



*Replicating the John J. Earley Concrete Mix  
to Restore the*

# *Nashville Parthenon*

**Historic Cast Stone & Concrete: Preservation, Restoration  
& Replication Techniques**

**NTHP Field Session**

**A Closer Look – 10 Years After**

*Nashville Parthenon Restoration*



QUINN EVANS  
ARCHITECTS

# What is Concrete?

...a mixture of sand, gravel, and crushed rock or other aggregate held together by a hardened paste of cement and water.

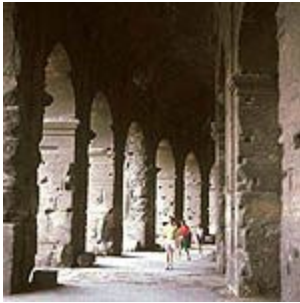


When water is added to the dry ingredients, the mix undergoes a chemical reaction and hardens.

*Parthenon, Nashville, TN*

# A Brief of History of Concrete...

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Romans discovered that if they mixed lime putty with pozzalana, a fine volcanic ash, the two formed a mixture that set strongly and hardened under water.

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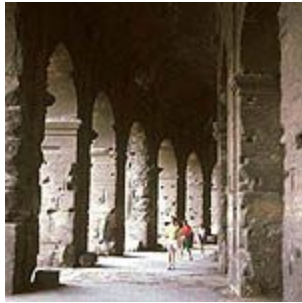


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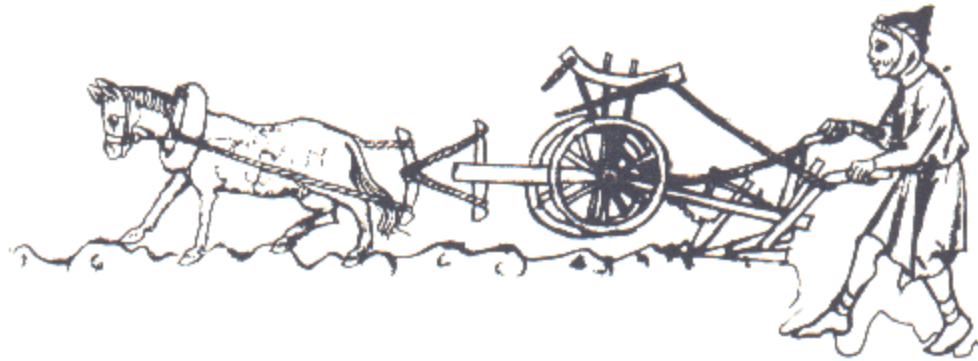
This was the first hydraulic cement, a major component of roman building practice, and was used for buildings, bridges,



and aqueducts.

## A Brief of History of Concrete...

During the Dark Ages, the use of concrete died out, except in isolated locations where natural cements existed.



## A Brief of History of Concrete...



*Thomas Fuller House  
Beaufort, SC - ca. 1786*

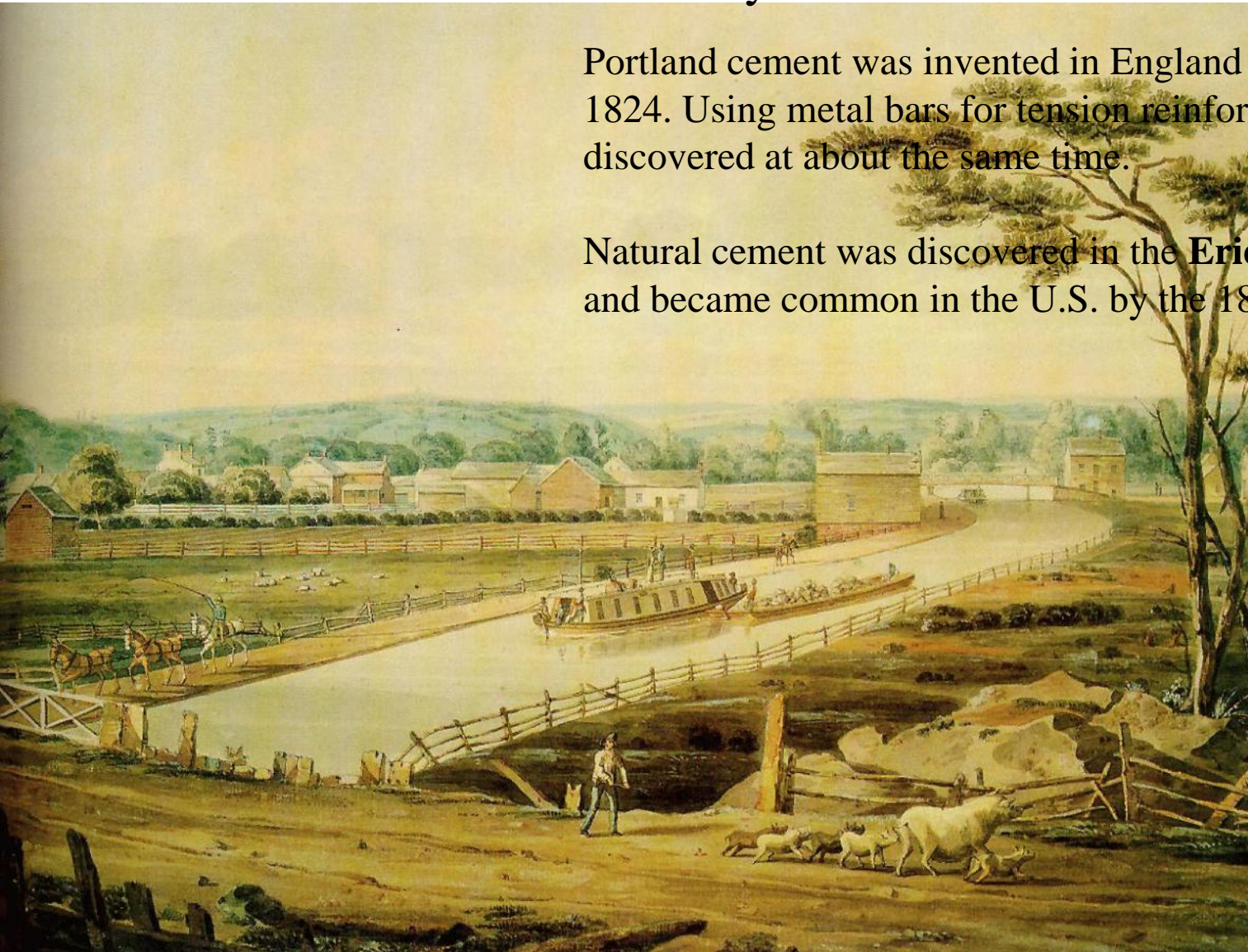
Southern coastal areas used a mixture of lime, sand, and an aggregate of shells, gravel, or stone mixed with water to create “tabby.”

The Spanish introduced “tapia” or “tabby” construction along the East Coast in the early 1500's. They burned shells to extract lime, then mixed it with sand, shells, gravel or stone mixed with water. This mass was shaped in great wooden molds to form durable walls and pillars arising one foot at a time.

## A Brief of History of Concrete...

Portland cement was invented in England and patented in 1824. Using metal bars for tension reinforcement was discovered at about the same time.

Natural cement was discovered in the **Erie Canal** in 1818 and became common in the U.S. by the 1850s.



*Erie Canal, 1829*



## Brief of History of Concrete...

Portland cement was first manufactured in the U.S. in Pennsylvania in 1871. - grinding together, firing, and regrinding roughly 2 parts limestone and 1 part clay or shale – reliability of cements led to increased acceptance after 1900.

*Fallingwater, PA,  
built in 1939*



*Baha'i Temple, IL, built in 1933*

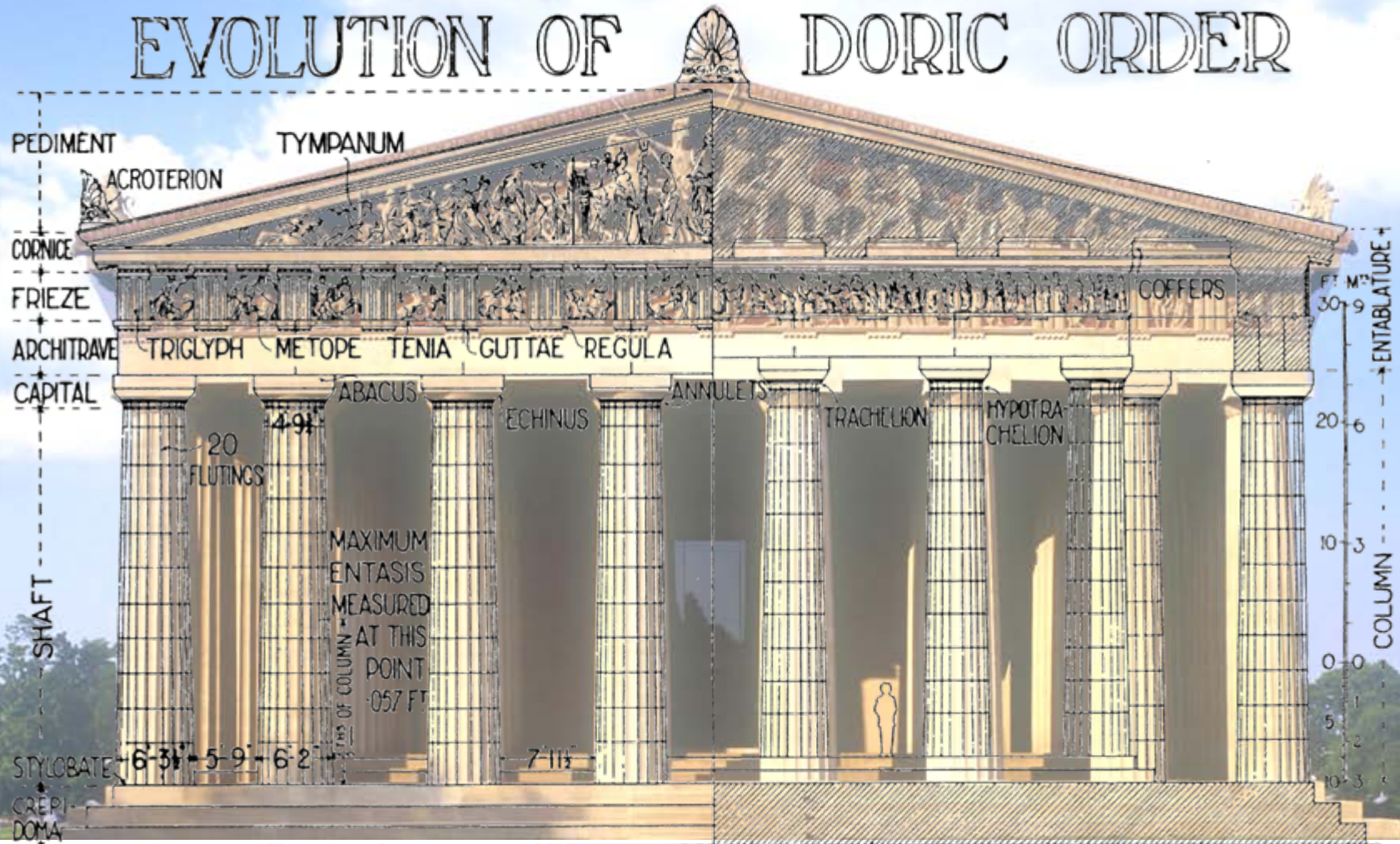
Concrete is differentiated from other cement-water-aggregate mixtures by its aggregate size:

- Fine aggregates less than 1/4" are for mortar, stucco, or cement plaster.
- Coarse aggregates greater than 1/4" added to cement, fine aggregates and water make concrete.



The Nashville Parthenon is constructed of concrete with decorative aggregates that simulate the color and texture of quarried stone.

# EVOLUTION OF DORIC ORDER



(A) HALF ELEVATION OF PARTHENON

(B) HALF SECTION THRO' PORTICO

“Evolution of Doric Order” reference drawing from *Sir Bannister Fletcher’s A History of Architecture*, revised 18th Edition. Charles Scribner’s Sons, New York. 1975, p. 205.

1897



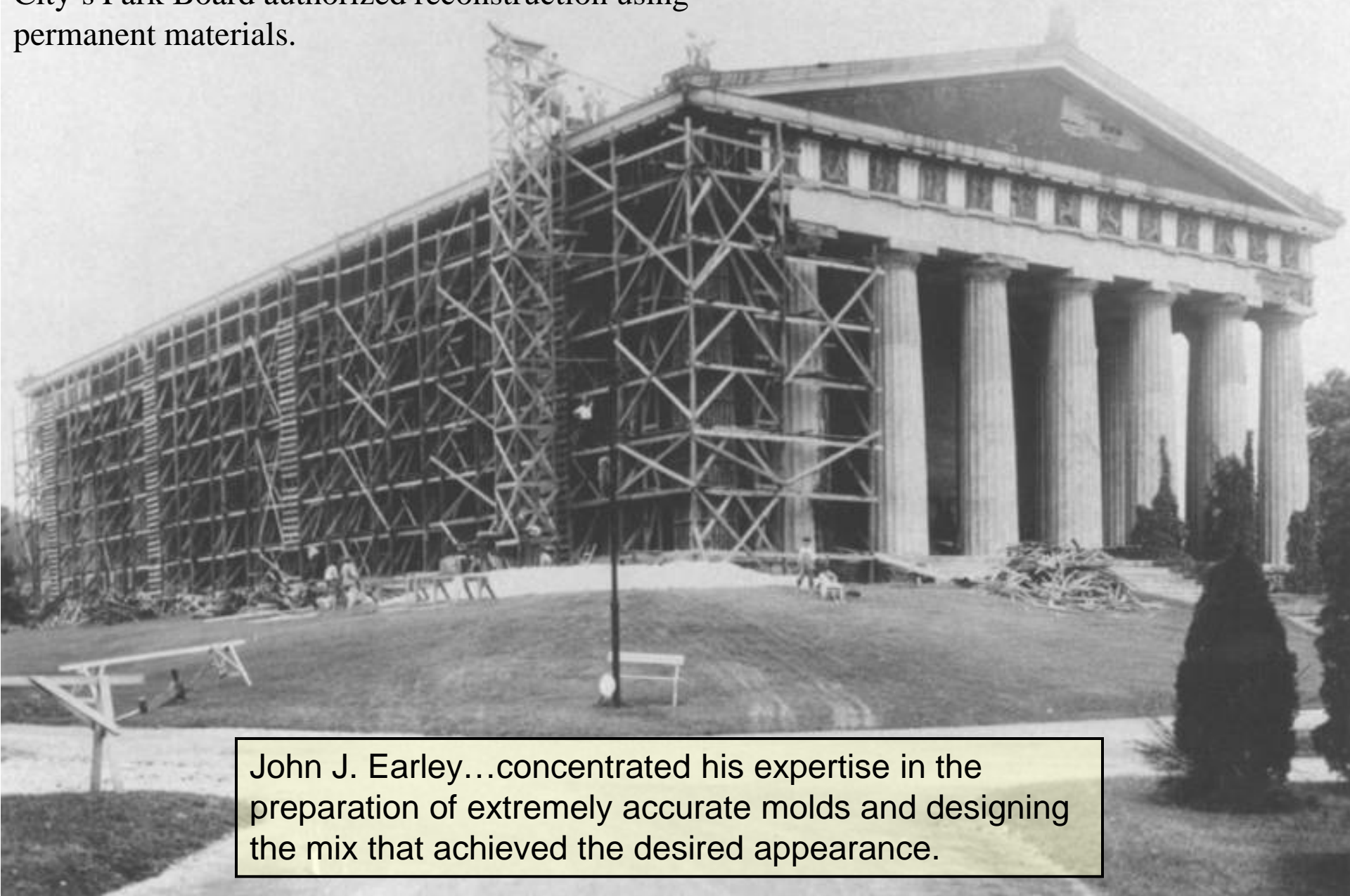
The Parthenon reflected the city's reputation as the "Athens of the South"

1897 Centennial Exposition included a full scale replica of the Parthenon to house an international art exhibition



**1925**

By 1921, conditions were so deteriorated that the structure was unsafe. Rather than lose their popular landmark, the City's Park Board authorized reconstruction using permanent materials.



John J. Earley...concentrated his expertise in the preparation of extremely accurate molds and designing the mix that achieved the desired appearance.

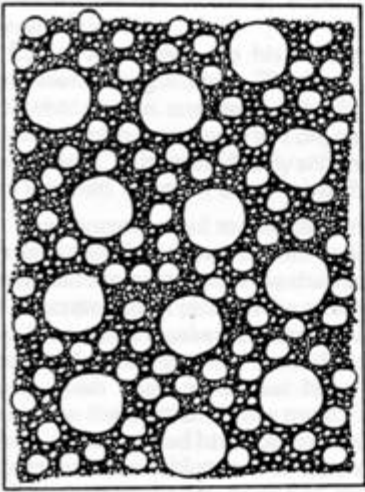


Fig. 1. Uniformly Graded Mix, With Particles Well-Distributed

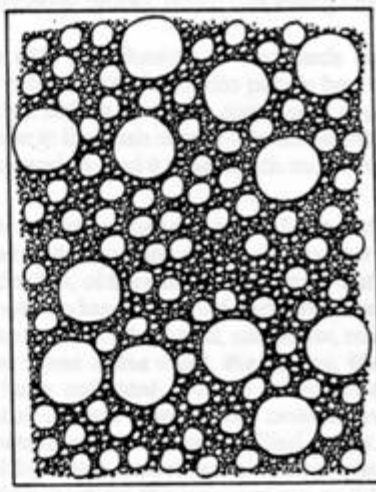


Fig. 2. Uniformly Graded Mix With Particles Bunched In Pockets

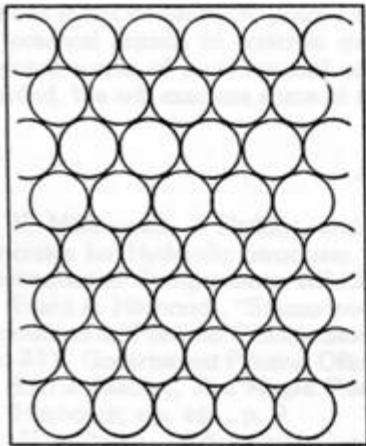


Fig. 3. Spheres On A Flat Surface

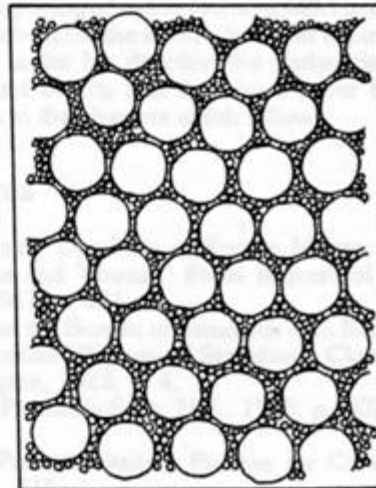


Fig. 4. Step-Graded Mix Of Two Particle Sizes. Ratio Of Particle Diameters Is 10:1

Typical mix for structural concrete in the early 20<sup>th</sup> century was 1:2:4 or one part cement to two parts sand and four parts gravel, or a 1:2 ratio of total aggregates

Earley's concrete mix experimentation (from *The Man Who Made Concrete Beautiful*) resulted in a possible 1:10 ratio of total aggregates, instead of the typical 1:2 ratio



West Pediment 1897 sculptures of Erechthonius, Hermes, and Athena were salvaged and modeled in clay by New York sculptors Belle Kinney and Leopold Scholz and recast on site under Earley's supervision



George Julian Zolnay, who had done the pediment sculptures for the 1897 replica...



...made clay models of the metopes, which were shipped to Earley's studio in Washington, DC and cast in concrete.



