Flood-Damage Resistive Residential Envelope Systems

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Floods have been a way of life in the U.S.

(FEMA News Photo)

They strike throughout the country - CA to FL, ND to LA

(FEMA News Photo)

Clean-up and reconstruction is always a challenge

(FEMA News Photo)

It doesn’t stop with getting rid of the mud and water

(FEMA News Photo)

This is usually just the beginning

(FEMA News Photo)

Once a Residence Has Flooded What Can Be Done?

- Require residents to move and demolish house
- Relocate house and residents to move to higher ground
- Raise the level of the house in same location
- Repair to pre-flood condition and hope it doesn't happen again
- Repair with flood damage resistant materials and systems (wet flood proof)
- Repair to make house dry flood proof

Presentation Outline

- Flood Resistant Building Codes – What are flood resistant materials?
- Flood Resistance & Energy Efficiency – HUD PATH/FEMA/DOE partnership
- Current Testing – Where are we now and where are we going
- Future Activity – Additional tests, best practices guide, representative flood waters, pre-standard development, computer model

What is Flood Damage Resistance?

- The ability of a material/component/system to withstand direct and prolonged contact with flood water
- No degradation that requires more than “cosmetic” repair to restore to original condition
- Flood damage resistance includes both physical factors and residents’ health factors

Flood Resistant Building Codes

- In 1994, BOCA, ICBO, and SBCCI produced a single, national model building code and created the International Code Council
- Provided opportunity to improve disaster-resistance factors in nation’s codes
- Working with others, FEMA added disaster-resistant provisions to the 2000 ICS

Flood Resistant Building Codes

- 2000 ICS, first to include flood, wind, and earthquake provisions that meet
  - NFIP minimum requirements
  - NEHRP recommended provisions
- Success created a dilemma
  - Codes require use of "flood resistant" materials below the base flood elevation
  - No test procedures to determine "flood resistance"

Flood Resistant Building Codes

- Current FEMA Technical Bulletin FIA TB 2-98 on flood resistant materials done in 1980’s (now outdated)
- In 2000, FEMA worked with NES to develop a laboratory testing protocol to evaluate the flood resistance of building materials
- Manufacturers have begun using that protocol

Flood Resistance and Energy Efficiency

- While the NES laboratory testing protocol was being developed, ORNL proposed field testing of building materials in assemblies
- FEMA, HUD/PATH, and DOE co-funded the ORNL work

Flood Resistance and Energy Efficiency

- FEMA, HUD/PATH, and DOE agreed on a joint program of testing, development of a best practices guide, a computer model, and other deliverables including the development of a pre-standard for materials producers and designers
- ORNL efforts began in FY 2000 with DOE.
- FEMA and HUD/Path becoming co-sponsors in FY 2001 with additional funding in FY 2002 & FY 2003
- Total project costs through FY 2002: $850K

