Report

Project Name	KY 152 Item 7-1116.00	Project Number	175562020
Lithology	Limestone, gray, moderately hard, shale stringers	Lab ID	UCR-16
Hole Number	B-1 #16 Depth (ft) 212.7'-213.4'		
Test Type	Unconfined compressive strength		

Core Preparation

Post Test

Stantec

Photo Report

Project Name	KY 152 Item 7-1116.00	Project Number	175562020
Lithology	Limestone, gray, moderately hard, shale stringers	Lab ID	UCR-16
Hole Number	B-1 #16 Depth (ft) 212.7'-213.4'		
Test Type	Unconfined compressive strength		

Post Test

Stantec

Unconfined Compressive Strength Of Intact Rock Core

KM 64-523-02

Project Name: KY 152 Item 7-1116.00
Project Number: 175562020
Lithology: Limestone, gray, moderately hard, shale stringers
Lab ID: UCR-17
Hole Number: B-1 #17
Depth (ft): 222.2'-223.1'
Date Received: 03-26-2013

Temperature (^oC): 23.9
Moisture Condition: As received, moist
Date Tested: 04-28-2013

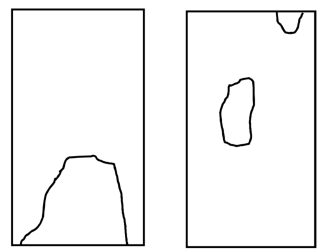
Side Planeness	Pass	Height (in)	4.390	Wet Unit Weight (pcf)	168.1
Perpendicularity	Pass	Diameter (in)	1.980	Dry Unit Weight (pcf)	167.9
End Planeness	Pass	Area (in^2)	3.080	Moisture Content[1] (%)	0.1
		Height/Diameter Ratio	2.217	Weight (lb)	1.315

Loading Rate (lbf/sec): 150
Peak Load (lbf): 107947

Failure Type: Undetermined

Compressive Strength (psi): 35050
Compressive Strength (psf): 5047200
Compressive Strength (tsf): 2523

Failure Sketches



Comments:

Alternate Compressive Strength Calculation[2]
(Where Height/Diameter Ratio < 2)

Correction Coefficient: N/A

Corrected Compressive Strength (psi): N/A
Corrected Compressive Strength (psf): N/A
Corrected Compressive Strength (tsf): N/A

[1] Post testing moisture content determination was performed as per ASTM D 2216, where as much of the whole specimen as available after compression testing was used in moisture content testing. Method B.

[2] The alternate compressive strength calculation is presented when the height to diameter ratio is less than 2, as per KM 64-523-02.

Reviewed By: JW

Form: tmp_ucr_km_input.xlsm
Preparation Date: 12-1999
Revision Date: 01-2008

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Lexington, Kentucky

Laboratory Document
Prepared By: JW
Approved By: TLK

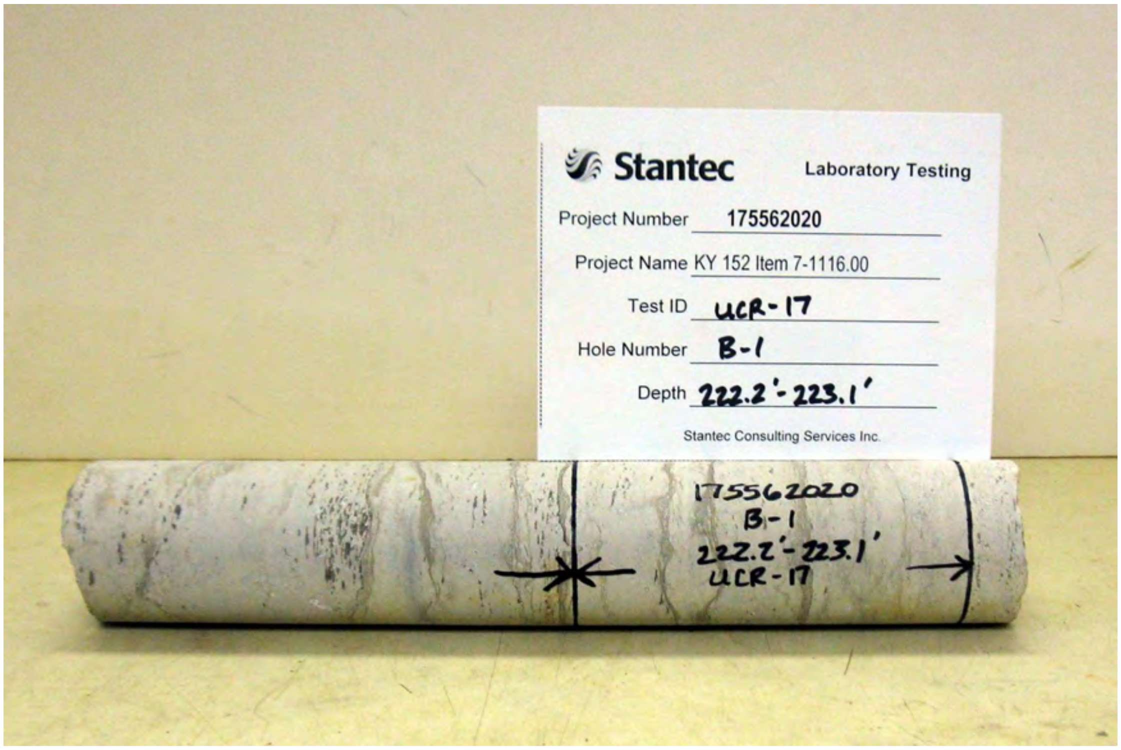
Stantec

Photo Report

Project Name KY 152 Item 7-1116.00
Lithology Limestone, gray, moderately hard, shale stringers
Hole Number B-1 #17 Depth (ft) 222.2'-223.1'
Test Type Unconfined compressive strength

Project Number 175562020
Lab ID UCR-17

As Received



Core Preparation

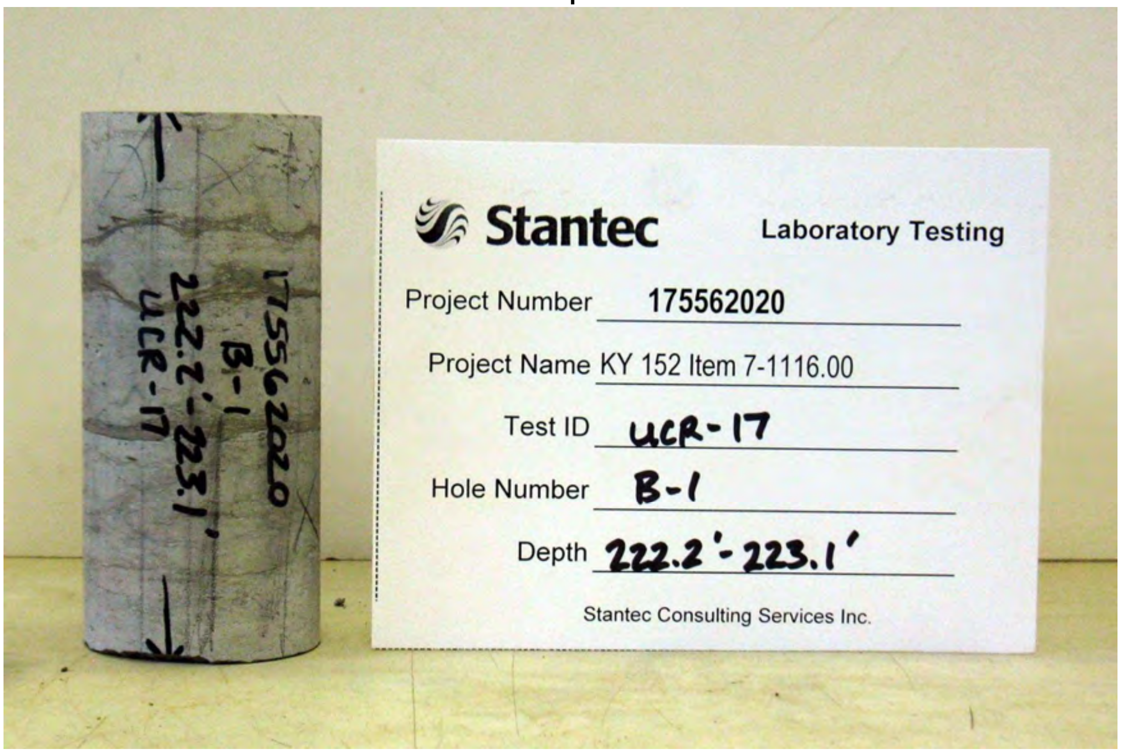


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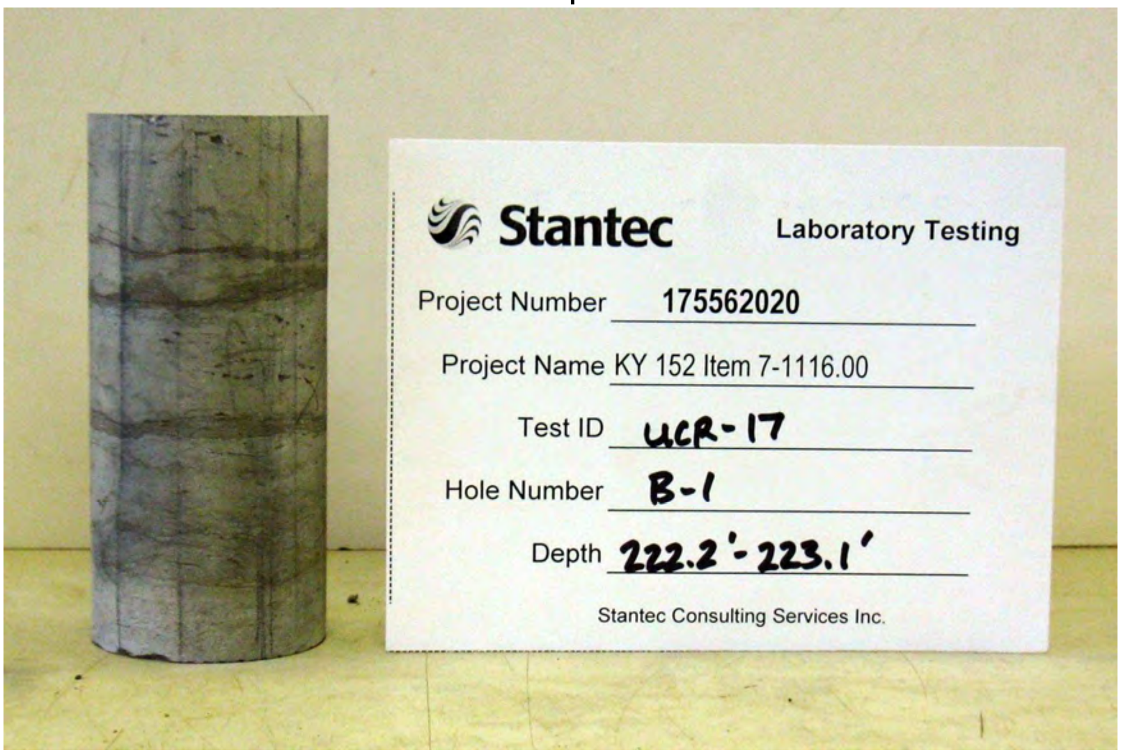
Photo Report

Project Name	KY 152 Item 7-1116.00	Project Number	175562020
Lithology	Limestone, gray, moderately hard, shale stringers	Lab ID	UCR-17
Hole Number	B-1 #17 Depth (ft) 222.2'-223.1'		
Test Type	Unconfined compressive strength		

