A Survey of Building and Content Damage Resulting from Hurricane Andrew in Nine Industrial Properties

A Report

Submitted to

prepared by

Norris Stubbs[1], Eng.Sc.D., P.E., and Dale Perry[2], Ph.D.

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[1]Associate Professor of Civil Engineering, Texas A&M University, College Station, Texas, 77843.

[2]Dockery Professor of Housing, College of Architecture, Texas A&M University, College Station, Texas, 77843.

EXECUTIVE SUMMARY

"Although the roofing system is a low percentage cost item compared to the square foot cost of the complete building, the system's cost and life expectancy should be carefully evaluated. Water penetration is usually the major problem in building construction and maintenance. If care is taken in the selection of a proper roofing system, much time, money, and aggravation will be avoided later on"
--- R.D. Herbert III, 1987

During the period 24 February to 26 February, two engineers from Texas A&M University and five insurance professionals from surveyed nine properties that experienced varying amounts of damage during the passage of Hurricane Andrew in August 1992. The group collected data relating to the history of each building, a detailed description of the building and its contents, evidence of any attempts by the owners to mitigate damage to the building or its contents, a description of the exposure of the property to the hurricane hazard, a description of the damage to the building and its contents, and evidence supporting the causes of damage to the building and its contents.

The data were analyzed by the group at Texas A&M. The analyses were performed at two levels: (a) for individual buildings and (b) for the buildings as a group. In the individual building analysis, causes of building and content damage were assigned and remedies were provided to mitigate these causes in future hurricanes. The analysis for each building is summarized in Tables 1-9 of the report. In the group analysis, the findings were analyzed for trends and relationships. Relationships investigated here include (a) damage as a function of wind speed, and (b) content damage as a function of damage sustained by the structure. Trends investigated here include analyses of comparative occurrence rates of damage types, causes of damage to the structure, causes of damage to the contents, and

recommended strategies to mitigate damage. The trends and relationships are listed in Tables 11 to 16.

On the basis of this analysis we offer six recommendations:

(1) We recommend that the owners perform periodic inspection and maintenance of the roofing to ensure that the roofing can resist design winds.

(2) We recommend that all glass openings and doors be protected in the event of a hurricane.

(3) We recommend that mechanical equipment situated on the roof be bolted down to resist the design wind speed.

(4) In the event of a hurricane, we recommend that all paths of moisture passage from the outside to any part of a water-sensitive machine (e.g., intake or exhaust vents) be eliminated.

(5) We recommend that secondary mitigative schemes be developed to protect critical contents from water damage. Such measures are content and industry specific and can range from the storing contents in water-proof cabinets to providing special coverings for heavy equipment.

(6) We recommend that all roll-up doors be protected by horizontal bracing member, during the event of a hurricane.

These recommendations are elaborated upon in the final section of the text.

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INTRODUCTION

In connection with the physical destruction and financial losses caused by Hurricane Andrew, the commissioned Dr. Norris Stubbs P.E., and Dr. Dale Perry to "conduct a damage assessment of selected buildings in Miami, Florida, answering the key questions of how and why did damage occur." During the period 24 February - 26 February, Dr. Stubbs and Dr. Perry along with five members of the surveyed nine properties preselected by . This report summarizes our assessment of the resulting damage to the selected buildings and their contents. We provide an assessment for each building as well as an assessment of the buildings as a group. The report is organized into five sections: a summary of the data gathering phase, a description of the assessment for the individual properties, a discussion of significant trends and relationships for the properties as a group, a discussion of some unexpected findings, and a listing of recommendations that can, if followed, mitigate damage to buildings and their contents during future hurricane events.

DATA GATHERING

The survey team consisted of the following members:

- Dr. Norris Stubbs, P.E., Dept. of Civil Engineering, Texas A&M University
- Dr. Dale Perry, Dept. of Architecture, Texas A&M University
- Anita J. Laico, International Dept., CHUBB & Son, Inc.
- Kirk O. Bailey, C.S.P., CHUBB & Son, Inc.
- Patrick B. Robinson, ASP, Loss Control Department, CHUBB & Son, Inc.
- Ron Lynch, Loss Control Department, CHUBB & Son, Inc.
- Joe Miskell, Personal Lines Appraisal, Chubb & Son, Inc.

The sites visited, their addresses, and the approximate time of the visit are listed below.

Wednesday 2/24

Site	Address	Time
	S.W. 8th St, Miami	9:00 AM
	S.W. 128th St., Miami	11:30 AM
	Old Cutler Rd., Miami	2:30 PM
	Thursday 2/25	
	N.W. 31st St., Miami	9:00 AM
	NW 165th St., Miami	11:00 AM
	NW 2nd Ave. Miami	3:00 PM
	Friday 2/26	
	N.W. 74th Ave., Miami	9:30 AM
	N.W. 79th Ave., Miami	Noon
	NW 42nd Ave., Miami	2:30 PM

At each site the survey group interviewed a representative of the property. The interview was followed by a tour of the facility. The interview and the tour were designed to yield information relating to at least the following items:

- a general description of the building,
- a detailed engineering description of the building,
- evidence of any attempts by the owners to mitigate damage to the structure,
- a description of the contents, any attempts to mitigate damage to contents,
- a description of the exposure of the building to the hurricane hazard,
- a description of the damage to the building and its contents, and
- evidence supporting the causes of damage to the building and its contents.

RESULTS

The summaries and findings for the survey of the nine properties are summarized in Tables 1-9. The findings for each property are organized into one of twelve categories:

- general building information,
- description of building,
- mitigation attempts to structure,
- description of contents,
- mitigation attempts to contents,
- description of hazards,
- damage to structure,
- damage to contents,
- causes of damage to structure,
- causes of damage to contents,
- remedial strategies for reducing damage to the structure, and
- remedial strategies for reducing damage to the contents.

The causes of damage to the structure were developed from a combination of the description of the damage, a knowledge of the design wind speed for the region, and a knowledge of the maximum hurricane winds experienced at the site. Data on the wind field distribution during Hurricane Andrew was provided by Dr. Timothy Reinhold, Department of Civil Engineering, Clemson University. Figure 1 provides the wind field distribution which may be overlaid on Fig. 2 (Map of South Florida) to determine wind speed at site locations. The wind speeds are referenced to a standard exposure (Exposure C or airport exposure) at a height of 10 meters (32.8 ft) above ground. The suggested remedies to mitigate damage to the structure and the contents follow directly from the assigned causes of the damage.

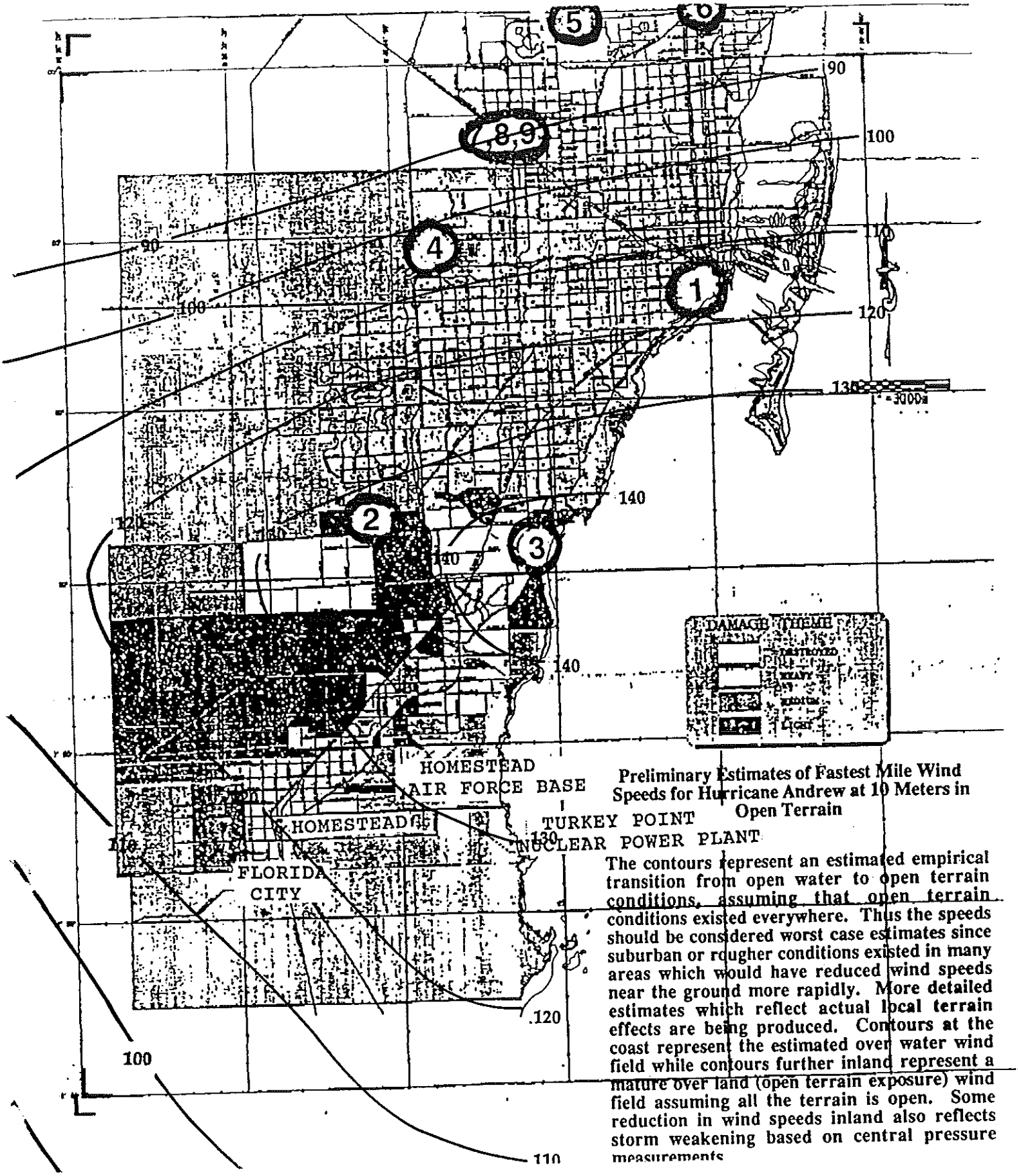


Figure 1: Estimates of Fastest-Mile Wind Speeds for Hurricane Andrew

Figure 2: Map of Miami Area Impacted by Hurricane Andrew

In each table, reference is made to wind speed and exposure. The exposure in which a specific building is sited is described below (ANSI/ASCE 7-88).