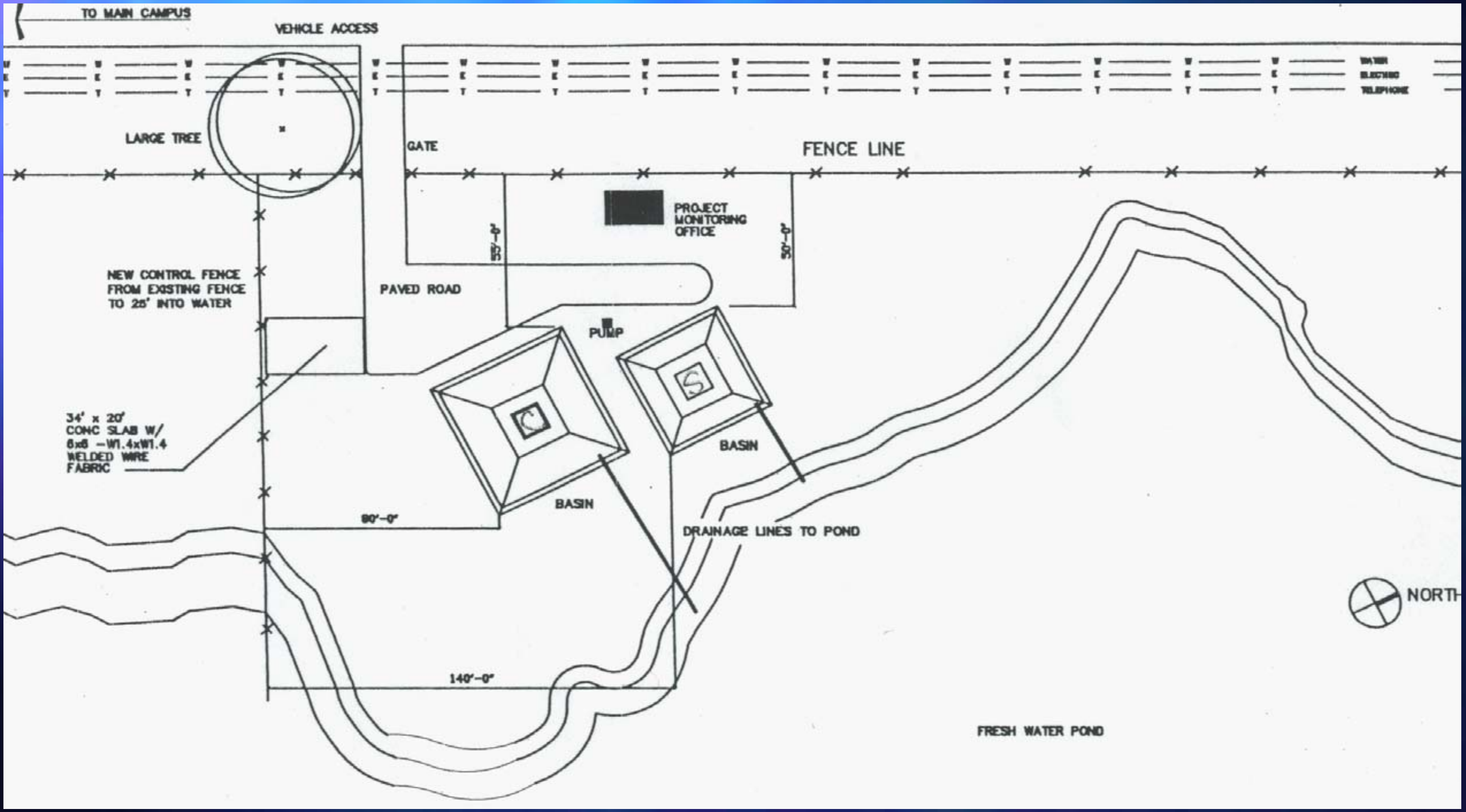
The ORNL/Tuskegee Field Test

- Researchers at ORNL and Tuskegee University have been field testing residential building systems to determine ways to minimize damage to houses when floods occur in the future

