Evolution of Stone Cladding Technology: monitoring and intervention techniques for stabilization

(Un) Loved Modern Conference 2009

Sydney, Australia

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Introduction

Architectural Complexes

- United Nations Headquarters
  New York, New York
- Lincoln Center for the Performing Arts
  New York, New York
- Rockefeller Empire State Plaza,
  Albany, New York

A.

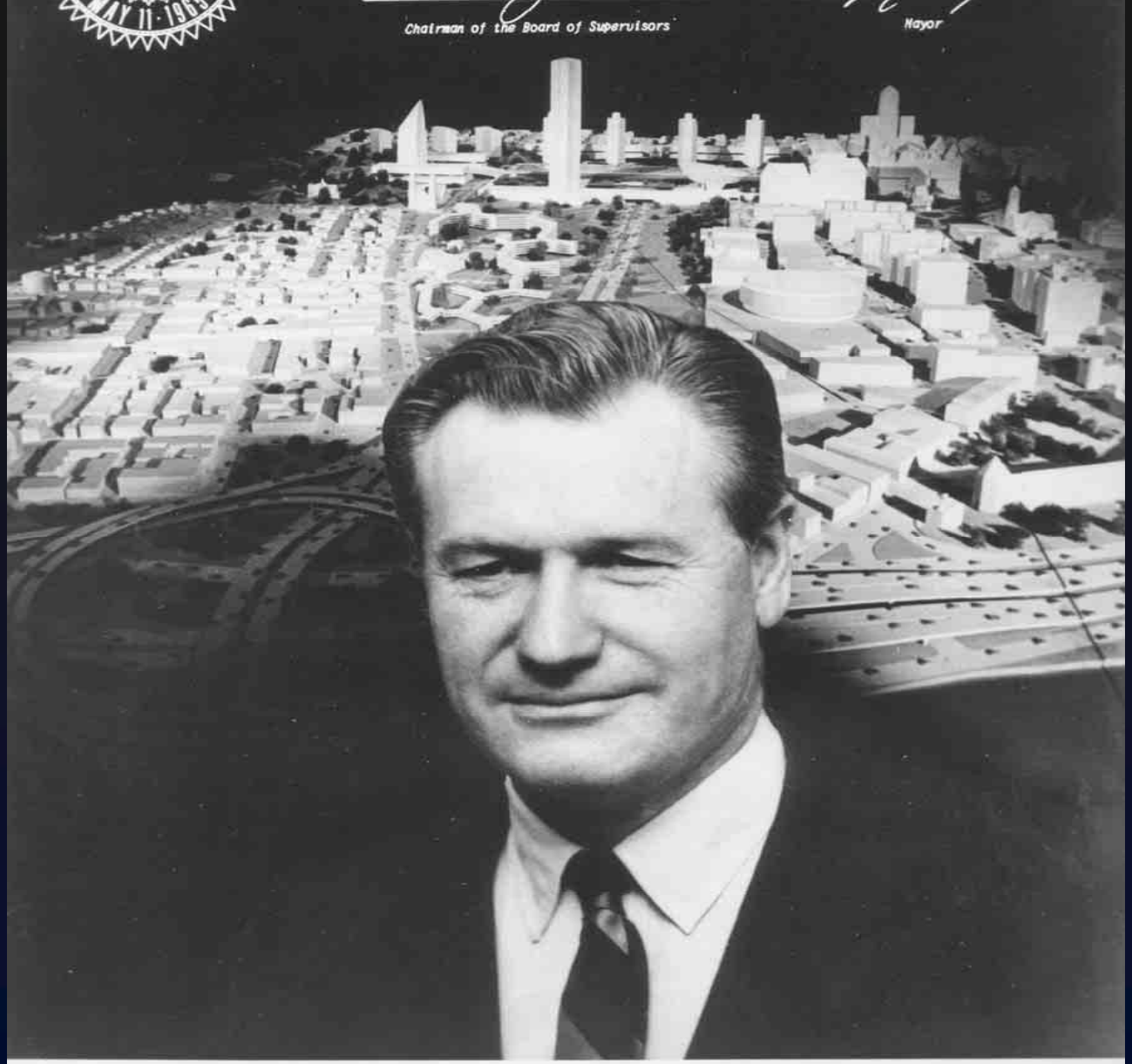
B.

C.