- Exposure A. Large city centers with at least 50% of the buildings having a height in excess of 70 feet. Use of this exposure category shall be limited to those areas for which terrain representative of Exposure A prevails in the upwind direction for a distance of at least one-half mile or 10 times the height of the building or structure, whichever is greater. Possible channeling effects or increased velocity pressures due to the building or structure being located in the wake of adjacent buildings shall be taken into account.

- Exposure B. Urban and suburban areas, wooded areas, or other terrain with numerous closely spaced obstructions having the size of single-family dwellings or larger. Use of this exposure category shall be limited to those areas for which terrain representative of Exposure B prevails in the upwind direction for a distance of at least 1500 feet or 10 times the height of the building or structure, whichever is greater.

- Exposure C. Open terrain with scattered obstructions having heights generally less than 30 feet. This category includes flat open country and grasslands.

- Exposure D. Flat, unobstructed areas exposed to wind flowing over large bodies of water. This exposure shall apply only to those buildings and other structures exposed to the wind coming from over the water. Exposure D extends inland from the shoreline a distance of 1500 feet or 10 times the height of the building or structure, whichever is greater.

Schematics of the four profiles are shown in Figure 3.

The following flooding related terms are also used in the tables (FEMA, 1990):

- Base Flood Elevation: The elevation of the water surface of the flood level that has a one percent or greater chance of occurrence in any given year (100 yr. return period).

- Zone AH: Areas of special flood hazard having shallow water depths and/or unpredictable flow paths between one and three feet, and with water surface elevation determined.

- Zone AE: Areas of special flood hazard with water surface elevation determined.

- Zone X: Area of minimal to moderate flow hazard.

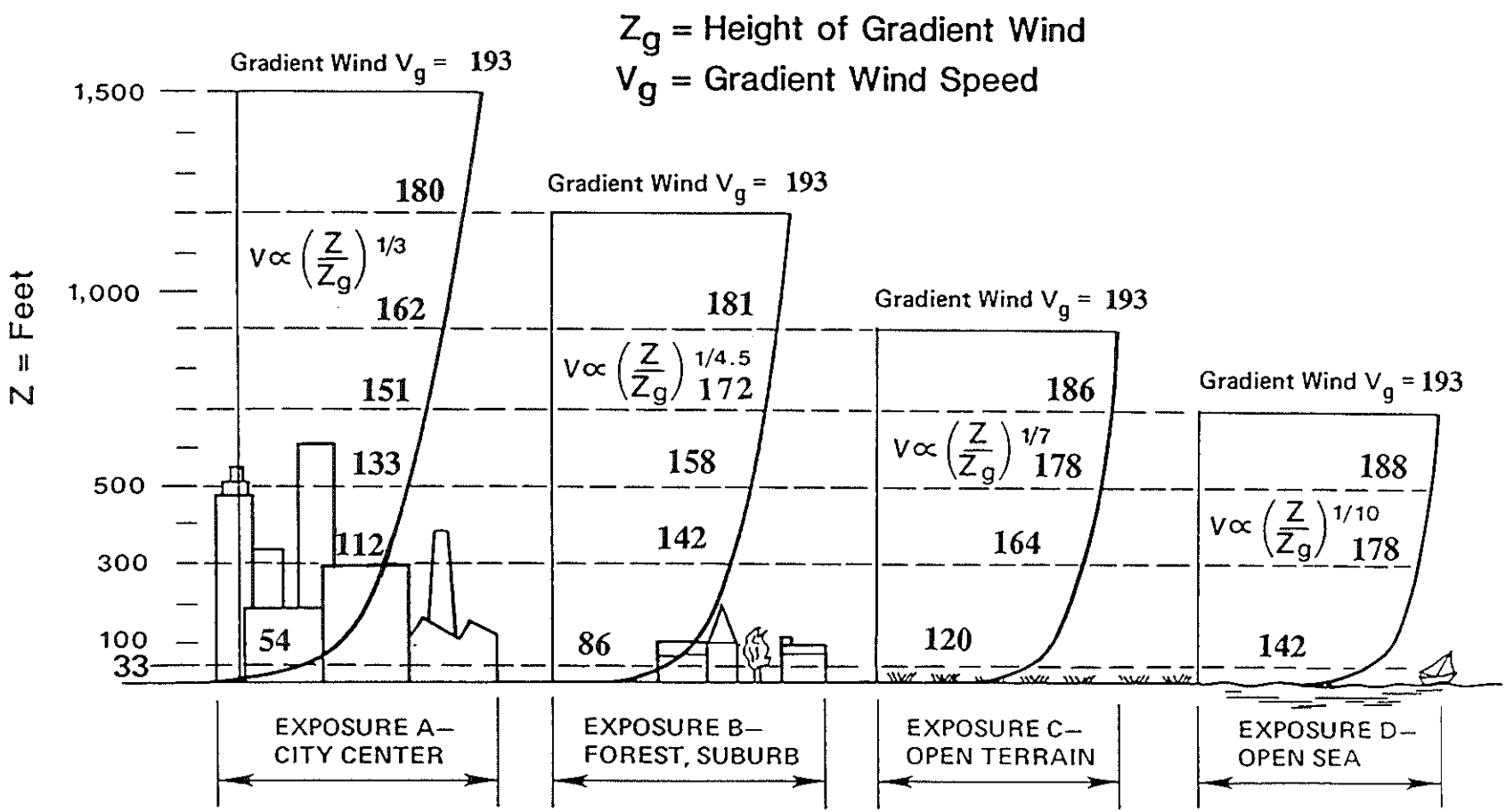


Figure 3: Profiles of Mean Wind Velocity (fasest-mile)

Photographs of the properties are provided in Figures 4-12.

One of the objectives of the analysis was to assign probable cause of failure for the various building components. In cases, such as missile or debris impact, the cause is obvious. In the case of the failure of other building components the following logic was utilized:

- Assume the design wind speed,
- Select the Exposure C wind speed for the site,
- Estimate the factor of safety for the building using the design wind speed and the measured/inferred wind speed, [note Factor of Safety = (measured speed/design speed)^2], and
- Assign the cause of failure of the building component according to the following rules:

(a) If the factor of safety is less than 1.0, the cause is improper design, installation, or maintenance

(b) If the factor of safety is greater than 1.0 but less than 1.15 the cause is marginal design, marginal quality or installation, or marginal maintenance;

(c) If the factor of safety is greater than 1.15, the cause of failure is operation at wind pressures exceeding design.

In this work the design speed for the South Florida Building Code is taken to be 120 miles per hour sustained (i.e., a one-minute average). This value transforms to 130 miles per hour fastest-mile. Thus if the speed at a site is V miles per hour, the factor of safety (F.S.) is given by

$$F.S. = (V/130)^2$$

Therefore from Table 1, since the roof of Building 1 failure in a wind environment of 112 miles per hour, the factor of safety of the roofing is $(112/130)^2 = 0.74$. We therefore assign, as a cause of failure, "improper design, installation, or maintenance."