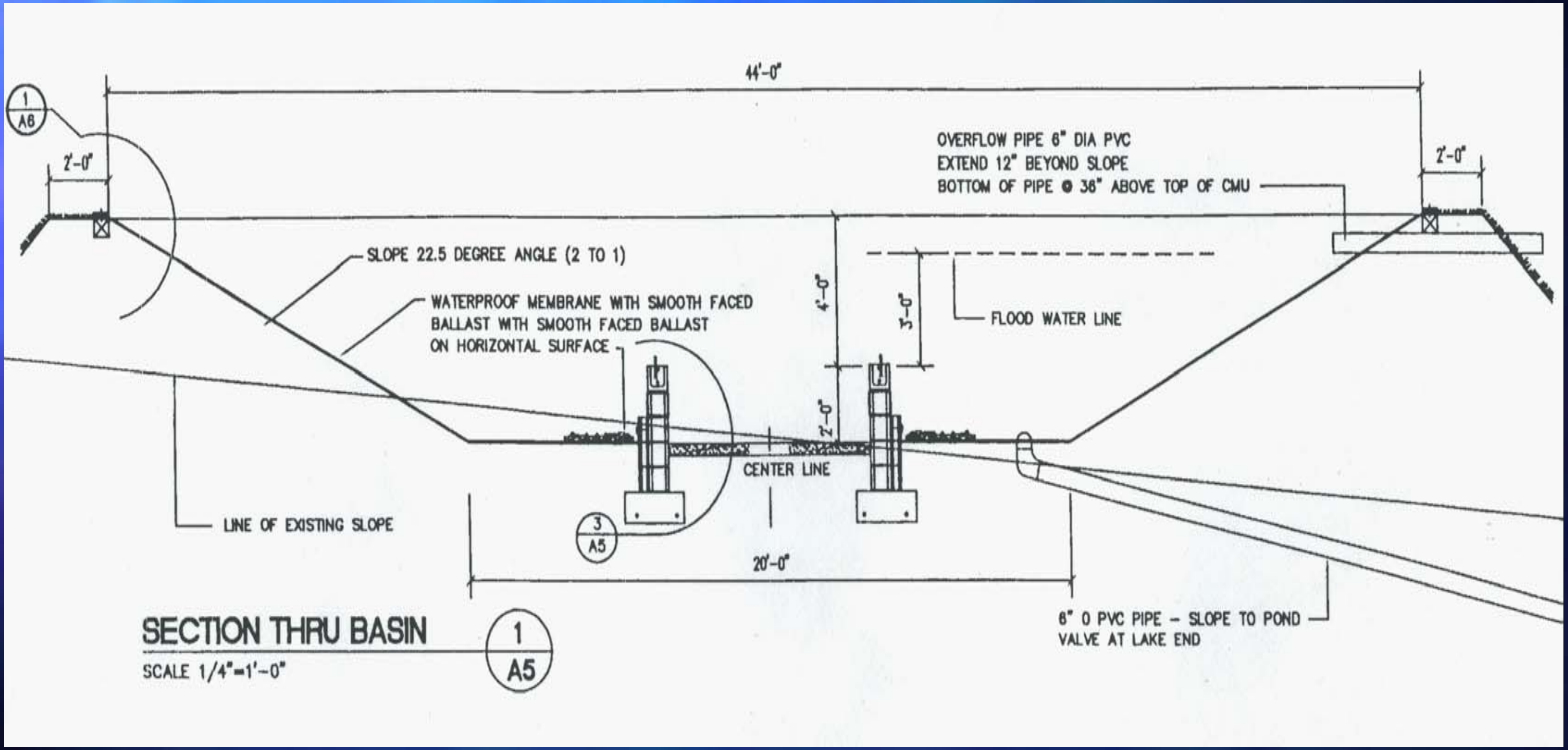
Field Test Methodology

- In order to test flood resistance, prototypical slab-on-grade and crawlspace test modules were constructed
- The modules simulated typical residential structures on a small scale
- These structures were constructed in an outside basin
- Flood water was pumped from a nearby agricultural lake

