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Concrete Masonry Storm Shelters

Masonry Structural Coalition

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Presentation Outline…

- IBC / ICC 500 Storm Shelters *(Tornado)*
- Concrete Masonry Storm Shelters
- 3D Modeling and Budget Collaboration
- Wrap-up & Discussion

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Somewhere to Hide…

Parsons Manufacturing
Roanoke, IL

Employees survived in the restrooms

NCMA

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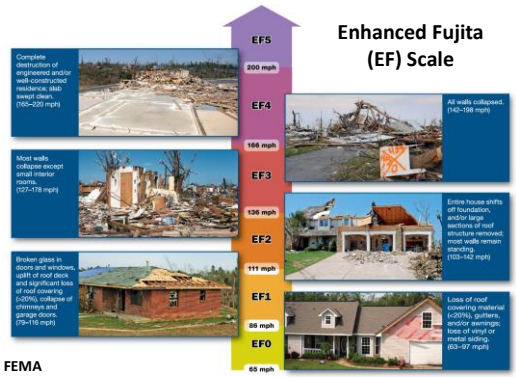
Enhanced Fujita (EF) Scale



FEMA

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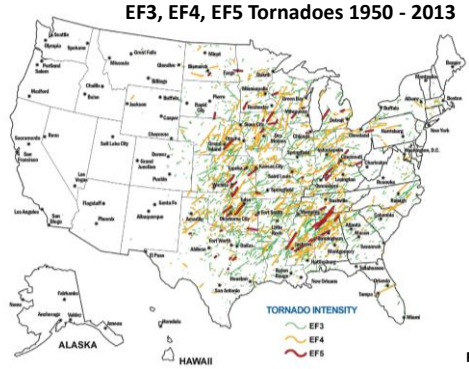
EF3, EF4, EF5 Tornadoes 1950 - 2013



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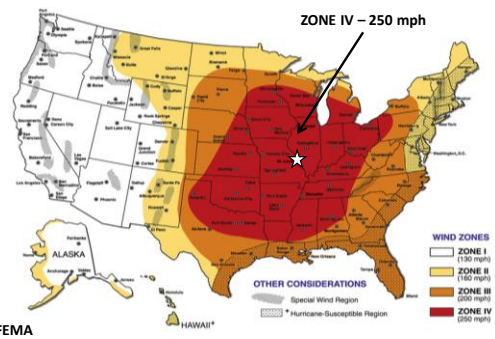
Tornado Design Wind Speeds



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IBC / ICC 500
Storm Shelters

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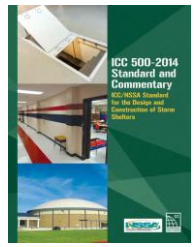
ICC 500 - 2014



Complying Structures are "Storm Shelters"

- International Code Committee (ICC)
- Jointly with the National Storm Shelter Association (NSSA)
- Codified shelter design requirements (consensus process)
- Publication Sequence:
  - 2002 Joint ICC/NSSA project begins
  - First Edition – 2008
  - Second Edition – 2014

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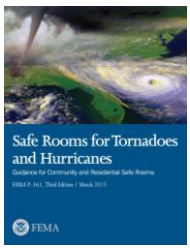
FEMA P-361



Complying Structures are "Safe Rooms"

- Federal Emergency Management Agency (FEMA)
- Recommended criteria and best practices, but not Code
- Publication Sequence:
  - First Edition – July, 2000
  - Second Edition– August, 2008
  - Third Edition – March, 2015
- P-361 will continue to be published in response to ICC 500 updates and on-going tornado investigations

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ICC 500 vs FEMA 361

FEMA P-361 Table A1-1	BEST AVAILABLE REFUGE AREA	ICC 500 STORM SHELTER	FEMA SAFE ROOM
Designed to minimum building code requirements	Maybe	Yes	Yes
Evaluated by a registered design professional and identified as least vulnerable area/room in building	Yes		
Designed specifically to provide life-safety protection per ICC 500		Yes	Yes
Designed specifically to provide near- absolute protection per FEMA P-361 criteria (including operational and emergency planning criteria)			Yes

FEMA SAFE ROOM GRANT REQUIREMENT

Whenever a safe room is constructed using FEMA grant funds, the FEMA P-361 Recommended Criteria become requirements in addition to the requirements of ICC 500.