Core Preparation



Post Test

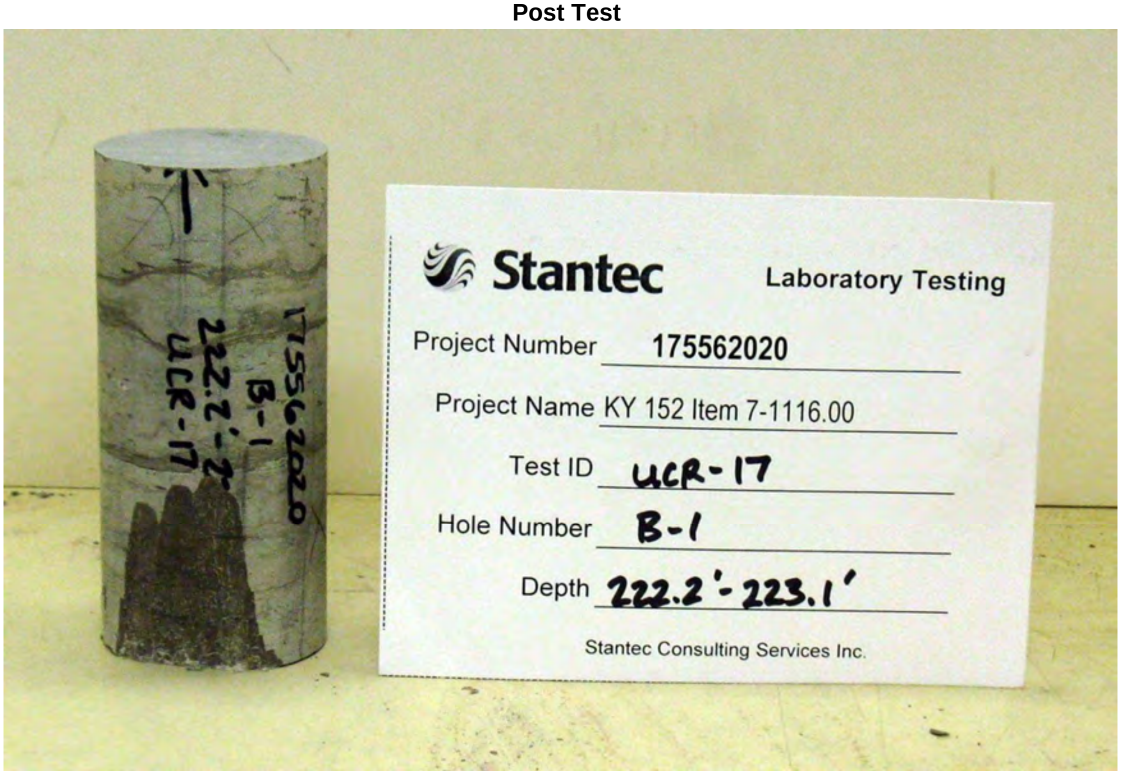


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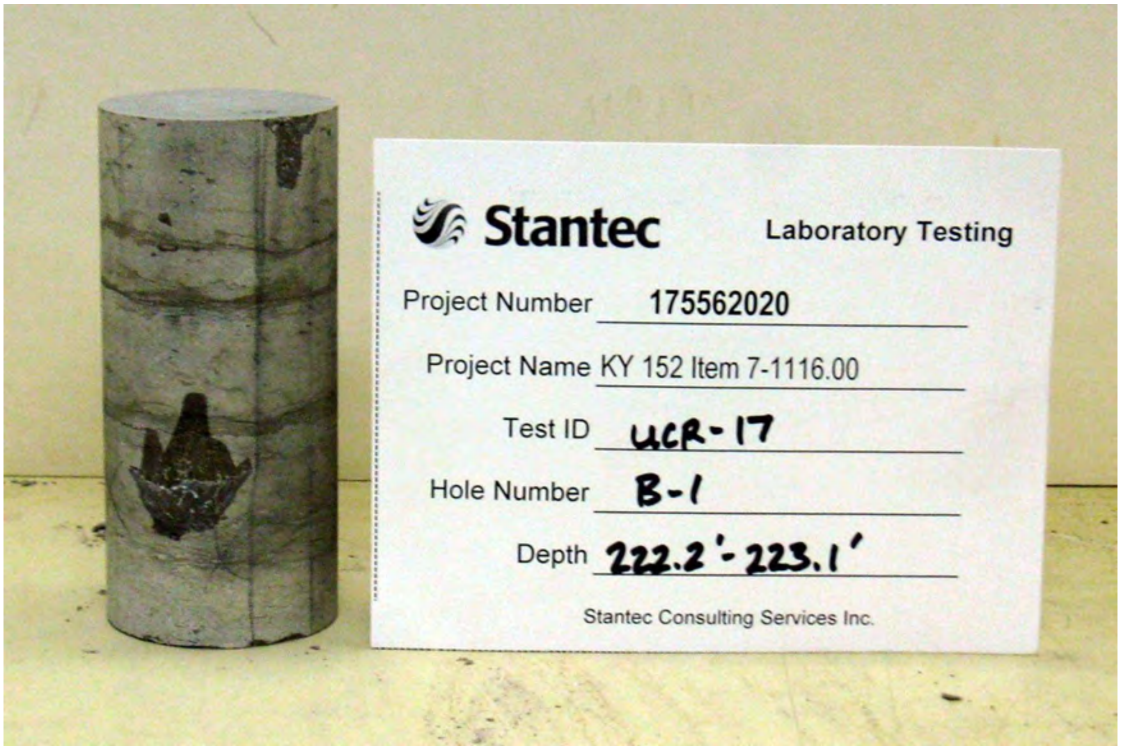
Photo Report

Project Name	KY 152 Item 7-1116.00	Project Number	175562020
Lithology	Limestone, gray, moderately hard, shale stringers	Lab ID	UCR-17
Hole Number	B-1 #17	Depth (ft)	222.2'-223.1'
Test Type	Unconfined compressive strength		

Post Test



Stantec

Unconfined Compressive Strength Of Intact Rock Core
KM 64-523-02

Project Name: KY 152 Item 7-1116.00
Project Number: 175562020
Lithology: Limestone, gray, moderately hard, shale stringers
Lab ID: UCR-18
Hole Number: B-1 #18
Depth (ft): 228.6'-229.0'
Date Received: 03-26-2013

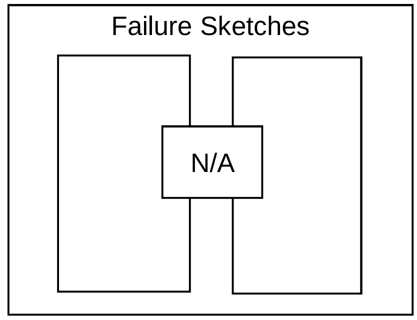
Temperature (^oC): 23.9
Moisture Condition: As received, moist
Date Tested: 04-28-2013

Side Planeness	Pass	Height (in)	4.368	Wet Unit Weight (pcf)	169.1
Perpendicularity	Pass	Diameter (in)	1.979	Dry Unit Weight (pcf)	168.9
End Planeness	Pass	Area (in^2)	3.075	Moisture Content[1] (%)	0.1
		Height/Diameter Ratio	2.207	Weight (lb)	1.314

Loading Rate (lbf/sec): 150
Peak Load (lbf): 107947

Failure Type: Undetermined

Compressive Strength (psi): 35110
Compressive Strength (psf): 5055840
Compressive Strength (tsf): 2528



Comments: ______________________

Alternate Compressive Strength Calculation[2]
(Where Height/Diameter Ratio < 2)

Correction Coefficient: N/A

Corrected Compressive Strength (psi): N/A
Corrected Compressive Strength (psf): N/A
Corrected Compressive Strength (tsf): N/A

[1] Post testing moisture content determination was performed as per ASTM D 2216, where as much of the whole specimen as available after compression testing was used in moisture content testing. Method B.

[2] The alternate compressive strength calculation is presented when the height to diameter ratio is less than 2, as per KM 64-523-02.

Reviewed By: JW

Form: tmp_ucr_km_input.xlsm
Preparation Date: 12-1999
Revision Date: 01-2008

Stantec Consulting Services Inc.
Lexington, Kentucky

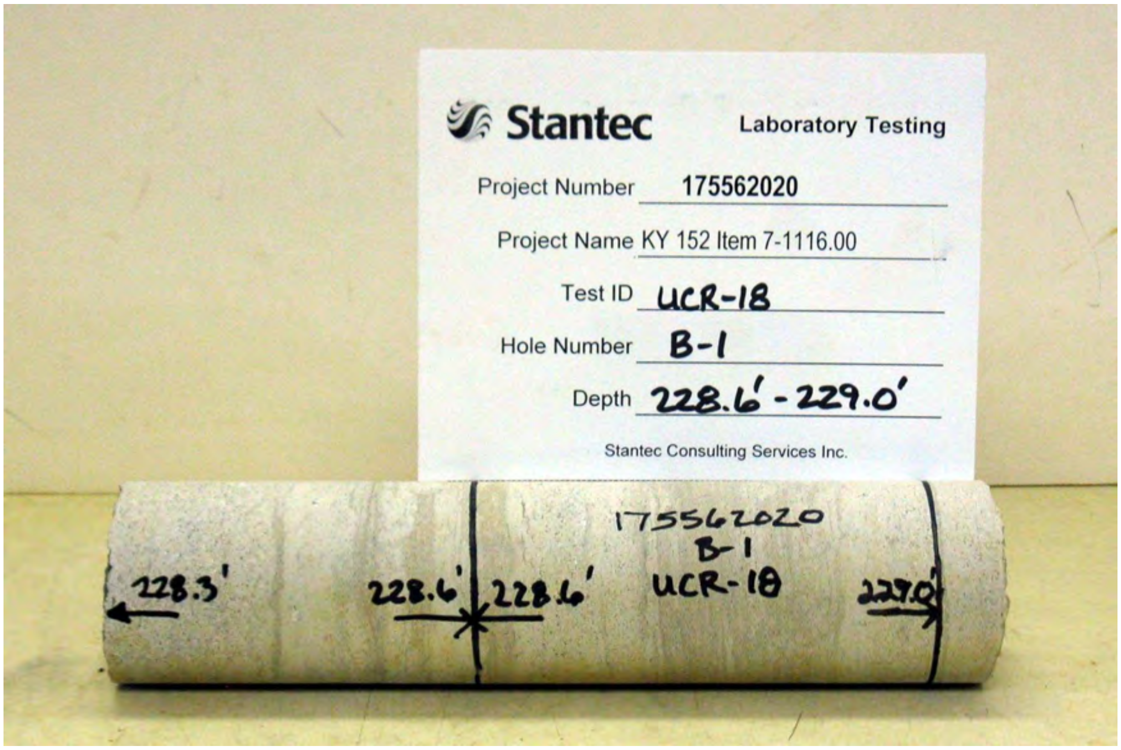
Laboratory Document
Prepared By: JW
Approved By: TLK

