CASE STUDY: DISASTER-RESISTANT GUAM HOUSING
BIG WIND RESIDENTIAL DISASTERS

DISASTER RESISTANT HOUSING (DRH)
WEBSITE ADDRESS:
http://www.tornadoproofhouses.com

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FOR THE FIRST TIME IN THE HISTORY OF MANKIND, WE TODAY HAVE A SOLUTION TO THE AGE OLD CHALLENGE OF BUILDING ATTRACTIVE ENERGY-CONSERVATIVE HOUSES THAT ARE COMFORTABLE AND AT THE SAME TIME SECURE FROM DESTRUCTION BY THE SEVEREST FORCES OF NATURE EARTHQUAKES, HURRICANES, TORNADOES.
This presentation is about:

**PERFORMANCE**

- PERFORMANCE OF Reinforced Concrete Single Family Houses designed according to DRS Box-Frame criteria under the forces of LARGE EARTHQUAKE S AND VERY HIGH WIND VELOCITIES

- It is **not** about design and construction procedures other than to emphasize their contributions to the construction and **STRUCTURAL** performance of **REINFORCED CONCRETE** houses
CONCRETE HOME DEFINITION

- Our definition of a “CONCRETE HOME” is:
  “Single family house built with cast-in-place or prefabricated (precast or tilt-up) reinforced concrete walls PLUS cast-in-place reinforced concrete roofs

- This presentation considers the structural resistance of authentic “Concrete Homes” (according to our definition) against disastrous forces, both natural and man-made

- If the roof is not a reinforced concrete slab intimately connected to reinforced concrete walls and floors – then most of the disaster-resistant attributes are not achievable

- MOST OF THE SO-CALLED “CONCRETE HOMES” BEING CURRENTLY CONSTRUCTED IN NORTH AMERICA ACCEPT THAT WOOD-FRAME ROOFS WILL BE SACRIFICED IN A BIG EVENT
DISASTERS IN GENERAL
DISASTER MAP OF THE USA
(Does not include fire storms, floods, storm surges or tsunamis)
DISASTERS CONSIDERED

- The presentation does not address all disasters that can impact the human environment.
- It will mainly discuss those disastrous forces that significantly impact human life and habitation year after year.

- Earthquakes
- Hurricanes = Typhoons = Cyclones
- Tornadoes
- Firestorms
- Floods
## Structural Disaster Resistance Compared

<table>
<thead>
<tr>
<th>Type of Construction</th>
<th>Fire</th>
<th>CAT 5 H-CANE</th>
<th>Richter 8 E-Quake</th>
<th>CAT 3 -5 Tornado</th>
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</thead>
<tbody>
<tr>
<td>Total Wood Frame</td>
<td>None</td>
<td>None</td>
<td>Partial</td>
<td>None</td>
</tr>
<tr>
<td>R/C Walls &amp; Frame Roof</td>
<td>None</td>
<td>Partial</td>
<td>Partial</td>
<td>Partial</td>
</tr>
<tr>
<td>R/C Walls &amp; R/C Roof</td>
<td>Total</td>
<td>Total</td>
<td>Total</td>
<td>Total</td>
</tr>
</tbody>
</table>
FIRESTORMS
The map shows locations that experienced wildfires greater than 250 acres, from 1980 to 2003. (23 years) Map not to scale.


Particularly impacted are regions in the western United States

Few states are unaffected
FLOODS
STORM SURGES
TSUNAMIS
Presidential disaster declarations related to flooding in the United States, shown by county: Green areas represent one declaration; yellow areas represent two declarations; orange areas represent three declarations; red areas represent four or more declarations between June 1, 1965, and June 1, 2003. Map not to scale. Sources: FEMA, Michael Baker Jr., Inc., the National Atlas, and the USGS (38 YEAR PERIOD)
FLOOD DAMAGE

- In a concrete house, the most vulnerable elements to water damage are non-structural and would be the interior gypsum board drywall and the wood trim and cabinetry.
- The coatings industry has developed interior wall treatments that are quite superior to conventional drywall boards.
- Plastic and acrylic trim is readily available.
LATERAL FORCE RELATED DISASTERS

TSUNAMIS
How Tsunamis Work: Tsunamigenesis

- Upward Wave
- Fault Line
- Crust
- Mantle

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ANATOMY OF A TSUNAMI
LATERAL FORCE
RELATED
DISASTERS
EARTHQUAKES
WELL-KNOWN EARTHQUAKES SHOWING RICHTER INTENSITY NUMBERS