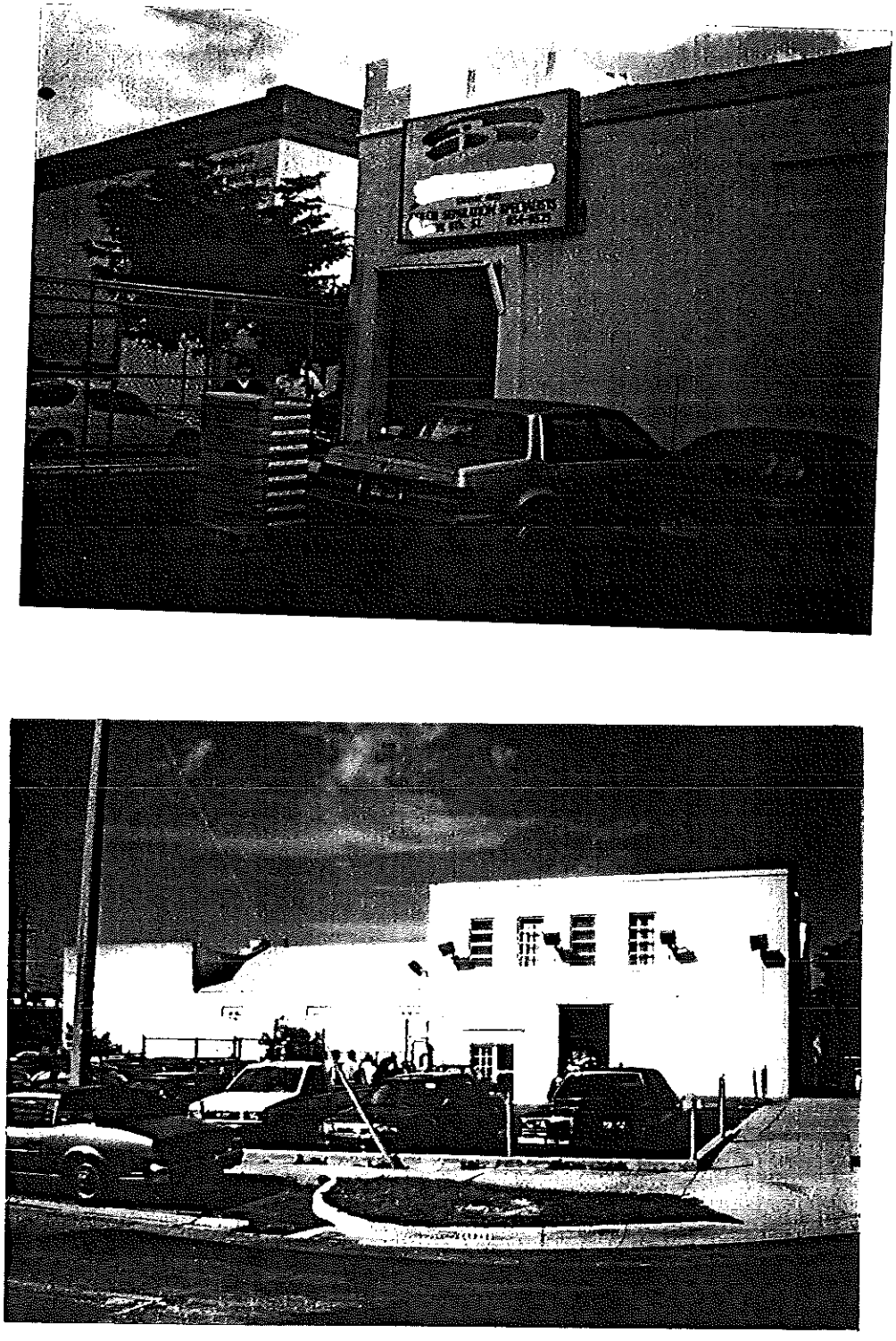


Figure 4: View of Building 1

Table 1: Summary of Findings for Building 1

GENERAL

Name:
Location: SW 8th St.
Use:
First Floor Footprint: 7200 sq. ft.
Age: 1970
Last Upgrade: 1988
Classification: 1-3 story masonry; non-residential; multiple unit
Major Subparts: A: 4500 sq. ft. footprint, 2-stories; B: 2700 sq. ft. footprint, 2 stories

DESCRIPTION OF BUILDING

PART A:

Foundation: Strip footing
Lateral bracing: Reinforced concrete frames/infilled masonry walls
Cladding: Masonry infill
Openings: one-metal roll-up door 8 ft. x 8 ft.; 10 small windows near top of walls; one 3 ft. x 7 ft. door
Roof: Timber, gable truss, with 2 in. x 10 in. purlins
Roofing: Composition shingles

PART B:

Foundation: Strip footing
Lateral bracing: Reinforced concrete frames/infilled masonry walls
Cladding: Masonry infill
Openings: one-metal roll-up door 8 ft. x 8 ft.; 10 small windows near top of walls; one 3 ft. x 7 ft. door
Roof: Double T -precast roof
Roofing: Built-up Roofing (BUR)

MITIGATION ATTEMPTS TO STRUCTURE

Openings: Boarded up 85% windows
Cladding: None
Other: None

DESCRIPTION OF CONTENTS

Electronic equipment computers; scanners; printing presses; photographic equipment; office equipment
Supplies: Paper, unprocessed photographic film
Valuables/Records: Processed film; electronic records; non-electronic records

MITIGATION ATTEMPTS TO CONTENTS

None

DESCRIPTION OF HAZARD

Windspeed: 112 mph, Exposure C
Building Exposure: B
Missile exposure: Low
Surge Exposure: 1 mile from shore; Base Flood Elevation (BFE) N/A; Zone X

DAMAGE TO STRUCTURE

PART A:

Roof: 50% roofing loss windward, 25% leeward
Cladding: None
Openings: Part A: 1 window failed (missiles)

PART B:

Roof: None
Openings: 2 windows failed (missiles)
Cladding: None

DAMAGE TO CONTENTS

Part A: Processed film, major; printed materials, minor; printing press, minor
Part B: Scanner (one), major; printing stock, moderate

CAUSES OF DAMAGE TO STRUCTURE

Roofing: Improper design, installation, or maintenance of roofing
Openings: Windows-missile impact

CAUSES OF DAMAGE TO CONTENTS

PART A:

Water penetration via roof and window on east face.

PART B:

Water penetration via windows on south & north faces caused damage to printing stock; intake of water into exhaust vent of scanner (saline content corroded critical parts; see Figure 13)

REMEDIAL STRATEGIES FOR REDUCING DAMAGE TO STRUCTURE

Roofing: Periodic inspection and maintenance of roofing
Openings: Provide appropriate protection for all windows

REMEDIAL STRATEGIES FOR REDUCING DAMAGE TO CONTENTS

1. Isolate sensitive equipment from outside environment

2. Provide secondary mitigation for contents

Figure 5: Detail of Roll-Up Door in Building 2

Table 2: Summary of Findings for Building 2

GENERAL

Name:
Location: SW 128th St.
Use:
Footprint: 7200 sq. ft. (leased space in 43,200 sq ft building)
Age: Post 1985
Last Upgrade: Unknown
Classification: 1-story reinforced concrete; non-residential; multiple unit

DESCRIPTION OF BUILDING

Foundation: Strip footing
Lateral bracing: Rigid frame/infilled masonry walls
Cladding: infilled masonry walls
Openings: 2-metal roll-up doors; 2-man doors
Roof: Precast double-T
Roofing: BUR/gravel ballast

MITIGATION ATTEMPTS TO STRUCTURE

Openings: None

DESCRIPTION OF CONTENTS

Supplies: Inventory of products for tinting and protective coatings of eyeglasses
Valuables: Records
Furniture: Office furniture

MITIGATION ATTEMPTS TO CONTENTS

None

DESCRIPTION OF HAZARD

Wind Speed: 130 mph, exposure C
Building Exposure: B, and shielded
Missile Exposure: Low
Surge Exposure: 9 miles inland, BFE 9 ft., Zone AH

DAMAGE TO STRUCTURE

Roof: Major-Double T's separated from bond beam
Roofing: Total
Non-structural interior: Total
Cladding: None
Openings: 2 roll-up metal doors failed (total failure)

DAMAGE TO CONTENTS

Supplies: Optical supplies totally destroyed
Furniture: Total destroyed
Valuables: Major damage to valuable records

CAUSES OF DAMAGE TO STRUCTURE

Failure of roll-up doors: Combination of high wind pressure and low door resistance
Failure of non-structural interior walls: High internal pressure
Roof: Improper design, installation, or maintenance of roof

CAUSES OF DAMAGE TO CONTENTS

Water penetration: Failure of roll-up doors and loss of roofing protection

REMEDIAL STRATEGIES FOR REDUCING DAMAGE TO STRUCTURE

Roof: Proper anchorage of roof to walls
Openings: Provide appropriate protection for roll-up doors

REMEDIAL STRATEGIES FOR REDUCING DAMAGE TO CONTENTS

(1) Provide proper means to protect furniture from water penetration and windborne debris.
(2) Provide secondary mitigative measures to protect office supplies and records

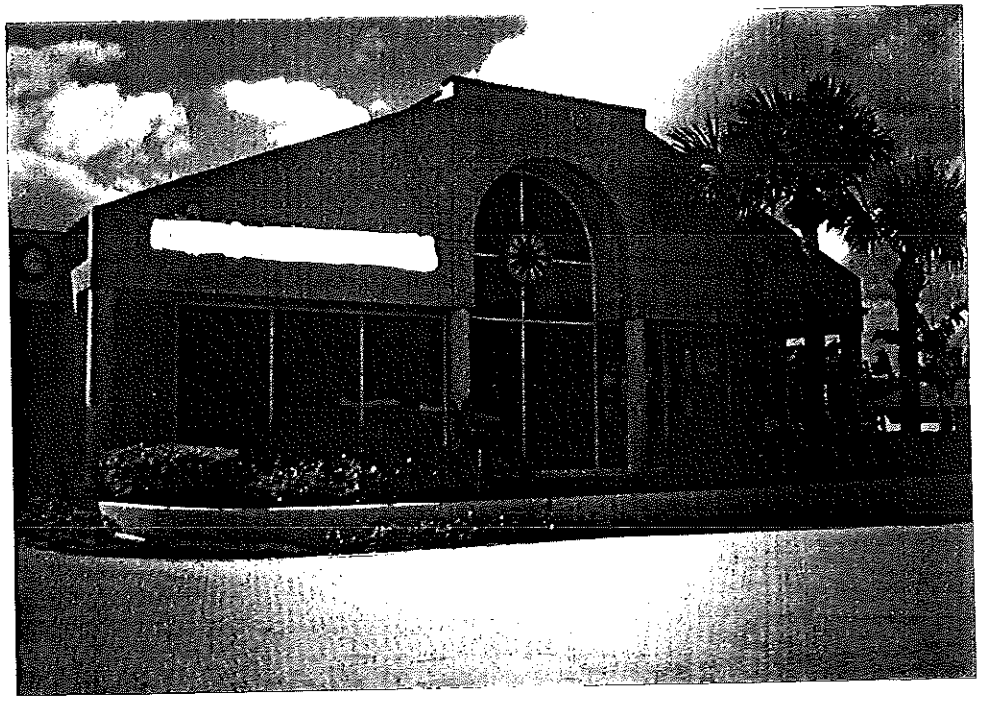


Figure 6: View of Building 3

Table 3 Summary of Findings for Building 3

GENERAL

Name:
Location: Old Cutler Rd.
Use:
Footprint: 3200 sq. ft.
Age: 1988
Last upgrade: 1988
Classification: 1 story reinforced concrete; non-residential; single unit