Stantec

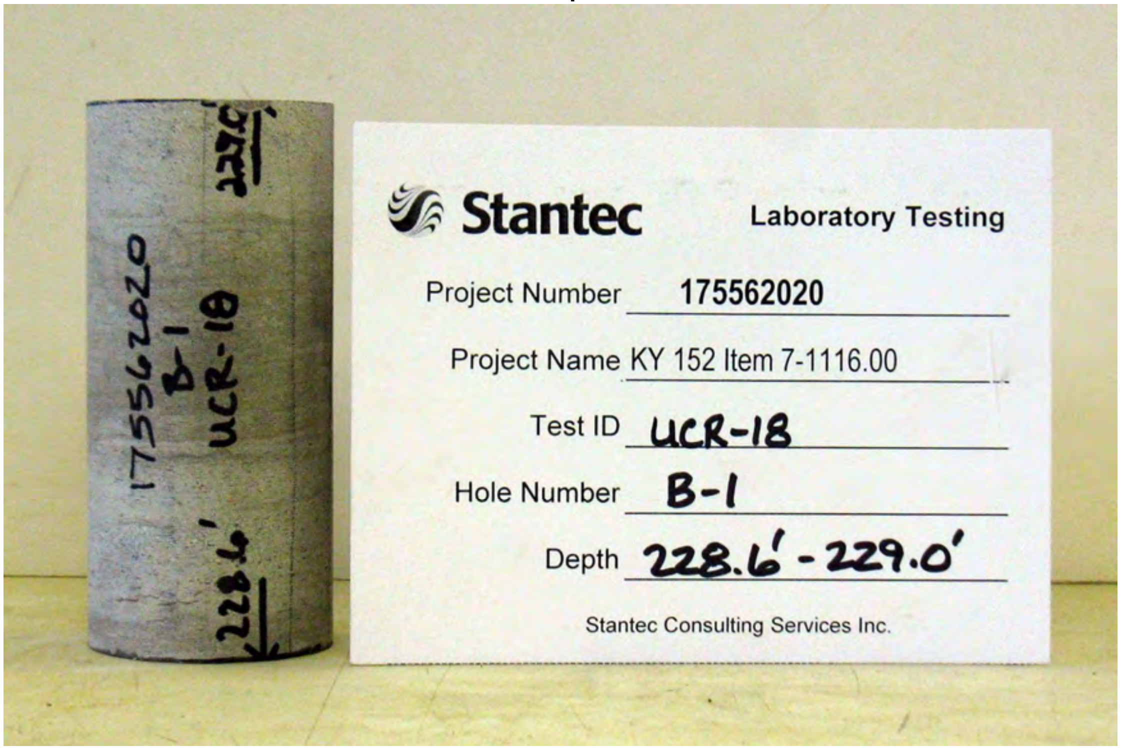
Photo Report

Project Name	KY 152 Item 7-1116.00	Project Number	175562020
Lithology	Limestone, gray, moderately hard, shale stringers	Lab ID	UCR-18
Hole Number	B-1 #18 Depth (ft) 228.6'-229.0'		
Test Type	Unconfined compressive strength		

As Received



Core Preparation



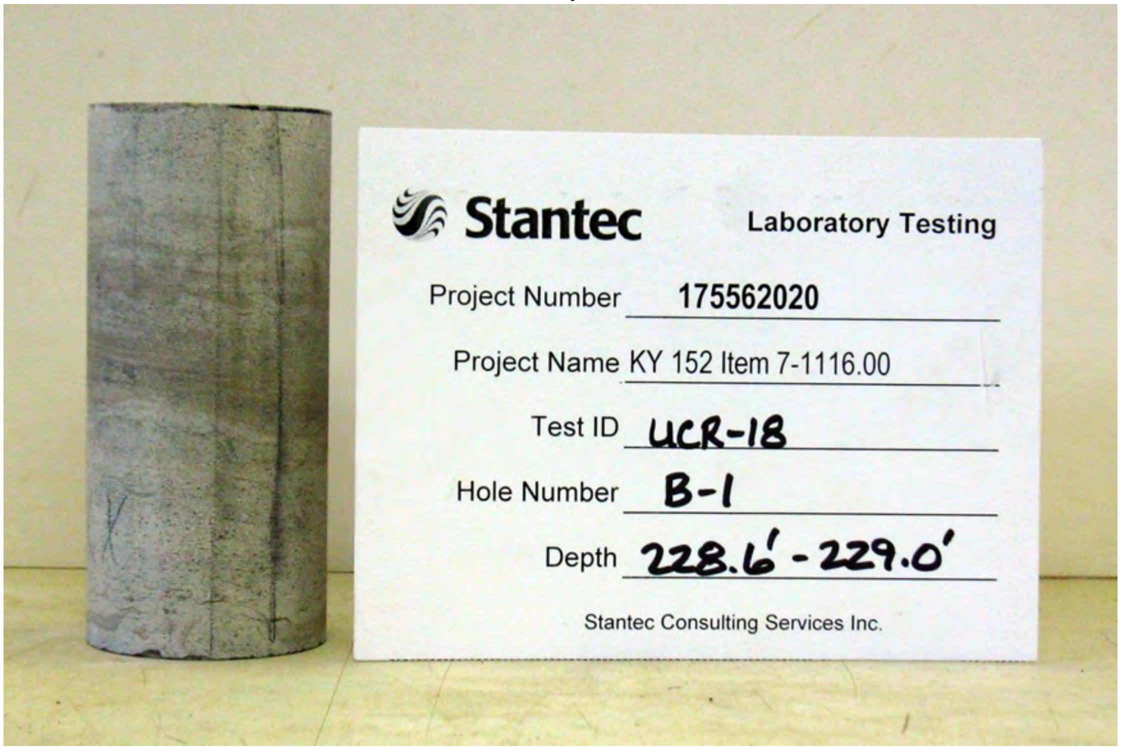
Stantec

Photo Report

Project Name KY 152 Item 7-1116.00
Lithology Limestone, gray, moderately hard, shale stringers
Hole Number B-1 #18 Depth (ft) 228.6'-229.0'
Test Type Unconfined compressive strength

Project Number 175562020
Lab ID UCR-18

Core Preparation



Post Test

Stantec

Unconfined Compressive Strength Of Intact Rock Core

KM 64-523-02

Project Name: KY 152 Item 7-1116.00
Project Number: 175562020
Lithology: Limestone, gray, moderately hard, shale stringers
Lab ID: UCR-19
Hole Number: B-1 #19
Depth (ft): 242.5'-242.9'
Date Received: 03-26-2013

Temperature (^oC): 23.9
Moisture Condition: As received, moist
Date Tested: 04-28-2013

Side Planeness	Pass	Height (in)	4.507	Wet Unit Weight (pcf)	167.4
Perpendicularity	Pass	Diameter (in)	1.980	Dry Unit Weight (pcf)	167.3
End Planeness	Pass	Area (in^2)	3.080	Moisture Content[1] (%)	0.1
		Height/Diameter Ratio	2.276	Weight (lb)	1.345

Loading Rate (lbf/sec): 137
Peak Load (lbf): 61961

Failure Type: Undetermined

Compressive Strength (psi): 20120
Compressive Strength (psf): 2897280
Compressive Strength (tsf): 1448

Failure Sketches

N/A

Comments:

Alternate Compressive Strength Calculation[2]
(Where Height/Diameter Ratio < 2)

Correction Coefficient: N/A

Corrected Compressive Strength (psi): N/A
Corrected Compressive Strength (psf): N/A
Corrected Compressive Strength (tsf): N/A

[1] Post testing moisture content determination was performed as per ASTM D 2216, where as much of the whole specimen as available after compression testing was used in moisture content testing. Method B.

[2] The alternate compressive strength calculation is presented when the height to diameter ratio is less than 2, as per KM 64-523-02.

Reviewed By: JW

Form: tmp_ucr_km_input.xlsm
Preparation Date: 12-1999
Revision Date: 01-2008

Stantec Consulting Services Inc.
Lexington, Kentucky

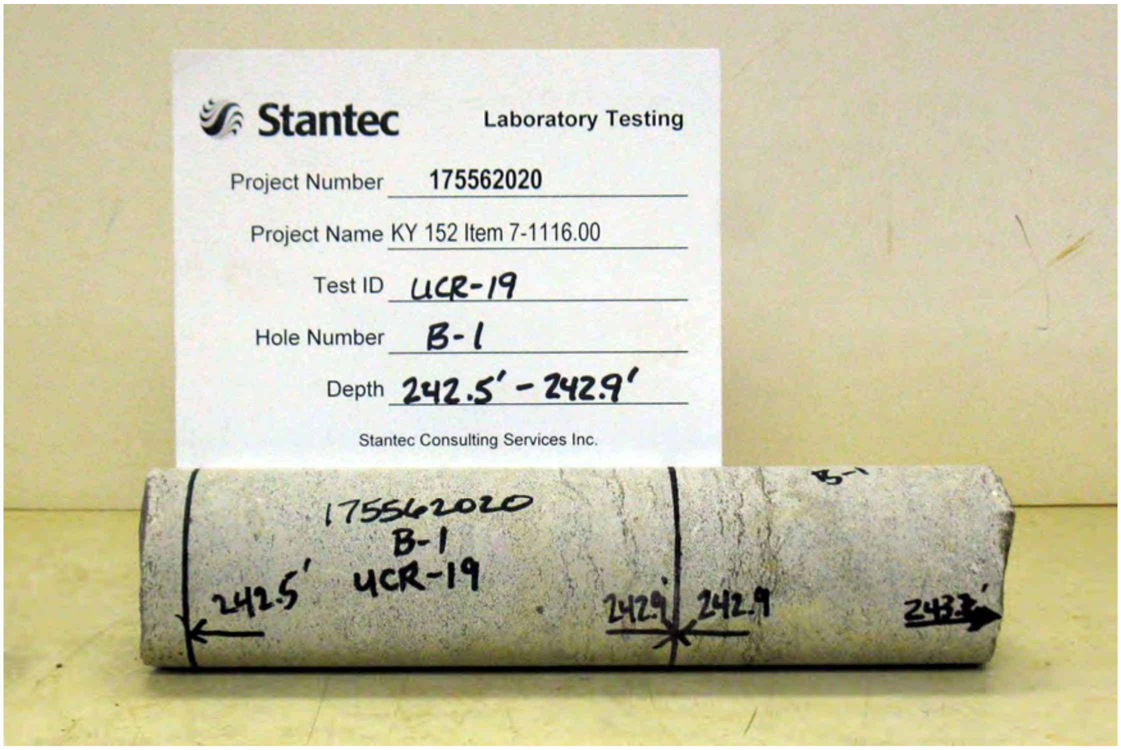
Laboratory Document
Prepared By: JW
Approved By: TLK