A. **United Nations Headquarters,** *New York, New York - built between 1947 - 1952*

B. **Lincoln Center for the Performing Arts,** *New York, New York - built between 1963 - 1970*

C. **Governor Rockefeller Empire State Plaza,** *Albany, New York - built between 1964 - 1972*



With personal appreciation for your important contribution to this

Empire State Plaza - Aerial View

Rockefeller Empire State Plaza - *125,000 Panels of Marble Dimension Stone*

Construction dates of Empire State Plaza

BUILDING	DATE
The Main Building Platform	
Swan Street Building	1971
The Justice Building	1972
Legislative Office Building (LOB)	1972
Erasmus Corning Tower	1973
Agency Buildings 1, 2, 3, and 4	1974
Cultural Education Center	1974
The Egg	1975

Marble Panels Distribution by Building

BUILDING	No. of panels
Swan Street Building	21,094
The Justice Building	6,637
Legislative Office Building (LOB)	12,990
Erasmus Corning Tower	26,810
Agency Buildings 1	8,291
Agency Building 2	8,427
Agency Building 3	8,395
Agency Building 4	8,264
Cultural Education Center	21,998
TOTAL:	**115,326**

Erastus Corning II Office Tower

West Rutland Vermont Marble

26,810 Panels

Corner Tower & Main Platform Building

Agency Buildings 2 and 3

West Rutland Vermont Marble

18,508 Panels

Agency Buildings 1 and 2

West Rutland
Vermont Marble

Legislative Office Building (LOB)