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IBC Storm Shelter Requirements

- 2009 and 2012 IBC references ICC 500-2008
- 2015 IBC references ICC 500-2014
- Prior to 2015 IBC:
  - Storm shelters not required
  - If designed/constructed they must comply with ICC 500
- 2015 IBC: ICC 500 storm shelters required for the following if located in the 250 mph tornado wind speed zone:
  - K-12 school buildings with occupant load > 50
  - 911 call stations
  - Fire, rescue, ambulance, and police stations
  - Emergency operations centers

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IBC Storm Shelter Requirements

- 2015 IBC Storm Shelter Exceptions for K-12
  - Day Care Centers
  - Accessory to religious worship facilities
  - Buildings that meet ICC 500 criteria

ICC 500 Storm Shelters

- Loads significantly greater than normal structures
  - Load Path Critical (structural members and connections)
  - High wind lateral and uplift loads
  - Missile loads (debris impact)

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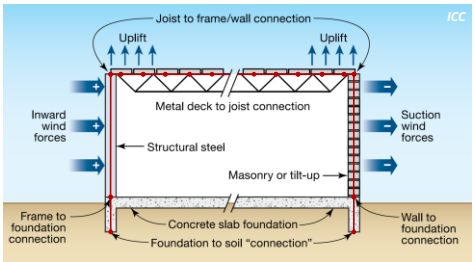
ICC 500 Storm Shelters – *Load Path*



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ICC 500 Storm Shelters – *Missile Loads*

Wall & roof systems, doors & windows, impact protection systems

Loads and Testing

15 lb 2x4 missile

100 mph impact

Speed for walls

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ICC 500 Storm Shelters – *Local Load Hazards*

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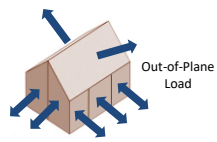
ICC 500 Storm Shelters – *Wind Loads*

Main Wind Force Resisting System Load (MWFRS)



Components & Cladding Load (C &C)

For mass wall materials C & C loads typically control

- Typical factored C & C shelter wind pressures:
  - Walls +190/-206 PSF (+190/-213 PSF Corner Zones)
  - Roofs -209 PSF (-238 PSF Corner Zones)

Except for very, very heavy roof systems, there will be net uplift

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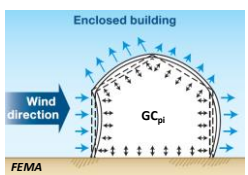
ICC 500 Storm Shelters – *Internal Pressures*

- Factor GC_{pi} = 0.18 for "enclosed building" but…
  - Design must account for Atmospheric Pressure Change (APC) by providing venting of 1.0 SF / 1,000 CF
  - Design must follow ICC 500 criteria for type and location
- GC_{pi} = 0.55
  - When no APC venting provided or APC venting area not calculated
- Factor of 3 increase on internal pressures



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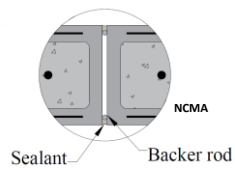
ICC 500 Storm Shelters – *Gaps and Voids*

- Includes air louvers, grates, grills
- Protection required unless:
  - No direct path to occupants, or…
  - ⅜" maximum movement / panel joint with sealant



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ICC 500 Storm Shelters – *Peer Review*

- Compliance Review
  - Professional peer review required for:
    - All shelters with occupancies > 50
    - Shelters for elementary/secondary schools and day care facilities (?) with occupancies > 16
    - Risk Category IV shelters (essential facilities)
  - Signed and sealed report to be submitted to Authority Having Jurisdiction prior to the issuance of a permit for constructing