Stantec

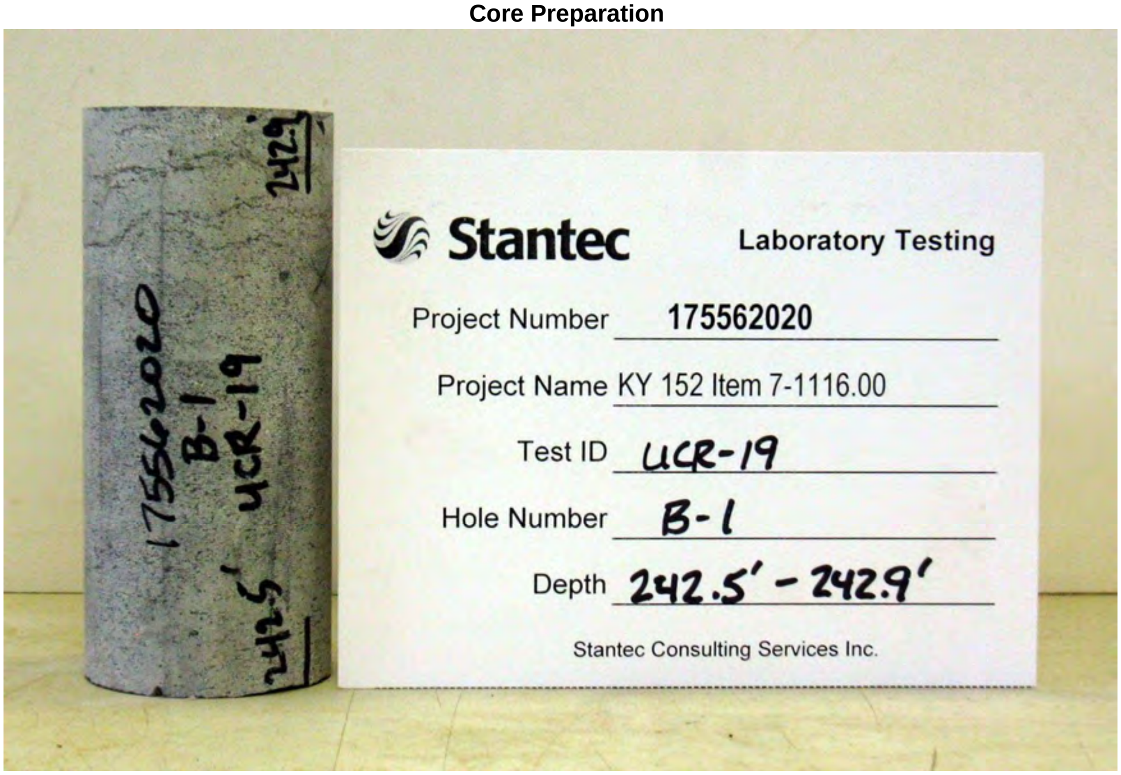
Photo Report

Project Name	KY 152 Item 7-1116.00	Project Number	175562020
Lithology	Limestone, gray, moderately hard, shale stringers	Lab ID	UCR-19
Hole Number	B-1 #19	Depth (ft)	242.5'-242.9'
Test Type	Unconfined compressive strength		

As Received



Core Preparation

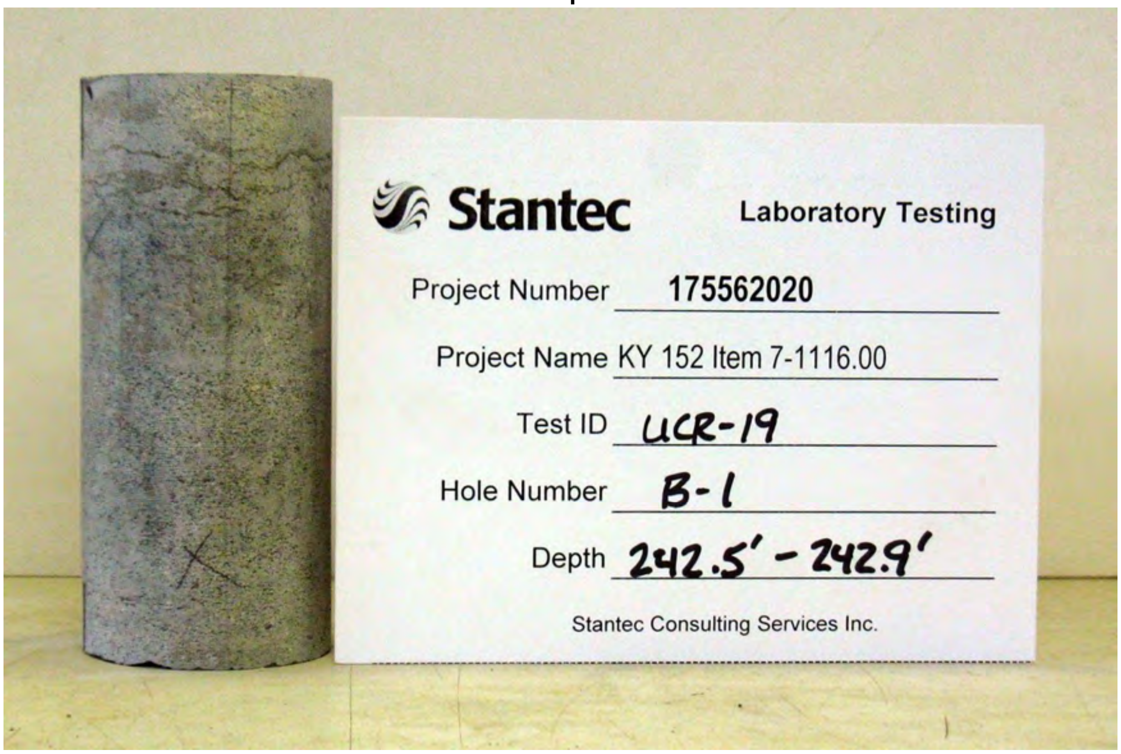


Stantec

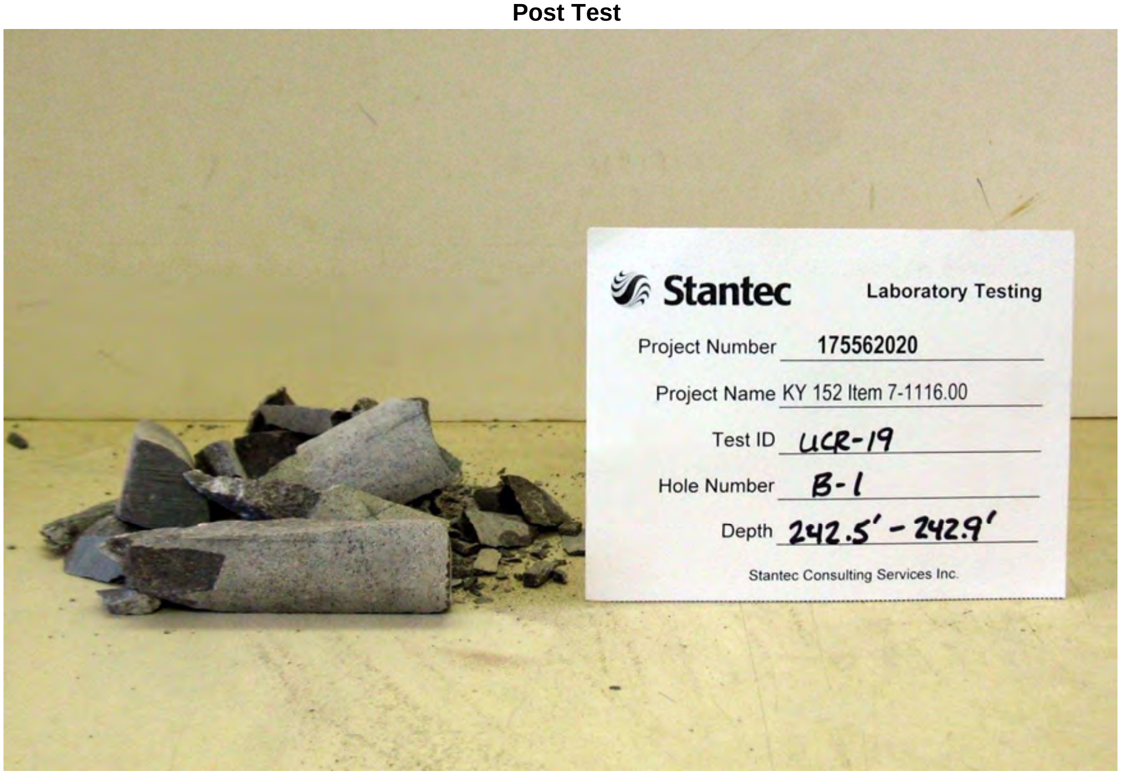
Photo Report

Project Name	KY 152 Item 7-1116.00	Project Number	175562020
Lithology	Limestone, gray, moderately hard, shale stringers	Lab ID	UCR-19
Hole Number	B-1 #19 Depth (ft) 242.5'-242.9'		
Test Type	Unconfined compressive strength		