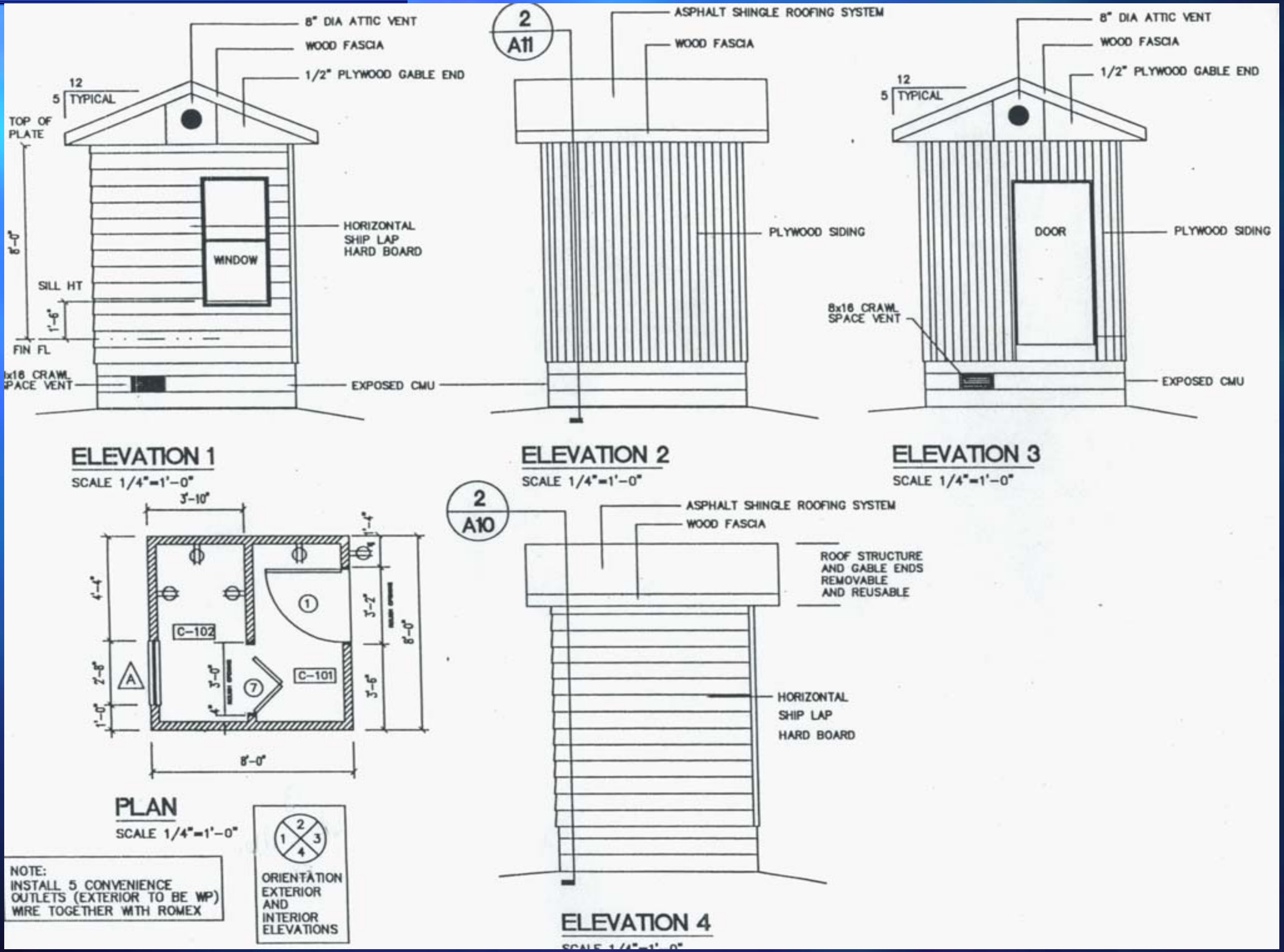
Tuskegee Field Test Facility



Tuskegee Test Basins



First Test Modules, Traditional Construction



First Test Modules

- The first slab-on-grade and crawlspace test modules were constructed according to “typical” construction practice
- No special attempt was made to use flood resistant materials or systems

First Slab-On-Grade Module

Specification for First Slab on Grade Test Module (S-1)

- Siding - plywood and hardboard lap
- Sheathing - OSB and plywood
- Insulation - fiberglass batt, exterior walls
- Interior - gypsum board with paper joint tape
- Flooring - one room, carpet on pad and one room, concrete with sealer, no covering
- Interior Walls - one room, latex flat white and one room, latex enamel on 3 walls and ceramic tile on 4^{th} wall

Specification for First Slab on Grade Test Module S-1 (cont.)

- Exterior door – solid wood, panel
- Interior door - hollow core interior grade
- Windows - double pane, aluminum
- Electrical - typical duplex electrical outlets and wiring installed above floor (below flood level)
- Ceiling - gypsum board, 2 coats interior latex paint
- Attic - wood framed, plywood roof decking
- Roofing - asphalt shingles

First Crawlspace Module

Specification for First Crawl Space Test Module (C-1)

- Siding - plywood and hardboard lap
- Sheathing - OSB and plywood
- Insulation - fiberglass batt, exterior walls
- Interior - gypsum board with paper joint tape
- Floors - wood joists, plywood subfloor
- Flooring - one room, carpet on pad and one room, sheet vinyl
- Interior Walls - one room, latex flat white and one room, vinyl wall covering on two walls, white latex enamel on two walls

Specification for First Crawl Space Test Module C-1 (cont.)

- Exterior door - steel w/ ½ light
- Interior door - hollow core
- Windows - double pane, aluminum
- Electrical - typical duplex electrical outlets and wiring installed above floor (below flood level)
- Ceiling - gypsum board, 2 coats interior latex paint
- Attic - wood framed, plywood roof decking
- Roofing - asphalt shingles

Timeline of Testing Protocol

Day –7 Completion of construction & finishing

Day –4 Initiation of monitoring instruments

Day 0 Flooding of basins/modules

Day +3 Draining of flood basins (72 hours)