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Concrete Masonry Storm Shelters

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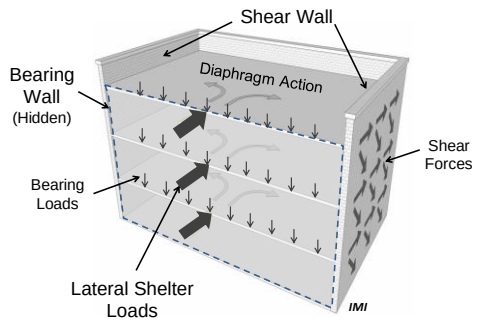
Concrete Masonry - *Robust Load Paths*



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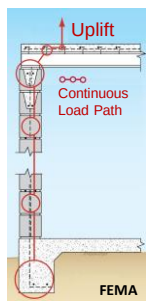
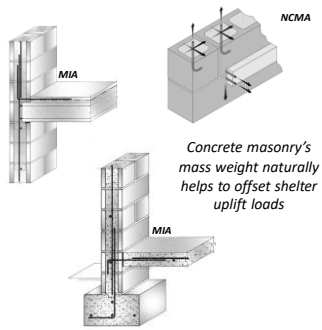
Concrete Masonry - *Robust Connections*





Concrete masonry's mass weight naturally helps to offset shelter uplift loads

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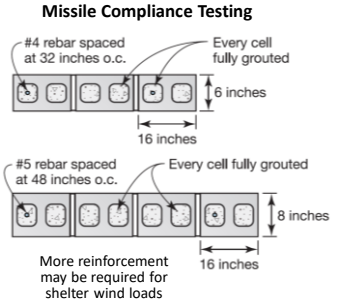
Resiliency/Redundancy

Texas Tech Concrete Masonry Missile Compliance Testing



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Resiliency/Redundancy

- Recent Texas Tech missile testing shows that CMU behind anchored brick veneer may be ungrouted
  - TMS 402 standard anchored veneer provisions must be checked/altered for shelter level wind loads
  - Tested: 8" CMU partially grouted, reinforced 24" o/c, modular clay brick veneer anchored 16" o/c each way to joint reinforcement, 2" cavity
  - Tested: 8" CMU partially grouted, reinforced 32" o/c, utility clay brick veneer anchored 16" o/c each way to joint reinforcement, 2" cavity
  - Both systems passed ICC 500 missile load criteria

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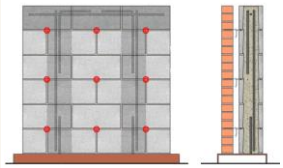
Resiliency/Redundancy

Texas Tech
CMU/Veneer Testing



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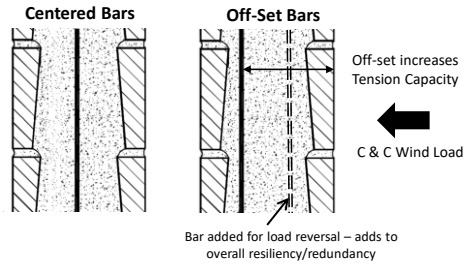
Resiliency/Redundancy – *Two Bar Layers*



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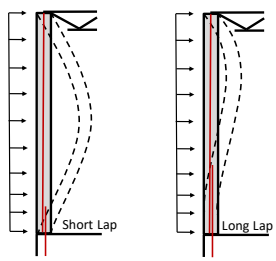
Resiliency/Redundancy – *Pinned vs. Fixed Base*



- Most designers assume "pinned" base
- Lap lengths required by shelter level bar size and location can allow for "fixed" base assumption
- Fixed bases reduce the effective span and moment of the wall
- Also makes wall less dependent on roof support