Core Preparation

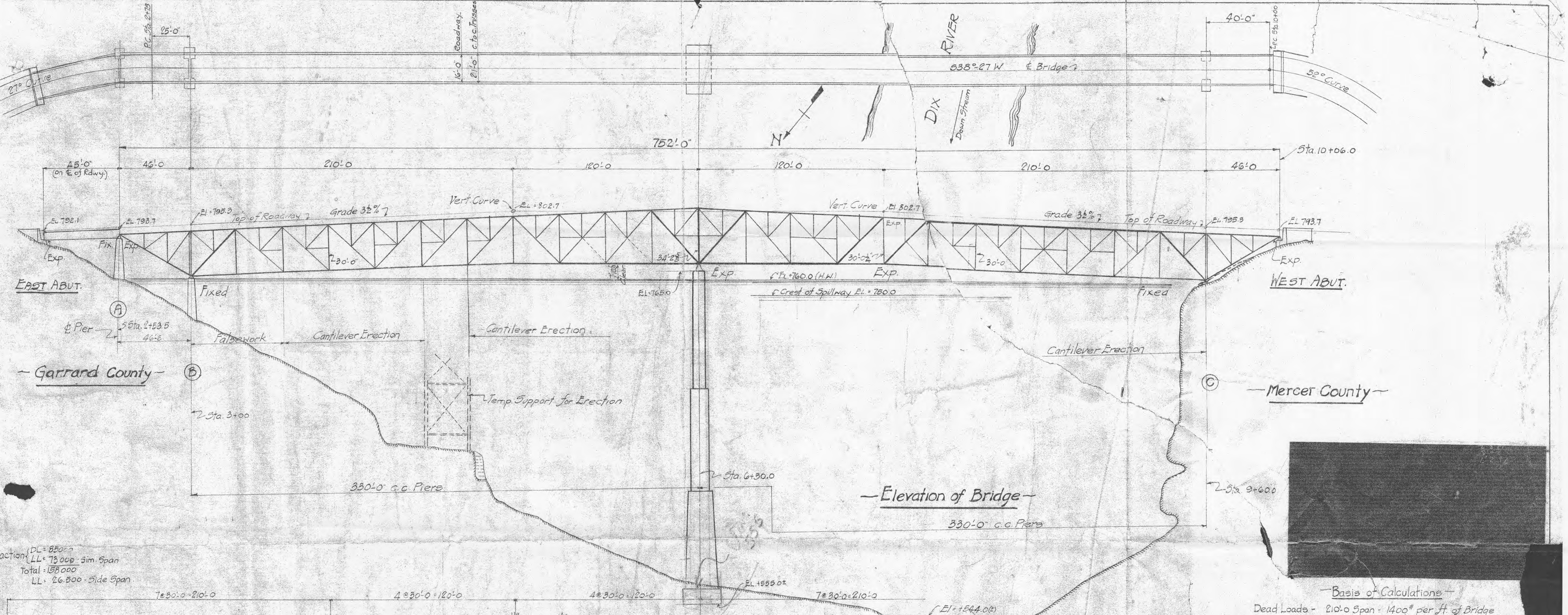


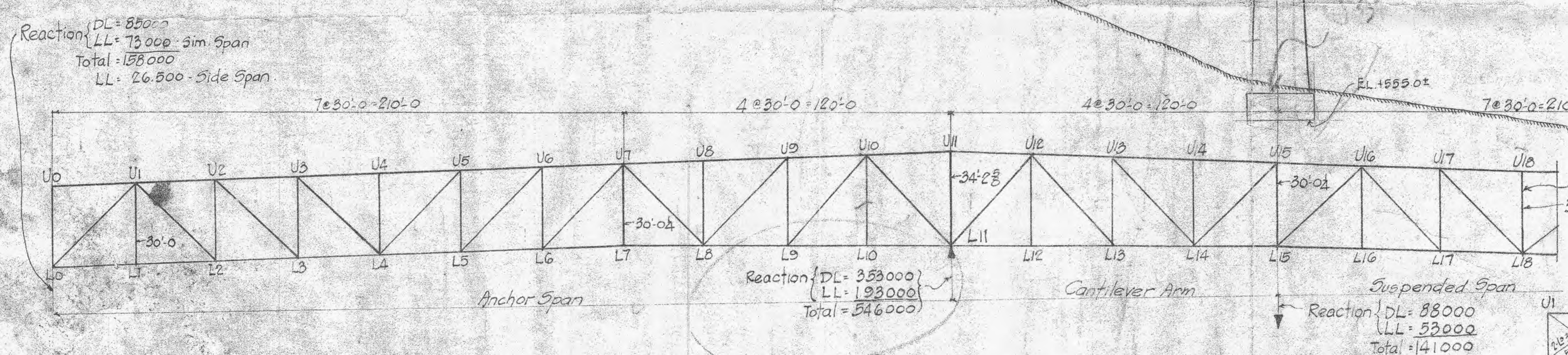
Post Test

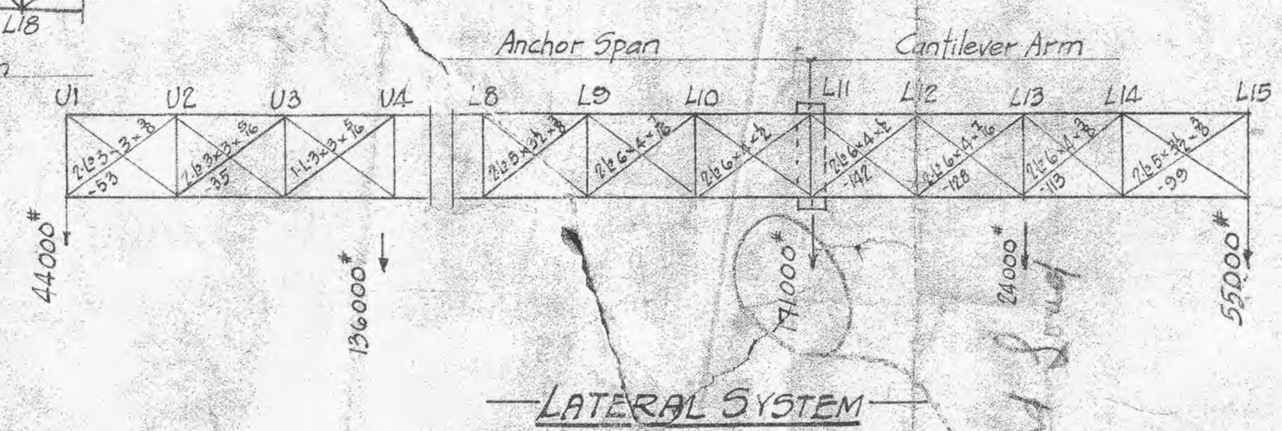


Appendix E

Historic Kennedy Mills Bridge Drawings







—Table of Stresses and Sections-Anchor Span—

Members	DL	Simp. Span LL	Side Span LL	Total	A-Req.	Sections
L0-U1	+101	+98	-76			2-15" ⊏ @ 33#
U1-U2	+126	+119	-52			do
U2-U3	+150	+158	-78			2-15" ⊏ @ 40#
U3-U5	+126	+185	-104			do
U5-U6	+72	+198	-130			do
U6-U7	+6	+198	-156			do
U7-U9	+216	+158	-208			2-15" ⊏ @ 33#
U9-U10	-360	+110	-230			4-Bars 6×1 3/16"
U10-U11	-461		-257			8 " 6"×1"
L0-L2	-72	-66	+26			2-15" ⊏ @ 33#
L2-L3	-120	-119	+52			do
L3-L4	-144	-158	+78			2-15" ⊏ @ 40#
L4-L5	-72	-198	+130			do
L5-L6	0	-198	+156			do
L6-L8	0	-198	+182			do
L8-L9	+352	-119	+230			2-Webs 20×½ 4 ∟s 4×4×½
L9-L11	+395	-70	[illegible]			2-Webs 20×⅝ 8-∟s 4×4×½
U1-L2	-67	-7	+37			4 ∟s 5×3×⅜
U2-L3	[illegible]	-63	+37			4 ∟s 5×3×5/16
U3-L4	0	[illegible]	0			do
L4-U5	[illegible]	-35	-37			do
L5-U6	-67	-28	-37			do
L6-U7	-101	-35	-37			4 ∟s 5×3×⅜
U7-L8	-134	-46	+38			2-15" ⊏ @ 33#
L8-U9	-168	-60	-37			2-Bars 6×1 3/16
L9-U10	-196	-76	-37			4-Bars 6×⅞
U10-L11	+234	+90	+76			2-15" ⊏ @ 50#
U2-L2	+42	+56	-27			4 ∟s 5×3×⅜
U3-L3	+18	+46	0			4 ∟s 5×3×5/16
U5-L5	+42	+38	+27			do
U6-L6	+66	+33	+27			4 ∟s 5×3×⅜
U9-L9	+138	+56	+57			4 ∟s 6×3½×⅜-1-Pℓ. 10½×⅜

—Table of Stresses and Sections-Suspended Span—

Members	DL	LL	Imp.	Total	A-Req.	Sections
L15-L17	-63	-39	-10	-112	7.0	2-12" ⊏ @ 20½#
L17-L18	-105	-65	-16	-186	11.7	2-12" ⊏ @ 25#
L18-L18	-126	-78	-19	-223	13.9	4-Bars 4×⅞
U16-U17	+115	+70	+18	+203	15.0	2-15" ⊏ @ 33#
U17-U18	+136	+82	+21	+239	18.0	do
L15-U16	+88	+55	+14	+157	18.0	do
U16-L17	-59	-40	-10	-109	6.9	4 ∟s 3½×3×5/16
U17-L18	-31	-26	-7	-64	4.0	do
U18-L18	0	-21	-5	-26		2 ∟s 3×2½×5/16
U18-L18	+14	+16	+4	+34		4 ∟s 3×2½×5/16
U17-L17	+35	+20	+5	+60		do

—Table of Stresses and Sections-Cantilever Arm—

Members	DL	LL	W	Total	A-Req.	Sections
L11-L13	+395	+217	+410	+1022	56	2-Webs 20×⅝-8 ∟s 4×4×½
L13-L14	+273	+150		+423	40	2-Webs 20×½-4 ∟s 4×4×½
U11-U12	-461	-257		-718	45	8-Bars 6×1"
U12-U13	-294	-159		-453	28.4	4- " 6"×1 3/16
U13-U15	-86	-52		-138	8.8	2 " 6"×1"
L11-U12	+234	+126		+360	3.0	2-15" ⊏ @ 50#
U12-L13	-196	-108		-304	19	4-Bars 6×⅞
U13-L14	-163	-92		-255	16	2 " 6×1⅜
L14-U15	+124	+75		+199	17	2-15" ⊏ @ 33#
U13-L13	+136	+79		+215	19	4 ∟s 6×3½×7/16-1-Pℓ. 10½×⅜
U15-L15						2-Bars 6×1 5/16

—Basis of Calculations—

Dead Loads - 210'-0 Span - 1400# per ft. of Bridge
120'-0 Cant. Span - 1900# " " "
1-330'-0 Anchor Span - 1600# " " "

Live Loads - 55# per sq. ft. or 880# per lin. ft. of Trusses
15 Ton Truck used in calculation of Floor.

Wind Loads - 30# per sq. ft. on exposed surfaces plus 100# for Chord.

Erection - Part of anchor span to be erected on falsework as shown in Elevation - Remainder to be erected by the Cantilever method.

Specifications:- Kentucky Department of State Roads & Highways Standard Specifications for State and Federal Bridge Construction dated 1922.

KENNEDYS MILL BRIDGE

over

DIX - RIVER

—BURGIN-BUENA VISTA ROAD—

MERCER AND GARRARD COUNTIES

KENTUCKY HYDRO-ELECTRIC CO.

Louisville Kentucky

Approved:
Department of State Roads and Highways, Kentucky.
By...........
By...........
By...........
By...........

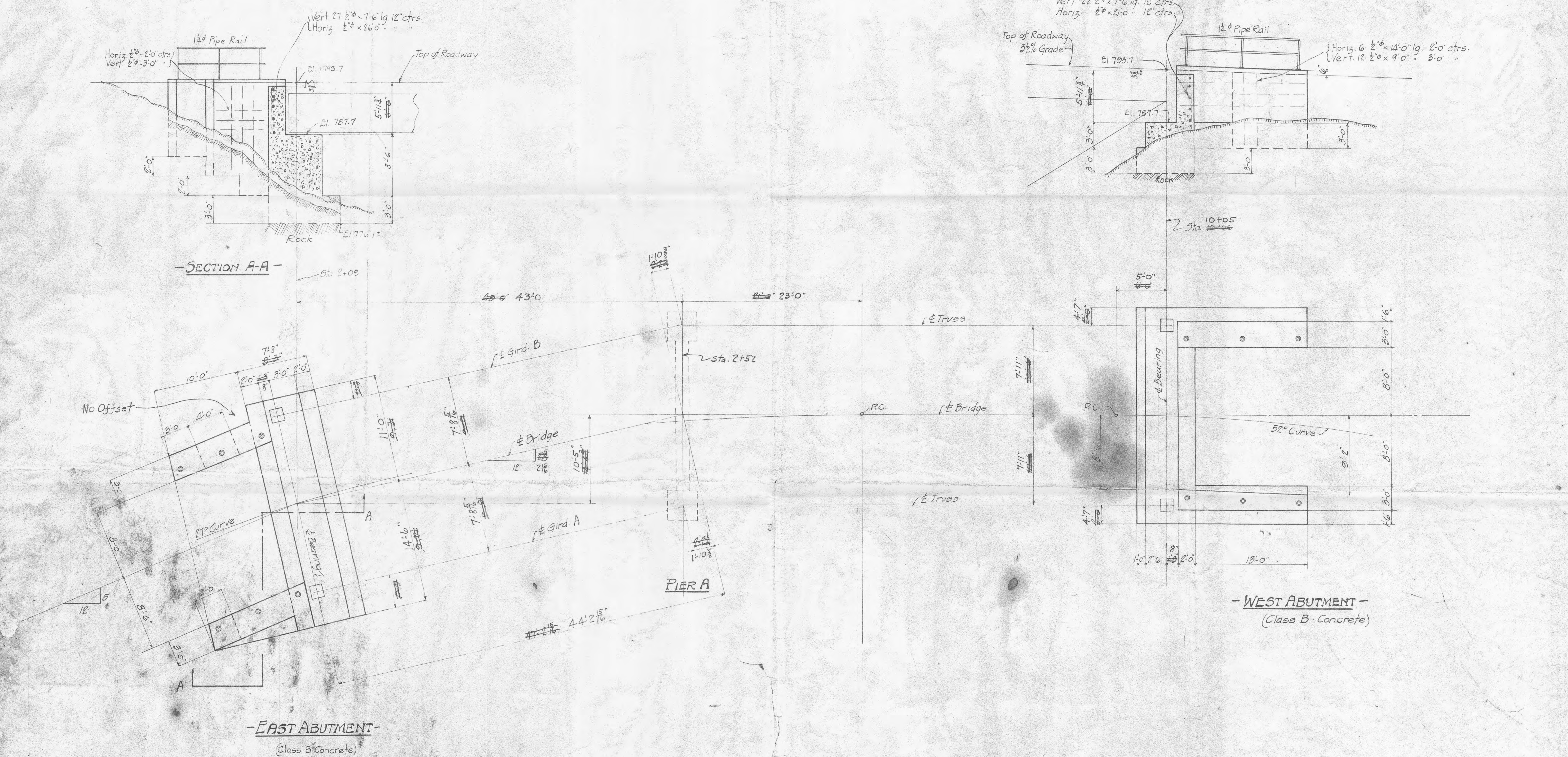
Kentucky Hydro Electric Co.
By...........