- 1812 New Madrid - Missouri 8.3
- 1906 San Francisco 7.3
- 1964 Alaska 9.2
- 1985 Mexico City 8.1
- 1989 Loma Prieta (San Francisco) 6.9
- **1993 Guam 8.1**
- 1994 Northridge (Los Angeles) 6.7
- 1995 Kobe Japan – 6.9
- 2010 Haiti 7.0 – 7.3
- **2010 Chile 8.8**

Red font = 8.0 or larger

Note that San Francisco, Kobe, Loma Prieta, Northridge and Haiti were rather minor -- compared to **Guam 1993**
LATERAL FORCE
RELATED
DISASTERS

HURRICANES
HURRICANES

(Source = FEMA: ANDREW IN FLORIDA)
### SAFFIR-SIMPSON HURRICANE SCALE —
(U.S. classification of hurricane intensity)

<table>
<thead>
<tr>
<th>Category</th>
<th>Wind speed</th>
<th>Storm surge</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>mph (km/h)</td>
<td>ft (m)</td>
</tr>
<tr>
<td>5</td>
<td>≥156 (≥250)</td>
<td>&gt;18 (&gt;5.5)</td>
</tr>
<tr>
<td>4</td>
<td>131–155 (210–249)</td>
<td>13–18 (4.0–5.5)</td>
</tr>
<tr>
<td>3</td>
<td>111–130 (178–209)</td>
<td>9–12 (2.7–3.7)</td>
</tr>
<tr>
<td>2</td>
<td>96–110 (154–177)</td>
<td>6–8 (1.8–2.4)</td>
</tr>
<tr>
<td>1</td>
<td>74–95 (119–153)</td>
<td>4–5 (1.2–1.5)</td>
</tr>
</tbody>
</table>

**Additional classifications**

| Tropical storm | 39–73 (63–117) | 0–3 (0–0.9) |
| Tropical depression | 0–38 (0–62) | 0 (0) |
STORM SURGES
EYE OF A HURRICANE --
STORM SURGE UPPER LEFT
STORM SURGE
During Katrina, storm surge at Pass Christian, east of New Orleans, was 27.8 feet
LATERAL FORCE
RELATED
DISASTERS

TORNADOES
EF5 TORNADO
Greensburg Kansas, 2007
http://www.kansas.com/static/slides/050507tornadoaerials/
TORNADOES CAN BE ALMOST FOUR TIMES AS DEVASTATING TO BUILDINGS AS A CATEGORY 5 HURRICANE (TYPHOON) OR A MAXIMUM CREDIBLE EARTHQUAKE IN NORTH AMERICA.

PUBLIC ATTITUDE SEEMS TO BE THAT WOOD-FRAMED HOUSES WILL BE SEVERELY DAMAGED AND THAT VERY LITTLE CAN BE DONE ABOUT IT. “SO LET THEM BLOW AWAY AND WE WILL REBUILD QUICKLY TO GET FOLKS OUT OF THE WEATHER”
## FUJITA F-SCALE FOR TORNADOES

Current designation is EF (Extended Fujita)

<table>
<thead>
<tr>
<th>CATEGOR Y</th>
<th>WIND SPEEDS (mph)</th>
<th>SUBJECTIVE DESCRIPTION</th>
</tr>
</thead>
<tbody>
<tr>
<td>F0</td>
<td>40-72</td>
<td>GALE</td>
</tr>
<tr>
<td>F1</td>
<td>73-112</td>
<td>MODERATE</td>
</tr>
<tr>
<td>F2</td>
<td>113-157</td>
<td>SIGNIFICANT</td>
</tr>
<tr>
<td>F3</td>
<td>158-206</td>
<td>SEVERE</td>
</tr>
<tr>
<td>F4</td>
<td>207-260</td>
<td>DEVASTATING</td>
</tr>
<tr>
<td>F5</td>
<td>261-318</td>
<td>INCREDIBLE</td>
</tr>
</tbody>
</table>
From THE TORNADO REPORT: www.tornadoproject.com/

Historical Records up through the end of the year 2000 show that:

Every state in the USA has experienced at least one tornado

Some states have been affected by quite a few as will be shown in the next slides