DESCRIPTION OF BUILDING

Foundation: Spread footings
Lateral bracing: Rigid frame
Cladding: Glass curtain wall; 8 in. concrete block
Roof: Wood rafters/plywood membrane
Roofing: Metal sheating/plywood

MITIGATION ATTEMPTS TO STRUCTURE

Placement of structure on berm

DESCRIPTION OF CONTENTS

Equipment: Computers; Office furniture
Valuables/Records: Safe deposit boxes in vault

MITIGATION ATTEMPTS TO CONTENTS

None

DESCRIPTION OF HAZARDS

Windspeed: 140 mph, Exposure C
Building Exposure: C
Missile Exposure: Moderate
Surge Exposure: 3/8 miles inland, elev 13 ft.; Zone X (judged vulnerable to wave action)

DAMAGE TO STRUCTURE

Roof: None
Roofing: Minor damage to skylight

Cladding: Glass curtainwall totally destroyed
Openings: None

DAMAGE TO CONTENTS

Office Furniture: Moderate

CAUSES OF DAMAGE TO STRUCTURE

Roofing: Wind pressure exceeded design pressure
Cladding: Wind pressure exceeded design pressure

CAUSES OF DAMAGE TO CONTENTS

Water penetration
Wind pressure

REMEDIAL STRATEGIES FOR REDUCING DAMAGE TO STRUCTURE

Cladding: Provide appropriate protection for all curtainwalls

REMEDIAL STRATEGIES FOR REDUCING DAMAGE TO CONTENTS

Provide secondary mitigation to furniture

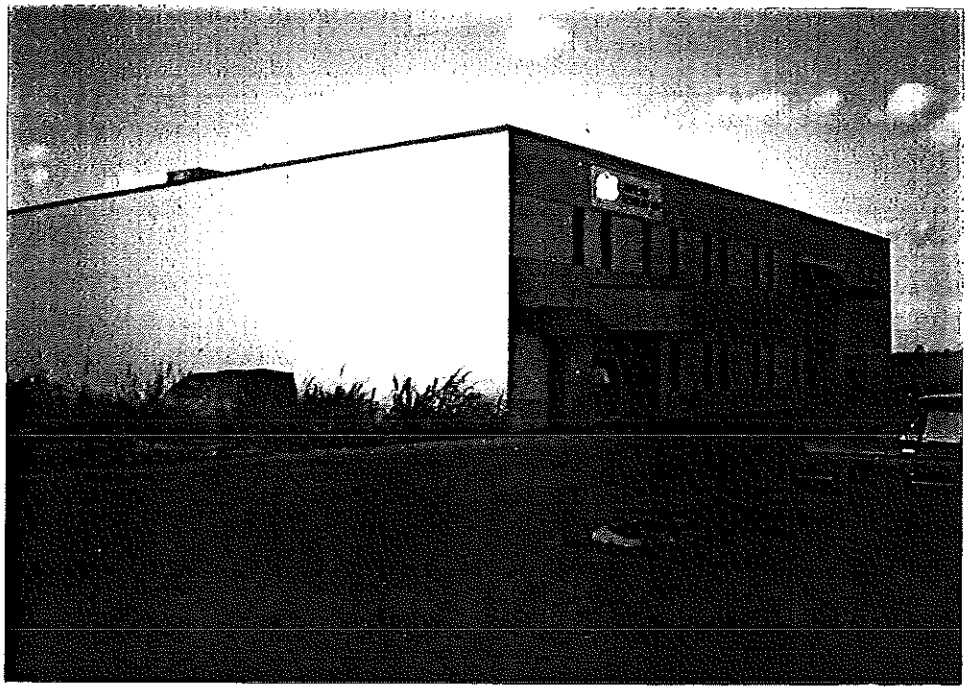


Figure 7: View of Building 4

Table 4: Summary of Findings for Building 4

GENERAL

Name:
Location: NW 31st Street
Use:
Footprint: 11,000 sq. ft.
Age: 1991
Last Upgrade: N/A
Classification: 2 story reinforced concrete; non-residential; single-unit

DESCRIPTION OF BUILDING

Foundation: Strip footing
Lateral bracing: Rigid frame with infilled walls
Cladding: Masonry infilled
Openings: 1-metal roll-up door; 22 small windows on front; 2-man doors
Roof: Precast Double-T
Roofing: BUR w/gravel ballast

MITIGATION ATTEMPTS TO STRUCTURE

Boarded up front glass windows

MITIGATION ATTEMPTS TO CONTENTS

None

BUILDING CONTENTS

Computers; machinery; sensitive dimensioning equipment; metal stock; high-tech manufacturing equipment
Valuables/records; Electronic records, plans

DESCRIPTION TO HAZARD

Wind speed: 105 mph, Exposure C
Building Exposure: B
Missile exposure: Low
Surge Exposure: 9 miles inland, BFE 7 ft., Zone AH

DAMAGE TO STRUCTURE

Roof: None
Roofing: 1 lost A/C unit; damage to heat exchanger coils; flashing damage
Cladding: None
Openings: None
Canopy: Lost
Fence: 100%
Fence surrounding Argon Tank: 100%

DAMAGE TO CONTENTS

None

CAUSES FOR DAMAGE TO STRUCTURE

Roofing: Improper installation or maintenance of roof flashing
Air conditioning units: Missile impact from gravel ballast

REMEDIAL STRATEGIES FOR REDUCING DAMAGE TO STRUCTURE

(1) Eliminate gravel ballast hazard on roof
(2) Provide periodic inspection and maintenance of roofing

Figure 8: View of Building 5

Table 5: Summary of Findings for Building 5

GENERAL INFORMATION

Name:
Location: NW 165th St.
Use:
Footprint: 95,000 sq. ft. (Parts A & B)
Age: 1972
Last upgrade:
Classification: 1 story masonry; non-residential; multiple unit
Major Sections: Part A: 31,500 sq. ft.; Part B: 43,500 sq. ft.

BUILDING DESCRIPTION PART A (Front)

Foundation: Strip footing under walls; spread footings under interior columns
Lateral bracing: Masonry shear walls
Cladding: Masonry walls
Openings: Four metal roll-up doors; Nine windows; multiple skylights
Roof: Steel bar joints supported by steel columns, masonry walls
Roofing: Steel deck, BUR with gravel ballast

BUILDING DESCRIPTION PART B

Foundation: Strip footing, walls; spread footings, interior columns
Lateral bracing: Masonry shear walls
Cladding: Masonry
Openings: Nine roll-up metal doors; Twelve windows on back wall
Roof: Precast double-T
Roofing: Ethylene propylene diene monomer (EPDM) membrane adhered to insulation board supported by metal deck

MITIGATION STRATEGIES TO BUILDING

Boarded-up windows

BUILDING CONTENTS, PART A

Office furniture; records; textile fabrics; dying machines

BUILDING CONTENTS, PART B

Dying machine; weaving machines; dye-making machines; yarns, fabric; dyes

MITIGATION STRATEGIES TO CONTENTS

Covered machines with plastic

DESCRIPTION OF HAZARD

Wind speed: 70 mph, Exposure C
Building Exposure: B
Missile damage: Low
Surge Exposure: 9 1/2 miles inland; Zone X

DAMAGE TO STRUCTURE, PART A

Roofing: 100% damage; A/C units, vents 100% damage
Openings: Glass windows (small no.)