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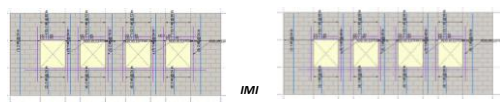
Cost-Effective Shelter Level Transition



Non-shelter wall	Shelter Wall
8" CMU Partial grout	8" CMU Full grout
#5's at 64" o.c. and jambs	#6's at 24" o.c. and jambs
Light roof and pinned base	Heavy roof, fixed base

Note: Partially grouted shelter walls possible with engineered veneer

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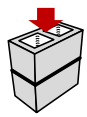
Cost-Effective Shelter Level Transition

- System Compressive Strength Update
  - 2009 IBC
    - Type S Mortar
    - Min. block strength required 1,900 *psi*
    - Min. default *f'm* (w/o testing) 1,500 *psi*
  - 2015 IBC
    - Type S Mortar
    - Min. block strength required 2,000 *psi*
    - Min. default f'_m (w/o testing) 2,000 *psi*



Result of industry testing correlating code values to final in-place strengths
Maximum f'_m (without testing) is 3,000 *psi* (Type S mortar and 4,500 *psi* CMU)

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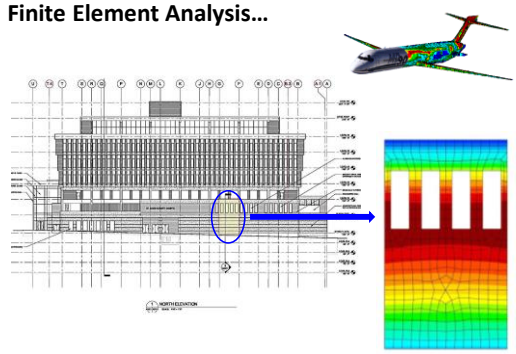
Finite Element Analysis…



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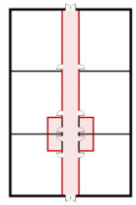
Storm Shelter Options – *Interior Corridors*

- Interior corridor sheltering
  - Close by to occupants (+)
  - Few furnishings (+)
  - Lowest structural demand (+)
  - Heavy roof or floor above (+/-)
  - Limited occupant space (-)
  - Numerous door openings (-)
  - Meeting ICC 500 restroom requirement (-)



Note: All shelter envelope doors and windows must be impact resistant or otherwise protected

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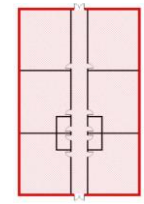
Storm Shelter Options – *Classroom Wings*

- Classroom wing sheltering
  - Sheltering "in-place" (+)
  - Increased structural demand (-)
  - Heavy roof or floor above (+/-)
  - More occupant space (+)
  - More furnishings (-)
  - Fewer door openings (+)
  - Numerous window openings (-)
  - Meeting ICC 500 restroom requirement may be easier (+/-)



Note: All shelter envelope doors and windows must be impact resistant or otherwise protected

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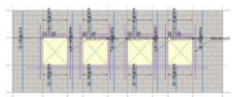
Storm Shelter Options – *Classroom Wings*

- Example Design
  - 12' wall height
  - 8" CMU fully grouted
  - f'_m = 2,000 psi
  - #6 bar each jamb
  - #6 24"o/c elsewhere
  - Fixed base (40" lap)
  - Joint reinforcement 16" o/c
  - Full internal pressure

IMI



Example for illustration purposes, not for construction

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Storm Shelter Options – *Gymnasiums*

- Gymnasium Sheltering
  - Familiar location (+)
  - Sheltering "in-place" (-)
  - Highest structural demand (-)
  - Heavy roof or floor above (+/-)
  - Good occupant space (+)
  - Few furnishings (+)
  - Few door openings (+)
  - Few window openings (+)
  - Locker rooms may provide ICC 500 restroom requirement if within shelter envelope (+/-)

Similar for other multi-use large rooms such as music rooms, cafeterias, etc.