592 Serious Tornadoes
- Over 11,000 deaths
- Over 70,000 injuries
- $ billions in destruction. Houses totally disassembled
TORNADO ACTIVITY IN THE UNITED STATES*
Summary Per 1,000 Square Miles

Number of Recorded Tornadoes per 1,000 Sq. Mi.
- < 1
- 1 - 5
- 6 - 10
- 11 - 15
- > 15

* Based on NOAA, Storm Prediction Center Statistics

Figure 1.1 The number of tornadoes recorded per 1,000 square miles
FLAGSTAFF ARIZONA
Category EF1  (Little one) Tornado
October 2010
DESIGN OF DISASTER RESISTANT SHELLS “DRS”
WOOD FRAME ROOFS VERSUS REINFORCED CONCRETE

- WHEN THE WALLS ARE REINFORCED CONCRETE AND THE ROOF IS WOOD FRAME, THE CONCRETE WALLS ARE BRACED OUT-OF-PLANE ONLY AT THEIR BOTTOMS AND AT THEIR ENDS.
- REINFORCED CONCRETE WALLS ARE NO LONGER SUPPORTED AT THEIR TOPS AFTER THE WOOD FRAME ROOF IS GONE.
- WHEN THE ROOF IS AN R/C SLAB (DIAPHRAGM), WALLS ARE PERMANENTLY SUPPORTED ON ALL FOUR EDGES.
- STRUCTURE BECOMES A 3-DIMENSIONAL “BOX”.
FOUR INCH ICF CONCRETE WALLS

- IT HAS BEEN DEMONSTRATED THAT FOUR INCH THICK ENGINEERED REINFORCED CONCRETE WALLS USED IN A **DRS** CONFIGURATION ARE STRUCTURALLY ADEQUATE FOR USE IN SINGLE FAMILY HOUSES WHICH WILL NEED TO RESIST THE MAXIMUM HISTORICAL RECORDED FORCES OF:
  - **EARTHQUAKES**
  - **HURRICANES = TYPHOOONS = CYCLONES**
  - **TORNADOES (ALMOST FOUR TIMES AS SEVERE AS THE ABOVE)**
WHY A CONCRETE ROOF?

- **Reinforced Concrete roofs** provide substantial strength increase and disaster resistance over any other roof system.
- **Concrete shells** with monolithic reinforced concrete walls and roofs are significantly stronger than non-monolithic concrete walls and roofs.
STRUCTURAL ANALYSIS

of

790 Square Foot Residence with 4” Thick ICF Walls Subjected to Hurricanes, Tornadoes & Earthquakes
High Wind Forces and Resistance Capability of Structural Systems
307 mph Wind and Seismic Compared
Transverse Wind

(Tornado Velocity = 350 mph)
(Hurricane Velocity = 307 mph)
IN-PLANE SHEAR DESIGN
TORNADO (307 MPH) FORCE

Pu = 53.3k

END WALLS (t=4"
HORIZONTAL REINFORCING = #3 @ 12” OC MIN
VERTICAL REINFORCING = #5 @ 12” OC
IN-PLANE SHEAR DESIGN
MAXIMUM CALIFORNIA SEISMIC FORCE

\[ P_u = 11.6^k \]

END WALLS (t=4"")
HORIZONTAL REINFORCING = #3 @ 12" OC MIN
VERTICAL REINFORCING = #3 @ 12" OC MIN
OUT-OF-PLANE WIND LOADS
TORNADO (307 MPH) FORCE

MAXIMUM DESIGN PRESSURE $P_u = 177$ PSF

END WALLS ($t=4"$)
HORIZONTAL REINFORCING = $#5 @ 10"$ OC
VERTICAL REINFORCING = $#3 @ 12"$ OC MIN
SEISMIC $P_u = 24$ PSF
REINFORCING = $#3 @ 12"$ OC EW MIN
IN-PLANE SHEAR DESIGN
TORNADO (307 MPH) FORCE

Pu = 39.1 k

FRONT SHEAR WALL (t=4")
HORIZONTAL REINFORCING = #3 @ 12" OC MIN
VERTICAL REINFORCING = #5 @ 12" OC
ICF CONCRETE SYSTEM
ROOF PLAN

(VELOCITY = 307 MPH)
WOOD TRUSSES
ROOF PLAN

(VELOCITY = 307 MPH)
TORNA DO WIND PRESSURES
(PARTIALLY ENCLO SURE STRUCTURE ASSUMED)

