ERDC/CERL CR-01-1

Construction Engineering Research Laboratory

US Army Corps of Engineers®
Engineer Research and Development Center



# Historic Limestone Conservation Study for Fort Riley, Kansas

Mayda S. Jensen

October 2001



Not Sent to DTIC

# Contents

# Foreword

This study was conducted for the Directorate of Environment and Safety, Fort Riley, Kansas, under Military Interdepartmental Purchase Request (MIPR) 0093270017, dated 23 November 1999. The technical monitor was Dr. Rahim Borhani, Fort Riley Historic Architect.

The work was managed and supervised by the Land and Heritage Conservation Branch (CN-C) of the Installations Division (CN), Construction Engineering Research Laboratory (CERL). The CERL Principal Investigator was Julie L. Webster, CEERD-CN-C. The study and report preparation were executed by Jensen Conservation Services, Inc., 13515 C Street, Omaha, NE 68144 under DACA42-00-T-0178. Dr. Lucy A. Whalley is Chief, CEERD-CN-C, and Dr. John T. Bandy is Chief, CEERD-CN. The Technical Director of the Military Lands business area is Dr. William D. Severinghaus, CEERD-CV-T, and the Director of CERL is Dr. Alan W. Moore.

CERL is an element of the Engineer Research and Development Center (ERDC), U.S. Army Corps of Engineers. The Commander and Executive Director of ERDC is COL John W. Morris III, EN, and the Director is Dr. James R. Houston.

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# HISTORIC LIMESTONE CONSERVATION STUDY

**FOR**

# FORT RILEY, KANSAS

**PREPARED BY**

*Mayda S. Jensen*

**JUNE, 2001**

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*Jensen Conservation Services, Inc.*

# HISTORIC LIMESTONE CONSERVATION STUDY

FOR

# FORT RILEY, KANSAS

## INTRODUCTION

Fort Riley, Kansas is located one hundred-thirty (130) miles west of Kansas City, MO. The US Army installation has responsibility for the maintenance and protection of approximately two hundred-ninety (290) historic structures, all of which contribute in some way to the significance of the three (3) Fort Riley Historic Districts listed on the National Register of Historic Places. Virtually all of Fort Riley's historic structures are in active use and require continuous maintenance and rehabilitation. The historic limestone stain removal research contract, for which the following is a report of findings and recommendations, was created with the purpose of helping Fort Riley meet these daily maintenance requirements within the constraints set forth by the National Historic Preservation Act.

## OBJECTIVES

The objectives of the study were to:

a) perform an analytical study of stains found on Fort Riley historic limestone structures;
b) provide documentation of that analysis;
c) make recommendations for appropriate and cost-effective preservation and maintenance treatments, specifically cleaning, for the historic limestone material.

## METHODOLOGY

The scheduling and implementation of three (3) site visits met the objectives of this study. Conservator Mayda Jensen attended the first two meetings, and was accompanied in her site visits by Architect Dr. Rahim Borhani.

The first site visit took place April 10, 2001. At that time, Dr. Borhani introduced Ms. Jensen to the layout of the historic districts of Fort Riley. After discussions with the Chief Historic Architect, four historic structures on the base were identified as potential sites for collection and analysis of stains.

**METHODOLOGY continued**

Each of the four structures was visited, and after discussing their needs, three buildings were selected for stain sample collection. Those buildings are:

Chapel 0006;
King Field House, Building 0202
and the Museum, Building 0205.

Accompanied, again by Dr. Borhani, architectural elevations of the three historic structures were requested and received.

Ms. Jensen returned to each of the three historic structures and collected four (4) stain samples from each historic limestone structure. Locations of the sample collection sites are indicated on the architectural elevations. Locations were documented in photographic form as well. Samples were collected using sterile, dry cotton swabs. Each sample was returned to, and sealed inside a sterile storage tube.

Samples of biological stains collected in the above manner from historic structures on the Fort Riley Post were hand delivered by Mayda Jensen to Midwest Laboratories, Inc., Wednesday, April 11, 2001, the day following the Fort Riley site visit and collection. Samples of stains collected on the sterile swabs were placed on sterile agar beds in the testing laboratory and were incubated. Samples were examined and data was collected at two different periods in the analytical cycle. First, a mold count was taken from each sample. Second, the mold was identified for type. Findings from each sample are recorded in report form as prepared by the Midwest Laboratories, Inc. and are included with this report.

The second site visit occurred on May 03, 2001. At that time Ms. Jensen met with Dr. Borhani before and after the cleaning tests were performed to discuss findings and to show Dr. Borhani where each test was performed. Cleaning tests were performed on the east elevation of the King Field House, on each side of the entrance, because the water spigot was nearby.

One test was performed to demonstrate the effectiveness of water blasting, without additives, or biocides. The remaining tests were prepared to demonstrate the effectiveness of ProSoCo products as follows:

766 Limestone Masonry Prewash followed by Limestone & Masonry Afterwash;
T-2031 Architectural Antimicrobial.

In addition, a sample of ProSoCo water repellent product was applied to a block of limestone, which was otherwise unaltered from its natural state.

The effectiveness and results of test cleaning and improved water repellency of the limestone were discussed with Dr. Borhani. Test sample areas were documented in photographic form. The tests were allowed to age for approximately three (3) weeks, to indicate the full effectiveness of and final appearance produced by the cleaning and water repellent products. Photo documentation of the test panels constituted the third site visit and was performed by representative of ProSoCo, Inc., the manufacturer of limestone cleaning products demonstrated on site.

**RESULTS AND DISCUSSION**

Limestone decay is a natural process involving the transformation of the stone matrix to a soil matrix by the destruction of the composition through natural processes. Biological attack on the limestone, by means of the formation and growth of mycelium (rootlets) of fungal cells, is naturally occurring and progressive. Spores of fungus are naturally occurring and airborne. When deposited on the surface of a limestone building facade, the spores become active when growing conditions are correct and balanced. The needs of fungus spores to become active are for three agents: heat, moisture and a food source.

When the spores of fungal cells become active, they consume the food sources immediately available and send out mycelium or rootlets, which absorb moisture and nutrients to continue feeding and supporting the newly activated fungal growths. In the case of the Fort Riley limestone structures, tests indicated the presence of both Yeast and Aspergillus sp. In the active adult stages, these fungal growths are known to consume foods containing nitrogen. Airborne soil and some pollutants provide the necessary nitrogen. As the fungal cells grow and spread, the soil samples may be consumed. During this stage of expansion, the fungus put down rootlets that expand and spread. They absorb nitrogen and other food sources from their points of contact. It is in this stage of expansion and nutrient absorption that stone decay takes place.

Pressure, brought to bear on the limestone by the expansion and spread of the mycelium, accompanied by weakening of the stone matrix through loss of minerals, combine to cause fracture and splitting of the limestone. As the fungal cells grow and multiply, and as the growths spread unchecked on the limestone facades, damage to the stone increases to a stage that shows loss, splitting and spalling to the naked eye. Magnification is not needed to observe the loss eventually, even though the decay began on a microscopic level.

Yeast and Aspergillus sp. were both identified in the biological stain samples collected from the Fort Riley buildings listed above. From field observations, the fungus are well developed and actively deteriorating the limestone facades of some historic structures. If left unchecked, Yeast and Aspergillus sp. strains will continue to flourish at the expense of the limestone in the historic facades. For these reasons, it is best to interrupt the life cycle of the fungus and prevent its growth and spread on the limestone of Fort Riley historic structures.

It would appear from review of the limestone structures at Fort Riley, results of analysis of biological stains and test cleaning; the following conclusions may be drawn.

1) The natural appearance of the limestone at Fort Riley, after quarrying and construction, is a soft, slightly gray-white shade. Over time, and with weathering of the stone under the broad eaves characteristic of Historic Fort Riley construction, a large volume of the limestone can be observed to exhibit a slight yellow-ochre cast. This coloration may be attributed to the oxidation of naturally occurring iron within the stone matrix, to ferrous oxide. Stone that continues to exhibit the gray-white shades of the limestone can be found in areas of building construction that expose the facades to weathering, rainfall, snow, etc., which cause slow but steady exfoliation of the limestone surface. This on-going process removes any iron or ferrous oxide stains that have formed at the surface, exposing fresh, gray colored limestone in its wake.

2) Where biological materials are forming, limestone facades are generally less protected. Areas of building fabric which are exposed to rainfall, dripping roofs, leaking gutters, etc., are often quite prone to growth of biological stains. For example, pylons of Chapel 0006 exhibit a pronounced contrast in biological staining to some adjacent walls, which benefit from the protection of the broad eaves.

**RESULTS AND DISCUSSION continued**

3) Other factors that contribute to the formation of biological staining include the texturing of the limestone blocks themselves. The older original church on Post has hand hewn limestone blocks with relatively smooth faces. Blocks of this earlier construction appear much cleaner, exhibiting far fewer biological materials than the nearby Chapel 0006, which incorporates the more heavily textured stone. The more highly textured stones were observed to have collected soil. The nitrogen in the soil deposits is a required ingredient in the support of biological growth. Prevailing winds are frequently northwesterly in this region, providing for the introduction and deposit of airborne soil, particularly on west and north facing walls.

4) Moisture, or humidity, and warmth are two other ingredients required to support the growth of fungus. Northern exposures of the buildings reviewed during this study were observed to support more significant volumes of biological growth than southern exposures. The northern exposures of buildings of Post construction would typically remain moist longer than southern exposures in spring and summer months in Kansas. This modest difference in drying rates would, over time, produce significantly greater volumes of biological materials on northern exposures of building construction.