FEMA

Note: All shelter envelope doors and windows must be impact resistant or otherwise protected

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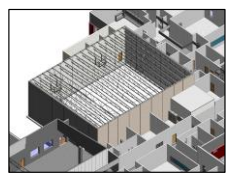
Storm Shelter Options – *Gymnasiums*

- Example Design
  - 26' 8" wall height
  - 12" CMU fully grouted
  - f'_m = 3,000 psi
  - 2 - #6 bars 8" o/c
  - Pinned base (40" lap)
  - Joint reinforcement 16" o/c
  - Full internal pressure



Example for illustration purposes, not for construction

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Storm Shelter Options – *Restrooms*

- Restroom sheltering
  - Probably not an option for ICC 500
  - Make a lot of sense for providing "best available refuge" areas
  - Especially with baffled entries as used at airports, etc.
  - Concrete masonry a great option since often used for restroom construction already

NCMA

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ICC 500 Required Inspections / Observations

- Special inspections highly stressed for ICC 500 storm shelters as part of required overall quality assurance plan
- ICC 500 special inspections based on IBC Chapter 17
- Structural systems, including masonry, are required to be specially inspected already…although frequency of inspections may increase for storm shelters
- ICC 500 places emphasis on "post-installed" anchors
  - Important since post-install anchor materials and design is generally not covered by the IBC or material standards including TMS 402
  - For masonry, post-installed means installed after grouting
- IBC "structural observations" of structural systems by registered professional kick in for storm shelters due to high wind loads

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Credentialed Storm Shelter Installer (CSSI)

- Mason Contractor Association of America (MCAA) certification program for masonry storm shelter installers
- Program is broken down into five different topic areas:
  - Introduction and Background
  - Anchoring Dowels
  - Connections
  - Reinforcing and Grouting
  - Quality Control and Assurance

MCAA Credentialed Storm Shelter Installer

- Topics specifically designed for the installer and cover every facet critical to the successful installation of a storm shelter

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3D Modeling and Budget Collaboration

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Masonry Model Collaboration

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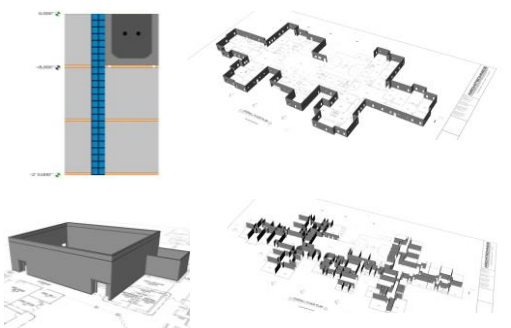

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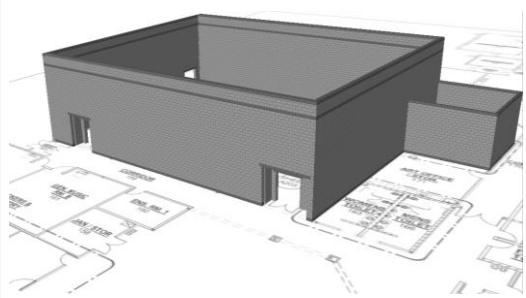
Masonry Model Collaboration



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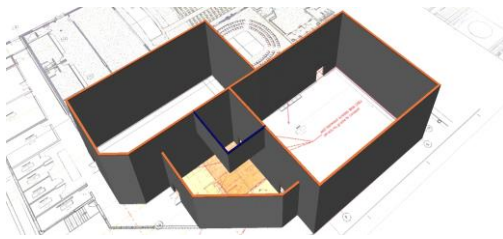
Masonry Model Collaboration



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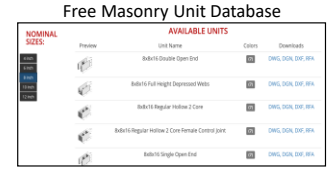
BIM-M **www.bimformasonry.org**