DAMAGE TO STRUCTURE, PART B

Roofing: One A/C unit

DAMAGE TO CONTENTS, PART A

Three (3) motors, three (3) transformers; supplies (fabric)

DAMAGE TO CONTENTS, PART B

Minimal damage to one weaving machine

CAUSE OF DAMAGE TO STRUCTURE, PART A

Roofing: Improper design, installation, or maintenance of roofing
Glass window damage: Missile impact

CAUSE OF DAMAGE TO CONTENTS, PART A

Water penetration

REMEDIAL STRATEGIES FOR REDUCING DAMAGE TO STRUCTURE

Roofing: (a) Provide inspection and maintenance of roofing; (2) Provide appropriate protection for all openings

REMEDIAL STRATEGIES FOR REDUCING DAMAGE TO CONTENTS

Provide secondary protection for contents

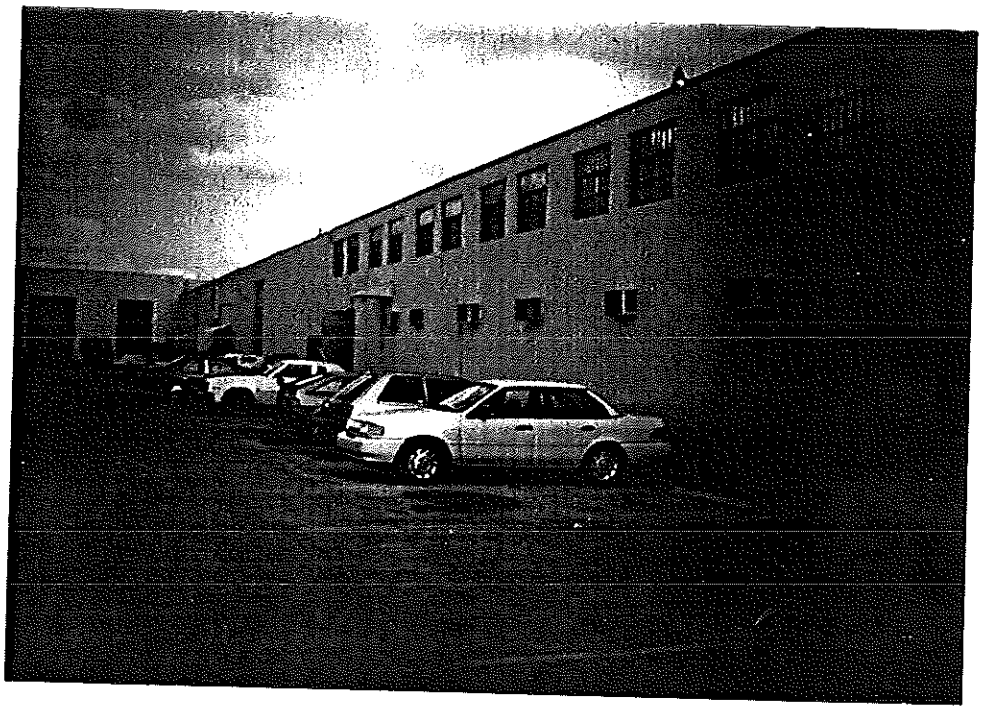


Figure 9: View of Building 6; Part A

Table 6: Summary of Findings for Building 6

GENERAL

Name:
Location: NW 2nd Ave.
Use:
Footprint: 40,000 sq. ft.
Age: 20 yrs.
Last upgrade: 1989
Classification: 1 story masonry; non-residential; multiple unit

DESCRIPTION OF BUILDING

Foundation: Strip footing, walls; spread footings, interior columns
Lateral bracing: Masonry shear walls
Cladding: Masonry
Openings: 36 glass windows, near top along two longitudinal walls; 7 roll-up metal doors
Roof: Steel bar joists supported by masonry walls and interior steel columns; steel purlins
Roofing: Solid insulating panels between purlins, BUR

BUILDING DESCRIPTION, PART B

Foundation: Strip footing, walls; spread footings, interior columns
Lateral bracing: Masonry shear walls
Cladding: Masonry
Openings: 2 roll-up metal doors
Roof: Precast double T's supported by masonry walls and reinforced concrete interior columns
Roofing Materials: BUR

MITIGATION STRATEGIES FOR BUILDINGS

None

BUILDING CONTENTS, PARTS A&B

Office furniture/supplies; metal machining equipment; metal presses; metal stock

MITIGATION STRATEGIES FOR CONTENTS

Sand bagging around perimeter of office to prevent internal flooding

DESCRIPTION OF HAZARD

Wind speed: 70 mph, exposure C
Exposure B:
Missile exposure: Low
Surge Exposure: 5 miles inland; elevation 12 ft.; Zone X

DAMAGE TO STRUCTURE A

Roofing: Total
Openings: 10% glass damage

DAMAGE TO STRUCTURE B

None

DAMAGE TO CONTENTS

Water damage to machines, lathes, milling machines

CAUSES OF DAMAGE TO STRUCTURE, PART A

Roof: Improper design, assembly, or maintenance or roofing
Openings: Missile impact to glass windows

CAUSES OF DAMAGE TO CONTENTS

Water penetration

REMEDIAL STRATEGIES FOR REDUCING DAMAGE TO BUILDING

(1) Provide periodic inspection and maintenance of roofing; (2) Provide appropriate protection of windows

REMEDIAL STRATEGIES FOR REDUCING DAMAGE TO CONTENTS

Provide secondary mitigation scheme for contents.

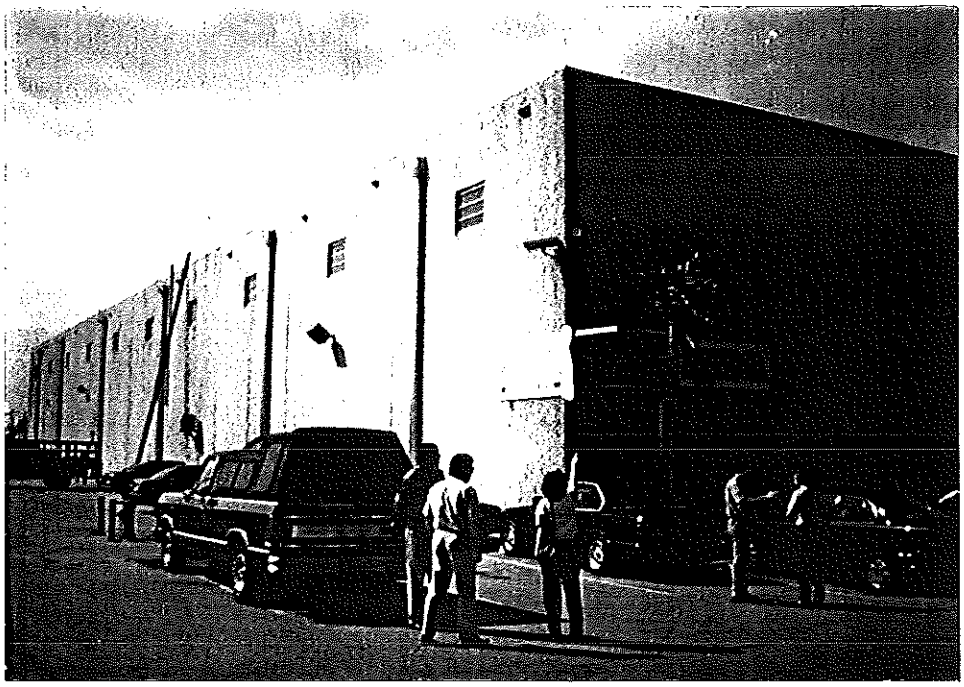


Figure 10: View of Building 7

Table 7: Summary of Findings for Building 7

GENERAL

Name:
Location: NW 74th Ave.
Use:
Footprint: 75,000 sq.ft.
Age: 33 yrs
Last Upgrade:
Classification: 1 story reinforced concrete with infilled masonry; non-residential; 1 unit

DESCRIPTION OF BUILDING

Foundation: Strip footings, walls; spread footings, interior columns
Lateral bracing: Rigid frame
Cladding: Masonry infill
Openings: 8-metal roll-up doors (10 ft. x 15 ft); windows along each face
Roof: Steel bar joist, metal decking
Roofing: BUR

MITIGATION ATTEMPTS FOR BUILDING

Windows boarded-up

DESCRIPTION OF CONTENTS

Equipment: Printing
Printing paper; records; office furniture

MITIGATION ATTEMPTS FOR CONTENTS

None

DESCRIPTION OF HAZARD

Wind speed: 80 mph, Exposure C
Building Exposure: B
Missile exposure: Low
Surge Exposure: 12 miles inland, BFE 6 ft., Zone AH

DAMAGE TO STRUCTURE

Roofing: Damage to roof flashing; Roof leakage noted previously (prior to hurricane), and often; 2 A/C units damaged
Openings: Damage to 30% glass windows on East face

DAMAGE TO CONTENTS

15-20 rolls of paper

DAMAGE TO STRUCTURE

A/C and flashing damage caused by wind

DAMAGE TO CONTENTS

Water penetration from broken windows and roof

REMEDIAL STRATEGIES FOR REDUCING DAMAGE TO STRUCTURE

(1) Provide periodic inspection and maintenance of roofing; (2) provide appropriate protection for all windows