C. L. Keller
E. B. Bergendahl } Engineers
Ashland Block
Chicago

Scale........
Date........

Drawing No 1


27° Curve
25'-0
16'-0 Roadway
20'-0 c. to c. Trusses
RIVER
DIX
Down Stream
S38°-27 W
℄ Bridge
40'-0
30° Curve
N
750'-0
50'-0
45'-0
210'-0
120'-0
120'-0
210'-0
45'-0
Top of Roadway
Grade 4½%
Vert. Curve
El. 803.87
Vert. Curve
El. 803.87
Grade 4½%
Top of Roadway
30'-0
Fixed
Exp.
El. 760.0 (H.W.)
Exp.
℄ Crest of Spillway El. 780.0
Fixed
West Abt. and Fill
Cantilever Erection
Garrard County
Temp. Support for Erection
Sta. 3+00
Mercer County
Sta. 6+30.0
Elevation of Bridge
Sta. 9+60.0
El. 544.0(±)
KENNEDY MILL BRIDGE



KENNEDYS MILL BRIDGE

over

DIX · RIVER

BURGIN · BUENA VISTA ROAD

MERCER AND GARRARD COUNTIES

KENTUCKY HYDRO-ELECTRIC CO.

Louisville, Kentucky

Approved:
DEPARTMENT OF STATE ROADS AND HIGHWAYS, KENTUCKY
By..........
By..........
By..........
By..........

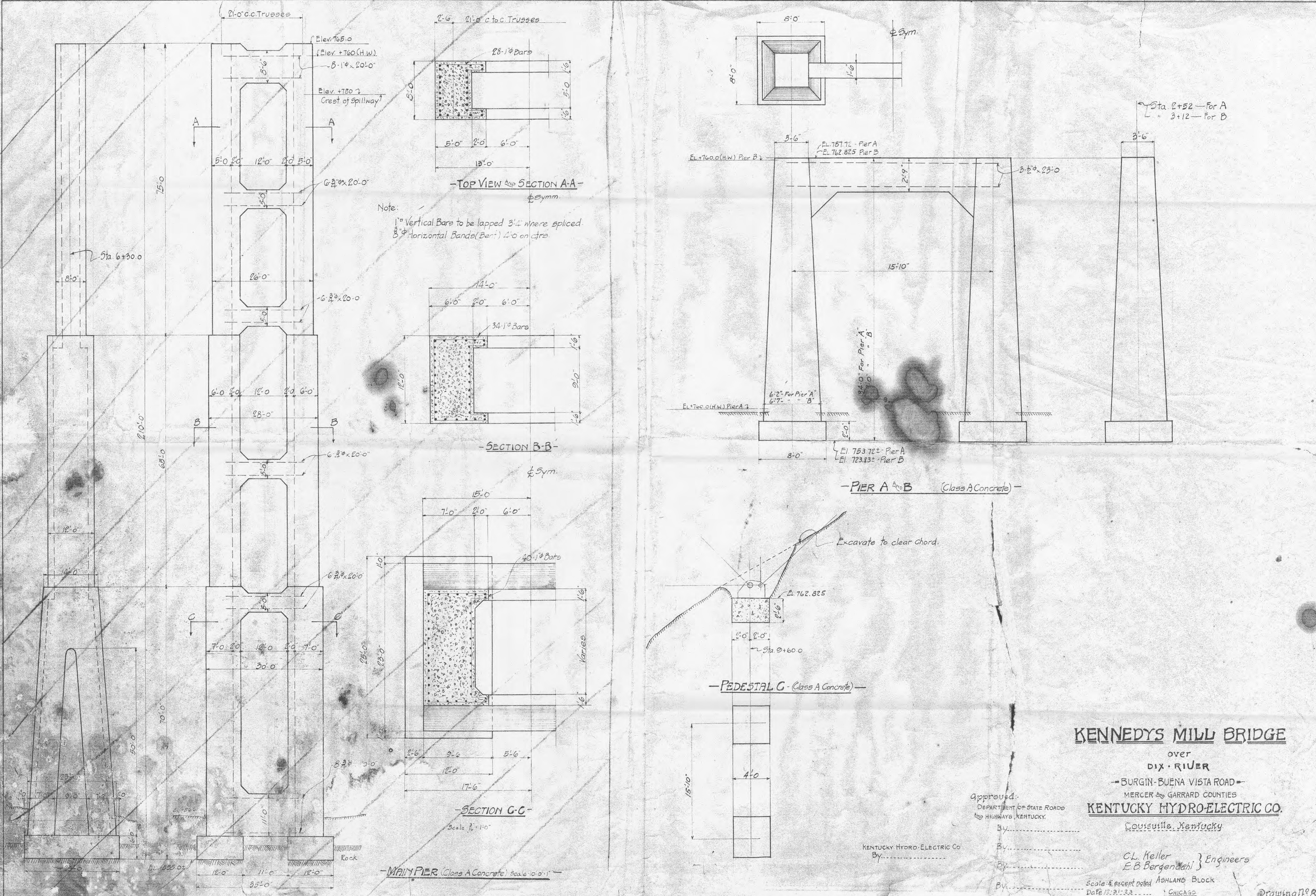
KENTUCKY HYDRO-ELECTRIC CO.
By..........

C. L. Keller
E. B. Bergendahl } Engineers

ASHLAND BLOCK
CHICAGO

Scale $\frac{3}{16}$" = 1'-0"
Date 12-31-23

Drawing No 9



21-0" c.c. Trusses
Elev. 765.0
Elev. +760 (H.W.)
Elev. +750
Crest of Spillway
Sta. 6+30.0
-TOP VIEW AND SECTION A-A-
Note:
1"φ Vertical Bars to be lapped 3'-4" where spliced.
3/4"φ Horizontal Bands (Bent) 4'-0 on ctre.
28-1"φ Bars
34-1"φ Bars
40-1"φ Bars
-SECTION B-B-
-SECTION C-C-
Scale 1/2"=1'-0"
Rock
-MAIN PIER (Class A Concrete) Scale 0'-0"=1'-
Sta. 2+52 — For A
" 3+12 — For B
EL. 787.72 - Pier A
EL. 762.825 Pier B
EL. +760.0 (H.W.) Pier B
EL. +760.0 (H.W.) Pier A
El. 753.72 - Pier A
El. 723.13 - Pier B
-PIER A AND B (Class A Concrete)-
Excavate to clear chord.
El. 762.825
Sta. 9+60.0
-PEDESTAL C- (Class A Concrete)-
KENTUCKY HYDRO-ELECTRIC CO
By
Approved:
DEPARTMENT OF STATE ROADS AND HIGHWAYS, KENTUCKY.
By
By
By
By
KENNEDYS MILL BRIDGE
over
DIX · RIVER
-BURGIN-BUENA VISTA ROAD-
MERCER AND GARRARD COUNTIES
KENTUCKY HYDRO-ELECTRIC CO.
Louisville, Kentucky
C.L. Keller
E.B. Bergendahl } Engineers
Scale: 1/4" except noted
Date 12-31-23
ASHLAND BLOCK
CHICAGO
Drawing No. 8


GARRARD COUNTY
MERCER COUNTY
SCALE HOR 1" = 20'
VER 1" = 20'
SECTION
KENNEDY'S MILL BRIDGE SITE
DIX RIVER
BURGIN – BUENA VISTA ROAD
L.F. HARZA
623 MONADNOCK BLDG
CHICAGO ILL.
Aug. 14.'23.
ELEV
STA

Rock Mass Rating

Determination of Rock Mass Parameters for Drilled Shafts and Spread Footings

Rock coring operations performed for the referenced bridge encountered one rock type and two rock layers at the west abutment of the proposed bridge location. The rock layers can be divided as follows;

Layer	Rock Type	Elevation
I	Limestone	779.5 to 720.5
II	Limestone	720.5 to 460.3

Representative Unconfined Compressive Strength

Refer to the laboratory testing data for Unconfined Compressive Strength of intact rock for Layers I and II.

Layer I use q_u = 1,053 tsf = 2,106 ksf
Layer II use q_u = 1,720 tsf = 3,440 ksf

For Layer II Does not meet Army Corps of Engineers two thirds higher rule. Use 1,425 tsf, 2,850 ksf.

Determination of Representative Unit Weight

Refer to the laboratory testing data for Unconfined Compressive Strength of intact rock for Layers I and II.

Layer I use γ_{wet} (average) = 166.9 pcf
Layer II use γ_{wet} (average) = 167.6 pcf

Determination of Effective Normal Stress within Bearing Zone

See Attached Excel Spreadsheet.

Layer I use σ (average) = 4.01 ksf
Layer II use σ (average) = 26.73 ksf

Rock Mass Rating

See Attached Excel Spreadsheet developed by Stantec and based on Table 10.4.6.4-1 from AASHTO LRFD.

Layer I use RMR = 67
Layer II use RMR = 76

Herrington Lake 175562020

Determination of Effective Stress within Bearing Zone

Hole No.	Rock Layer	Midpoint of UC Sample (ft)	Top of Soil (ft)	Top of Rock (ft)	Effective Stress (ksf)	UC (tsf)	Avg (tsf)	2/3 Higher	STD RQD	Avg RQD
B-1	1	722.3	786.0	779.5	6.350	1787			84	
B-1	1	735.1	786.0	779.5	5.012	1350			99	
B-1	1	745.5	786.0	779.5	3.926	616	1053	1053	59	74
B-1	1	754.7	786.0	779.5	2.965	247			61	
B-1	1	765.7	786.0	779.5	1.816	1266			67	
B-1	2	534.3	786.0	779.5	26.166	1439			71	
B-1	2	525.0	786.0	779.5	27.144	1588			47	
B-1	2	515.3	786.0	779.5	28.164	1849			45	
B-1	2	504.9	786.0	779.5	29.258	1101			86	
B-1	2	495.0	786.0	779.5	30.300	1296			100	
B-1	2	484.2	786.0	779.5	31.436	1402			92	
B-1	2	474.8	786.0	779.5	32.424	1282	1720	1425	96	82
B-1	2	464.8	786.0	779.5	33.476	1767			90	
B-1	2	590.0	786.0	779.5	20.307	2204			96	
B-1	2	580.6	786.0	779.5	21.296	2021			90	
B-1	2	572.9	786.0	779.5	22.106	1629			90	
B-1	2	563.3	786.0	779.5	23.116	2523			73	
B-1	2	557.2	786.0	779.5	23.757	2528			100	
B-1	2	543.3	786.0	779.5	25.219	1448			67	

Rock
Layer 1 Wet Density = 166.9 pcf
Layer 2 Wet Density = 167.6 pcf

Soil
Wet Density = 120.0 pcf

Average Effective Stress
Layer 1 = 4.01 ksf
Layer 2 = 26.73 ksf

175562020 - Layer One

Table 10.4.6.4-1 Geomechanics Classification of Rock Masses.
Source 2012 Edition of the AASHTO LRFD Bridge Design Specifications.