Day +8 Re-entry and opening doors/windows

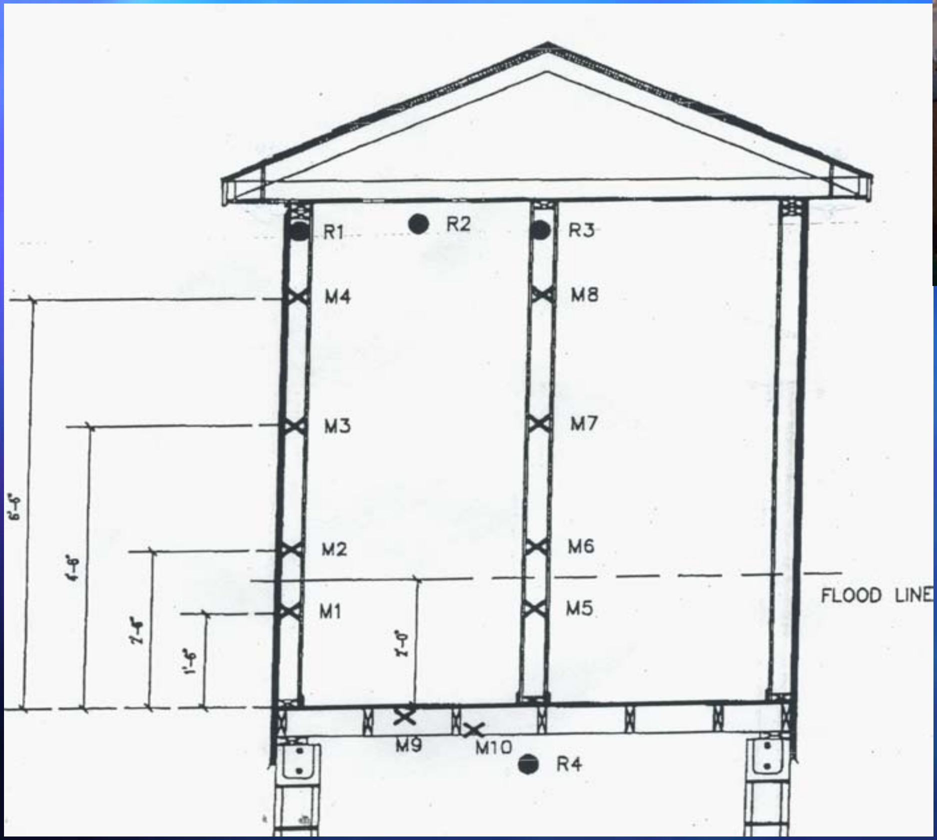
Day +8 Remove mud, carpets; rinse surfaces

Day +10 Sanitize surfaces and continue drying

Day +30 End of measurements this module

Beyond Day 30 Restoration efforts, final documentation, and autopsy

Instrumentation



Sensors

- RH
- Temperature
- Moisture

Flooded Slab-on-Grade Module

Flooded Crawlspace Module

First Tests-- State of the Exterior of Both Modules

- Exterior walls were stained below flood level
- Plywood siding was warped
- Hardboard siding was OK
- Cracks in wood corner trim boards
- Exterior door was stained and more difficult to open

First Tests--State of the Interior of Both Modules

- Strong musty smell
- Waterline on gypsum board walls above the waterline
- Carpet was saturated and muddy
- Interior doors stained and split at bottom
- No mildew or mold until Day +10, minor growth thereafter

First Tests--State of the Interior of Both Modules (cont.)

- Paper drywall tape peeling off walls
- Paint blistering (semi-gloss peeled less than flat)
- Ceramic tiles on floor and walls firmly affixed (grout slightly deteriorated and discolored)

First Tests--Gypsum Drywall Performance

- Exterior walls remained "wet" and difficult to refinish (bending tests S-1 showed significant loss in strength)