5) Stain samples collected from Chapel 0006 adjacent to the water spigot, were found to be negative for the presence of biological growth. On further examination, stains in these areas were found to be on the stone surface (the stain was scratched with fingernails, and found to be easily removed). It appears stains associated with water spigots are mineral in nature, and may contain manganese and bromine from the local water. Bromine is reportedly in the local water (personal communique with Dr. Borhani). Bromine is a sufficiently active molecule to attract and trap any manganese present in the limestone. A compound resulting from the chelation of bromine and manganese would plate out on the stone and appear as the red-brown mineral stain observed during site visits.

**CONCLUSIONS**

From the results of biological stain sampling and analysis, observation of Fort Riley historic limestone construction and test cleaning results, a number of conclusions can be drawn.

Limestone used in most of the historic construction on the Fort Riley Post appears to have a significant presence of naturally occurring iron. The iron has given stone facades a beautiful yellow-ochre coloration on walls that remain protected from weathering, soil accumulation and a continuously moist state. Stone that has acquired the desirable yellow patina of age, without disfigurement from biological staining, should be left as is, and not cleaned with chemical solutions.

Because of the iron content in the limestone, it is strongly recommended that cleaning compounds that contain bleach (sodium hypochlorite) **not be used.** Oxygen in the bleach solution will chelate the iron in the stone and form disfiguring stains of rust (ferrous oxide) in the limestone. Also, one byproduct of bleach used on limestone is sodium chloride, or common salt, which is a large and fast growing crystal. When bleach is used on limestone, sodium chloride crystal formation within the stone matrix is fast and powerful, and can cause flaking and exfoliation of the limestone surface, from the chemical reaction.

From the test cleaning procedures, it was observed that simple pressure washing was ineffective in removal of biological stains.

**CONCLUSIONS continued**

Effective cleaning was achieved by use of both ProSoCo cleaning agents listed below. Benefits and drawback to using each are discussed below.

**T-2031 Architectural Antimicrobial.**

T-2031 Architectural Antimicrobial was effective in killing the biological materials on limestone of the King Field House 0202. The fungicide turned the Aspergillus mold from black-green color to red-brown shades as the fungus died. In one test patch the antimicrobial was allowed to dwell un-aided. In another, it was agitated and re-applied before washing. In a third test, the antimicrobial was agitated and rinsed without re-application.

The recently formulated product T-2031 Architectural Antimicrobial contains products that have been approved by the EPA for the uses proscribed. The active ingredients are fungicides that have been engineered to attack molds. As such, the product is safe not only for handlers and the public, but does not harm landscaping or plant materials.

**766 Limestone & Masonry Prewash and Limestone & Masonry Afterwash**

These two limestone-cleaning products are used in conjunction with each other. The former product is alkaline in nature and is applied to damp stone. The product is gel-like in consistency and will dwell on vertical stone for approximately two hours if needed. 766 Prewash requires infrequent misting with clear water to prevent premature drying on the stone facade, however, thirty to forty-five minute dwell times were found to be effective on the King Field House 0202. The Prewash must be agitated with stiff bristle brushes to produce best cleaning results.

When the biological materials and cleaning products are removed by pressure washing, the stone is treated with Limestone & Masonry Afterwash. This mild acid neutralizes the limestone after the alkaline cleaning products are removed. This combination of limestone cleaning products was highly effective in the test panel prepared on the King Field House 0202.

**Mineral Stain Removers**

Beyond the objective of this study to address removal of biological stains, is the need to remove mineral stains. On the King Field House 0202 copper stains have recently disfigured the entrance. On Chapel 0006, mineral stains were observed near two water spigots. These stains appear to be a combination of bromine (from the water) and manganese (from the limestone). ProSoCo products are recommended. Mineral Stain Remover is a good product for use on the mineral stains surrounding water spigots. It is used sparingly and should be monitored during use.

**Water Repellent**

The scope of the limestone research project was directly focused on identification of biological stains and recommending effective and affordable means of their removal. In addition to the cleaning tests, one limestone block was treated with water repellent Natural Stone Treatment. The sample was prepared to demonstrate the effectiveness of the material while appearing invisible on the limestone face. In order to break the cycle of biological formation on the stone, it is recommended the use of a water repellent be considered in the on-going maintenance plan for Fort Riley Post. Three ingredients are known to be needed to support the growth of aspergillus on the limestone: moisture, heat and nitrogen. Warm summers in Kansas are a given. Nitrogen -rich soil is delivered airborne. Regular cleaning (pressure

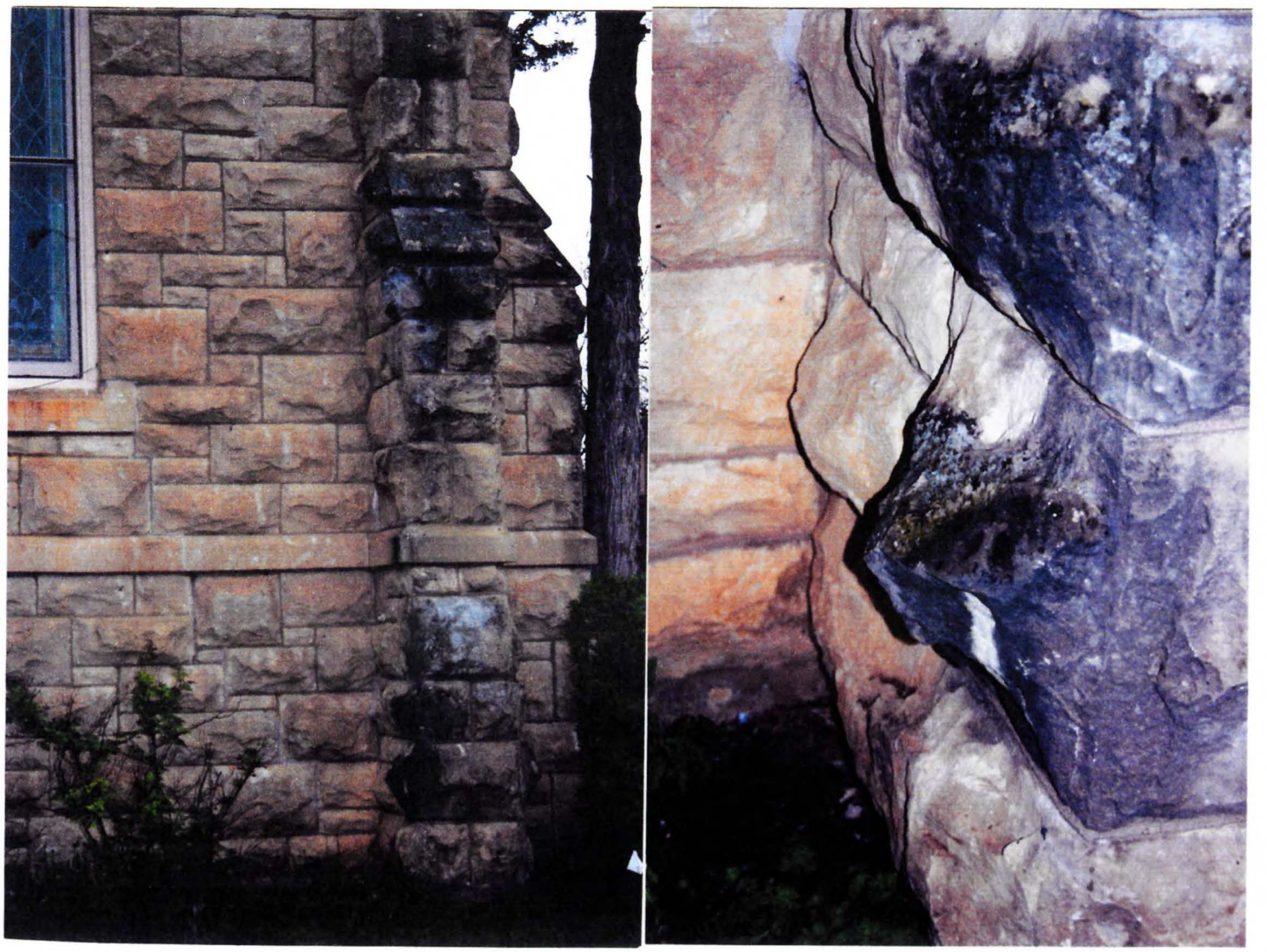
washing) of historic structural facades will remove airborne soil deposits, but at a regular and significant cost of time, water and equipment. If the moisture content of the stone facade were altered by the application of a water repellent, the cyclical growth of biological materials would be interrupted and slowed. Application of a water repellent requires a one time cost for materials, labor and equipment and should be followed by a period of effectiveness for approximately seven to ten years.

**PRODUCT PRICING STRUCTURE**

| | |
|---|---|
| 766 Limestone Prewash | $21.46/gallon, available only in 5 gallon pails |
| Limestone Afterwash | $17.54/gallon, if purchased in 5 gallon pails |
| Natural Stone Treatment (Water Repellent) | $35.70/gallon, if purchased in 5 gallon pails |
| T-2031 or D-2 Architectural Antimicrobial | $76.00/gallon, if purchased in 5 gallon pails |

**PHOTOGRAPHIC ILLUSTRATIONS**

Samples of limestone stains were collected and analyzed from the locations illustrated in the following photographs.



Sample 1 was collected from the pylon on the South Elevation of Chapel 0006.

**PHOTOGRAPHIC ILLUSTRATIONS**

Sample 2 was collected from the limestone adjacent to the water spigot on Chapel 0006. The water spigot is on the West Elevation.