Parthenon exterior was restored and the interior redesigned to replicate the historic interior plan and a lower level museum and gallery of art

**1931**



By the late 1980s, the exterior concrete had deteriorated and again posed a risk to the visiting public

**1994**



1994



- Samples were taken from all over the building for study and analysis:
- whole roof tiles, weathered and stock
  - chunks from sculpture elements
  - cores from sound material

Tests included:

- petrography
- chloride content
- compressive strength
- freeze-thaw

...but did not result in determining the exact mix, due to great variety in samples



Results influenced the mix design of the repair concrete:

- coarse aggregates of siliceous gravel,  $\frac{1}{4}$ " top size, light gray and dark buff, hard and angular
- fine aggregates of natural and crushed siliceous sand, composed of light gray and light buff-colored quartz
- beige cement matrix with high cement content
- low water-cement ratio
- low chloride content
- low air content, too low for protection against freeze thaw damage
- compressive strength 6,320 to 9,140 psi



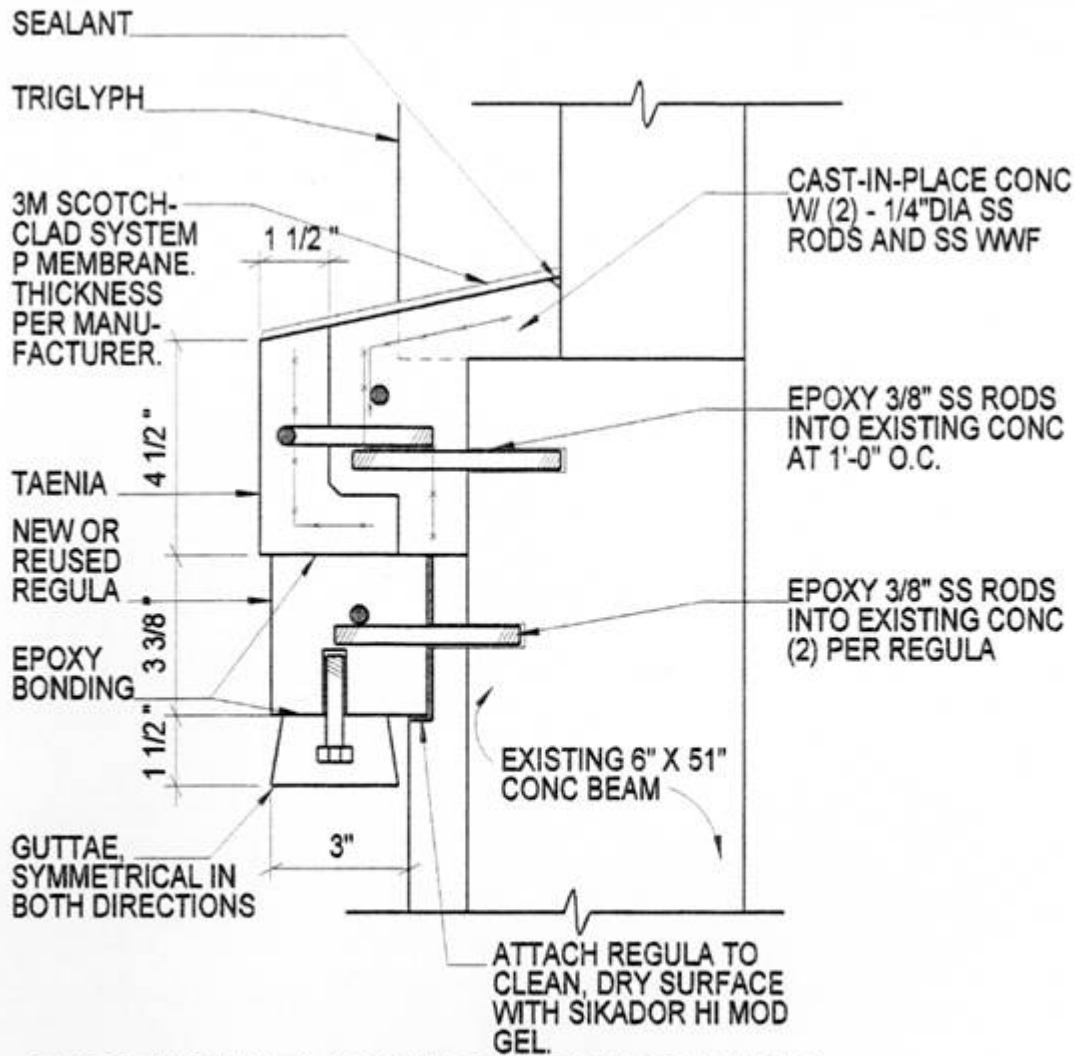


Cross-sectional photograph  
through regula and guttae

### Mix Design:

White cement	94 lbs.
Nutty pebble, size A	47 lbs.
Brown, size A	235 lbs.
Bar sand	94 lbs.
Yellow pigment	94 grams
Black pigment	47 grams
Water	375 fl. ozs.
MB Acryl Set	125 fl. ozs.

Actual mix is 1:1:3 or one  
part cement to one part sand  
and three parts pebble  
aggregate, or a 1:3 ratio of  
total aggregates



## SECTION THROUGH TRIGLYPH

SCALE: 3" = 1'-0"



Section through Triglyph, and mockup sample, show typical cast-in-place concrete and anchoring of pre-cast elements.



BLUE GRISW 3 @ stone      ARE eye-

WHITE	-	40.455 oz =	2.528 LBS
GREY	-	40.455 oz -	2.528 LBS
BLUE 1/8-3/16	-	<del>108 oz</del> 108 oz	<del>7.125 LBS</del> 6.75 LBS
BLUE FINES	-	14.4 oz	14.4 oz
WHITE PLAY SAND		50.64 oz	3.165 LBS
WATER	-	18 oz - 16.5	18 oz
LATEX		18 oz 16.5	18 oz

Pre-cast pieces produced by  
 J.B. & Sons, Incorporated in  
 central New Jersey



25

J.B. & Sons work area for measuring, mixing, and curing pre-cast elements



Assembly-line preparation of box geison



Red and blue colored grout is buttered into the mold and vibrated for 2-3 seconds



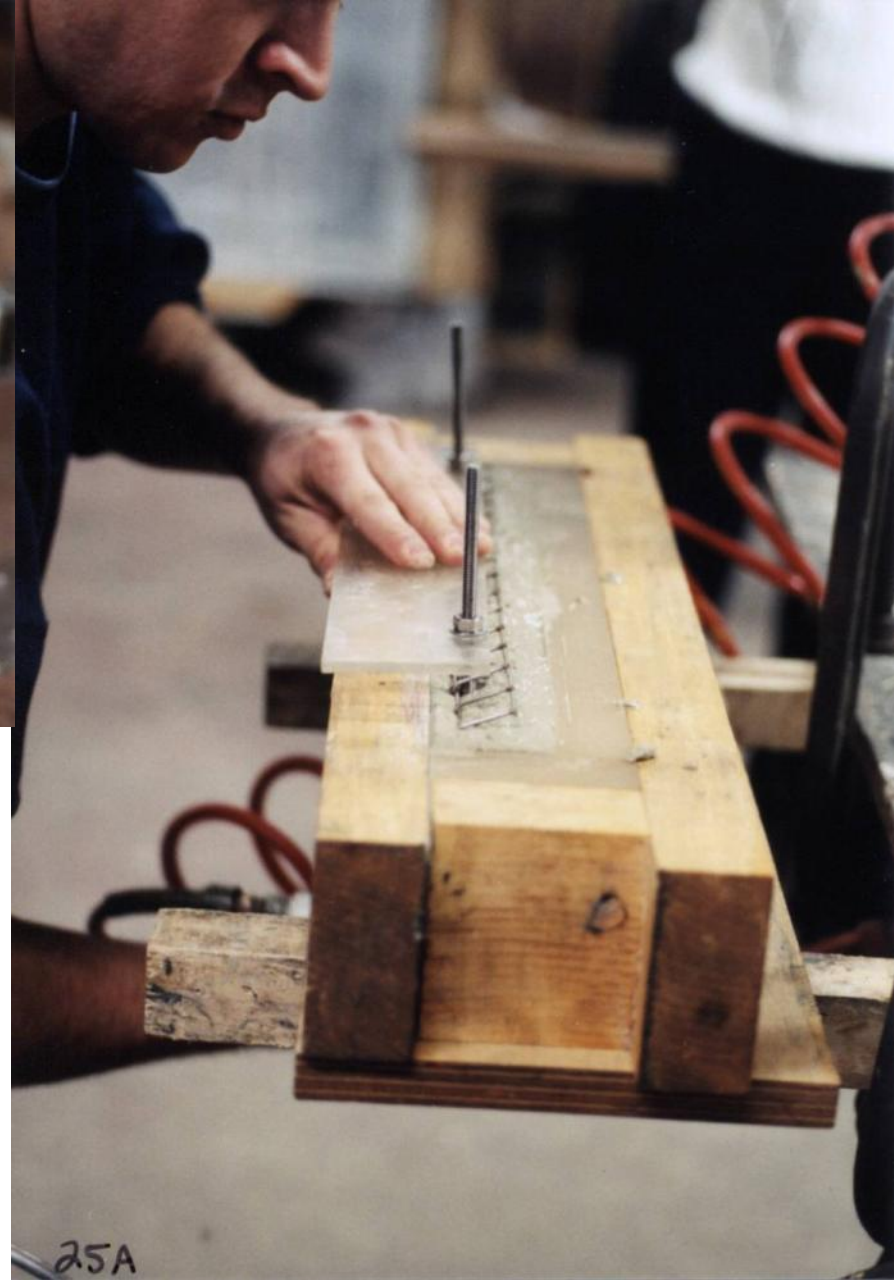
After curing for 45 minutes, buff-colored mix is poured to fill mold flush



