Case Study of New, Top-down Flood Protection Using Advanced Tensioned Fabric Softgoods Technologies in New York City post Superstorm Sandy

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Presentation Format

• Flood Protection Efforts in New York City  
  Mike Hall - Arup

• Point-of-Use Stowed Tension Fabric Membrane Stairwell Protection Device Development Overview  
  Alan George – ILC Dover

• Questions

Presentation Objectives:

• Illustrate Unique Flood Mitigation Solutions
• Provide you with another tool for your toolbox
Taken from above the entrance to the Brooklyn Battery vehicular tunnel
This was the entrance to the Queens Mid-Town vehicular tunnel
Inside South Ferry Station after the water was pumped out. Where did those timbers come from?
South Ferry Station

$600M in damage to this station alone
Resilient Tunnel Plug project was in process but NYCT Concept of Operations was to stop water from the top-down and not bottom-up
8 Stations – Narrow Stairs
Challenge Location

Potential flooding from a Category 3 or greater hurricane.
Narrow Stairs
(Alternative to Marine Doors & Stop Logs)

* Traditional Solution – Marine Doors or Stop Logs at base of stairs
  - Large head of water \((14' \text{ Threat} + 16 \text{ steps} = 25' \text{ of water})\)
  - High Loads imparted to existing structures
  - Stair wells fill with water – pumping/clean out.

* Alternative solution
  - Permanently in place
  - Easily and quickly deployable
  - Easily retractable
  - Minimal labor requirements
  - Normal Load into stations box
  - Simple construction
System Overview

**Storage Container**
- Behind K-rails
- Front portion opens to deploy cover
- Access to container behind railing

**Guide Rails**
- Replace coping
- Forms seal at edge of system

**Existing K-rails**

**Stowed**

**Top Step Box**
- Clamp system for cover below grade
- Non-slip tread on top plate

**Deployed**

**Cover**
- Webbing and coated fabric assembly
- Fire retardant Kevlar materials

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**Loads to Consider**

\[ P_1 = \rho \times \text{water height} = 873.6 \text{ psf} \]
\[ P_2 = \rho \times d_h = 31.2 \text{ psf} \]
Total Water Pressure = \( P_1 + P_2 = 904.8 \text{ psf} \)

Where:
\( \rho \) = density of water = 62.4 lb/ft\(^3\)
\( d_h \) = surcharge depth = \( (1.25 \times \text{water velocity}^2)/2g \)
\[ = (1.25 \times (5 \text{ ft/sec})^2)/(2 \times 32.2 \text{ ft/sec}^2) = 0.5 \text{ ft} \]

\[ P_3 = 29 \text{ psf for Cat 2 Hurricane} \]

\[ F_i = W \times V \times C_D \times C_B \times C_{\text{str}} \]
\[ = 1000 \text{ lbs} \times 5 \text{ ft/sec} \times 1.0 \times 1.0 \times 0.4 \]
\[ = 4000 \text{ lbs} \]

Where:
\( W \) = weight of object
\( V \) = velocity of water
\( C_D \) = depth coefficient
\( C_B \) = blockage coefficient
\( C_{\text{str}} \) = structure coefficient (0.4 for concrete pile or steel moment resisting frames 3 stories or less in height above grade)

**Takeaway – There are multiple loads to consider for site and the flood barrier**

Source: DG312, MTA Flood Resiliency Design Guide
Loads to Consider

**F_p** = \((P_1 + P_2) \times A_c\) = 904.8 psf * 72 ft\(^2\) = 65,146 lbs

**P_r** = \(F_p / A_r\) = 65,146 lbs / 22.5 ft\(^2\) = 2895 psf

Where:

- **F_p** = Plug Load
- **P_r** = Reaction Pressure
- **A_c** = cover area = \(L_f \times W_f\)
- **L_f** = frame length = 12 ft
- **W_f** = frame width = 6 ft
- **A_r** = Load reacting area = Gateguide Perimeter * Gateguide width
  = (side length * 2 + top step width) * Gateguide width = 22.5 ft\(^2\)

**Key** – Bearing wall can handle downward compression load but cannot withstand inward loads

**Takeaway** – only want normal load on the stairwell structure, all others taken by flood protection structure
Stairwell Protection Devices

- Advertising Panel and Stainless Steel Mount
- NYCT Way-Finding Signage
- Flex-Gate Roll Box
- K-Rail at NYCT Entrance Stair
Prototype Installation
Canal Street S5 (Junction of Canal and Varick)
Prototype Installation

So far so good…
Prototype Testing
Prototype Testing

Results:
- 6 GPM at 3 ft Head Pressure (0.17 GPM/Linear foot)
Completed Prototype

Before

After

Before

After
Top Level Project Requirements

- Stow at the Point-of-Use
- Resist 14ft water head
- Minimal leakage (< 0.1 GPM/Linear ft. of seal perimeter)
- Deploy in 30 MPH winds
- No encroachment on stairwell
- No loading on the stairwell
- Simple operation
- Withstand vandalism
- Scalable to other types of stairwells

[50+ Requirements]

Takeaway – Consider Client’s Concept of Operations as well as physical requirements
Stairwell Flex-Gate™

Section View - Deployed

- Container & Spool
- Existing Railing
- Guide Rails

• Operation
  • Clear the subway
  • Remove hand rail sections
  • Remove Top Step Cover
  • Open Guiderail protective plates
  • Deploy the cover
  • Lock in place

Takeaway – Speed is King to allow the system to stay open as long as possible and recover quickly
Flex-Gate™ Testing

Deployment & Retraction

Guide Sealing at Pressure

Guide Pull Out Force
Flex-Gate™ Testing

- 6.9 psi proof test (~16ft water or 1.25x operational pressure)
- Leakage at operational pressure was 10.6 GPM or 0.29 GPM/ft

<table>
<thead>
<tr>
<th>Item</th>
<th>Quantity</th>
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<tbody>
<tr>
<td>Flex-Gate (Softgoods)</td>
<td>~ 70lbs.</td>
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<tr>
<td>Top Plate</td>
<td>7,500 lbs.</td>
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<tr>
<td>Water</td>
<td>~1500 gal. (12,500 lbs.)</td>
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Ongoing Efforts