**PHOTOGRAPHIC ILLUSTRATIONS**


Sample 3 was collected from the cornerstone on the North Elevation of Chapel 0006.

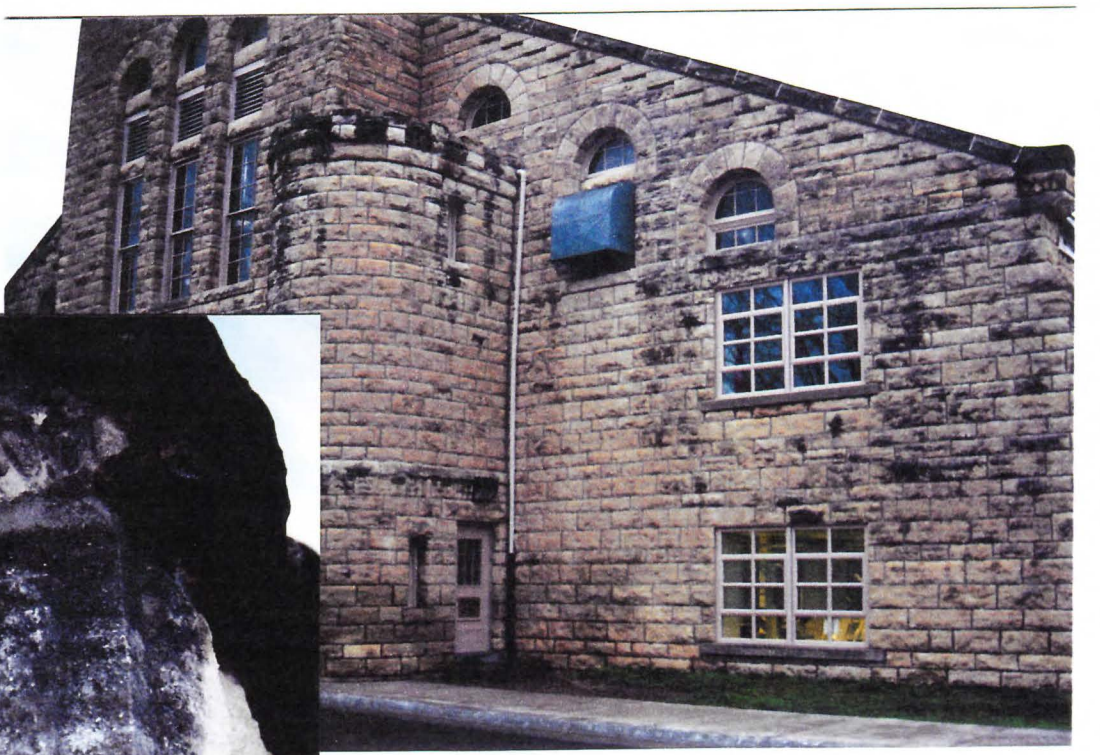
**PHOTOGRAPHIC ILLUSTRATIONS**

Sample 4 was collected from the pylon located on the East Elevation of Chapel 0006, near the North end of the building.

**PHOTOGRAPHIC ILLUSTRATIONS**


Sample 5 was collected from the East Elevation of Museum Building 0205, near the directional arrow sign in the above photo. Sample 6 was collected from the South Elevation of the same building corner, adjacent to the downspout illustrated here.

**PHOTOGRAPHIC ILLUSTRATIONS**

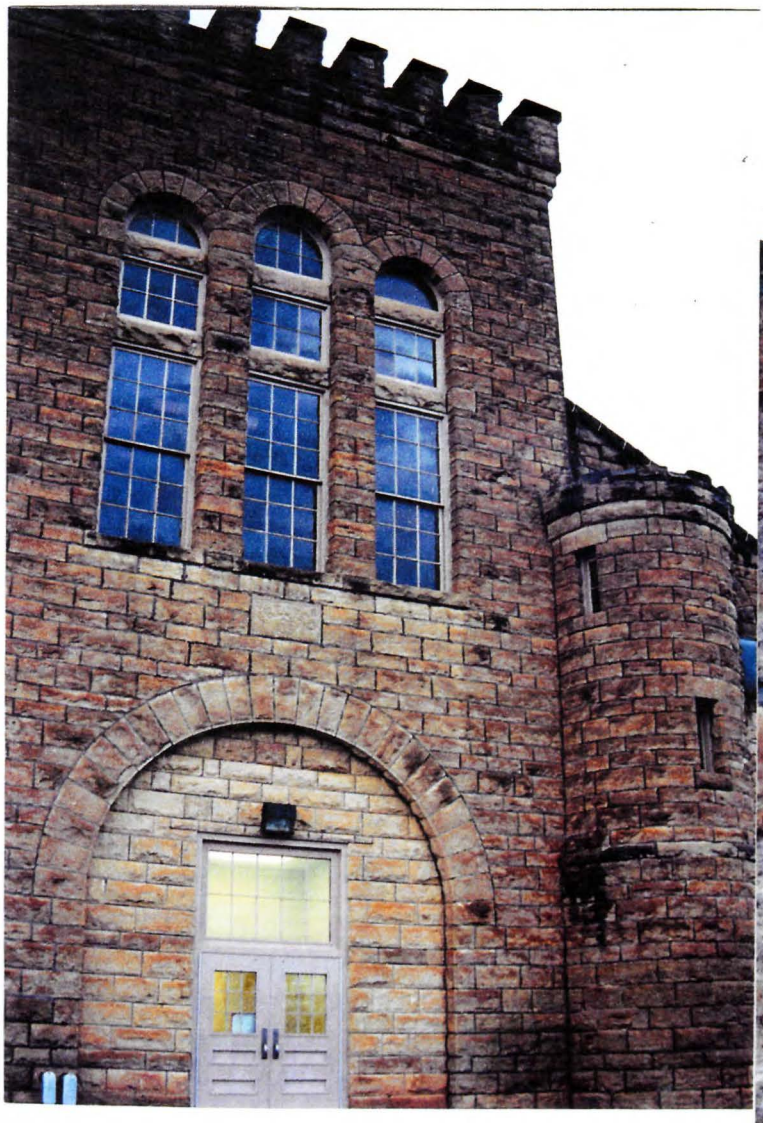


Sample 7 was collected from the North Elevation of King Field House 0202, from the pylon at the north west corner.

**PHOTOGRAPHIC ILLUSTRATIONS**

Sample 8 was collected from King Field House 0202, North Elevation, from the turret.

**PHOTOGRAPHIC ILLUSTRATIONS**



Sample 9 was collected from the South Elevation of King Field House 0202, near the doorway.

**PHOTOGRAPHIC ILLUSTRATIONS**

Sample 10 was collected from the South Elevation of King Field House 0202.

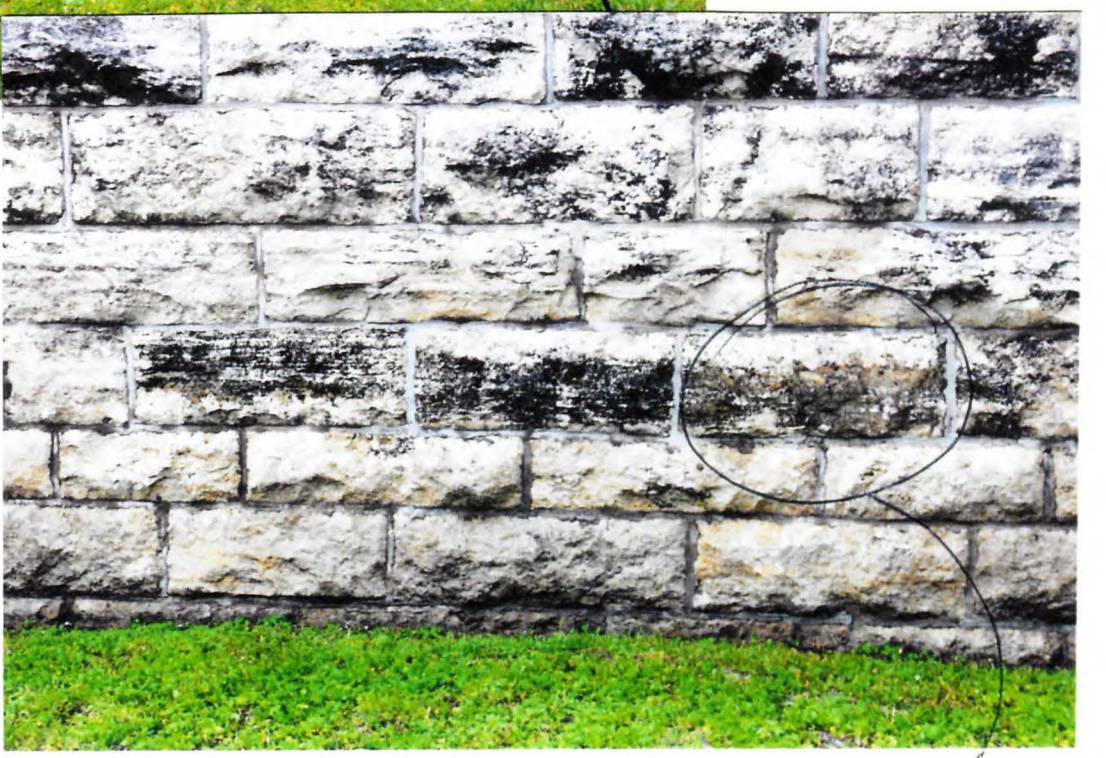
**PHOTOGRAPHIC ILLUSTRATIONS**

Samples 11 and 12 were collected from the West Elevation of the Museum Building 0205, windows 3 and 6, counting right from the doorway in the photograph above.