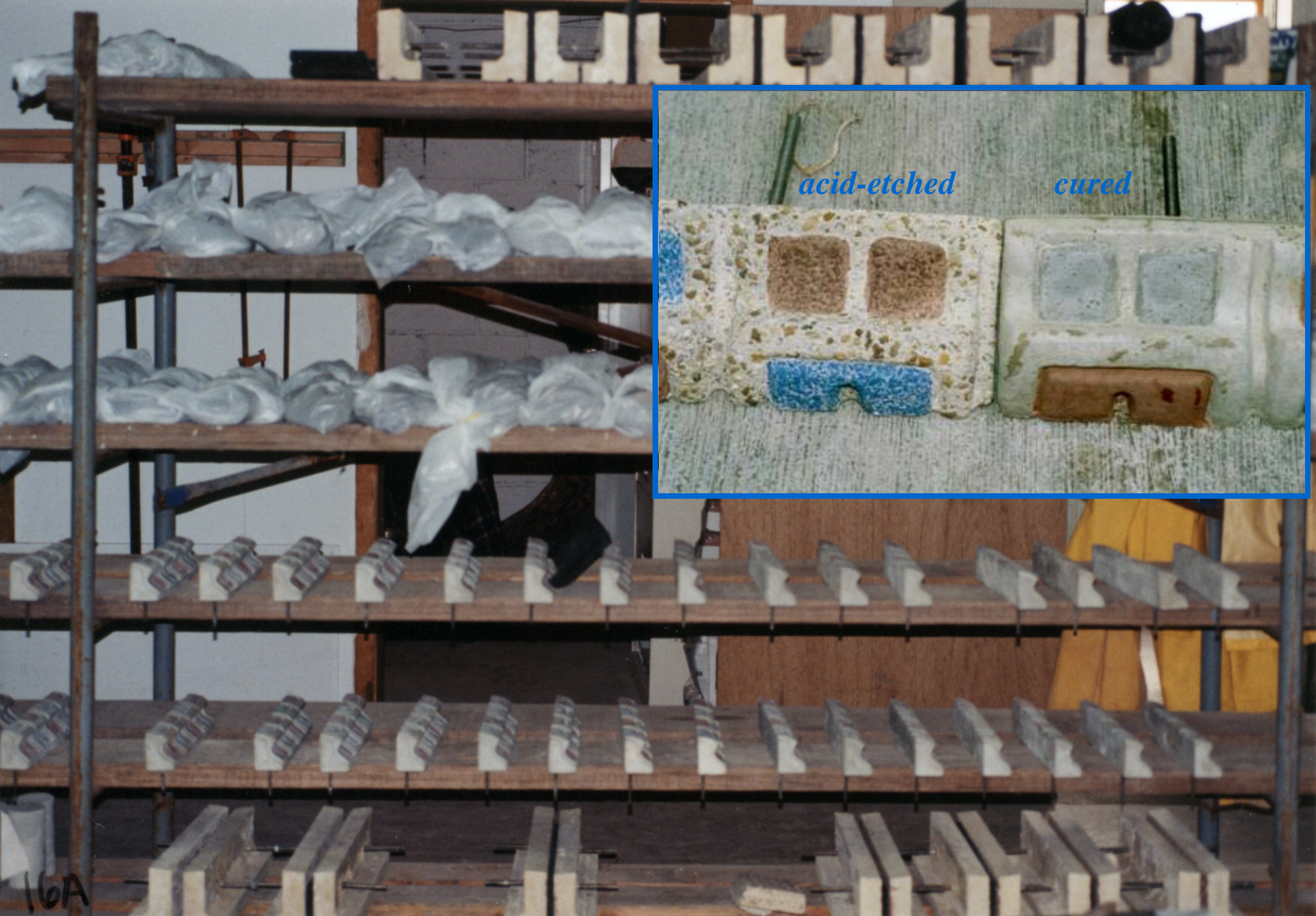
Brief vibration settles mixture into the mold, ready for reinforcement



Stainless steel reinforcement is pre-formed for insertion into the box form



2-3 minute vibration ensures no voids and releases air bubbles



Cured in burlap and plastic for 7 days, then acid-etched to expose the aggregate

EPOXY DOWEL 1/4" DIA  
SS THREADED ROD INTO  
3/8" DIA X 3" HOLE WITH  
HILTI HIT HY 150 INJECTION  
ADHESIVE OR EQUAL.

RECESS FOR SEALANT.

NEW PRECAST CONCRETE  
GEISON.

EPOXY DOWEL 1/4" DIA  
SS THREADED ROD INTO  
3/8" DIA X 3" HOLE WITH  
HILTI HIT HY 150 INJECTION  
ADHESIVE OR EQUAL. USE  
DOUBLE NUTS AND WASHERS  
TO SECURE 1" X 1" X 16 GA SS  
WIRE MESH WITH ONE  
FASTENER PER SQUARE FOOT.

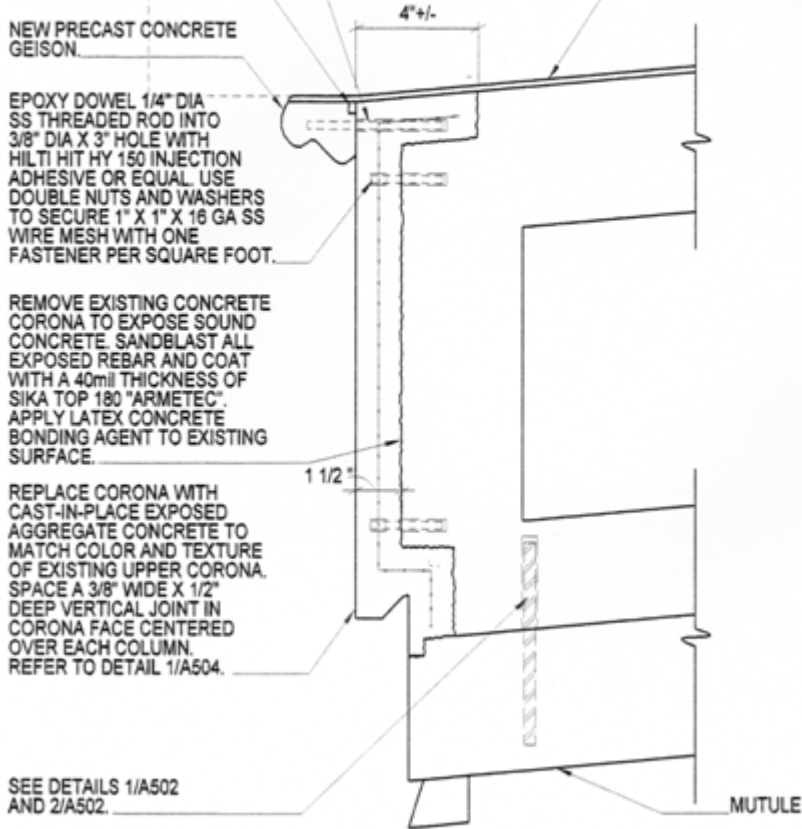
REMOVE EXISTING CONCRETE  
CORONA TO EXPOSE SOUND  
CONCRETE. SANDBLAST ALL  
EXPOSED REBAR AND COAT  
WITH A 40mil THICKNESS OF  
SIKA TOP 180 "ARMETEC".  
APPLY LATEX CONCRETE  
BONDING AGENT TO EXISTING  
SURFACE.

REPLACE CORONA WITH  
CAST-IN-PLACE EXPOSED  
AGGREGATE CONCRETE TO  
MATCH COLOR AND TEXTURE  
OF EXISTING UPPER CORONA.  
SPACE A 3/8" WIDE X 1/2"  
DEEP VERTICAL JOINT IN  
CORONA FACE CENTERED  
OVER EACH COLUMN. REFER TO  
DETAIL 1/A504.

SEE DETAILS 1/A502  
AND 2/A502.

PRECAST CONCRETE  
EAVE (NORTH AND SOUTH  
ELEVATIONS)

COAT PEDIMENT FLOOR  
AND TOP OF GEISON  
WITH 3M SCOTCH-CLAD  
SYSTEM P DECK COATING

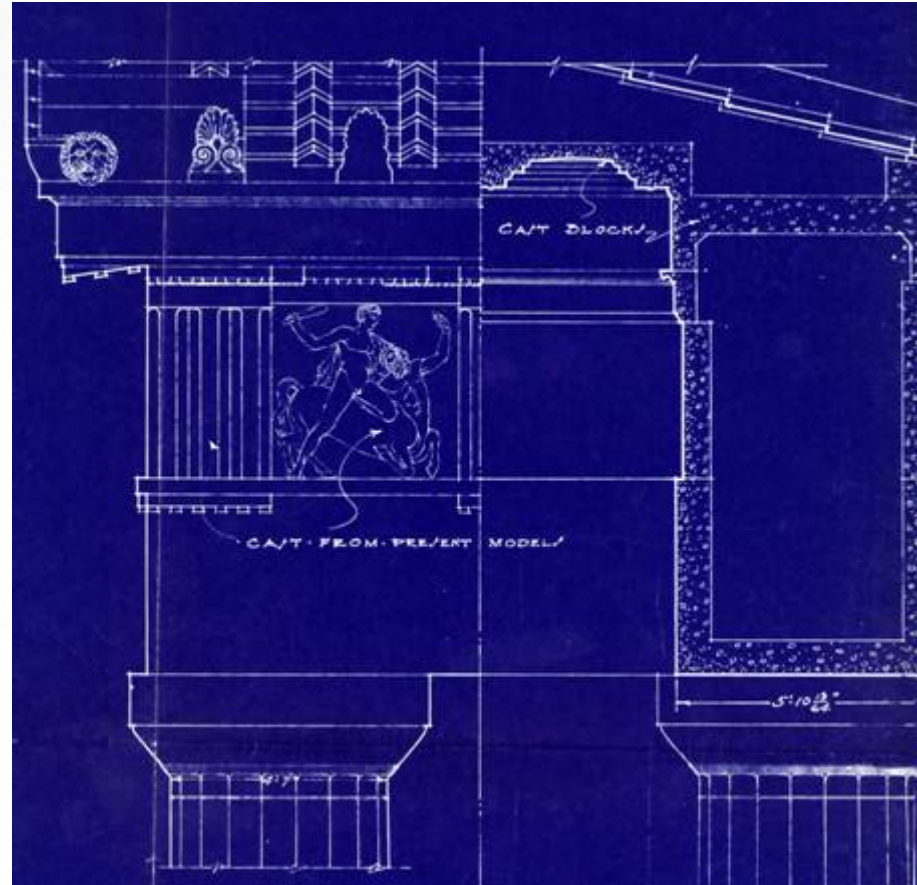


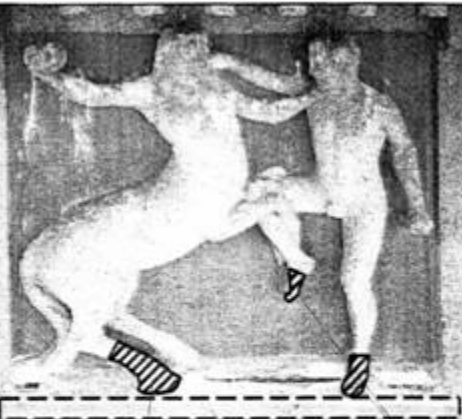
## SECTION THROUGH CORONA

SCALE: 3" = 1'-0"