REMEDIAL STRATEGIES FOR REDUCING DAMAGE TO CONTENTS

Provide secondary mitigation scheme for contents

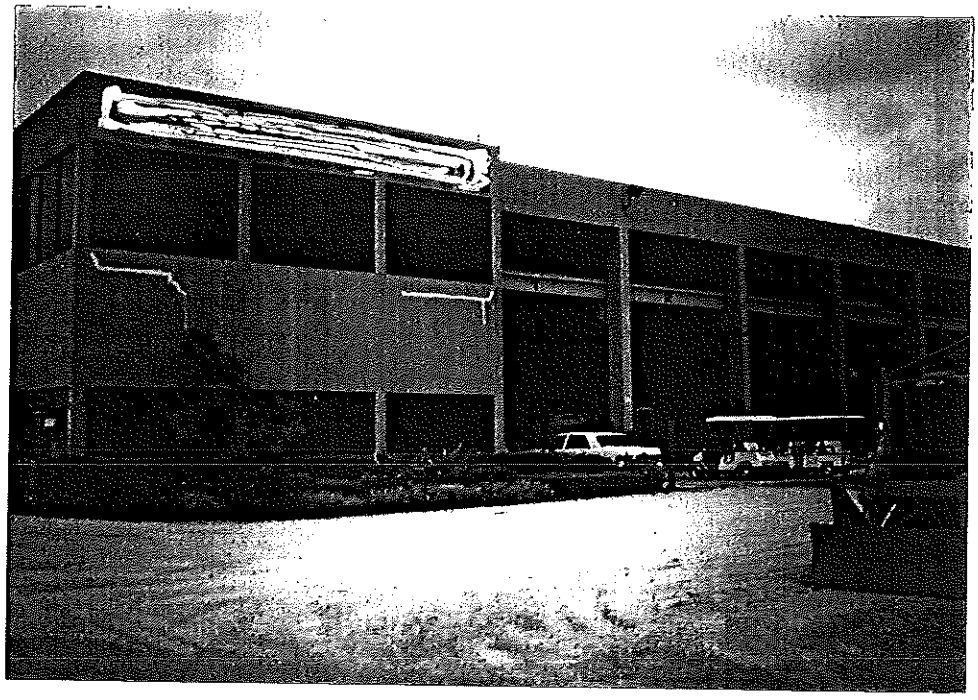


Figure 11: View of Building 8

Table 8: Summary of Findings for Building 8

GENERAL

Name:
Address: NW 79th Ave.
Use:
Footprint: 26,000 sq.ft.
Age: 1981
Last Upgrade: None
Classification: 1 story, reinforced concrete; non-residential; multiple unit
Major Sub-parts: Office/show room, Part A; Equipment maintenance, Part B

DESCRIPTION OF BUILDING PART A

Foundations: Strip footings under masonry walls
Lateral bracing: Rigid frame w/infilled masonry walls
Cladding: Masonry infilled
Openings: Glass windows; 2 man doors; 1 metal roll-up door
Roof: Steel bar joists; composite metal/concrete deck
Roofing: BUR on composite metal/concrete deck

BUILDING DESCRIPTION, PART B

Foundation: Strip footings, masonry wall; spread footings, interior reinforced concrete columns
Lateral bracing; Rigid framing
Cladding: Open (two sides)
Roof: Bar joists with composite concrete/steel deck
Roofing: BUR with composite concrete/steel deck; 30 skylights

MITIGATION, PARTS A&B

Shield building by surrounding it with heavy equipment

BUILDING CONTENTS, PART A

Office equipment; valuable records; computers

BUILDING CONTENTS, PART B

Maintenance equipment; antique cars; heavy equipment

DESCRIPTION OF HAZARD

Wind Speed: 80 mph, Exposure C
Building Exposure C:
Missiles: Low
Surge Exposure: 12 miles inland, BFE 6 ft.; Zone AH

DAMAGE TO STRUCTURE, PARTS A&B

Roofing: 100%
A/C: 6 damaged units

DAMAGE TO CONTENTS, PART A

Wall coverings, ceiling tile, office furniture, carpet

CAUSES FOR DAMAGE TO STRUCTURE, PARTS A&B

Roofing: Improper design, installation, or maintenance of roof

CAUSES FOR DAMAGE TO CONTENTS, PART A

Water penetration

REMEDIAL STRATEGIES FOR MITIGATING DAMAGE TO STRUCTURE

(1) Provide periodic inspection and maintenance of roofing
(2) Ensure that A/C units are properly anchored
(3) Eliminate obstruction of roof drainage part by skylight

Figure 12: View of Building 9

Table 9: Summary of Findings for Building 9

GENERAL

Name:
Address: NW 42nd Ave.
Use:
Footprint: 172,000 sq. ft
Age: 1978-1987
Classification: 1 and 2 story, reinforced concrete; non-residential; multiple units (4)

DESCRIPTION OF BUILDING, PART A (PRINT SHOP)

Foundation: Strip footing, masonry walls; spread footings, interior columns
Lateral bracing: Rigid framing w/masonry infilled walls
Cladding: Masonry
Openings: Windows; 5-metal roll-up doors; 8-man doors
Roof: Steel bar joists with metal desk
Roofing: BUR

MITIGATION ATTEMPTS FOR BUILDING

None

DESCRIPTION OF CONTENTS, PART A

Printing presses; storage for publications, printing stock

MITIGATION ATTEMPTS FOR CONTENTS

None

DESCRIPTION OF HAZARDS

Wind speed: 80 mph; Exposure C
Building Exposure: B
Missile exposure: Low
Surge Exposure: 12 mi inland, Elevation 7 ft.; Zone AE

DAMAGE TO STRUCTURE, PART A

Roofing: 100%

DAMAGE TO CONTENTS, PART A

Completed publications

CAUSES OF DAMAGE TO STRUCTURE

Roofing: Improper design, installation, or maintenance of roof

CAUSES OF DAMAGE TO CONTENTS

Water penetration

REMEDIAL STRATEGIES FOR REDUCING DAMAGE TO BUILDING

(1) Provide periodic inspection and maintenance of roofing
(2) Provide appropriate protection to openings

REMEDIAL STRATEGIES FOR REDUCING DAMAGE TO CONTENTS

(1) Provide secondary mitigation scheme for contents

TRENDS AND RELATIONSHIPS FOR SURVEY POPULATION

A summary of findings for the nine properties is provided in Table 10. From this table we extract the following trends and relationships that might be of interest to the insurance industry:

- damage to structure as a function of windspeed,
- content damage magnitude as a function of damage to structure,
- comparative occurrence of damage types,
- comparative occurrences for causes of damage to the structure,
- comparative occurrences for causes of damage to the contents, and
- comparative occurrences of recommended strategies to mitigate damage to the structure.

The relationship between the damage sustained by the buildings and wind speed is provided in Table 11. As expected, damage to the building increases as the wind speed increases. Only the structure experiencing the 140 mph winds suffered major cladding damage. Only damage to the roofing, openings, and cladding is recorded.

The relationship between damage to the contents and damage sustained by the building is presented in Table 12. In the table, the buildings are listed in the order of increasing damage. For example, Building No. 4 ( ) sustained the least damage (Damage to roof flashing) while Building No. 2 ( ) sustained the most damage (Total openings, Total roofing). Between the extremes of damage to the structure, the damage to the contents varied from "none" to "total".

The comparative occurrence of damage types is summarized in Table 13. Roofing

damage occurred in nine out of nine instances or 100 percent of the surveyed population. Note that the most prevalent roofing system encountered in the present sample of buildings (36 percent) was Built-up Roofing (i.e., felt with a bitumen matrix and gravel ballast). Cladding damage occurred in one out of nine instances or 6 percent of the surveyed population. According to Table 13, Eighteen instances of damage were noted. Thus the nine instances of roofing damage accounts for 50 percent of the damage cases. Note that opening and roofing damage accounts for approximately 80 percent of damage instances.

From Table 10 note that eight out of nine (or 89 percent) of the properties reported content damage.

The comparative occurrence rates of the causes of damage to the structures in the survey population are summarized in Table 14. Weak roofing (i.e., a roof that failed to perform at the design wind speed) was indicated in 5 out of nine cases. From Table 14, controllable causes (i.e., weak roofing, missile impact, and weak openings) account for sixty four (64) percent of the causes of damage in the population.

The relative occurrence rate for identified causes of damage to contents is summarized in Table 15. Two major causes are identified: water contact and wind pressure. In the survey population, the major cause for content damage was water contact.

The comparative occurrence rates of recommended strategies to mitigate structural and content damage are summarized in Table 16. For the building itself the most frequently cited recommendation is to perform periodic inspection and maintenance of the roofing. The second most frequently cited recommendation is to protect <u>all</u> openings in the event of an imminent hurricane. In several properties the windows that failed were precisely the

ones that were not boarded up. In the case of content damage, the single recommendation in every case is to provide some form of secondary defense for contents. The specific system will depend upon the nature of the business and the characteristics of contents. In the case of Building No. 1 ( ), for example, valuable negatives were stored in the attic space on open shelves. Perhaps the negatives could be stored in a water proof cabinet such that even if the roof leaks no water contact can be made with the prints.

Table 10. Summary of Findings

VARIABLE OF INTEREST	Inspected Property (1)	(2)	(3)
Damage to Structure	Major Roof Damage Minor Opening Damage (2 roll-up doors)	Major Roof Damage Total Opening Damage	Minor Roofing Damage Major Cladding Damage
Damage to Contents	Moderate Content Damage	Total Content Damage	Moderate Content Damage
Cause of Damage to Structure	Weak Roof Missile Impact	Weak Opening Weak Roof	High Winds Surge
Cause of Damage to Contents	Water Contact	Water Contact Excessive Wind Pressure	Water Contact Wind Pressure
Type of Contents	EE,FU,CH,EM,OP,PA,EM	EE,OP,CH,FU, VR	FU,EE,VR
Age of Structure			3 yrs
Ownership of Structure	Company Owned	Leased Property	Company Owned
Recommended Mitigation to Structural Damage	Periodic Inspection and Maintenance of Roof	•Anchor Roof to Wall •Protect Roll-up Doors	Protect Cladding During Hurricane
Recommended Mitigation for Content Damage	Secondary Mitigation to Critical Contents	•Secondary Mitigation for Contents	None
Cost of Str. Damage (Replacement Cost)	Not reported	N/A	$131,600 ($1,200,000)
Cost of Content Damage (Replacement Cost)	$1,493,000 (4,200,000)	$438,000 ($438,000)	$99,500 (Unknown)
Wind Speed	112 Mph. Exp. C	130 Mph. Exp. C	140 mph.