**PHOTOGRAPHIC ILLUSTRATIONS**

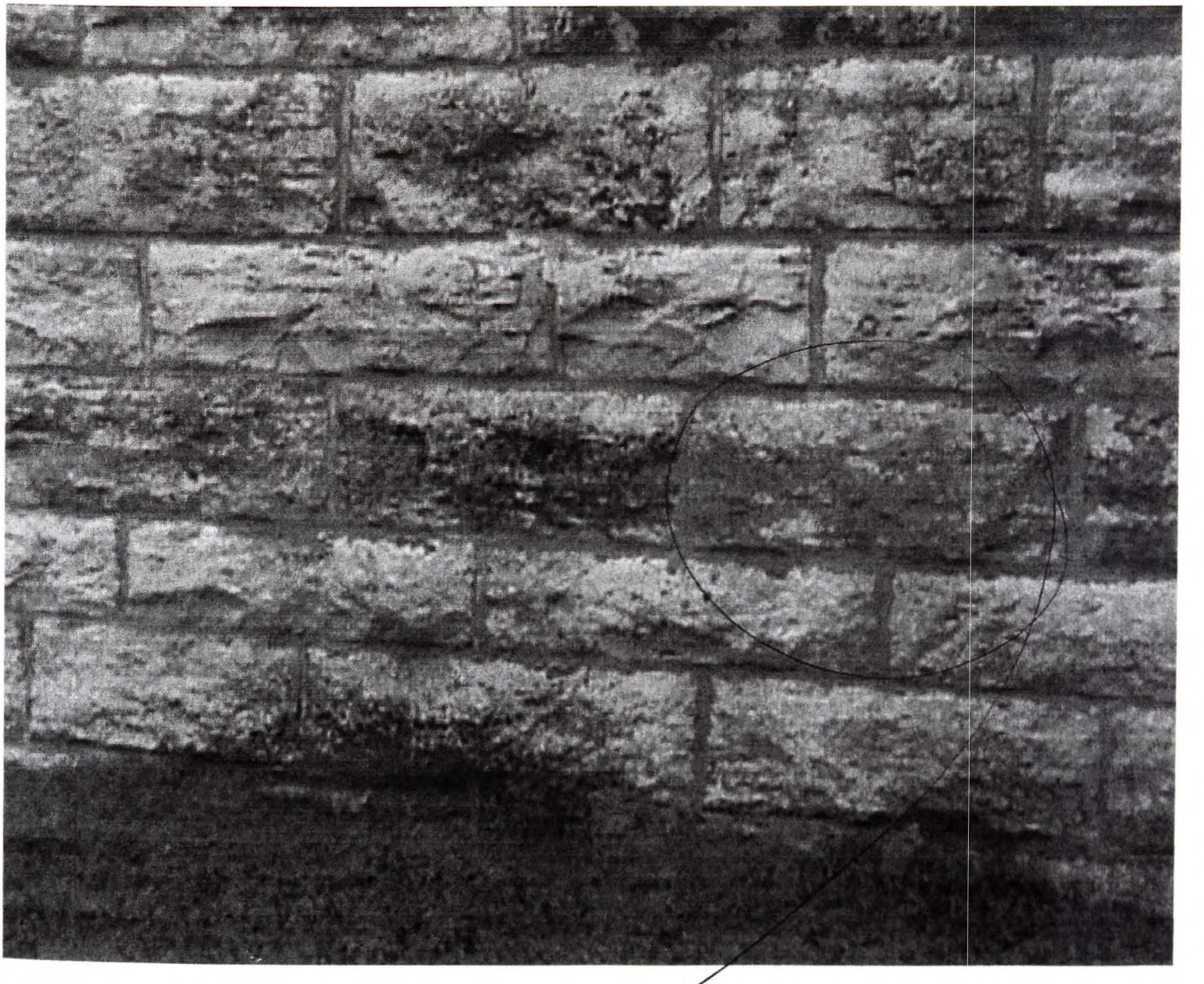
The King Field House 0202 East Elevation is shown here, near the north entrance, before cleaning samples are prepared. The wet looking block in the second picture has had T-2031 Architectural Antimicrobial product applied to it.

**PHOTOGRAPHIC ILLUSTRATIONS**



In the upper photo, the T-2031 product is being rinsed with pressure washer. Immediate effects of cleaning are visible in the lower image. On the following page, the cleaned stone is circled. The effect was achieved after an elapsed time of four weeks.

**PHOTOGRAPHIC ILLUSTRATIONS**



T-2031 Test Area

**PHOTOGRAPHIC ILLUSTRATIONS**

To the north of the north entrance on the East Elevation of the King Field House, the 766 Limestone and Masonry Prewash is being tested. These images illustrate the stone before cleaning, and at the beginning of the rinse cycle. On the following page, the effectiveness of the cleaner is demonstrated after a four week time frame.

766 Test Area

Jensen Conservation Services, Inc.
13515 C Street, Omaha, NE 68144
Phone 402.691.0100 Fax 402.691.0300

## SCOPE OF WORK

### T-2031 Architectural Antimicrobial

**Preparation**
**Protect** people, vehicles and property from product splash, residue and wind drift. Protect and/or divert auto and pedestrian traffic.

**Surface Preparation**
Cleaning effectiveness is reduced where surface and air temperature fall below 50 degrees F. Do not apply at temperatures below 30 degrees F. If freezing conditions exist before application, let masonry thaw.

**Equipment**
T-2031 Architectural Antimicrobial can be applied with many conventional sprayers. Adjust sprayer to lowest pressure setting to produce an even flow of material. For most efficient spray application, use large, airless sprayer with a minimum capacity of 1 gallon per minute.

Use pressure-water rinsing equipment fitted with a fan-type spray tip no smaller than 15 degrees for removal. Equipment that provides 400 -900 psi at a flow rate of 4-6 gallons (15 -23 liters) of water per minute is generally most effective. Heated water 150 degrees to 180 degrees F. may improve efficiency.

**Application**
**ALWAYS TEST** each type of surface and each type of stain for suitability, dilution and desired results before overall application. Test using the following application instructions. Let the surface dry thoroughly before inspection. Do not dilute T-2031 Architectural Antimicrobial.

**Application Instructions**
1. Remove thickest encrustations of biological growth and soil residues by hand, using the blunt end of a paint brush handle or a wooden scraper.
2. Apply T-2031 Architectural Antimicrobial to dry limestone.
3. Spray the Antimicrobial over the surface of the limestone at no more than 50 psi.
4. Allow the Antimicrobial to dwell for approximately 5 to 10 minutes.
5. Agitate the area of applied Antimicrobial with a stiff-bristled brush with nylon fibers.
6. Rinse the stone with pressure water at settings of 600 to 900 psi and 4 to 6 gallons per minute.
7. Re-apply the Antimicrobial and allow drying and continuing working.
8. Best results are visible after approximately five (5) weeks.

### 766 Limestone Prewash & Masonry Afterwash

**Preparation**
**Protect** people, vehicles, property, plants, wood, electric and all nonmasonry surfaces from product, splash, residue, wind drift and fumes. Product may corrode some metals, will darken and damage wood surfaces and will attack and remove paint coatings. Protect and/or divert auto and pedestrian traffic.

**Surface Preparation**
Cleaning effectiveness is reduced where surface and air temperature fall below 50 degrees F. Do not apply at temperatures below 30 degrees F. If freezing conditions exist before application, let masonry thaw.

**Equipment**
Apply with deep-napped synthetic roller or nylon brush. Do not use natural fiber. 766 Limestone & Masonry Prewash can be applied with many conventional mechanical sprayers. Sprayers should be equipped with viton, Teflon or other caustic-resistant seals and parts. Spray hose should be poly-lines, chemical-resistant and pressure-rated for the spray. Spray tips should have a minimum orifice size of 1/4" to prevent tip fouling. Do not place in aluminum containers or spray equipment.

Adjust sprayer to lowest pressure setting to produce an even flow of material. For most efficient spray application, use large, airless sprayer with a minimum capacity of 1 gallon per minute. Product may be diluted with water to facilitate spray application.

Use pressure-water rinsing equipment fitted with a fan-type spray tip no smaller than 15 degrees for removal. Equipment that provides 400 -900 psi at a flow rate of 4-6 gallons (15 -23 liters) of water per minute is generally most effective. Heated water 150 degrees to 180 degrees F may improve efficiency.

**Application**

**ALWAYS TEST** each type of surface and stain before overall application to ensure suitability and desired results. Apply test area according to the following application procedures. Allow area to dry thoroughly before inspection and approval.

**Dilutions**
Use 766 Limestone & Masonry Prewash in concentrate during initial testing. If test panels with concentrated material are cleaned effectively, additional tests may be run using a solution of 766 Limestone & Masonry Prewash diluted with up to 3 parts water to 1 part concentrate.

**Application Instructions**
1. Always prewet the surface with clean water.
2. Apply a heavy coating of 766 to the surface using a brush or roller (or by low-pressure spray).
3. Let the prewash dwell on the surface 30 - 60 minutes.
**Note:** Longer dwell times may be required with lower temperatures.
4. Pressure rinse, making sure to flush each portion of the masonry surface with concentrated water pressure.
5. Neutralize the surface immediately with Limestone & Masonry Afterwash following the instructions below.