1  
A224 A500  
A236

*1925 reconstruction drawing*





**W01**  
**NOTES:**

- 1 PATCH CRACKS.
- 2 PATCHED AND CRACKED SILL. REPAIR.
- 3 REPLACE MISSING FEET.
- 4 ERODED TOES. REPAIR.

**W02**  
**NOTES:**

- 1 SPALLED SILL AT BOTTOM WITH EXPOSED AND CORRODING REINFORCEMENT. CRACK EXTENDING FROM SPALL. REPAIR.

**W03**  
**NOTES:**

- 1 SMALL AREA OF EXPOSED AND CORRODED REINFORCEMENT IN RED PANEL. REPAIR.

**W04**  
**NOTES:**

- 1 CRACKED AND SPALLED SILL WITH EXPOSED AND CORRODING REINFORCEMENT. REPAIR.
- 2 REPLACE FEET.
- 3 REPLACE HOOF.

**KEY:**

- INSTALL PRECAST ELEMENT
- CRACK REPAIR
- IN SITU REPAIR
- EXPOSED REINFORCEMENT

**METOPE GENERAL NOTES:**

- 1. CUT OUT AND REPAIR JOINTS BETWEEN METOPE AND TRIGLYPH. CONTINUE REPAIR THROUGH SLOPED SILL. PATCH TRIANGULAR CORNERS WITH BUFF MIX. RAKE BACK JOINT AND FILL WITH SEALANT TO MATCH APPROPRIATE ADJACENT SURFACE. PRESS COLORED AGGREGATE INTO JOINT.
- 2. REMOVE SURFACE DEPOSITS, INCLUDING MORTAR DROPPINGS, EPOXY SLURRY, AND BIRD GUANO, USING APPROVED METHODS.

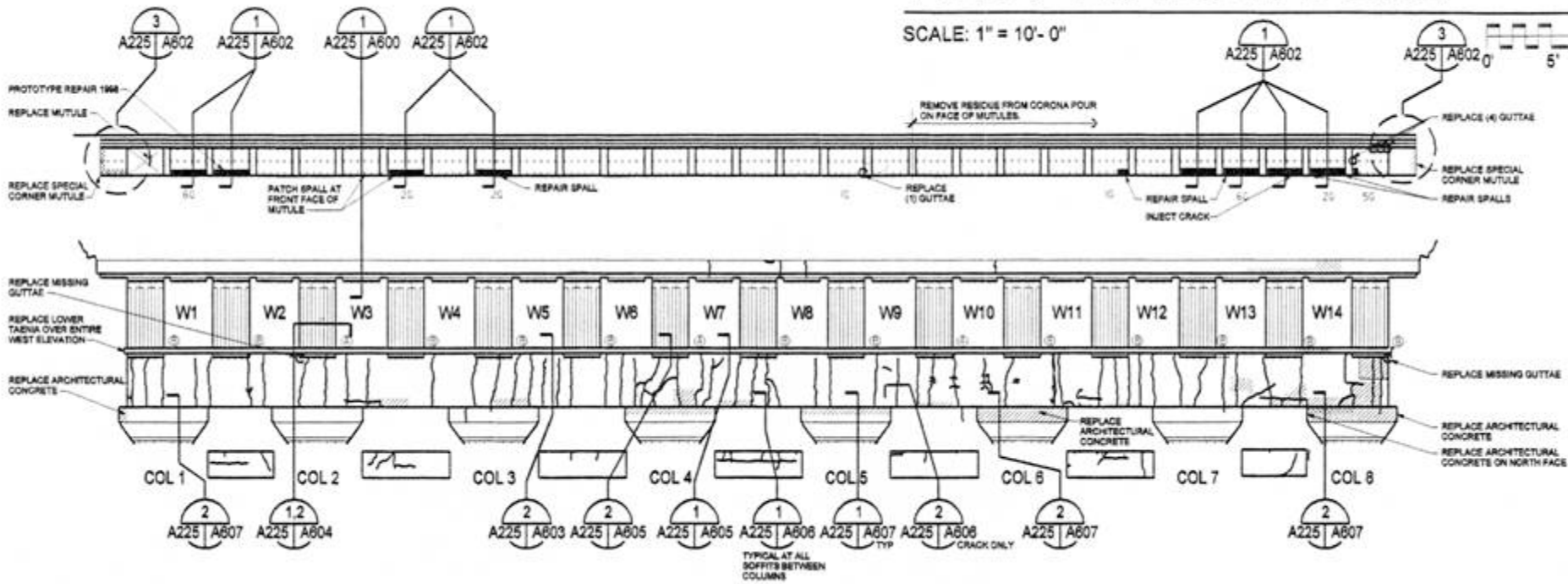
**The Parthenon**  
Nashville, Tennessee

West Elevation  
QE/A # 97128-04

Restoration Architect: <b>QUINN EVANS ARCHITECTS</b> Ann Arbor, MI 734.663.5888	Architectural Conservator: Tracy Coffing Pittsburg, PA 412.761.2724	Structural Engineer: Ross Bryan Associates, Inc. Nashville, TN 615.329.1500	Drawing Title Metopes: W01-04 Date 100% Check Set 16 June 2000 Sheet Number A220
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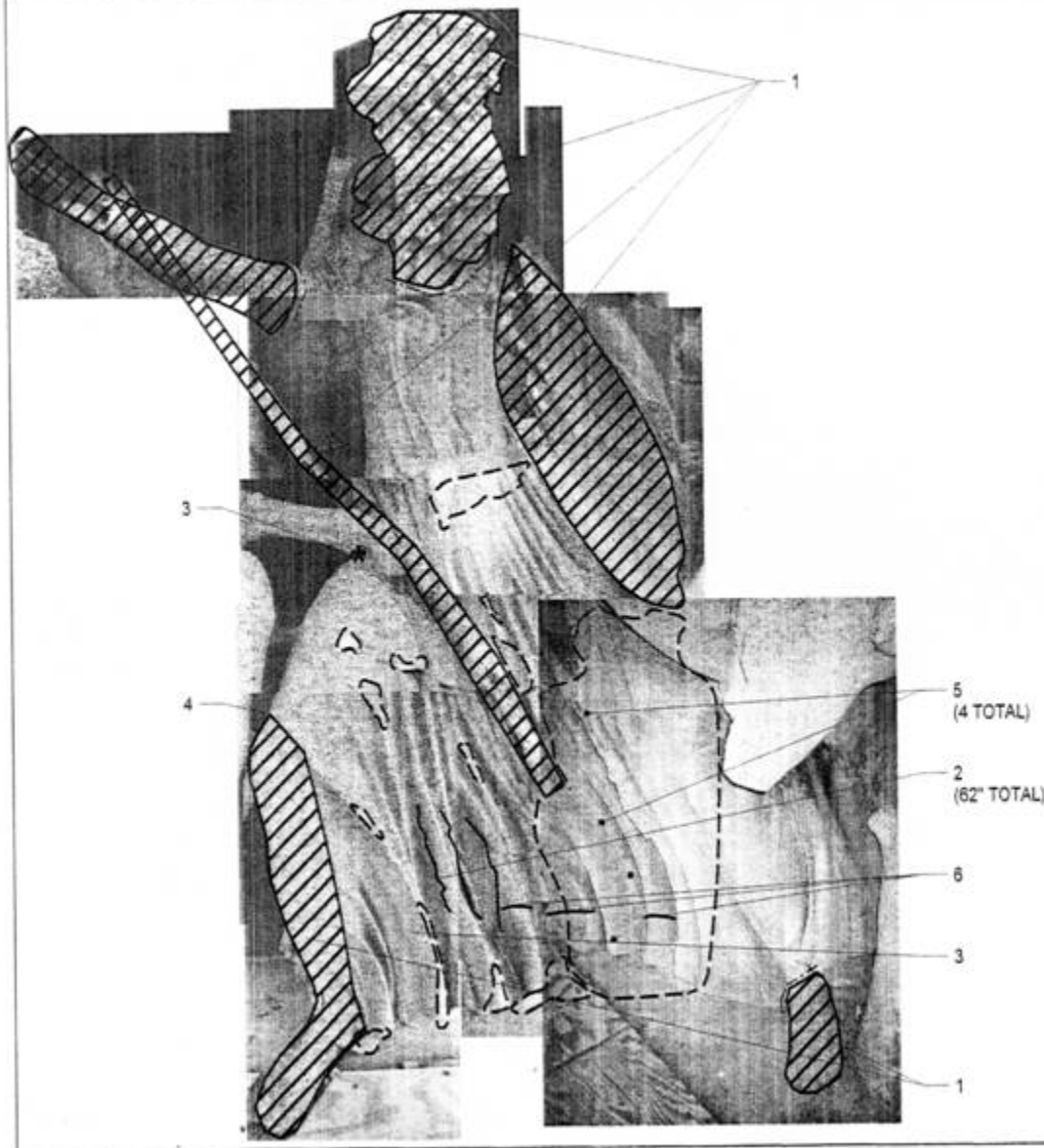
# WEST ENTABLATURE

SCALE: 1" = 10'-0"











# WEST 09: Athena



## KEY:

	INSTALL PRECAST ELEMENT		NEW CUT LINE
	IN SITU REPAIR		CRACK REPAIR
	REMOVE SURFACE DEPOSITS		EXPOSED REINFORCEMENT

## WORK NOTES:

- 1 PROVIDE ELEMENTS.
- 2 REPAIR CRACKS IN SKIRT, TOTAL OF 62".
- 3 CLEAN EXPOSED REINFORCEMENT AND PATCH.
- 4 REPAIR LARGE SPALL BEHIND RIGHT LEG.
- 5 CUT OUT THREADED ANCHORS AND PATCH.
- 6 CUT OUT AND PATCH CRACKS.
- 7 PATCH TYMPANUM.