Table 10 (Cont'd) - Summary of Findings

VARIABLE OF INTEREST	Inspected Property (4)	(5)	(6)
Damage to Structure	Very Minor Roofing Damage Damage to A/C units	Major Roofing Damage Minor Opening Damage	Total Roofing Moderate Opening Damage
Damage to Contents	None	Moderate Damage	Major Content Damage
Cause of Damage to Structure	Weak Connection of AC units	Weak Roofing Missile Impact	Weak Roofing Missile Impact to Glass
Cause of Damage to Contents	N/A	Water Contact	Water Contact
Type of Contents	EE,OP,EM,HE,CH,FU,VR	EE,EM,CH,TX,F,VR	EE,EM,HE,VR
Age of Structure	1 yr	20 yrs	20 yrs
Ownership of Structure	Company Owned	Company Owned	Company Owned
Recommended Mitigation to Structural Damage	Eliminate Ballast Impact Maintenance of Roofing Protect Openings	Periodic Inspection and Maintenance of Roofing Protect Openings	Periodic Inspection and Maintenance of Roofing Protect Openings
Recommended Mitigation for Content Damage	None	Secondary Mitigation	Secondary Mitigation
Cost of Str. Damage	$27,000 ($1,200,000)	$577,000 ($4,200,000)	$362,000 ($1,300,000)
Cost of Content Damage	None	$160,000 ($18,000,000)	$47,000 ($3,952,000)
Wind Speed	105 Mph	70 Mph	70 Mph

EE - Electronic Equipment
EM - Electromechanical Equipment
FI - Film
TX - Textiles
FU - Furniture
OP - Optical Equipment
PA - Paper
VR - Valuable Records
CH - Chemicals
HE - Heavy Equipment
MS - Metal Stock

Table 10 (Cont'd) - Summary of Findings

VARIABLE OF INTEREST	Inspected Property		
	(7)	(8)	(9)
Damage to Structure	Moderate Damage to Openings A/C Units	Major Damage to Roofing Major Damage to AC Units	Total Loss of Roofing
Damage to Contents	Minor Damage to Contents	Minor Damage to Contents	Moderate Damage to Contents
Cause of Damage to Structure		Weak Roofing	Weak Roofing
Cause of Damage to Contents	Leaking Roof	Water Contact	Water Contact
Type of Contents	EE,EM,HE,PA,FU,CH,OP,VR	HE,EM,EE,FU,VR	EE,EM,HE,FU,CH,PA,VR
Age of Structure	33 yrs	11 yrs	13 yrs
Ownership of Structure	Leased Property	Company Owned	Company Owned
Recommended Mitigation to Structural Damage	Periodic Inspection and Maintenance of Roof Protection of Openings	Periodic Inspection and Maintenance of Roof	Periodic Inspection and Maintenance of Roof
Recommended Mitigation for Content Damage	Secondary Mitigation	Secondary Mitigation	Secondary Mitigation
Cost of Str. Damage	N/A	$175,000 ($1,800,00)	Not claimed ($9,700,000)
Cost of Content Damage	$141,000 ($11,000,000)	Not filed	$389,700 ($18,000,000)
Wind Speed	80 Mph	80 Mph	80 Mph

Table 11 - Damage to Structure as a Function of Wind Speed

Wind Speed Range Fastest Mile	No. Buildings	Estimated Wind Speed at Site	Range of Damage
< 75 mph	2	(70)	Minor Opening - Total Roofing
75 to 95	3	(80)	Moderate Opening - Total Roofing
96 to 110	1	(105)	Very Minor Roofing
111 to 130	2	(112,130)	Major Roof, Total Opening
131 to 150	1	(140)	Minor Roofing, Major Cladding

Table 12 - Content Damage as a Function of Damage to Structure

Damage to Structure	(Building No)	Content Damage
Very Minor Damage to Roofing	4	None
Minor Roofing, Major Cladding	3	Moderate
Major Roofing, Minor Opening	1,5	Moderate
Moderate Damage to Roof, Minor Opening	7	Minor Damage
Major Damage to Roof	8	Minor Damage
Total Roofing	6	Major Contents
Total Opening, Total Roofing	2	Total Content

Table 13 - Comparative Occurrence Rate of Damage Types

Type of Damage	Times Noted	Occurrence Rate (Percentage)	Relative Frequency (Percentage)
Roofing Damage	9	100	50
Opening Damage	5	56	28
Cladding Damage	1	11	6
Roofing Equipment Damage	3	33	17

Table 14 - Comparative Occurrence Rate of Causes of Damage to Structure

Causes of Damage	Times Noted	Occurrence Rate (Percentage)	Relative Frequency (Percentage)
Weak Roofing	5	55	36
High Winds	2	22	14
Missile Impact	3	33	21
Weak Opening	1	11	7
Surge	2	22	7
Weak Anchorage of Roof Equipment	2	22	14

Table 15 - Occurrence Rate of Causes of Damage to Contents

Causes of Damage	Times Noted	Occurrence Rate (Percentage)	Relative Frequency (Percentage)
Water Contact	8	89	80
Wind Pressure	2	22	20

Table 16 - Occurrence Rate for Recommended Strategies to Mitigate Damage

Recommended Strategy	Times Noted	Occurrence Rate (Percentage)	Relative Frequency (Percentage)
Perform Periodic Inspection and Maintenance of Roofing	7	78	28
Protect Openings in High Wind	6	67	24
Protect Glass Cladding	1	11	4
Eliminate Roof Ballast	1	11	4
Isolate Sensitive Equipment from Outside Environment	1	11	4
Provide Secondary Mitigation for Contents	7	78	28
Ensure Proper Anchorage of Roof to Wall	2	22	8

UNEXPECTED FINDINGS

The single unexpected finding in this survey was the realization of the damage path to the Color Separation Scanner at . The machine is located on the second floor of Part B of the structure (See Table 1) and is positioned against the south wall of the building. An intake vent from the exterior of the south wall is connected directly to the machine. During the hurricane, water entered the vent and the moisture found its way to the interior of the machine. The salt water reacted chemically with the machine parts to effectively corrode the internal parts. This path of damage is quite different from the more obvious water contact via a leaking roof or a broken window.

OVERALL RECOMMENDATIONS

The following recommendations to mitigate damage to the building and their contents are based on the trends and relationships we examined for the survey building population. The trends and relationships inturn were based on a group of nine building that might be loosely classified as 1-3 story, reinforced concrete/masonry, non-residential structures. These building experienced wind speeds in the range of 73-140 mph (fastest-mile).

(1) Our analysis indicates that in 36 percent of damage incidents, the assigned cause damage was impaired design, installation, or maintenance of roofing. We recommend a periodic inspection program (a) to uncover and repair any design and installation defects, and (b) to detect and repair unwanted conditions that may have developed during regular service. Since roofing systems vary with age, size and function of the building, we recommend an inspection and maintenance strategy which may apply to all roofing systems

rather than a specific plan that, although adequate, will have a limited scope of application. The elements of the inspection and maintenance program should contain at least the following elements:

- The type of roof system should be defined. This step should be performed jointly by the owner, or his representative, a qualified roofing contractor, and an engineer familiar with systems reliability. The definition should include such elements as the decking, the insulation, the water proofing membrane, any protective surfacing, flashing, penetrations, drainage, and roofing accessories such as skylights and mechanical and electrical equipment.

- Modes of failure for the particular type of roof system should be identified. The roof fails if it leaks. The ways that a roof may leak depend upon the details of the system. Each way that a given roof can fail is called a failure mode. The owner, the roof contractor, and the engineer should join to define the failure modes.

- The frequency of occurrence of the various types of failure modes should be defined. This data should be developed for the particular type of roof in the environment of study. Data should be gathered from a sample of roofing contractors in the region. Organizations such as the National Roofing Contractors Association may provide valuable data.

- The consequence of the occurrence of each type of failure mode should be determined. Different failure modes yield different consequences. A probable economic loss should be associated with each type of failure. The reliability engineer and the owner can estimate such values.

- The failure modes should be ranked on the basis of their consequence and their probability of occurrence. Identify critical failure modes for inspection.

- Specific inspection approaches which directly address the targeted failure modes should be selected. These approaches to be provided by the roofing contractor may be selected from available diagnostic methods ranging from visual inspection to nondestructive moisture detection.

- Finally, the inspection frequency should be tied directly to the occurrence rate of the mode.

(2) Our analysis indicates that in 21 percent of the damage incidents, the cause of damage was missile impact to glass windows. Therefore, we recommend that all glass openings be

protected in the event of a hurricane. The ability to protect glass openings when a hurricane is imminent will depend on the materials at hand. Whenever possible, the owner should be encouraged to store sheets of plywood which may be fastened directly into the wall studs and sills. Fastening to the window framing (jams and sills) may not be adequate if they have not been designed to resist the code specified wind loading.