**Limestone & Masonry Afterwash**

**Preparation**
**Protect** people, vehicles, property, plants, and all nonmasonry surfaces from product, splash, rinse, residue, wind drift and fumes. Protect and/or divert auto and pedestrian traffic.

**Surface Preparation**
Cleaning effectiveness is reduced where surface and air temperature fall below 50 degrees F. Do not apply at temperatures below 40 degrees F. If freezing conditions exist before application, let masonry thaw.

**Equipment**
Apply Limestone & Masonry Afterwash with a soft-fibered, masonry washing brush or low-pressure spray equipment. Do not apply with pressure above 50 psi. Pressure settings in excess of 50 psi drive the cleaner into the surface, making complete rinse difficult. Stains may result. Fit equipment with acid-resistant hoses and gaskets. Use pressure-rinsing equipment with 500 to 600 psi at a water flow rate of 4 to 8 gallons per minute and a 15-degree to 40-degree fan spray tip.

**Application**
**ALWAYS TEST** each type of surface and each type of stain for suitability, dilution and desired results before overall application. Test using the following application instructions. Let the surface dry thoroughly before inspection.

**Dilutions**
Dilute one part fresh water to one part concentrated cleaner before application. Pour cold water into empty polyethylene or polypropylene bucket, then carefully add Limestone & Masonry Afterwash. Never pour water into Afterwash.

**Application Instructions**
It is necessary to apply 766 Limestone & Masonry Prewash and Limestone & Masonry Afterwash as a two-part cleaning system to completely restore and neutralize masonry surfaces.

1. Immediately after rinsing 766 Limestone & Masonry Prewash from masonry surface, apply the prepared Afterwash to the wet surface.
2. Let the Afterwash stay on the surface for three to five minutes.
3. Pressure rinse from the bottom of the treated area to the top. Make sure to cover each portion of the masonry surface with a concentrated stream of water. To avoid streaking, keep wall surfaces immediately below area being cleaned running wet and free of cleaner rundown and residues.

**Natural Stone Treatment**

**Preparation**
**Protect** people, vehicles, property, plants, and all nonmasonry surfaces from product, splash, rinse, residue, wind drift and fumes. Protect and/or divert auto and pedestrian traffic.

**Surface Preparation**
Cleaning effectiveness is reduced where surface and air temperature fall below 50 degrees F. Do not apply at temperatures below 40 degrees F. If freezing conditions exist before application, let masonry thaw. Do not apply Natural Stone Treatment during rainfall or when rainfall is in the forecast for seventy-two (72) hours following application.

**Equipment**
Natural Stone Treatment can be applied with many conventional mechanical sprayers. Sprayers should be equipped with viton, Teflon or other caustic-resistant seals and parts. Spray hose should be poly-lines, chemical-resistant and pressure-rated for the spray. Spray tips should have a minimum orifice size of 1/4" to prevent tip fouling. Do not place in aluminum containers or spray equipment.

Adjust sprayer to lowest pressure setting to produce an even flow of material. For most efficient spray application, use large, airless sprayer with a minimum capacity of 1 gallon per minute.

**Application**
**ALWAYS TEST** each type of surface and each type of stone for suitability and desired results before overall application. Test using the following application instructions. Let the surface dry thoroughly before inspection.

**Application Instructions**
It is necessary to apply Natural Stone Treatment to clean, dry stone. Limestone should be allowed to air dry for two weeks following treatment with 766 Limestone Prewash & Afterwash and six weeks following treatment with T-2031 Architectural Antimicrobial.

1. Do not dilute Natural Stone Treatment.
2. Apply using spray equipment at pressures of no greater than 50 psi.
3. Apply product from the bottom of the structure, progressing upward.
4. Apply product until stone is saturated and the product excess runs down.
5. Product dries in seventy-two hours and cures in two weeks.

Midwest Laboratories, Inc.SM
13611 "B" Street • Omaha, Nebraska 68144-3693 • (402) 334-7770 • FAX (402) 334-9121
www.midwestlabs.com

Report Number
01-122-2097

# REPORT OF ANALYSIS

For: (11743) JENSEN CONSERVATION
(402)691-0100

Date Reported: 05/07/01
Date Received: 04/11/01

**Mail to:**

**JENSEN CONSERVATION**
**13824 C PLAZA**
**OMAHA NE 68144-**

Lab number: 631985

| Analysis | Level Found | Units | Detection Limit | Method | Analyst-Date |
|---|---|---|---|---|---|
| Sample ID: KING FIELD HOUSE 7 N. ELEV. ON PYLON | | | | | |
| Total Mold Count | 20 | cfu/g | 10 | FDA XVIII | kej-05/02 |
| Aspergillus sp. (other) | 20 | cfu/g | 10 | FDA XVIII | kej-05/02 |
| Yeast | 490 | cfu/g | 1 | FDA XVIII | kej-05/02 |
| Sample ID: KING FIELD HOUSE 8 N. ELEV. ON TURRET | | | | | |
| Total Mold Count | n.d. | cfu/g | 10 | FDA XVIII | kej-05/02 |
| Yeast | n.d. | cfu/g | 1 | FDA XVIII | kej-05/02 |
| Sample ID: KING FIELD HOUSE 9 S. ELEV. NEAR DOORWAY | | | | | |
| Total Mold Count | n.d. | cfu/g | 10 | FDA XVIII | kej-05/02 |
| Yeast | 80 | cfu/g | 1 | FDA XVIII | kej-05/02 |

Midwest Laboratories, Inc.SM
13611 "B" Street • Omaha, Nebraska 68144-3693 • (402) 334-7770 • FAX (402) 334-9121
www.midwestlabs.com

# REPORT OF ANALYSIS

Account: 11743 JENSEN CONSERVATION
Report Number: 01-122-2097

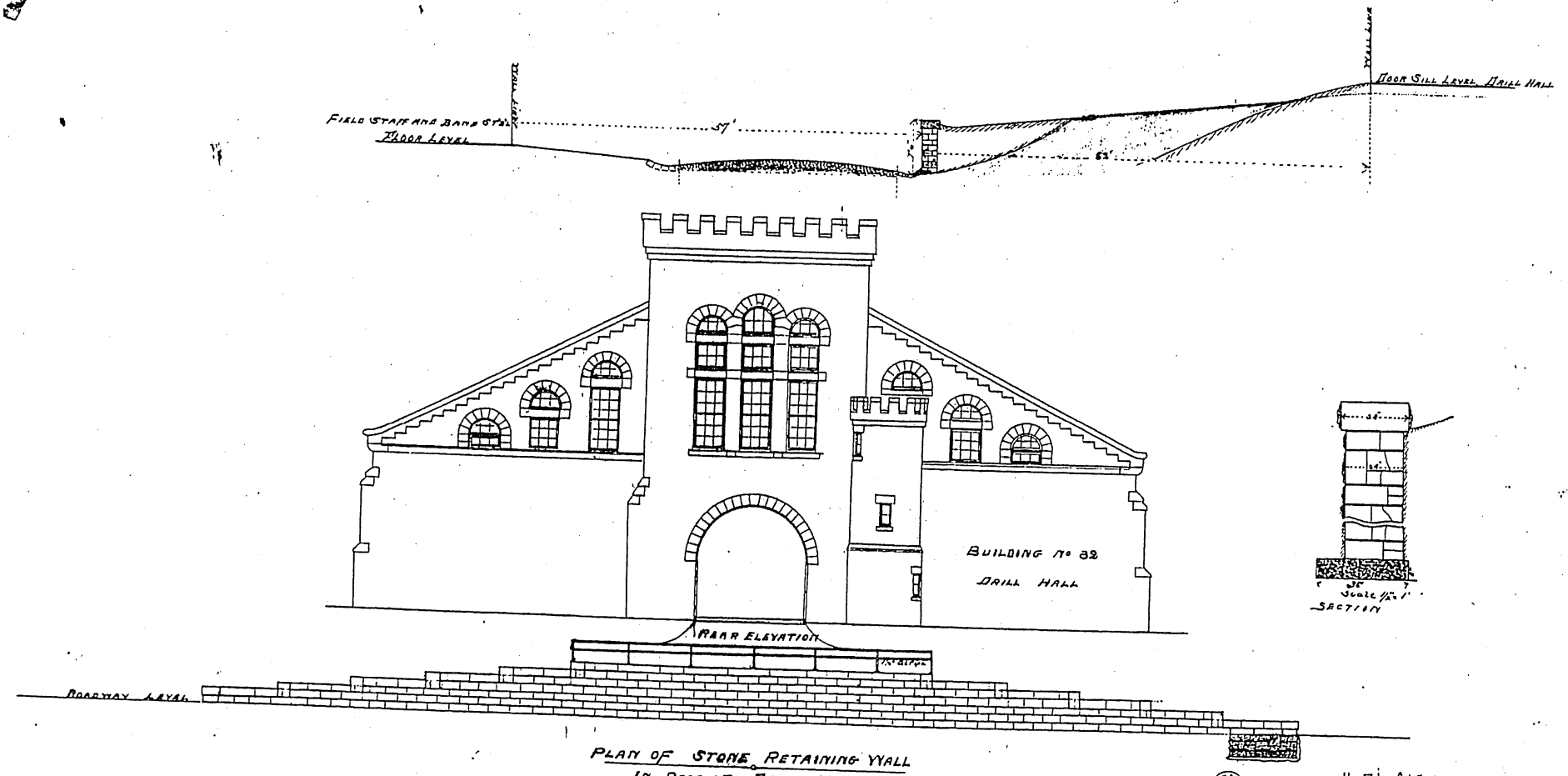


| Analysis | Level Found | Units | Detection Limit | Method | Analyst-Date |
|---|---|---|---|---|---|
| Sample ID: KING FIELD HOUSE 10 S. ELEV. BROADWALL | | | | | |
| Total Mold Count | 40 | cfu/g | 10 | FDA XVIII | kej-05/02 |
| Aspergillus sp. (other) | 40 | cfu/g | 10 | FDA XVIII | kej-05/02 |
| Yeast | 660 | cfu/g | 1 | FDA XVIII | kej-05/02 |

Notes:
n.d. - Not Detected.