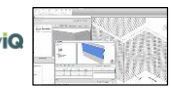
Free Revit Guide

Free Masonry Unit Database



Free Revit Tools

NEW!
MasonryIQ by 3DiQ



Low Cost Powerful Revit Plugin

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Budgetary Collaboration

- Real-time market budget numbers
- Alternate comparisons
  - Masonry to masonry
  - Masonry to other systems

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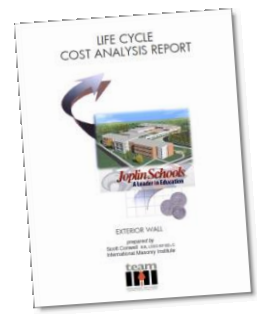
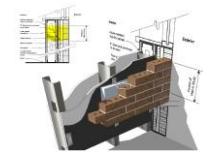
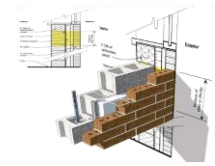
Life Cycle Cost Reports







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Relative Cost Study…

- 2016 using R. S. Means Concrete and Masonry Cost Data
- Union wage data
- Installing contractor prices
- City cost index for St. Louis
- Loadbearing CMU Compared To…
  - *Precast Concrete*
  - *Tilt-Up Concrete*

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CMU – Precast – Tilt-Up Summary

- Head to Head Comparison
  - 8" CMU $12.79/SF
  - Precast Concrete $31.56/SF
  - 7 ½"Tilt-Up Concrete $15.98/SF
- Floor Slab Considerations (Tilt-up)
  - Floor slab MEP obstructions
  - Additional cost of 6" vs. 4" slab (+ $2.28/SF of wall, 100' x 200' x 20' Tall Building)

Source: 2016 Means Concrete and Masonry Cost Data

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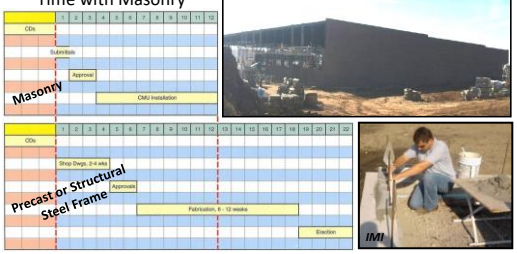
Scheduling With Masonry…

Reduced Lead/Fabrication Time with Masonry



Masonry can begin as soon as footings/foundations are installed

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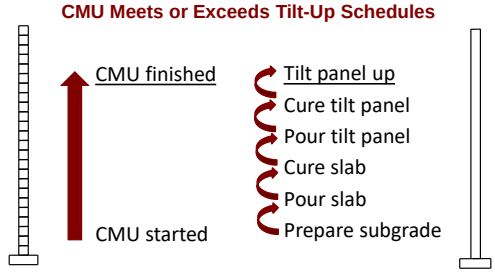
CMU & Tilt-Up Scheduling

CMU Meets or Exceeds Tilt-Up Schedules



Masonry can begin as soon as footings/foundations are installed

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Wrap Up and Discussion

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Concrete Masonry Storm Shelters

- Provide the necessary strength and flexibility for various shelter sizes, wall heights and configurations
- Cost-effective shelter level transition
  - Built-in system resiliency/redundancy
  - Tight system tolerances
  - Single and double bar layers per cell options
  - Code updated system strength ($f'm$)
  - Veneer can be an integral part of structural solution
- Readily available local materials and labor

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Concrete Masonry Storm Shelters

- Inherent Envelope Attributes
  - Familiar aesthetic
  - Durability
  - Sustainability
  - Energy conservation
  - Moisture resistance
  - Sound resistance
  - Fire resistance

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Presentation Outline…

- IBC / ICC 500 Storm Shelters *(Tornado)*
- Concrete Masonry Storm Shelters
- 3D Modeling and Budget Collaboration
- ***Wrap-up & Discussion***

Thank You for your time!

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