White Georgia
Cherokee
Marble

12,990 Panels

NORTH-WEST ELEVATION LOOKING SOUTH

The Justice Building

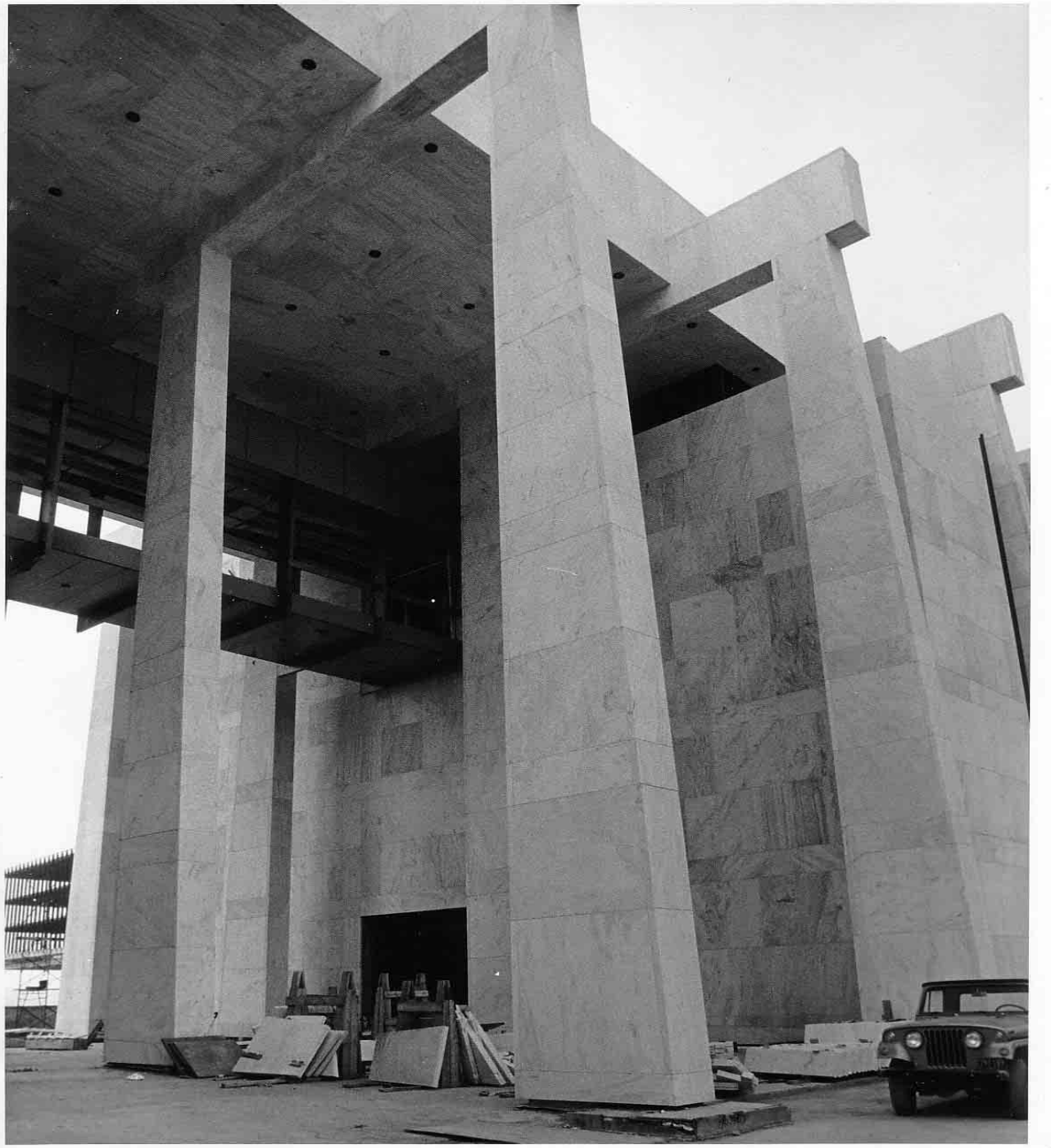
White Georgia Cherokee Marble

6,637 Panels

The Swan Building

White Georgia
Cherokee
Marble

21,094 Panels



The Cultural Education Center

Georgia Melange Marble

21,998 Panels

Investigation and Identification of Curtain Wall Technology:

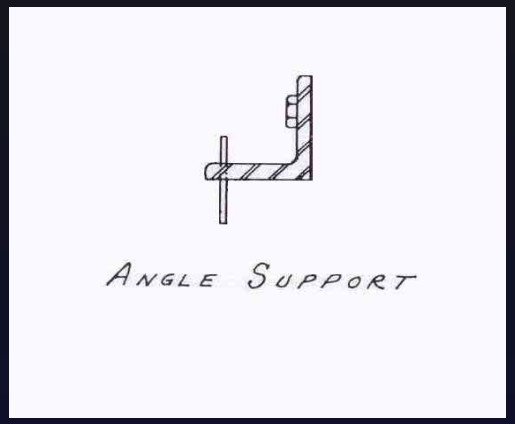
- Dimension Stone Cladding
- Identification of Stone Cladding Connections
- Stone Cladding Typology & Classification
  - Monolith Slab Wall
  - Vertical Clad Fins
  - Composite Marble Panels

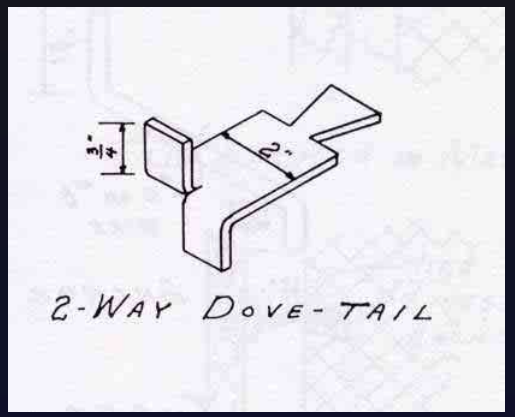
Dimension Stone Cladding

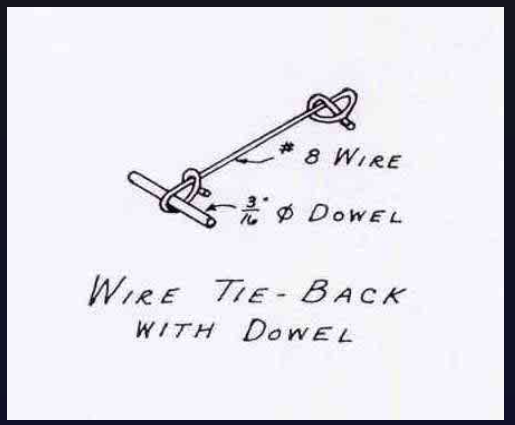
Rockefeller Empire State Plaza - *125,000 Panels of Marble*