Respectfully Submitted

Heather Ramig/Sue Ann Seitz
Client Services




Plan of Stone Retaining Wall
In Rear of Drill Hall
Fort Riley Kans

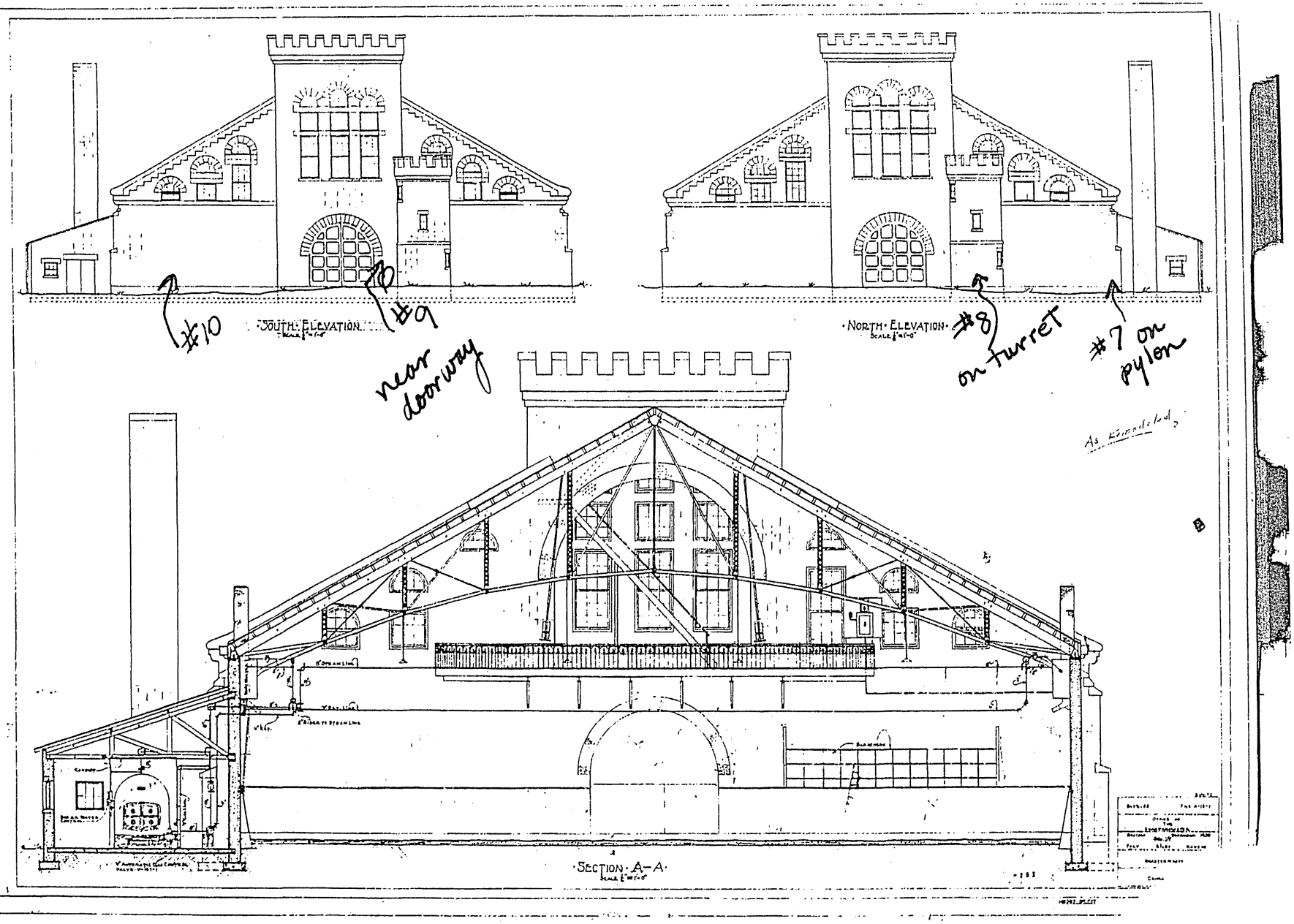
Scale 1/4" = 1'

U. File A15-1

H0202_02.CIT

n\view.dgn Jul. 23, 1996 15:14:02

H0202_02.cit

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H0202_05.cit

Report Number
01-122-2098

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**REPORT OF ANALYSIS**

For: (11743) JENSEN CONSERVATION
(402)691-0100

Date Reported: 05/07/01
Date Received: 04/11/01

**Mail to:**

**JENSEN CONSERVATION**
**13824 C PLAZA**
**OMAHA NE 68144-**

Lab number: 631989

| Analysis | Level Found | Units | Detection Limit | Method | Analyst-Date |
|---|---|---|---|---|---|
| Sample ID: MUSEUM 205 #5 E. ELEV. CORNER BLOCK | | | | | |
| Total Mold Count | 40 | cfu/g | 10 | FDA XVIII | kej-05/02 |
| Aspergillus sp. (other) | 40 | cfu/g | 10 | FDA XVIII | kej-05/02 |
| Yeast | n.d. | cfu/g | 1 | FDA XVIII | kej-05/02 |
| Sample ID: MUSEUM 205 #6 S. ELEV. DOWNSPOUT | | | | | |
| Total Mold Count | 120 | cfu/g | 10 | FDA XVIII | kej-05/02 |
| Aspergillus sp. (other) | 120 | cfu/g | 10 | FDA XVIII | kej-05/02 |
| Yeast | 600 | cfu/g | 1 | FDA XVIII | kej-05/02 |
| Sample ID: MUSEUM 205 #11 W. ELEV. FROM WINDOWSILL | | | | | |
| Total Mold Count | n.d. | cfu/g | 10 | FDA XVIII | kej-05/02 |
| Yeast | n.d. | cfu/g | 1 | FDA XVIII | kej-05/02 |

*The above analytical results apply only to the sample(s) submitted.*

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# REPORT OF ANALYSIS

Account: 11743 JENSEN CONSERVATION
Report Number: 01-122-2098

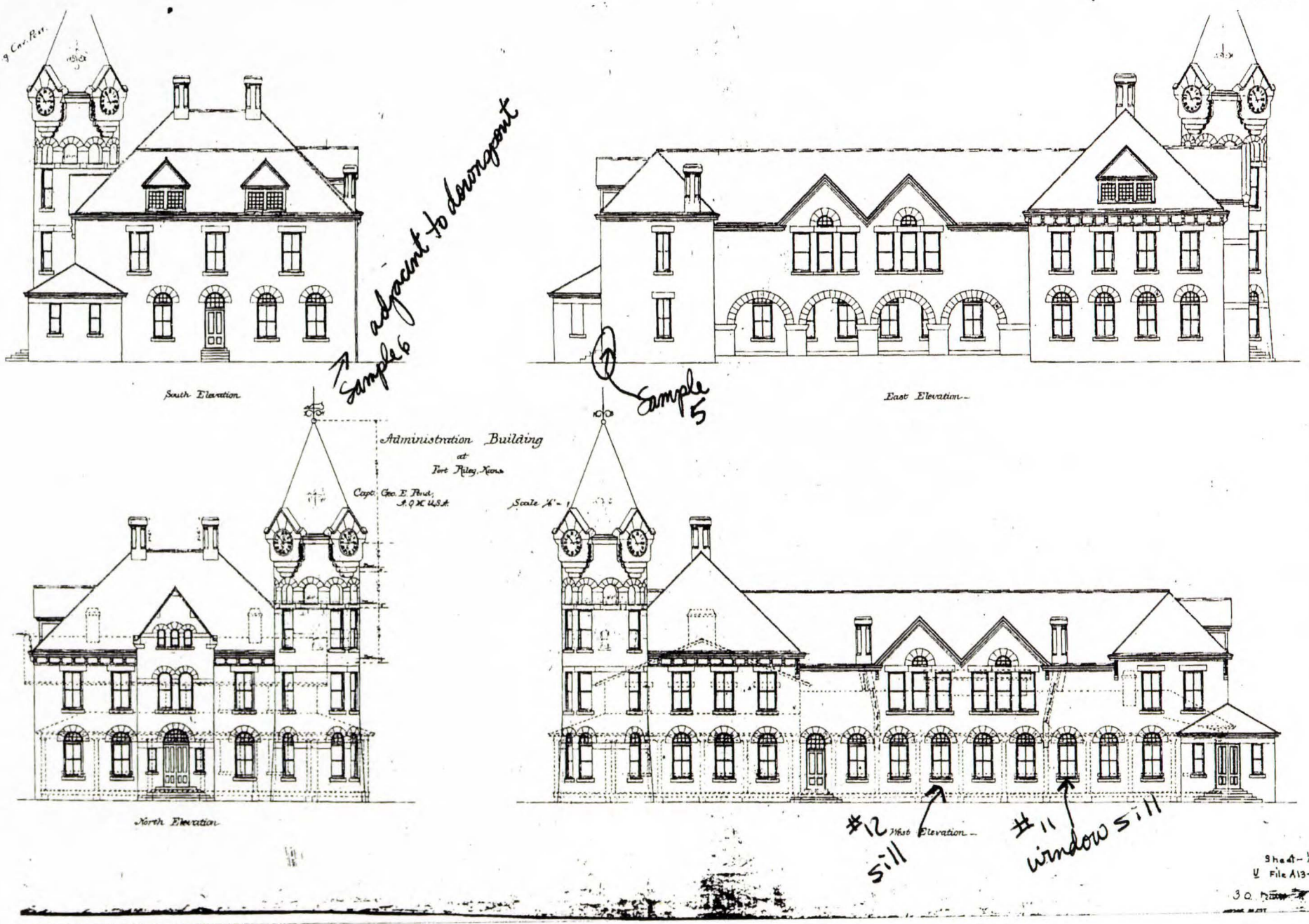


| Analysis | Level Found | Units | Detection Limit | Method | Analyst-Date |
|---|---|---|---|---|---|
| Sample ID: MUSEUM 205 #12 W. ELEV. WINDOWSILL | | | | | |
| Total Mold Count | n.d. | cfu/g | 10 | FDA XVIII | kej-05/02 |
| Yeast | 50 | cfu/g | 1 | FDA XVIII | kej-05/02 |

Notes:
n.d. - Not Detected.