Above Water 3.20MPa

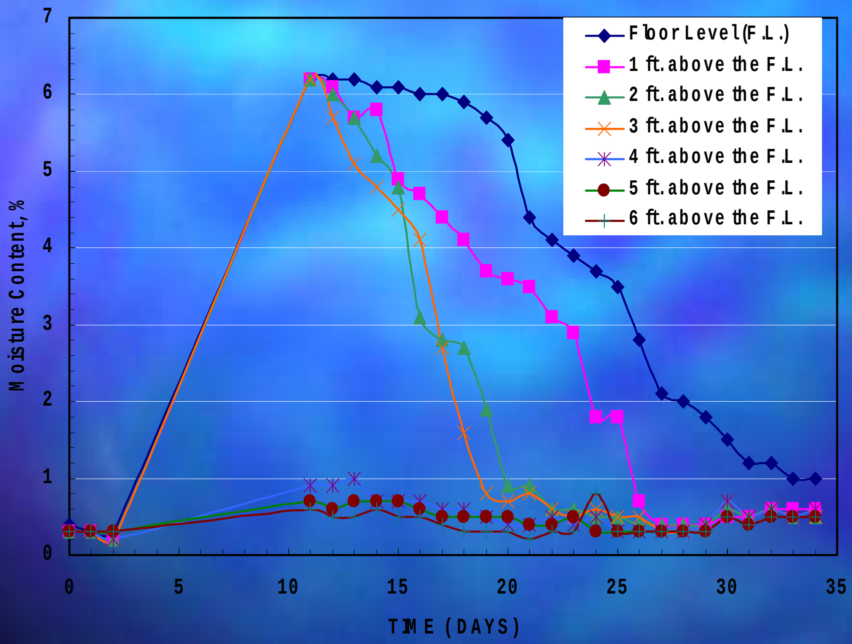
Below Water 1.64MPa

- Interior walls able to be sanded and re-painted (bending tests showed no significant loss in strength)

Above Water 3.68MPa

Below Water 3.56MPa

First Tests -- Insulation



- When wall cavities opened, batt insulation was damp
- Exterior gypsum board walls remained “wet” - see chart
- Thermal performance not tested

Second Tests

- In the second modules, different materials were used
- An attempt was made to use materials and systems that were more flood damage resistant
- Again, both slab-on-grade and crawlspace modules were constructed and flooded

Specifications for Second Test Modules C2 and S2

- Siding - Both vinyl and fiber cement were used
- Sheathing - Plywood and Fiberrock
- Insulation - Exterior walls insulated with spray polyurethane foam (SPUF)
- Interior wall surfaces - Fiberrock sheathing (WR), Fiberrock wallboard, and Gypsum drywall

Second Test - Conditions After Flooding (Exterior)

- Both exterior sidings in good condition, but some cracking of wood trim corners
- Exterior doors were stained
- Windows appeared unaffected

Second Test - Conditions After Flooding (Interior) Cont.

- Strong musty smell upon entry
- Walls stained below water line
- Major mildew and mold growth concentrated in a 20" band above waterline upon entry

Second Test - Conditions After Flooding (Interior)

- Mud and dirt on simulated wood and tile floors
- Wallboard joint compound and paint was peeling
- Interior hollow core door delaminated
- Interior solid wood six panel door stained

Second Test, Cleanup Procedures

- Day +8 (after draining), remove mud, rinse surfaces
- Day +10, simulated wood flooring removed from one module, washed and stored for possible reuse
- Day +10 interior surfaces washed and sanitized with solution of water, bleach, and Tri-sodium-phosphate

Second Test, Restoration Procedures, Beyond Day +30

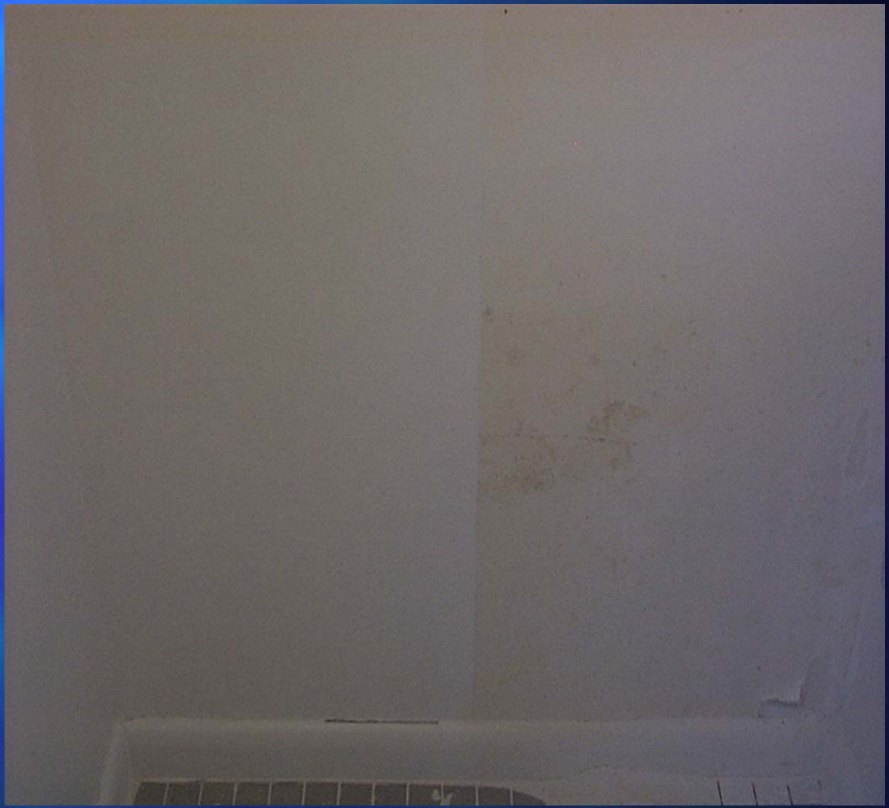
- Loose paint and joint tape removed, walls sanded, and re-painted,