Dimension Stone Cladding

Stone Cladding Connections

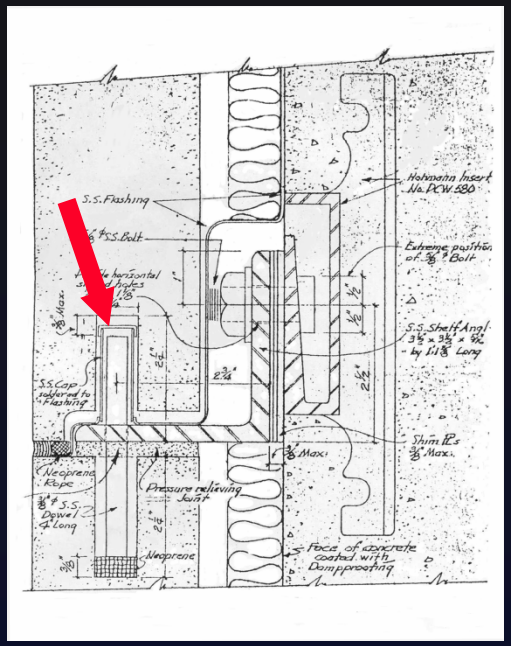






Stone panel connector types from an in-house manual developed in the 1960's by the Vermont Marble Company.

Stone Cladding Typology: Monolith Slab Wall



C.

A. B. D.

A. **Agency Building,** *20 Story Building - Installation of Vermont Marble Dimension Stone Panels*

B. **Agency Building Plan Section Drawing,** *Detail Vertical Section - Pin anchor at shelf Angle*

C. **Agency Building,** *Spall Deficiency* **D.** *Marble Panel out of plane, as highlighted by tangential light*

Stone Cladding Typology: Marble Clad Fins

A.

B.

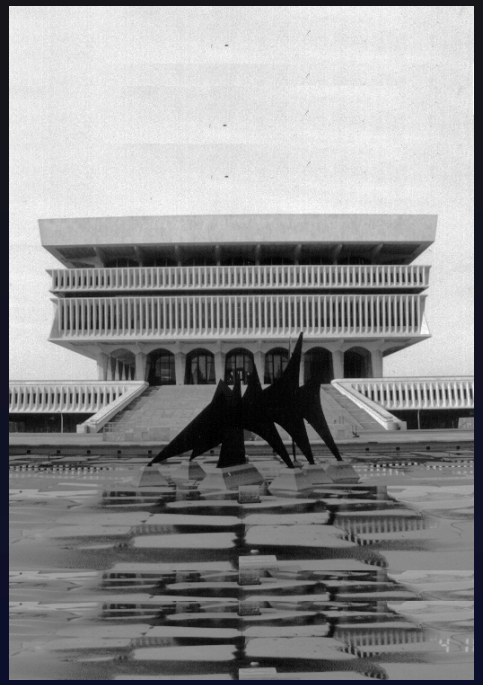
C.

A. **Agency Building,** *20 Story Building - Vermont Marble Stone Clad over concrete fins*

B. **Corning Tower,** *40 Story Building- Installation of Vermont Marble Dimension Stone Panels*

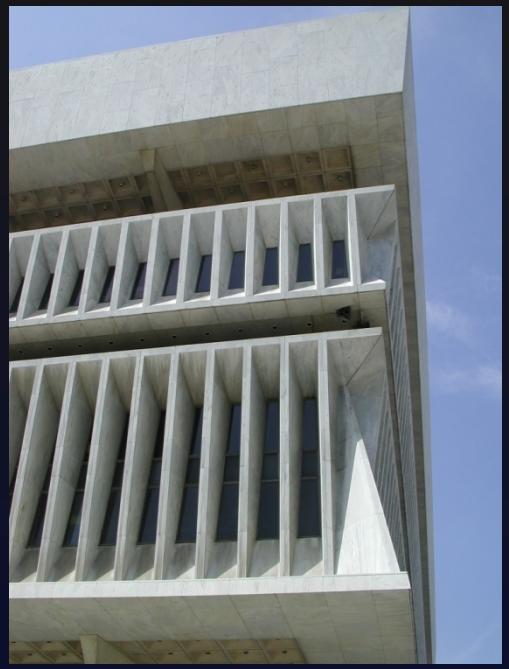
C. **Corning Tower,** *40 Story Building- Exposed anchor deficiency of Vermont Marble Panel*

Stone Cladding Typology: Composite Marble Panel



A.

B.



C.