Respectfully Submitted

Heather Ramig/Sue Ann Seitz
Client Services




n\view.dgn Jul. 23, 1996 15:19:50

H0205_01.cit

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Report Number
01-122-2096

# REPORT OF ANALYSIS

For: (11743) JENSEN CONSERVATION
(402)691-0100

Date Reported: 05/07/01
Date Received: 04/11/01

**Mail to:**

**JENSEN CONSERVATION**
**13824 C PLAZA**
**OMAHA NE 68144-**

Lab number: 631981

| Analysis | Level Found | Units | Detection Limit | Method | Analyst-Date |
|---|---|---|---|---|---|
| Sample ID: CHAPEL 6 1 SOUTH ELEVATION PYLON | | | | | |
| Total Mold Count | 160 | cfu/g | 10 | FDA XVIII | kej-05/02 |
| Aspergillus sp. (other) | 160 | cfu/g | 10 | FDA XVIII | kej-05/02 |
| Yeast | 70 | cfu/g | 1 | FDA XVIII | kej-05/02 |
| Sample ID: CHAPEL 6 2 END BY SPIGOT | | | | | |
| Total Mold Count | n.d. | cfu/g | 10 | FDA XVIII | kej-05/02 |
| Yeast | n.d. | cfu/g | 1 | FDA XVIII | kej-05/02 |
| Sample ID: CHAPEL 6 3 FRONT CORNERSTONE | | | | | |
| Total Mold Count | 70 | cfu/g | 10 | FDA XVIII | kej-05/02 |
| Aspergillus sp. (other) | 70 | cfu/g | 10 | FDA XVIII | kej-05/02 |
| Yeast | 750 | cfu/g | 1 | FDA XVIII | kej-05/02 |

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# REPORT OF ANALYSIS

Account: 11743 JENSEN CONSERVATION
Report Number: 01-122-2096

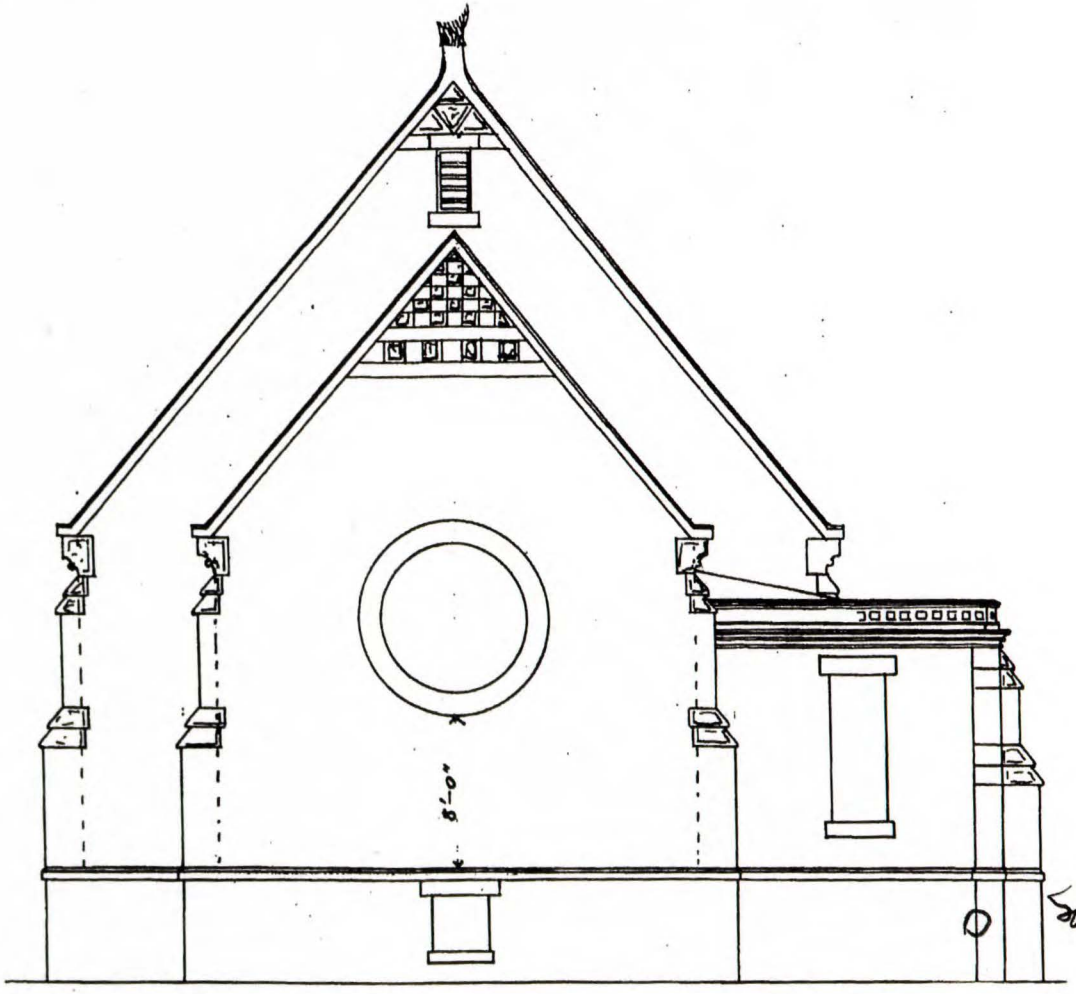


| Analysis | Level Found | Units | Detection Limit | Method | Analyst-Date |
|---|---|---|---|---|---|
| Sample ID: CHAPEL 6 4 EAST E1 ON PYLON | | | | | |
| Total Mold Count | 70 | cfu/g | 10 | FDA XVIII | kej-05/02 |
| Aspergillus sp. (other) | 70 | cfu/g | 10 | FDA XVIII | kej-05/02 |
| Yeast | 570 | cfu/g | 1 | FDA XVIII | kej-05/02 |

Notes:
n.d. - Not Detected.

Respectfully Submitted

Heather Ramig/Sue Ann Seitz
Client Services




Sample #1 from pylon

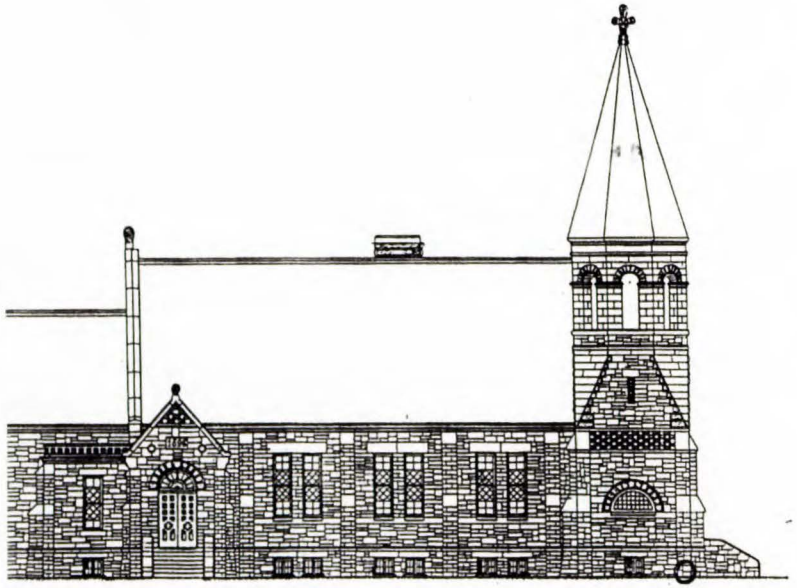
Rear Elevation of Chancel & Vestry
of Chapel
Fort-Riley, - Kansas.
Scale 1/8" = 1'

Sheet - 2/5
U File A18-5

Constructing Quartermaster's Office,
Fort-Riley, Kansas August 12. 1892.