  passed – like new
- Exterior door sanded and re-painted,

  passed – like new
- Interior HC door removed,

  failed - to be replaced
- Interior 6 panel door refinished,

  failed - due to staining



Second Test – What About the Wall Cavities?

- During “autopsy” wall cavities were opened
- The SPUF was not wet
- The gypsum wallboard dried, though it was stained
- After sanitizing, there was no evidence of mold on room side of inside walls or in wall cavities

Second Test – Where Does Water Enter?

- During the flooding of the second module, cameras recorded the entry of flood water
- In the slab-on-grade module water first appeared to enter at the joint between the floor slab and the wall plate
- In the crawlspace module water first appeared through joints in the floor

Implications of Where Flood Water Entered First

- In slab-on-grade, this points to importance of sealing between floor slab and wall plates (has implications for air infiltration as well)
- Because water did not appear to come through the walls, it may be possible to dry flood proof for low depth (< 3 ft.) floods

Third Test Modules (Under Construction)

- The crawlspace module will use plastic backed carpeting and water resistant padding. Other flood damage resistant materials will also be tested.
- The slab-on-grade module will be sealed in an attempt to provide “dry flood-proofing” (no water inside).

What Steps Used to Attempt Dry Flood-proofing?

- All rough opening joints at windows and doors, under thresholds, etc. will be thoroughly sealed
- The joint between the slab and wall plates will be sealed
- SPUF insulation in all wall cavities
- Exterior door and window “temporary dams” will be affixed to seal openings during flood

What is a Door or Window Dam?

- Extruded polystyrene foam boards will be cut to the size of the window and exterior door.
- Using 100% silicone caulk, the foam boards will be glued/sealed to the door and window frames.

Preliminary Findings from Testing

- Punching holes in gypsum board for drainage of no benefit
- Batt insulation (wet) is a major contributor to the failure to gypsum board on walls
- Cleaning and sanitizing walls did remove and prevent the return of mold
- Vinyl or fiber cement siding more easily restored than plywood or hardboard
- Ceramic tile (wall and floor) worked well
- If permitted

Planned Future Program Activities

- Future field experiments
- Description of representative flood waters for use in testing
- Final report of experiments
- Best practices guide
- Pre-standard development
- Computer simulation model

Future Field Experiments

- Previously tests used water from a nearby agricultural lake
- Key components of representative U.S. flood waters will be identified, e.g. petrochemicals, sewage, fertilizers, staining agents, etc.
- The best materials and systems will be tested in flood water containing these additional components

Best Practices Guidance Will:

- Analyze/evaluate field test data to determine performance of materials and systems
- Provide flood damage resistance findings regarding:

  - available materials/systems

  - clean-up and restoration methods

Development of a Flood Resistance Pre-Standard Will:

- Permit the develop future flood resistance codes and standards for residential envelopes
- Validate and refine test protocols developed by NES and ORNL
- Provide information to manufacturers for identifying existing materials and developing improved materials for use

Computer Modeling Tool Will:

- Take materials and systems from experiments and apply differing drying rates from:
  - Climatic data
  - Seasonal data
  - Water data
- Permit location specific evaluation of performance

Computer Modeling Tool Will:

- Enable contractors and code officials to evaluate potential flood damage resistance materials and systems for their specific jurisdiction
- Provide designers and manufacturers with a tool to identify which materials and systems will work in various locations

Questions?

Comments!

Suggestions?