## STATUARY GENERAL NOTES:

1. SCULPTURE/MOLD MAKING/CASTING INCLUDES:
  - a. Remove excess concrete and reinforcing in preparation for sculpture/mold making/casting.
  - b. Prepare templates showing condition and location of existing reinforcing and profile of remaining sculpture at the removal interface.
  - c. Prepare substrate, and install new sculptural parts.
2. Remove surface deposits, including mortar droppings, epoxy slurry, and bird guano, using approved method.

## The Parthenon Nashville, Tennessee

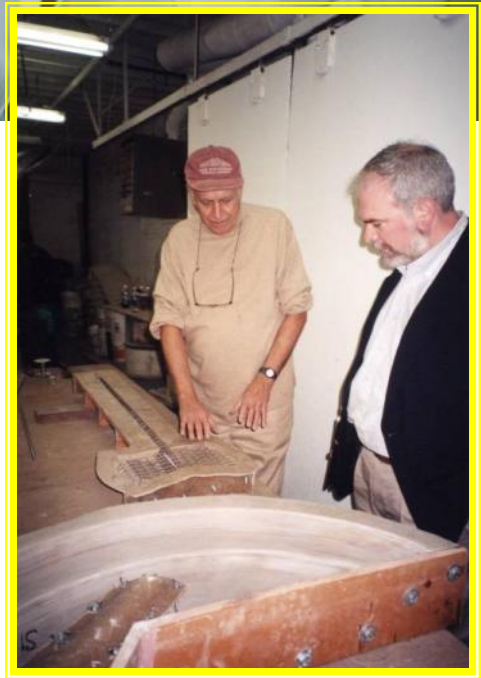
West Elevation  
QE/A # 97128-04

Restoration Architect: <b>QUINN EVANS ARCHITECTS</b> Ann Arbor, MI 734.963.5868	Architectural Conservator: <b>Tracy Coffing</b> Pittsburg, PA 412.781.2724	Structural Engineer: <b>Ross Bryan Associates, Inc.</b> Nashville, TN 615.329.1300	Drawing Title <b>Statuary: W09</b>
			Date 100% Check Set 16 June 2000
			Sheet Number A209

West pediment sculpture restoration drawing of Athena, shows types of repairs and extent of replacement elements.

Multi-step process:

- rough molds made on site
- initial castings in plaster
- touched up in the studio
- new fiber glass molds
- reinforcement to fit piece
- concrete casts in studio



*Dr. George Kreier*



Dr. Kreier's Philadelphia studio was a bone yard of body parts.



Dr. Kreier shows the project team how he'll reinforce the new pieces.



Finished pieces were delivered to the site in batches of 20-30 pieces - arms, legs, heads, and whole bodies.

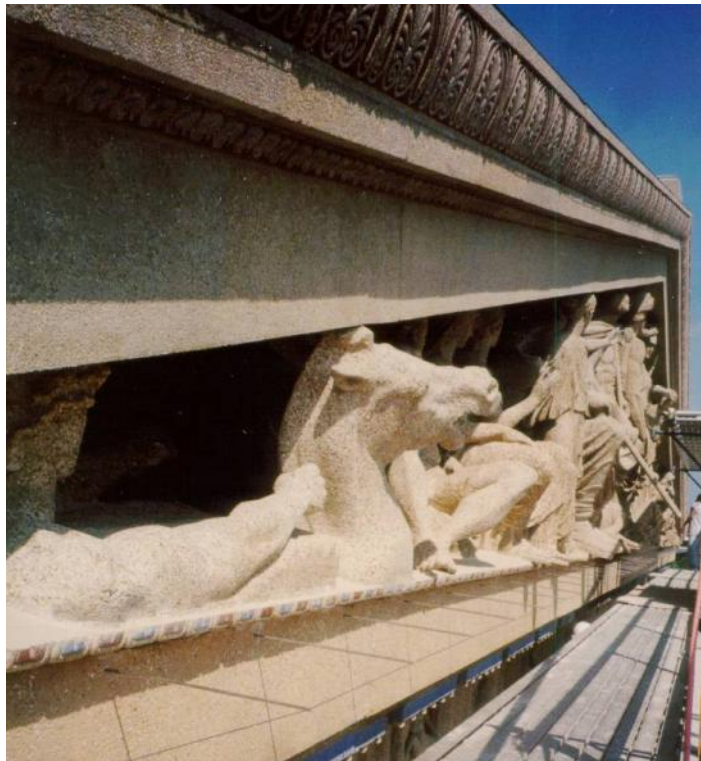


Dr. Kreier and Ken McAbee from Western Waterproofing test the mating of two pieces of the Athena sculpture before inserting anchoring steel and lifting her into position.



Tim Luppe from Orion inspects the close aggregate match in Dr. Kreier's new pieces.





Curt Garrigan and Wesley Paine test new arms.



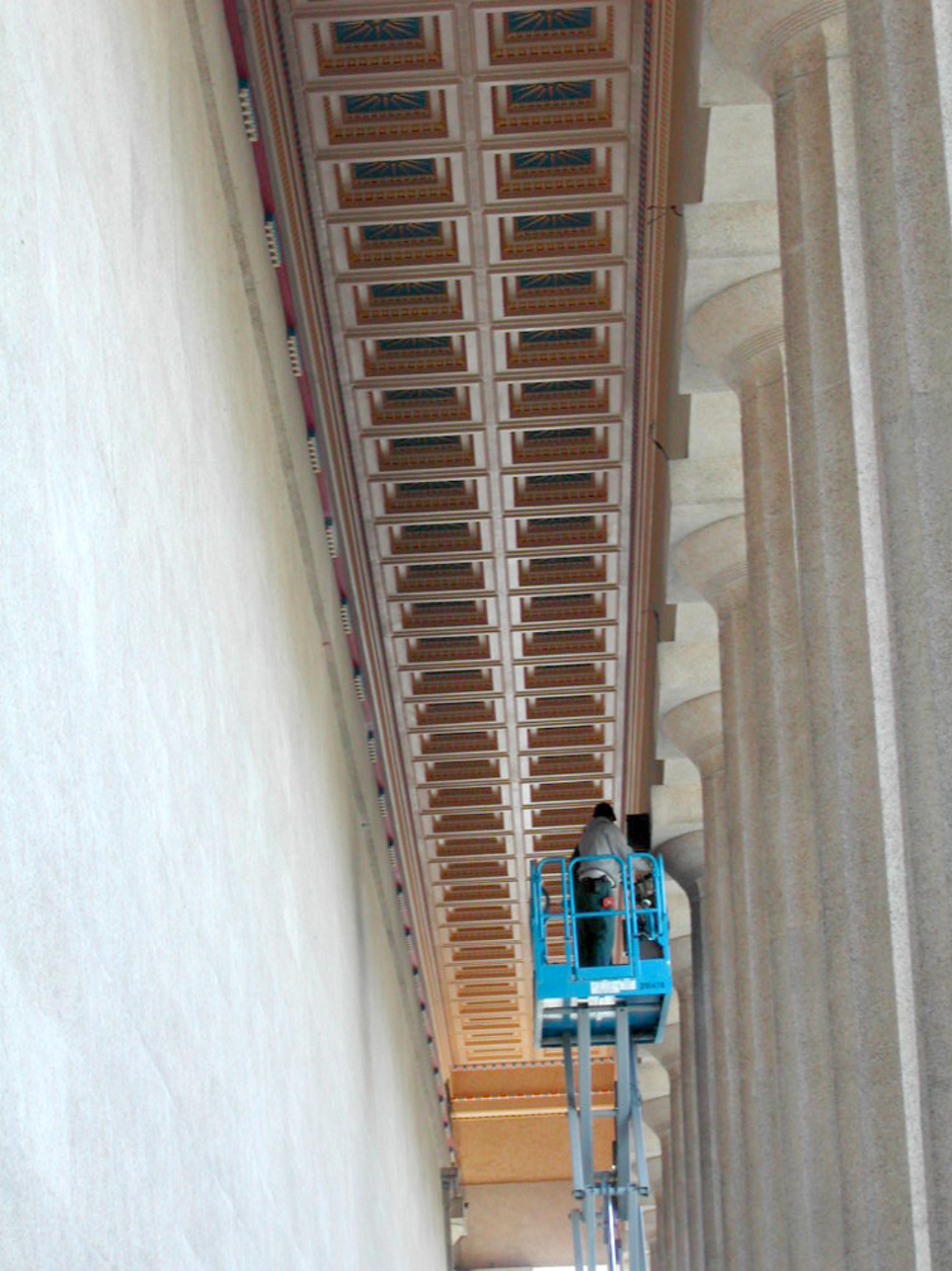
Artists worked from scaffolding to model large and small details in situ.