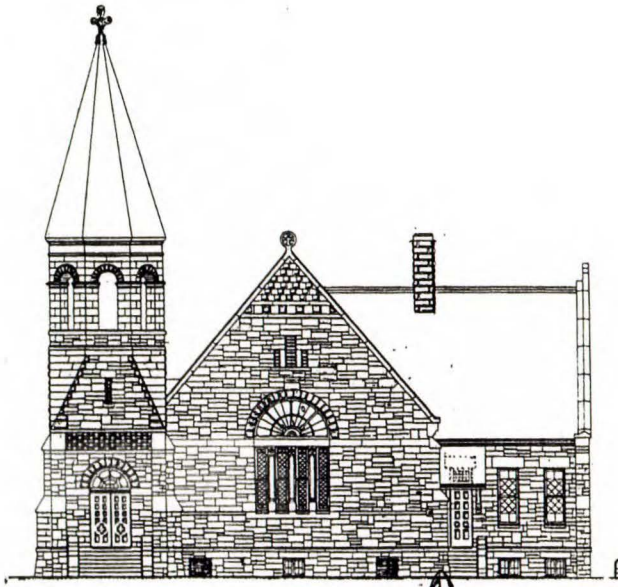
George Ruhlen
Captain 2nd A. Q. M. U.S. Army.
In Charge of Construction.

H0006_02.CIT



East Side Elevation.

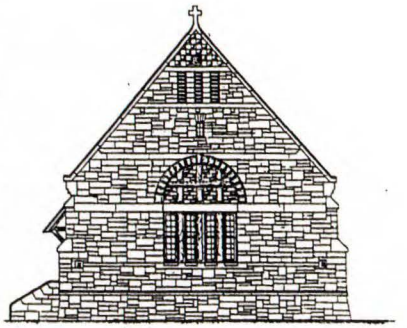
#4 from pylon



North Front Elevation.

Scale 1in=1ft.

#3 from cornerstone



End Elevation of School Room.

#2 from spigot

Original Tracing by R.

U File A18-1

HOOD6_08.CIT

H0006_08.cit

**NOTES FROM E-MAIL DISCUSSION OF REPORT**

On Monday, September 4, 2001 Julie L. Webster submitted questions to Mayda Jensen by e-mail. Her questions are copied below, merged with Mayda's responses composed and sent September 17, 2001.

"Dear Julie:

Thank you for ending the four follow up questions about the Fort Riley Limestone Conservation Study. In answer to your questions, I send the following clarifications.

1. Question:

The report states that the T-2031 Architectural Antimicrobial was tested in 3 ways: (a) dwell unaided; (b) agitated & reapplied; and (c) agitated w/o reapplication. Were the results in these 3 test areas the same? If not, how did they differ?

Answer:

The 3 test areas differed from each other.

Sample a) that allowed the T-2031 to dwell unaided resulted in the least effect on the biological growth. The product killed some biological growth, but the final effect appeared to be the removal of approximately fifty- percent (50%) of the fungal materials.

Sample b) produced the cleanest effect of these three means of applying the same product. The final result appears to have removed approximately ninety to ninety-five percent (90 - 95%) of the fungal materials.

Sample c) produced a cleaning effect between the effects of samples a) and b), resulting in the removal of approximately seventy- percent (70%) of the biological materials.

2. Question:

We'll need a price per gallon on the T-2031 product for comparison purposes.

Answer:

T-2031, also sold as D-2 Architectural Antimicrobial, retails for $76.00 per gallon when purchased in 5-gallon units. The product has coverage of 350 to 400 square feet per gallon.

By the way, while pricing the T-2031, I discovered the draft report quoted "two star pricing" or wholesale prices for the other products. Here are the **retail** per-gallon prices for the four recommended products.

766 Limestone Prewash $21.46 per gallon, available only in 5 gallon pails
Limestone Afterwash $17.54 per gallon, when purchased in 5 gallon pails
T-2031 or D-2 Architectural Antimicrobial
$76.00 per gallon, when purchased in 5 gallon pails
Natural Stone Treatment (Water Repellent)
$35.70 per gallon.

I apologize for the need to correct these prices. I will reflect these prices in the corrected, final version of the report.

3. Question:

How does the level of effort of a single application of T-2031 compare to that of two applications (pre- and after-wash) of the 766 product? Twice the man-hours?

Answer:

A single application of T-2031 is equivalent to a single application of the Neutralizing Afterwash, only. These to water borne products are misted on from pressurized canisters, such as one would use to apply lawn pesticides. Application of the thicker consistency 766 Pre-wash portion of the product requires about twice as long as a single application of the T-2031.

Therefore, application of 766 Pre-wash, agitation, rinsing, application of Afterwash, followed again by rinsing would require about two to three times as many many hours as T-2031. The T-2031 only requires mist application, agitation, dwell, rinsing and reapplication. Also, the 766 will cause the soil at the base of the building to be slippery, until it is absorbed. Further, the 766 causes irritation to the skin, in the form of shallow burns, requiring the applicator to wear protective goggle, gloves, and clothing.

4. Question:

If the T-2031 product has a life of 7-10 years, what is the reapplication cycle of the 766 pre- and after-wash product?

Answer:

Actually, my report indicate the life spay of the recommended **water repellent**, Natural Stone Treatment, lasts 7 to 10 years. It is the water repellent that causes rain to run right off the stone. By this action, the stone dries quickly after a rain, and does not stay damp. Therefore, airborne soils do not have as much occasion to stick to the stone, and the entire cycle which supports the growth of biological materials is interrupted.

If the Army chooses to skip the recommended step of applying water repellent, stones will remain damp after rains, and will encourage the deposition of soil and trapping of airborne spores and the cycle of biological growth will begin again. There are too many factors of weather, stone surface, exposure to wind and sun, local conditions of humidity, temperature, rain cycles, freeze thaw, airborne spore counts, etc., to be able to predict a re-cleaning cycle for buildings at Fort Riley. In order to stay ahead of a significant soil and biological materials build up; however, we recommend annual washing of building facades, after the initial intensive cleaning. The annual maintenance cleaning would probably entail the use of detergent solutions and water washing with pressure washers. It is possible some areas would require the reapplication of 766 or T-2031 annually, again, if no water repellent were applied.

I hope this is clearer. Water repellents should allow for seven to ten years between rewashing and reapplication of the water repellent. Without water repellents, an annual re-cleaning will be necessary to stay ahead of significant biological re-growth.

Julie, I hope this e-mail clarifies the information in my earlier report draft. When I hear from you, I will correct the pricing structure and insert these clarifications in the final report and send it out.

I look forward to hearing from you.

Mayda Jensen"

No further e-mail messages were found after the correspondence on September 17, therefore, the retail prices were inserted in the final report, instead of the wholesale prices, and this e-mail text was added for clarification.

# REPORT DOCUMENTATION PAGE

*Form Approved*
*OMB No. 0704-0188*



**1. REPORT DATE (DD-MM-YYYY)**
10-2001

**2. REPORT TYPE**
Final

**3. DATES COVERED (From - To)**

**4. TITLE AND SUBTITLE**
Historic Limestone Conservation Study for Fort Riley, Kansas

**5a. CONTRACT NUMBER**

**5b. GRANT NUMBER**

**5c. PROGRAM ELEMENT NUMBER**

**6. AUTHOR(S)**
Mayda S. Jensen

**5d. PROJECT NUMBER**
MIPR 0093270017, dated 23 Nov 99

**5e. TASK NUMBER**

**5f. WORK UNIT NUMBER**

**7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)**
U.S. Army Engineer Research and Development Center (ERDC)
Construction Engineering Research Laboratory (CERL)
P.O. Box 9005
Champaign, IL 61826-9005

**8. PERFORMING ORGANIZATION REPORT NUMBER**
ERDC/CERL CR-01-1

**9. SPONSORING / MONITORING AGENCY NAME(S) AND ADDRESS(ES)**
Directorate of Environment and Safety
407 Pershing Court
Fort Riley, KS 66442-6016

**10. SPONSOR/MONITOR'S ACRONYM(S)**

**11. SPONSOR/MONITOR'S REPORT NUMBER(S)**

**12. DISTRIBUTION / AVAILABILITY STATEMENT**
Approved for public release; distribution is unlimited.

**13. SUPPLEMENTARY NOTES**
~~Copies are available from the National Technical Information Service, 5285 Port Royal Road, Springfield, VA 22161.~~
Not Sent

**14. ABSTRACT**

Fort Riley is responsible for maintaining and protecting approximately 290 historic structures, all of which contribute in some way to the significance of the three Fort Riley Historic Districts listed on the National Register of Historic Places. Virtually all of Fort Riley's historic structures are in active use and require continuous maintenance or rehabilitation in order to keep them functioning in support of the mission while remaining presentable to project a positive installation image.

Some historic buildings at Fort Riley have unsightly stains forming on their stone surfaces. The identity of the stains was unknown and therefore untreatable. A study of the stains and appropriate removal techniques were needed to help Fort Riley to preserve facility aesthetics while complying with requirements of the National Historic Preservation Act.

The objectives of this study were to (1) identify the stains, (2) establish and test safe and effective methodology for removing the stain from a small sampling of historic buildings at Fort Riley, and (3) provide recommendations for appropriate preservation and maintenance treatments of Fort Riley limestone masonry for future management.

**15. SUBJECT TERMS**
Ft. Riley, KS
historic buildings
historic preservation
limestone
maintenance & repair
mycelium

| 16. SECURITY CLASSIFICATION OF: | | | 17. LIMITATION OF ABSTRACT | 18. NUMBER OF PAGES | 19a. NAME OF RESPONSIBLE PERSON |
|---|---|---|---|---|---|
| | | | | | Julie L Webster |
| a. REPORT | b. ABSTRACT | c. THIS PAGE | | | 19b. TELEPHONE NUMBER (include area code) |
| Unclassified | Unclassified | Unclassified | SAR | 42 | 217-373-6717 |

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