(3) Our analysis indicates that in 14 percent of damage incidents, the cause of the damage was the weak anchorage of mechanical equipment on the roof. We recommend that mechanical equipment situated on the roof be bolted down to resist the design wind speed. For the typical case, this will require bolting or screwing stringers to the roof purlins or roof deck to which the mechanical equipment can then be attached.

(4) Our analysis indicates that it is possible for moisture/water to come into contact with water-sensitive equipment in ways other than via a leaking roof or an impaired window. Therefore, in the event of a hurricane, we recommend that all paths of moisture passage from the outside to the piece of equipment (e.g., intake or exhaust vents) be eliminated.

(5) Our analysis indicates that the main cause of damage to contents is water contact. Therefore, we recommend that secondary mitigative schemes be developed to protect critical contents from water damage. Such measures are content and industry specific and can range from the storing contents in water-proof cabinets to providing special coverings for heavy equipment. However, we recommend the following three strategies to reduce content damage in the event of a hurricane:

- Reduce the water hazard to the content
- Provide mitigation measures given that the building enveloped is breached, and
- Minimize the value of contents exposed at any given time.

To accomplish the first strategy, we can perform such actions as

- Relocate contents to sites beyond the hazard
- Relocate contents to less hazardous parts of the building
- Improve the resistance of the building envelope to water penetration via an aggressive maintenance program
- Improve the resistance of the building via a redesign and replacement of parts of the building envelope

To accomplish the second strategy, we can perform such actions as

- Create waterproof areas at the site for water sensitive contents,
- Enclose the contents in water proof chambers, or
- Provide temporary measures to protect contents

To accomplish the third strategy, we can

- Control the quantity of raw materials in stock
- Control the quality of material in process
- Control the inventory of finished materials

The application of combinations of these ten actions can significantly reduce content damage.

(6) One of the buildings surveyed sustained major damage to the roof and 100% damage to the building contents as the result of the failure of two roll-up metal doors. This type of structural weakness is known to be found in the majority of 1-3 story commercial buildings. We recommend, therefore, that these doors be protected by horizontal bracing members spaced approximately 3 ft. on centers and securely fastened to the walls. For metal doors having the edge guide supports shown in Figure 5, blocking flood is required and the edge support should not be relied upon to provide wind resistance.

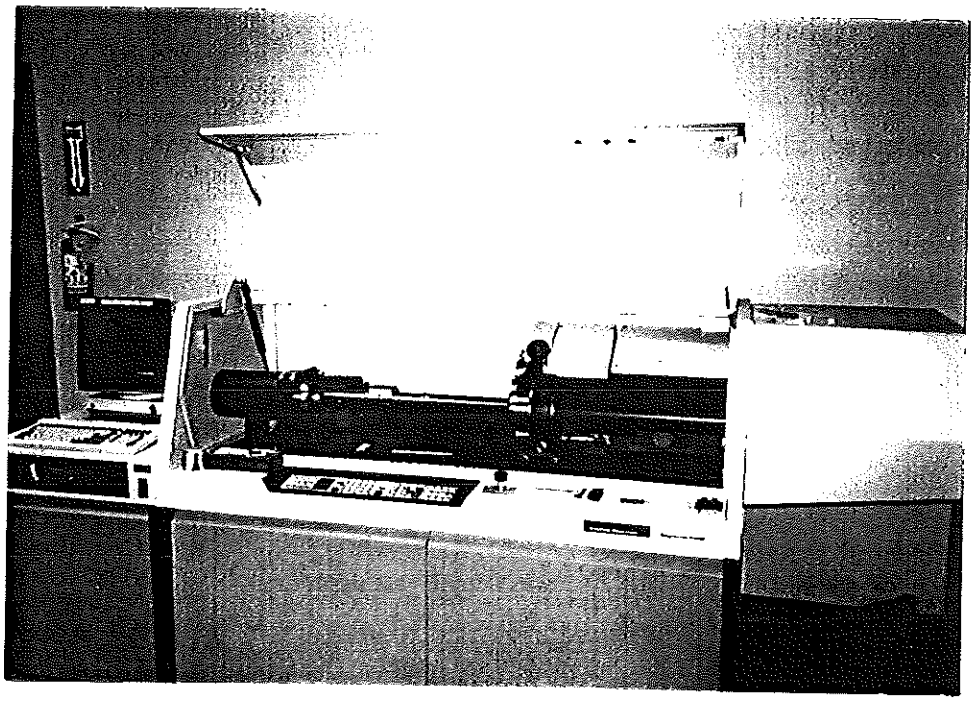
REFERENCES

1. ASCE 7-88.

2. South Florida Building Code.

3. National Flood Insurance Program (Regulations for Floodplain Management and Flood Hazard Identification), Federal Emergency Management Agency, 1990.

4. Herbert, R.D., ROOFING (Design Criteria, Options, Selection), R.S. Means Company, Inc., Kingston, MA, 1989.



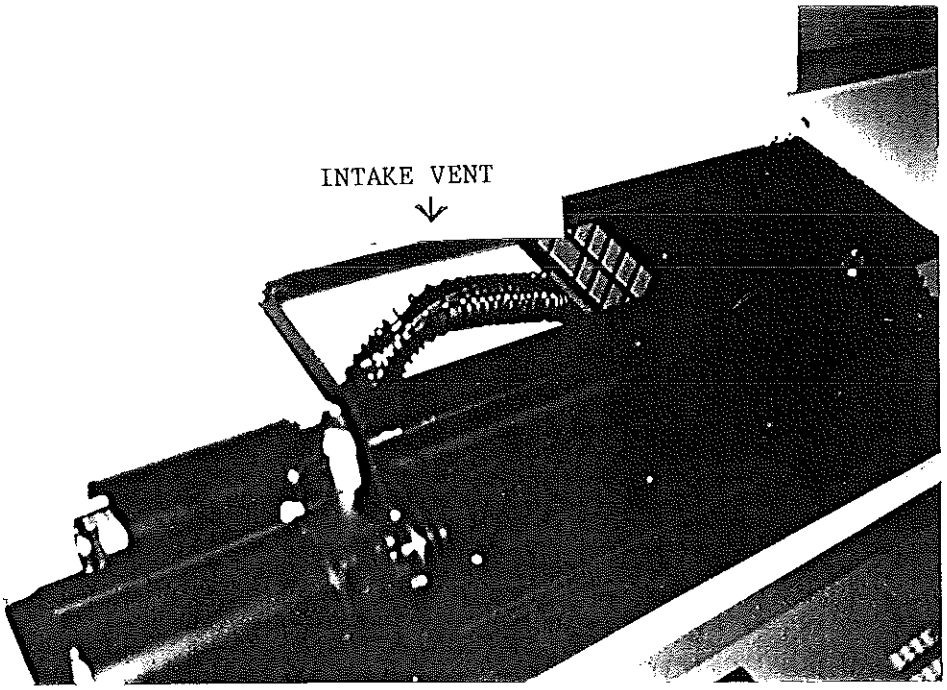


Figure 13: Color Separation Scanner at
Lower Picture Identifies Intake Vent

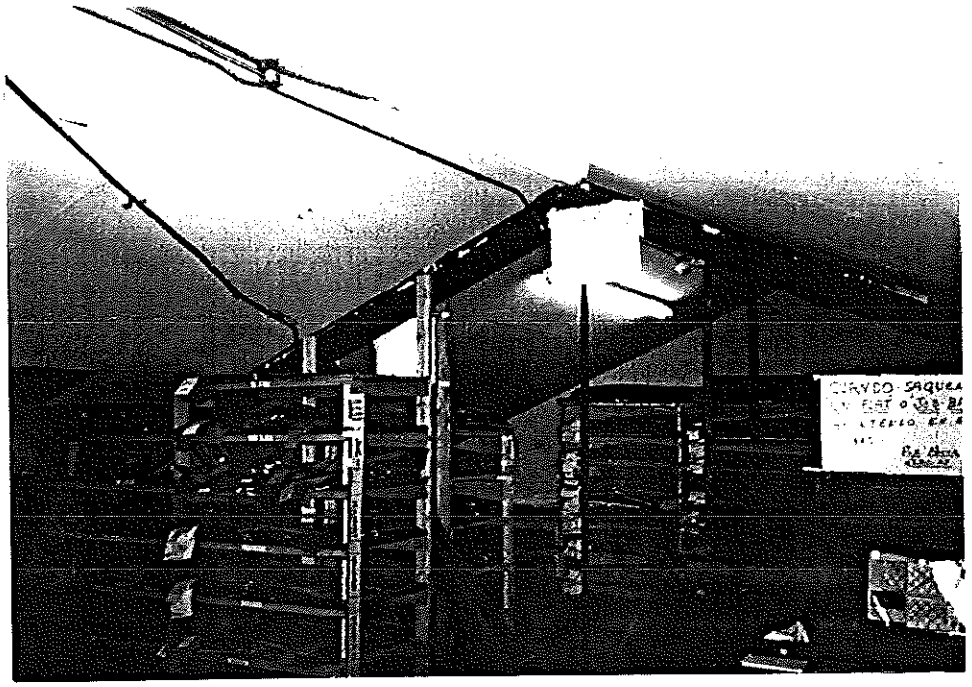


Figure 14. Example of valuable contents with no second line of defense against water contact.