A. **Cultural Education Center** - *Georgia Marble Prefabricated Composite Panel System*

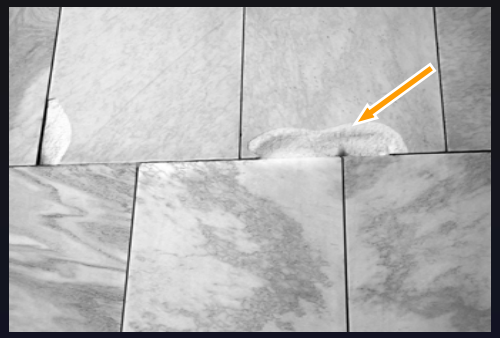
B. **Cultural Education Center -** *Fourth Level - Close up view of Octagonal Marble Clad Columns*

C. **Cultural Education Center -** *Close up view of 'Finned' Composite Marble Panel System*

Marble Cladding: Deficiency Categories

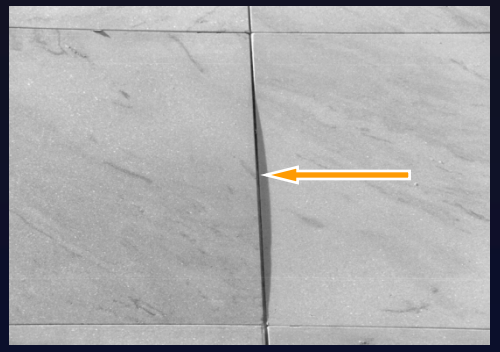
A.

C.



D.

B.



E.

A. **Crack at Marble Panel Backside -** *Incipient exfoliation of Marble Panel*

B. **Lean Top at Marble Panel -** *Marble panel shift out of plane or panel bow*

C. **Spall at Upper Left -** *Spall Deficiency* **D.** **Spall at Anchor** - *Spall Deficiency at Anchor*

E. **Panel Lean Lower Right -** *Panel shift out of plan, as highlighted by tangential light.*

Marble Stone Cladding: Previous Repairs

A.

B.

C.

A. Threaded Bolted Rods through Panel Wall

B. Random Traditional Dutchman Repairs at Marble Fascia

C. Anchor Bolt Stabilization through Marble Fascia

Monitoring Program for Stone Cladding and Curtain Wall Systems:

- Visual Observations and Survey
- Documentation of Deficiencies
- Database and Information Management
- Non-Destructive Testing (NDT)

Visual Observations & Survey

Lincoln Center for the Performing Arts -
New York State Theater, Industrial Rope Access during "Close-Up" Travertine Inspection

- Binocular Survey
- "Close-up" Inspection via hanging scaffold or "bucket truck"
- Industrial Rope Access

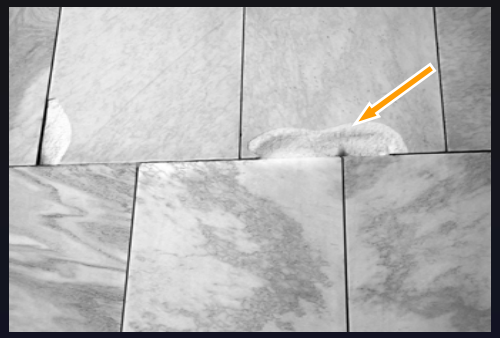
Documentation of Deficiencies

- Hand Held Computer Devices
- Information Management through catalog databases
- AutoCAD Drawings that are linked to catalog database information

Marble Stone Cladding: Deficiency Categories

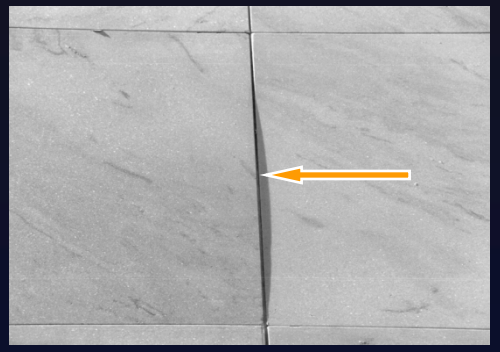
A.

C.



D.

B.