	Parameter		Ranges of Values						
1	Strength of intact rock material	Point load strength index	>175 ksf	85 - 175 ksf	45 - 85 ksf	20 - 45 ksf	For this low range, uniaxial compressive test is preferred		
		Uniaxial compressive strength	>4320 ksf	2160 - 4320 ksf	1080 - 2160 ksf	520 - 1080 ksf	215 - 520 ksf	70 - 215 ksf	20 - 70 ksf
	Relative Rating		15	12	7	4	2	1	0

	Parameter					
2	Drill core quality RQD	90% - 100%	75% - 90%	50% - 75%	25% - 50%	< 25%
	Relative Rating	20	17	13	8	3
3	Spacing of Joints	> 10 ft.	3 - 10 ft.	1 - 3 ft.	2 in - 1 ft	< 2 in
	Relative Rating	30	25	20	10	5
4	Condition of Joints	* Very rough surfaces * Not continuous * No separation * Hard joint wall rock	* Slightly rough surfaces * Separation < 0.05 in. * Hard joint wall rock	* Slightly rough surfaces * Separation < 0.05 in. * Soft joint wall rock	* Slicken-sided surfaces or * Gouge < 0.2 in. thick or * Joints open 0.05 - 0.2 in. * Continuous joints	* Soft gouge > 0.2 in. thick or * Joints open > 0.2 in. * Continuous joints
	Relative Rating	25	20	12	6	0

	Parameter					
5	Ground water conditions (use one of the three evaluation criteria as appropriate to the method of exploration)	Inflow per 30 ft. tunnel length	None	< 400 gal./hr.	400 - 2000 gal./hr.	> 2000 gal./hr.
		Ratio = joint water pressure/ major principal stress	0	0.0 - 0.2	0.2 - 0.5	> 0.5
		General conditions	Completely Dry	Moist only (interstitial water)	Water under moderate pressure	Severe water problems
	Relative Rating		10	7	4	0

Table 10.4.6.4-2 Geomechanics Rating Adjustment for Joint Orientations.

Strike and Dip Orientations of Joints		Very Favorable	Favorable	Fair	Unfavorable	Very Unfavorable
Ratings	Tunnels	0	-2	-5	-10	-12
	Foundations	0	-2	-7	-15	-25
	Slopes	0	-5	-25	-50	-60

Table 10.4.6.4-3 Geomechanics Rock Mass Classes Determined From Total Ratings.

RMR Rating	100 - 81	80 - 61	60 - 41	40 - 21	< 20
Class No.	I	II	III	IV	V
Description	Very Good Rock	Good Rock	Fair Rock	Poor Rock	Very Poor Rock

Total Rock Mass Rating = 67

Determination of Rock Mass Parameters for Drilled Shaft Design

Based on Procedures and Methods Outlined in the 2012 Edition of the AASHTO LRFD Bridge Design Specifications

175562020 - Layer One

Input Parameter			Notes
γ_{rock}	=	166.9 pcf	from lab testing
q_{ui}	=	1425.0 ksf	unconfined compressive strength of intact rock specimen from lab testing
RQD	=	74	rock quality designation - use avg. RQD from rock coring operations
RMR	=	67	Rock Mass Rating from Table 10.4.6.4-1 in AASHTO Specs
Rock	=	A	Rock Type A, B, C, D, or E from Table 10.4.6.4-4 in AASHTO Specs
σ_n'	=	4.01 ksf	average effective normal stress for zone of rock mass evaluation
E_i	=	5700 ksi	Elastic Modulus for Intact Rock from Table C.10.4.6.5-1 in AASHTO Specs
f_c'	=	3,500 psi	compressive strength of concrete
p_a	=	14.7 psi	atmospheric pressure
ν	=	0.23	Poisson's Ratio from Table C.10.4.6.5-2 in AASHTO Specs

Determine Shear Strength of Bedrock Mass (τ)

$$\tau = \left(\cot \phi_i' - \cos \phi_i'\right) m \frac{q_{ui}}{8}$$

EQ. 10.4.6.4-1

in which:

$$\phi_i' = \tan^{-1}\left\{4h\cos^2\left[30 + 0.33\sin^{-1}\left(h^{-\frac{3}{2}}\right)\right] - 1\right\}^{-\frac{1}{2}}$$

$$h = 1 + \frac{16\left(m\sigma_n' + sq_{ui}\right)}{3m^2 q_{ui}}$$

m = 0.757
s = 0.01084

Constants from from Table 10.4.6.4-4 in AASHTO Specs

where:

τ = shear strength of the rock mass

ϕ_i' = instantaneous friction angle of the rock mass (degrees)

h = 1.121

ϕ_i' = 45.97 degrees

τ = 36.62 ksf

use τ = 36.6 ksf

Determination of Rock Mass Parameters for Drilled Shaft Design

Based on Procedures and Methods Outlined in the 2012 Edition of the AASHTO LRFD Bridge Design Specification:

175562020 - Layer One

Determine Elastic Modulus of Bedrock Mass (E_m)

E_m should be taken as the lesser of E_i or the modulus determined using one of the following equations

$$E_m = 145\left(10^{\frac{RMR-10}{40}}\right)$$

EQ. 10.4.6.5-1 E_m = 3858.1 ksi

yields modulus values in terms of ksi

or

$$E_m = \left(\frac{E_m}{E_i}\right)E_i$$

EQ. 10.4.6.5-2 E_m = 4218.0 ksi

E_m/E_i = 0.74 ratio from Table 10.4.6.5-1 in AASHTO Specs based on RQD

Condition of Joints = closed   open or closed

use E_m =	3858 ksi

Determine Maximum Unit Side Friction in Rock Socket ($q_{s\ max}$)

$$q_s = 0.65\alpha_E p_a\left(\frac{q_{ui}}{p_a}\right)^{\frac{1}{2}} < 7.8p_a\left(\frac{f'_c}{p_a}\right)^{\frac{1}{2}}$$

EQ. 10.8.3.5.4b-1

q_s based on rock strength = 32.20 ksf

α_E = 0.9 from Table 10.8.3.5.4b-1 in AASHTO Specs

q_s based on concrete strength = 21.25 ksf

use $q_{s\ max}$ =	21.2 ksf

Determine Maximum Unit End Bearing in Rock Socket ($q_{p\ max}$)

If bedrock below the base of the shaft to a depth of 2.0B is either intact or tightly jointed, i.e. no compressible material or gouge-filled seams, and the depth of the socket is greater than 1.5B:

$$q_p = 2.5q_{ui}$$

EQ. 10.8.3.5.4c-1

Determination of Rock Mass Parameters for Drilled Shaft Design

Based on Procedures and Methods Outlined in the 2012 Edition of the AASHTO LRFD Bridge Design Specification
175562020 - Layer One

If the rock below the base of the shaft to a depth of 2.0B is jointed, the joints have random orientation, and the condition of the joints can be evaluated as:

$$q_p = \left[\sqrt{s} + \sqrt{(m\sqrt{s} + s)}\right] q_{ui}$$

EQ. 10.8.3.5.4c-2

m = 0.757
s = 0.01084

Constants from from Table 10.4.6.4-4 in AASHTO Specs

Describe the condition of the bedrock within a zone of 2.0B below the bearing elevation of the shaft (intact or jointed) jointed

q_p = 575.0 ksf

use $q_{p\ max}$ = 575.0 ksf

Determine Shear Modulus of Rock Mass (G_m)

From Hunt, "Geotechnical Engineering Techniques and Practices", page 128, Table 4.1

$$G = \frac{E}{2(1+\nu)} \longrightarrow G_m = \frac{E_m}{2(1+\nu)}$$

G_m = 1568.29 ksi

use G_m = 1568 ksi

Summary of Parameters

γ_{rock} =	166.9 pcf
q_{ui} =	1425.0 ksf
τ =	36.6 ksf
E_i =	5700 ksi
E_m =	3858 ksi
$q_{s\ max}$ =	21.2 ksf
$q_{p\ max}$ =	575 ksf
ν =	0.23
G_m =	1568 ksi

Determination of Factored Bearing Capacity for Spread Footings on Bedrock

Based on Procedures and Methods Outlined in:
Hoek, E., C. Carranza-Torres, and Corkum, B., "Hoek-Brown Failure Criterion - 2002 Edition"
Downloaded from RocScience, Inc. Website (www.rocscience.com) on 11/7/06.

175562020 - Layer One

Input Parameter			Notes	
sigci	=	1425.0 ksf	unconfined compressive strength of intact rock specimen from lab testing	
GSI	=	90	Geological Strength Index	Estimate using the interactive data input tables in RocLab 1.0 (based on rock type and joint spacing, aperture, arrangement, and orientation
mi	=	12	Intact Rock Paramter	
D	=	0	Disturbance Factor	
φ	=	0.45	LRFD Resistance Factor	

Determine Bedrock Mass Parameters using RocLab 1.0

Input data in RocLab 1.0 (may be downloaded for free from www.rocscience.com)

Hoek-Brown Failure Criterion

mb = 8.396
s = 0.3292
a = 0.500

Mohr-Coulomb Fit

c = 180.7 ksf
ϕ = 43.09 degrees

Rock Mass Parameters

Tensile Strength	=	-55.9 ksf
Unixial Compressive Strength	=	817.4 ksf
Global Strength	=	832.8 ksf (nominal strength)
Modulus of Deformation	=	230068.1 ksf

$$\text{Global Strength} = q_u = 2c\tan\left(45+\frac{\phi}{2}\right)$$

where:
q_u = nominal uniaxial compressive strength of rock mass
c = cohesion of rock mass
ϕ = friction angle of rock mass

Determine Factored Bearing Capacity of Bedrock Mass ($q_{factored}$)

$$q_{factored} = \varphi q_u$$

$q_{factored}$ = 374.8 ksf

use $q_{factored}$ = 375 ksf

\\US1243-F01\workgroup\1755\active\175562020\geotechnical\analysis\L1 Rock Mass Parameters for Drilled Shaft and Spread Footing Design.xls

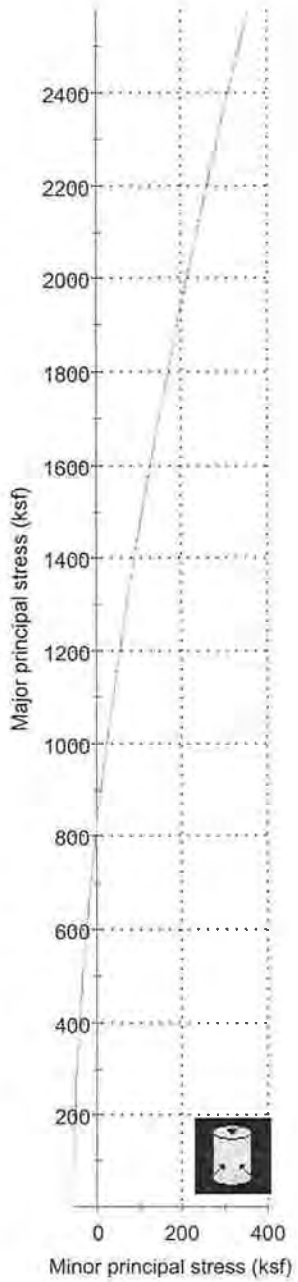
Analysis of Rock Strength using RocLab

Hoek-Brown Classification
intact uniaxial comp. strength (sigci) = 1425 ksf
GSI = 90 mi = 12 Disturbance factor (D) = 0
intact modulus (Ei) = 240000 ksf

Hoek-Brown Criterion
mb = 8.396 s = 0.3292 a = 0.500

Mohr-Coulomb Fit
cohesion = 180.668 ksf friction angle = 43.09 deg

Rock Mass Parameters
tensile strength = -55.871 ksf
uniaxial compressive strength = 817.416 ksf
global strength = 832.803 ksf
deformation modulus = 230068.05 ksf



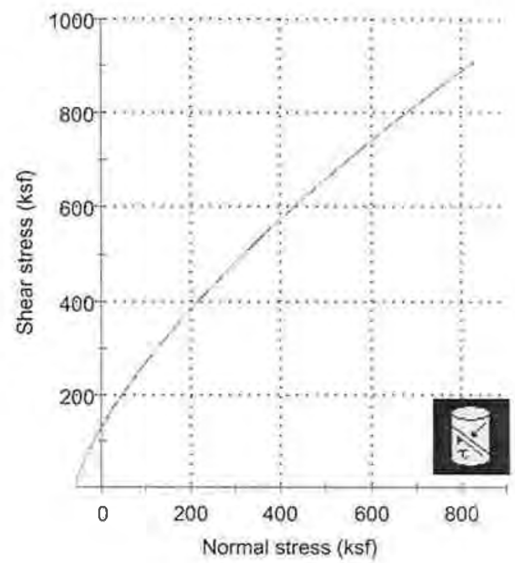


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Table 10.4.6.4-1 Geomechanics Classification of Rock Masses.
Source 2012 Edition of the AASHTO LRFD Bridge Design Specifications.