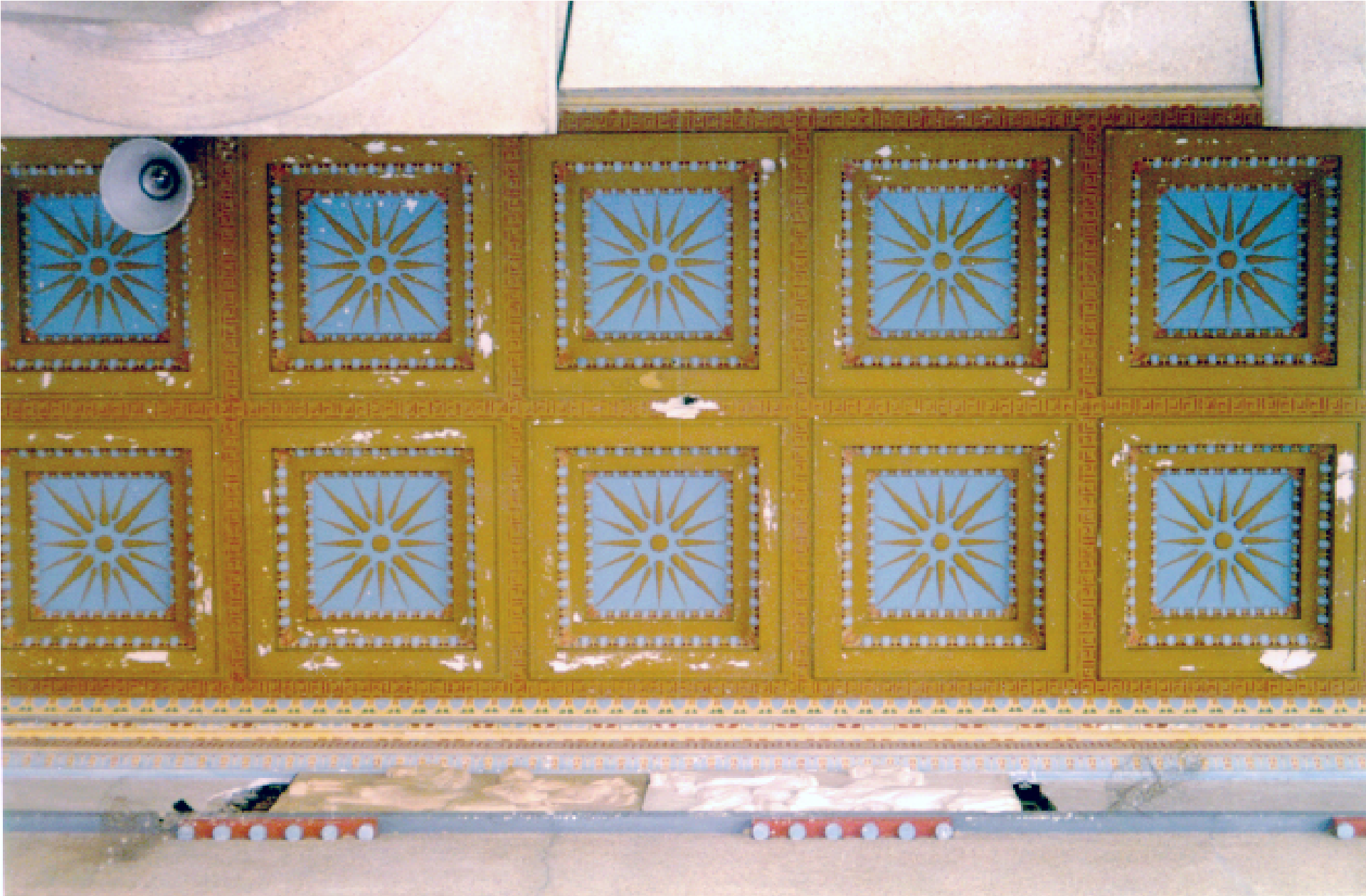


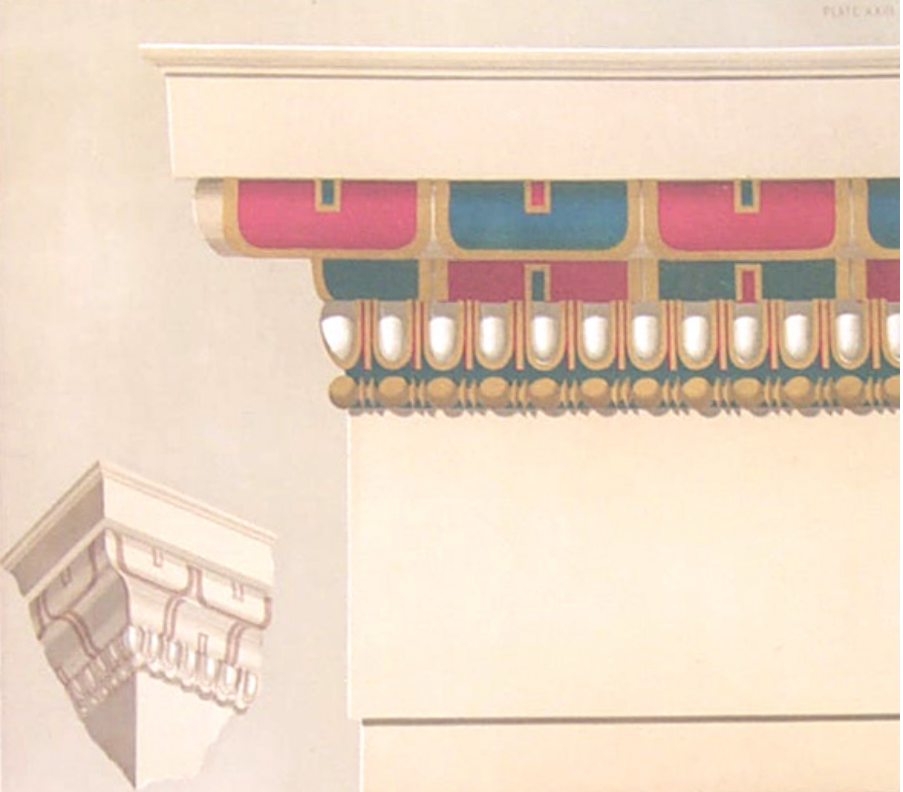
# Peristyle:

- Plaster
- Colors of Greece
- Lighting, and
- Pigeon Proofing







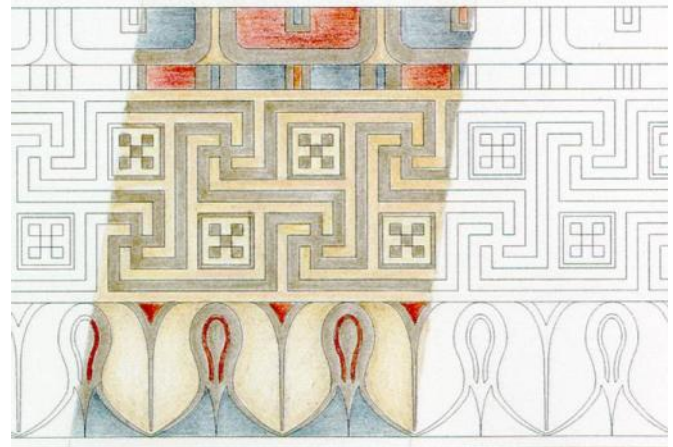
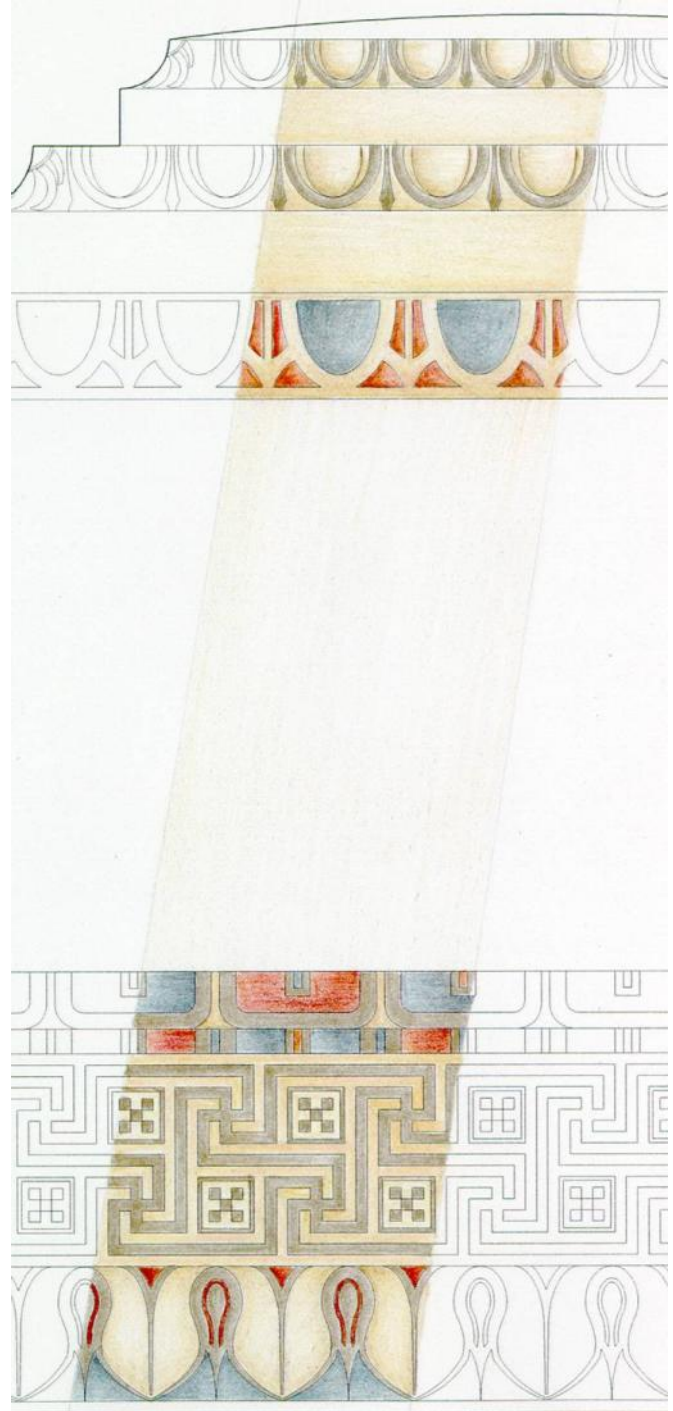