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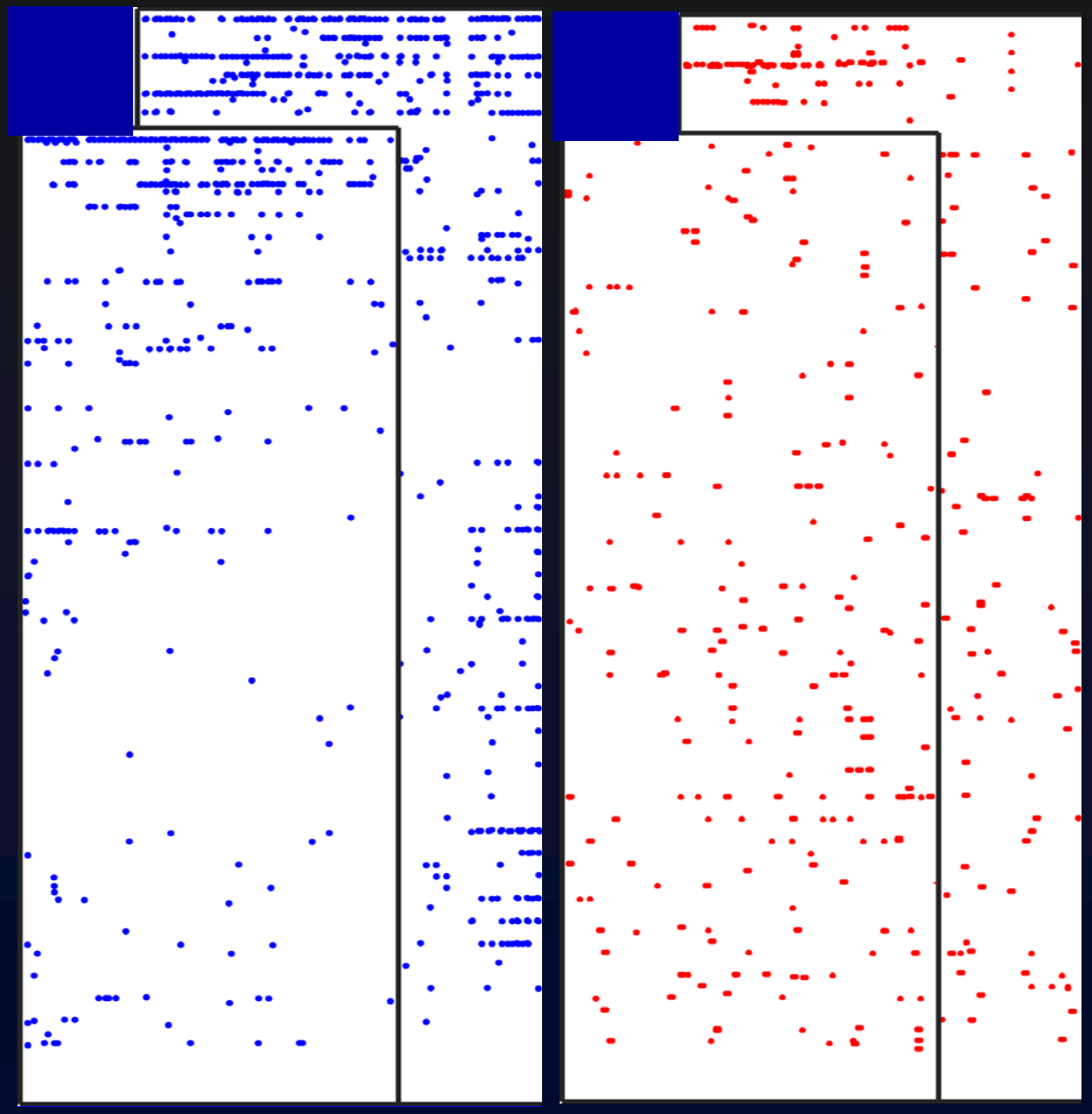
E. **Panel Lean Lower Right -** *Panel shift out of plan, as highlighted by tangential light.*

PATTERNS OF MARBLE DISTRESS

Cracking is concentrated at higher areas and corners of tower corresponding to higher wind speed



Spalling is randomly distributed

Marble Stone Cladding: Previous Repairs

A.

B.

C.

A. **Threaded Bolted Rods through Panel Wall**

B. **Random Traditional Dutchman Repairs at Marble Fascia**

C. **Anchor Bolt Stabilization through Marble Fascia**

Non-Destructive Testing (NDT)

- Impact Echo & Pulse Velocity Instrumentation
  - *One of several NDT methods that can be used in assessing the quality of stone*.