	Parameter		Ranges of Values						
1	Strength of intact rock material	Point load strength index	>175 ksf	85 - 175 ksf	45 - 85 ksf	20 - 45 ksf	For this low range, uniaxial compressive test is preferred		
		Uniaxial compressive strength	>4320 ksf	2160 - 4320 ksf ✓	1080 - 2160 ksf	520 - 1080 ksf	215 - 520 ksf	70 - 215 ksf	20 - 70 ksf
	Relative Rating		15	12	7	4	2	1	0
2	Drill core quality RQD		90% - 100%	75% - 90% ✓	50% - 75%	25% - 50%	< 25%		
	Relative Rating		20	17	13	8	3		
3	Spacing of Joints		> 10 ft.	3 - 10 ft.	1 - 3 ft. ✓	2 in - 1 ft.	< 2 in		
	Relative Rating		30	25	20	10	5		
4	Condition of Joints		* Very rough surfaces * Not continuous * No separation * Hard joint wall rock	* Slightly rough surfaces * Separation < 0.05 in. * Hard joint wall rock ✓	* Slightly rough surfaces * Separation < 0.05 in. * Soft joint wall rock	* Slicken-sided surfaces or * Gouge < 0.2 in. thick or * Joints open 0.05 - 0.2 in. * Continuous joints	* Soft gouge > 0.2 in. thick or * Joints open > 0.2 in. * Continuous joints		
	Relative Rating		25	20	12	6	0		
5	Ground water conditions (use one of the three evaluation criteria as appropriate to the method of exploration)	Inflow per 30 ft. tunnel length	None	< 400 gal./hr.	400 - 2000 gal./hr.	> 2000 gal./hr.			
		Ratio = joint water pressure/ major principal stress	0	0.0 - 0.2	0.2 - 0.5	> 0.5			
		General conditions	Completely Dry	Moist only (interstitial water) ✓	Water under moderate pressure	Severe water problems			
	Relative Rating		10	7	4	0			

Table 10.4.6.4-2 Geomechanics Rating Adjustment for Joint Orientations.

Strike and Dip Orientations of Joints		Very Favorable	Favorable	Fair	Unfavorable	Very Unfavorable
Ratings	Tunnels	0	-2	-5	-10	-12
	Foundations	0 ✓	-2	-7	-15	-25
	Slopes	0	-5	-25	-50	-60

Table 10.4.6.4-3 Geomechanics Rock Mass Classes Determined From Total Ratings.

RMR Rating	100 - 81	80 - 61	60 - 41	40 - 21	< 20
Class No.	I	II	III	IV	V
Description	Very Good Rock	Good Rock	Fair Rock	Poor Rock	Very Poor Rock

Total Rock Mass Rating = 76

Determination of Rock Mass Parameters for Drilled Shaft Design

Based on Procedures and Methods Outlined in the 2012 Edition of the AASHTO LRFD Bridge Design Specification:
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Input Parameter			Notes
γ_{rock}	=	167.6 pcf	from lab testing
q_{ui}	=	2850.0 ksf	unconfined compressive strength of intact rock specimen from lab testing
RQD	=	82	rock quality designation - use avg. RQD from rock coring operations
RMR	=	76	Rock Mass Rating from Table 10.4.6.4-1 in AASHTO Specs
Rock	=	A	Rock Type A, B, C, D, or E from Table 10.4.6.4-4 in AASHTO Specs
σ_n'	=	26.73 ksf	average effective normal stress for zone of rock mass evaluation
E_i	=	5700 ksi	Elastic Modulus for Intact Rock from Table C.10.4.6.5-1 in AASHTO Specs
f_c'	=	3,500 psi	compressive strength of concrete
p_a	=	14.7 psi	atmospheric pressure
ν	=	0.23	Poisson's Ratio from Table C.10.4.6.5-2 in AASHTO Specs

Determine Shear Strength of Bedrock Mass (τ)

$$\tau = \left(\cot\phi_i' - \cos\phi_i'\right) m \frac{q_{ui}}{8}$$

EQ. 10.4.6.4-1

in which:

$$\phi_i' = \tan^{-1}\left\{4h\cos^2\left[30 + 0.33\sin^{-1}\left(h^{-\frac{3}{2}}\right)\right] - 1\right\}^{-\frac{1}{2}}$$

$$h = 1 + \frac{16\left(m\sigma_n' + sq_{ui}\right)}{3m^2 q_{ui}}$$

m = 1.579
s = 0.04642
} Constants from from Table 10.4.6.4-4 in AASHTO Specs

where:

τ = shear strength of the rock mass
ϕ_i' = instantaneous friction angle of the rock mass (degrees)

h = 1.131
ϕ_i' = 45.27 degrees
τ = 161.42 ksf

use τ = 161 ksf

Determination of Rock Mass Parameters for Drilled Shaft Design

Based on Procedures and Methods Outlined in the 2012 Edition of the AASHTO LRFD Bridge Design Specification:

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Determine Elastic Modulus of Bedrock Mass (E_m)

E_m should be taken as the lesser of E_i or the modulus determined using one of the following equations

$$E_m = 145\left(10^{\frac{RMR-10}{40}}\right)$$ EQ. 10.4.6.5-1 E_m = 6476.9 ksi

yields modulus values in terms of ksi

or

$$E_m = \left(\frac{E_m}{E_i}\right)E_i$$ EQ. 10.4.6.5-2 E_m = 4674.0 ksi

E_m/E_i = 0.82 ratio from Table 10.4.6.5-1 in AASHTO Specs based on RQD

Condition of Joints = closed open or closed

use E_m = 4674 ksi

Determine Maximum Unit Side Friction in Rock Socket ($q_{s\,max}$)

$$q_s = 0.65\alpha_E p_a\left(\frac{q_{ui}}{p_a}\right)^{\frac{1}{2}} < 7.8p_a\left(\frac{f'_c}{p_a}\right)^{\frac{1}{2}}$$ EQ. 10.8.3.5.4b-1

q_s based on rock strength = 47.00 ksf

α_E = 0.93 from Table 10.8.3.5.4b-1 in AASHTO Specs

q_s based on concrete strength = 21.25 ksf

use $q_{s\,max}$ = 21.2 ksf

Determine Maximum Unit End Bearing in Rock Socket ($q_{p\,max}$)

If bedrock below the base of the shaft to a depth of 2.0B is either intact or tightly jointed, i.e. no compressible material or gouge-filled seams, and the depth of the socket is greater than 1.5B:

$$q_p = 2.5q_{ui}$$ EQ. 10.8.3.5.4c-1

Determination of Rock Mass Parameters for Drilled Shaft Design

Based on Procedures and Methods Outlined in the 2012 Edition of the AASHTO LRFD Bridge Design Specification

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If the rock below the base of the shaft to a depth of 2.0B is jointed, the joints have random orientation, and the condition of the joints can be evaluated as:

$$q_p = \left[\sqrt{s} + \sqrt{(m\sqrt{s} + s)}\right] q_{ui}$$

EQ. 10.8.3.5.4c-2

m = 1.579
s = 0.04642

Constants from from Table 10.4.6.4-4 in AASHTO Specs

Describe the condition of the bedrock within a zone of 2.0B below the bearing elevation of the shaft (intact or jointed) jointed

q_p = 2386.1 ksf

use $q_{p\ max}$ = 2386.0 ksf

Determine Shear Modulus of Rock Mass (G_m)

From Hunt, "Geotechnical Engineering Techniques and Practices", page 128, Table 4.1

$$G = \frac{E}{2(1+\nu)} \longrightarrow G_m = \frac{E_m}{2(1+\nu)}$$

G_m = 1900.00 ksi

use G_m = 1900 ksi

Summary of Parameters

γ_{rock} =	167.6	pcf
q_{ui} =	2850.0	ksf
τ =	161.4	ksf
E_i =	5700	ksi
E_m =	4674	ksi
$q_{s\ max}$ =	21.2	ksf
$q_{p\ max}$ =	2386	ksf
ν =	0.23	
G_m =	1900	ksi

Determination of Factored Bearing Capacity for Spread Footings on Bedrock

Based on Procedures and Methods Outlined in:
Hoek, E., C. Carranza-Torres, and Corkum, B., "Hoek-Brown Failure Criterion - 2002 Edition"
Downloaded from RocScience, Inc. Website (www.rocscience.com) on 11/7/06.

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Input Parameter			Notes	
sigci	=	2850.0 ksf	unconfined compressive strength of intact rock specimen from lab testing	
GSI	=	90	Geological Strength Index	Estimate using the interactive data input tables in RocLab 1.0 (based on rock type and joint spacing, aperture, arrangement, and orientation
mi	=	12	Intact Rock Paramter	
D	=	0	Disturbance Factor	
φ	=	0.45	LRFD Resistance Factor	

Determine Bedrock Mass Parameters using RocLab 1.0

Input data in RocLab 1.0 (may be downloaded for free from www.rocscience.com)

Hoek-Brown Failure Criterion

mb = 8.396
s = 0.3292
a = 0.500

Mohr-Coulomb Fit

c = 361.3 ksf
ϕ = 43.09 degrees

Rock Mass Parameters

Tensile Strength	=	-111.7 ksf
Unixial Compressive Strength	=	1634.8 ksf
Global Strength	=	1665.6 ksf (nominal strength)
Modulus of Deformation	=	230068.1 ksf

$$\text{Global Strength} = q_u = 2c\tan\left(45+\frac{\phi}{2}\right)$$

where:
q_u = nominal uniaxial compressive strength of rock mass
c = cohesion of rock mass
ϕ = friction angle of rock mass

Determine Factored Bearing Capacity of Bedrock Mass ($q_{factored}$)

$$q_{factored} = \varphi q_u$$

$q_{factored}$ = 749.5 ksf

use $q_{factored}$ = 750 ksf

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Analysis of Rock Strength using RocLab

Hoek-Brown Classification
intact uniaxial comp. strength (sigci) = 2850 ksf
GSI = 90 mi = 12 Disturbance factor (D) = 0
intact modulus (Ei) = 240000 ksf

Hoek-Brown Criterion
mb = 8.396 s = 0.3292 a = 0.500

Mohr-Coulomb Fit
cohesion = 361.337 ksf friction angle = 43.09 deg

Rock Mass Parameters
tensile strength = -111.743 ksf
uniaxial compressive strength = 1634.832 ksf
global strength = 1665.606 ksf
deformation modulus = 230068.05 ksf