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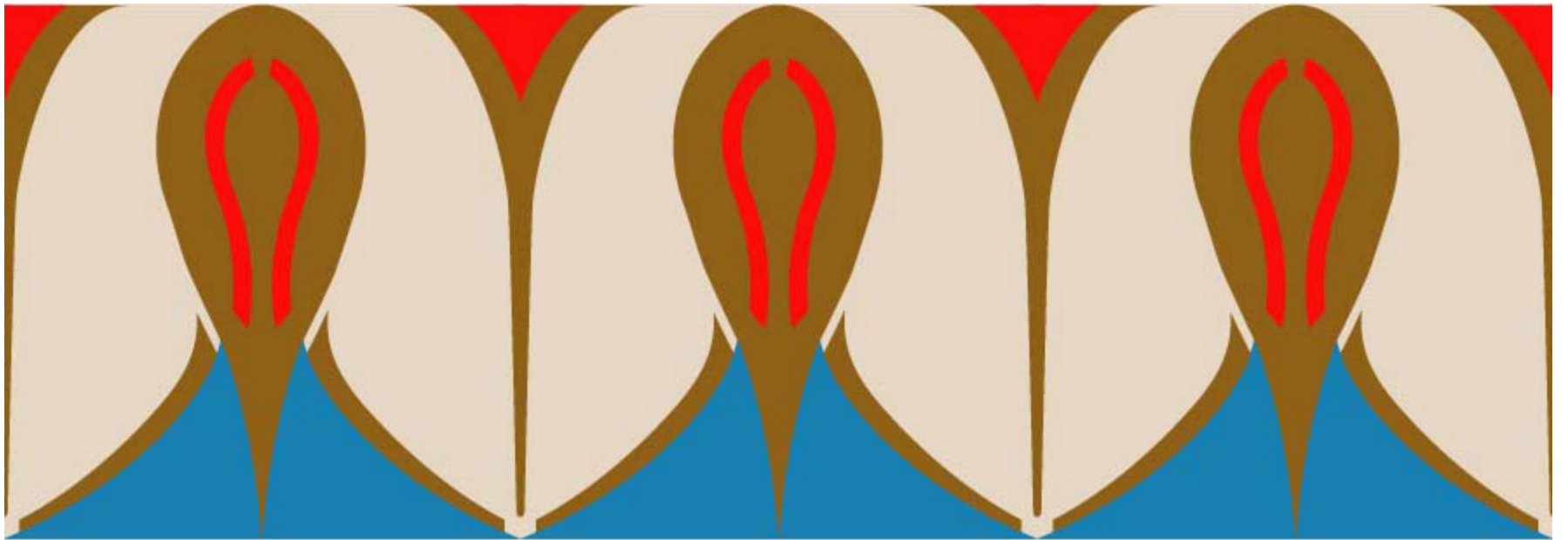


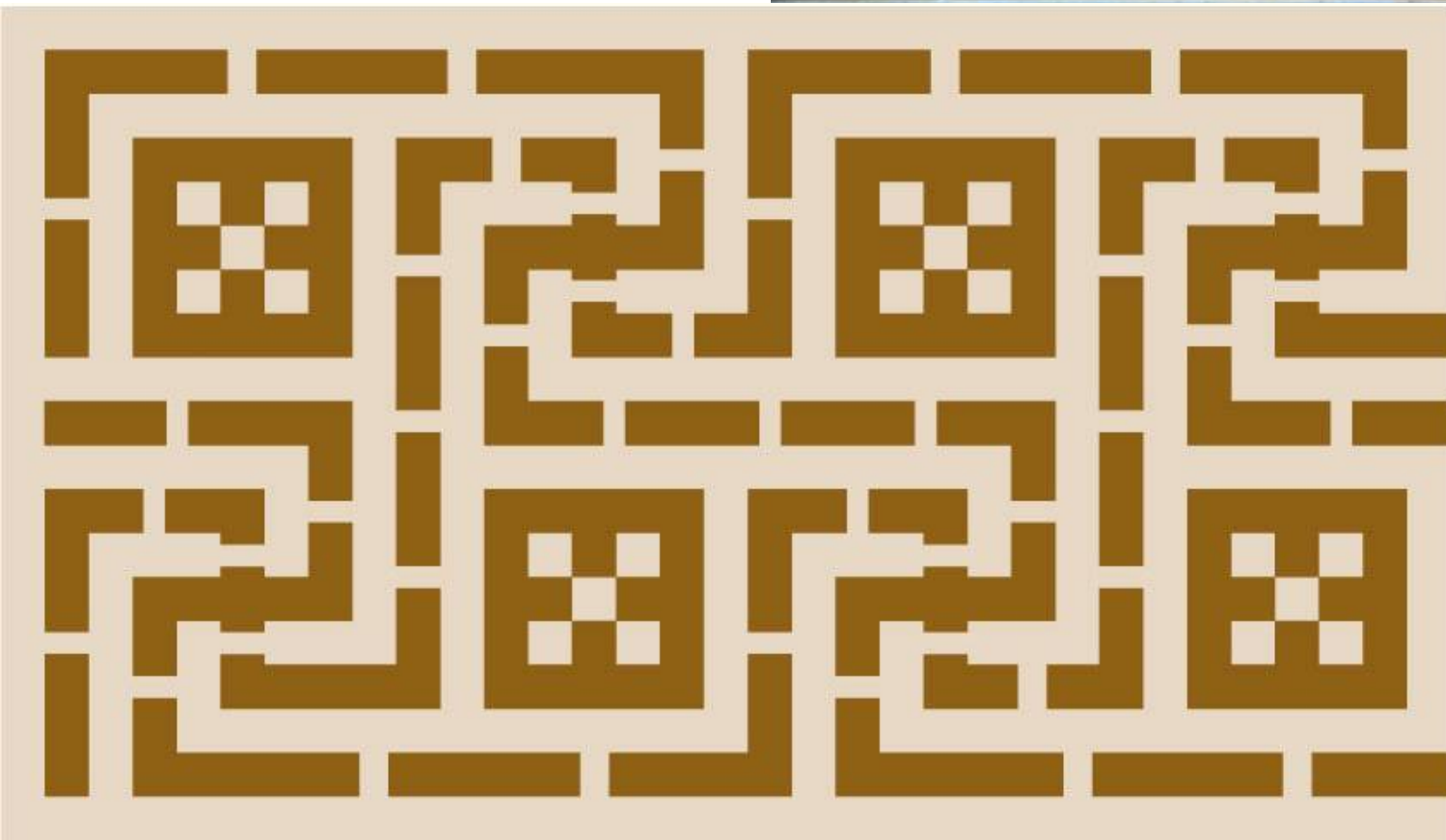
STRING COURSE OVER PANATHENIC FRIESE

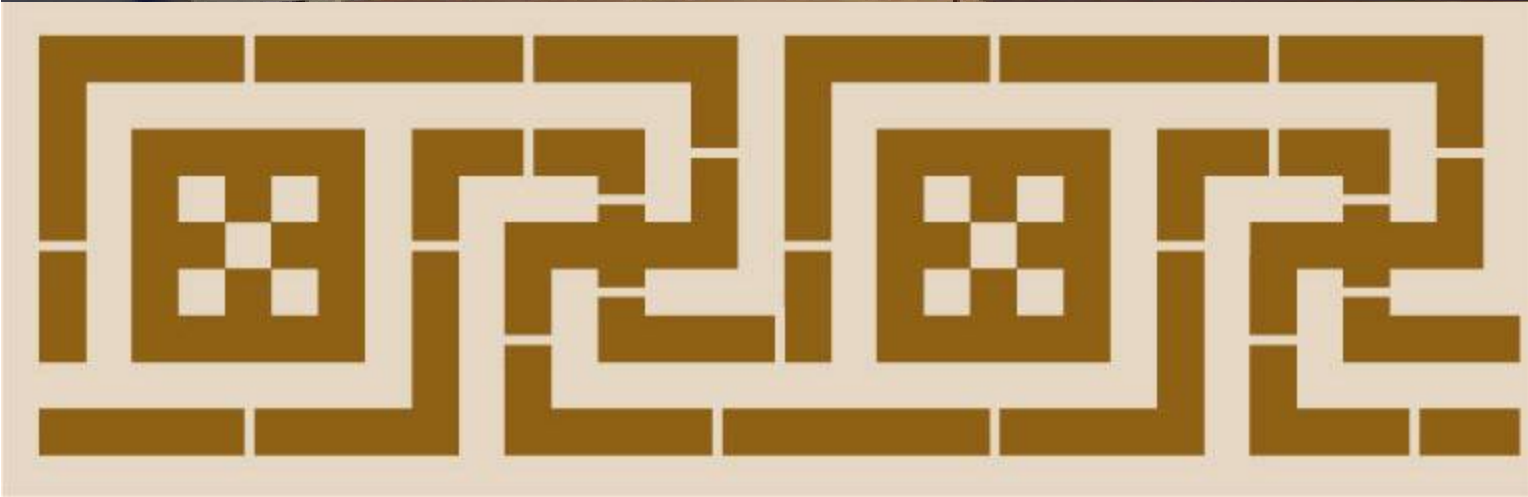
PARTHENON















# Peristyle:

- Final Cleaning





**Acroteria**



**Floral Acroteria**



# Gryphons

stabilized with epoxy ...



**Gryphons**

... then modeled with clay...



... and cast in concrete to be reset on their bases at the four corners of the roof.



Fake gryphons cast in a lightweight polymer material for the dedication “**fly-in**”



Free tours all day  
New Year's Eve



**... two cranes and shrouded surprise wait until dark**