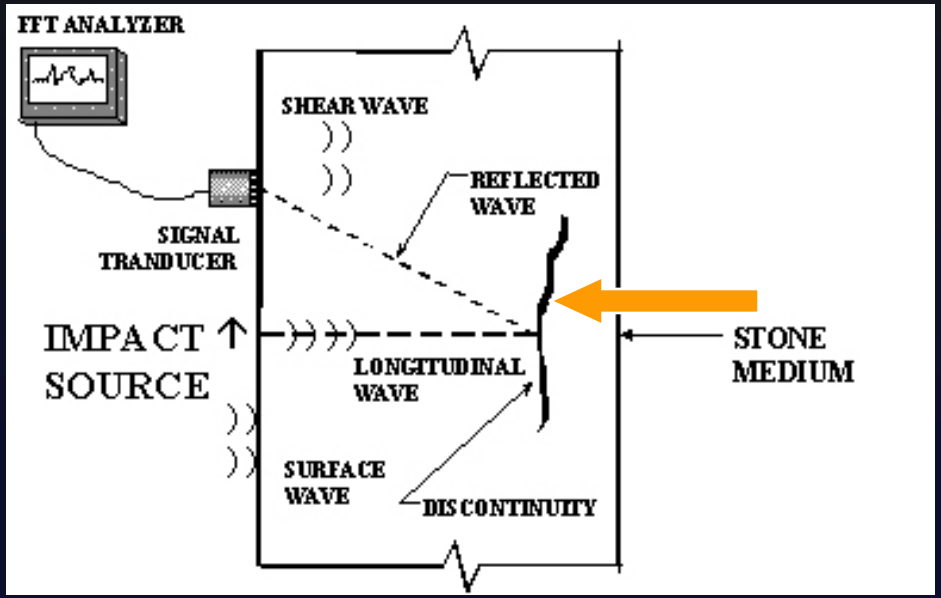
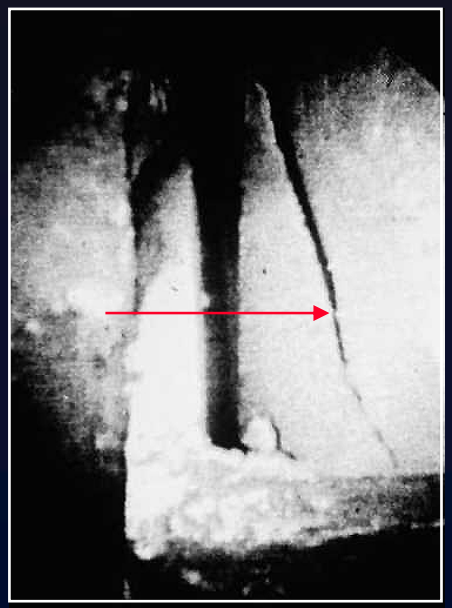


Diagram of Impact Echo Instrumentation: *Deficiencies that occur on the backside of a panel can be detected with Impact Echo testing.*

Non-Destructive Testing (NDT)

- Boroscope Instrumentation
  - *investigatation between panel joints over the backside of the stone panel and the cavity wall* .



Petrographic Examination and Physical Testing Programs for Dimension Stone:

- Petrograhic Examinations
- Geological Studies
- Materials Testing Program

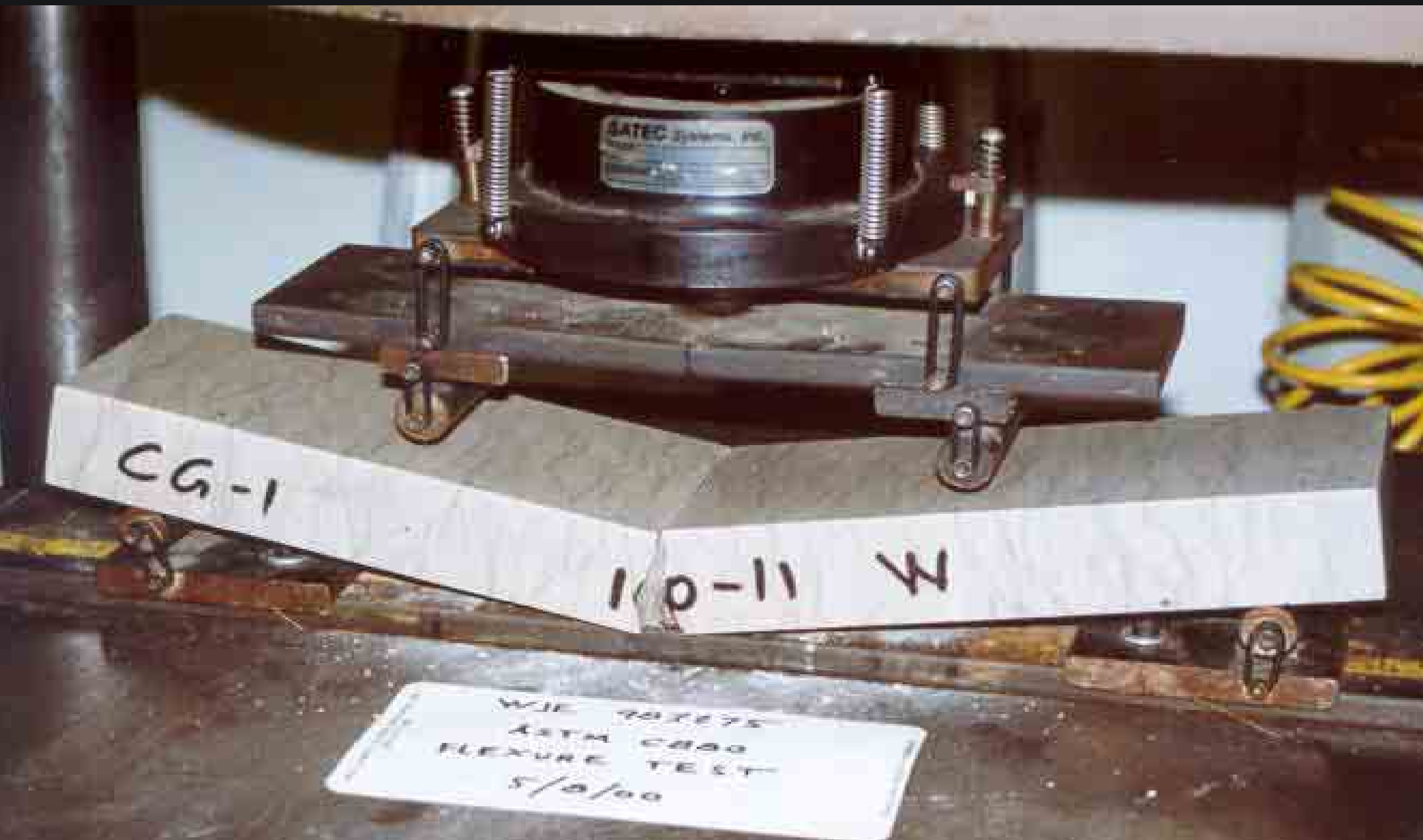
Petrographic Examination

- Field Petrographic Studies
- Microscopic Visual Study
- Geological Studies
  - X-Ray Diffraction to determine physical characteristics and properties of stone
  - Scanning Electron Microscope (SEM)
- Guidelines according to American Standard for Testing of Materials (ASTM)

Physical Testing Programs

- ASTM C666 - Test Method for Resistance to Rapid Freezing and Thawing (Procedure A)
  - measurement of porosity, capillary coefficient and, saturation coefficient
- ASTM C880 Flexural Strength Tests
- ASTM C1242 Standard Dimension Stone Anchors and Anchoring Systems
- ASTM C1354 Individual Stone Achorages in Dimension Stone

ASTM C880 flexural test on marble specimen



Assessment of Ongoing Repair Programs for Dimension Stone

- Full Panel Replacement
- Dutchman Repair
- Mechanical Clamp Anchor or “Stitch” Repair

Thin Dimension Stone Cladding Repairs

A.

B.

C.

A. **Full Marble Panel Replacement** - *Full panel removal and replace with stone in-kind.*

B. **Traditional Dutchman Stone Repair -** *Selective removal and replacement of deteriorated stone*

C. **Mechanical Clamp Anchor -** *A 'Stitch Repair' in progress with U-Clamps at each end of crack*

Technical Challenges in Maintaining Original Stone Cladding Systems

- Surveying large areas of stone and managing large amounts of collected data
- Design all parts of the cladding system for structural integrity and to maintain the original integrity of design and aesthetic.

Other Similar WJE Projects

Conclusions

- Consider Full Panel Replacement as a long term repair
- Testing material behavior to meet criteria, standards (i.e. EN, ASTM) and durability for both existing and new dimension stone
- Emphasis on performance of proper connection design