MANUFACTURED WOOD TRUSSES @ 24" OC

4" ICF WALLS

LOAD CASE B WIND
(VELOCITY = 307 mph)

ANCHORAGE REQUIRED
Tu = 4300 LB
200 mph (approx. 228)
TOTAL UPLIFT ON 4'x8' PLYWOOD SHEET
Tu = 1.3x4550# = 5920

WOOD TRUSSES @ 24" OC

ZONE 2 PRESSURE = -133 PSF TYP

ZONE 1 PRESSURE = -75 PSF TYP

ZONE 3 PRESSURE = -198 PSF TYP

FOUNDATION UPLIFT
Tu = 42.8k

WIND

WOOD TRUSSES
ROOF PLAN
(VELOCITY = 200 MPH)
135 mph
Hurricane & Tornado
WOOD TRUSSES
ROOF PLAN

(VELOCITY = 135 MPH)

Vu= 176 LBS-FT
(228 LBS-FT)

Vu= 340 LBS-FT
(442 LBS-FT)

TOTAL UPLIFT ON 4’x8’ PLYWOOD SHEET
Tu= 2090 (2720)

ZONE 2 PRESSURE=
-61 (-79) PSF TYP

ZONE 1 PRESSURE=
-34 (-45) PSF TYP

ZONE 3 PRESSURE= 
-91 (-118) PSF TYP

WOOD TRUSSES @ 24” OC

RIDGE

FOUNDATION UPLIFT
Tu= 42.8k

5/8” SP

3’-0” TYP

3’-0” TYP

WIND

### = HURRICANE PRESSURES
(###) = TORNADO PRESSURES
(1.3xHURRICANE)
Here is the first all-concrete DRS single family house constructed in the world – on the island of Guam – 1963
GUAM – Where it Started

WHY GUAM?
GUAM IS THE WORLD’S ONLY KNOWN
“DISASTER LABORATORY FOR CONCRETE HOUSES”
WHERE IS GUAM?
GUAM
(Note Military Bases)
WHY STUDY GUAM?

- **Western Pacific Region has a record of some of the most severe earthquakes in the world.**
- **Marianas Islands have a record of some of the most intense wind storms in the world.**
- **Guam has the largest and oldest inventory of reinforced concrete disaster-resistant-shell (DRS) single family houses on earth.**
- **It is likely that there are more concrete box-frame tract houses on the island of Guam than exist on the entire North American continent.**
“Earthquake risk in Guam is caused by the island’s proximity to the Mariana Trench, where the subduction of the Pacific Plate beneath the Philippine Plate occurs. This motion leads to earthquakes throughout the Mariana Island chain and north to Japan.”

The following map is from the U.S. Geological Survey. Shown are earthquakes of the Mariana Trench region (including Guam and Saipan to the north).

Each flyspeck represents a seismic event.
“On September 19, 1985, at 7:17 A.M., a Richter magnitude 8.1 earthquake occurred on the Pacific coast of Mexico. The damage was concentrated in a 25 km2 area of Mexico City, 350 km from the epicenter. Of a population of 18 million, an estimated 10,000 people were killed, and 50,000 were injured. In addition, 250,000 people lost their homes, and property damage amounted to $5 billion. Over 800 buildings crumbled, including hotels, hospitals, schools, and businesses. Communications between the Mexican capitol and the outside world were interrupted for many days.”
NEWSPAPER ITEM:

“Guam Earthquake of August 8, 1993” – 8.1

Even though damage to some structures from the 1993 Guam Earthquake was severe, little human injury and no fatalities occurred. Hardest hit were the island's hotels, which had the same design weaknesses typical to many high-rise hotels damaged in earthquakes worldwide. “

No reported damage to Box-Frame concrete houses
"Typhoon alley" is a term not taken lightly by the citizens of Guam. Although the last two years have been relatively quiet, there are an average of 31 tropical storms in the western north Pacific every year with one or more affecting the Island. Guam has been impacted by 16 typhoons since 1970 and devastated by four since 1960.

One, **TYHOON PAKA, 1997**, was one of the most powerful ever recorded. Winds to 240 mph -- This represents the velocity range of a Category F4 tornado.

(Paka is well documented on the Internet)
## Comparing Hurricane (Typhoon) Peak Wind Velocities

(Related to U. S. Saffir-Simpson Hurricane Categories)

### Guam Estimated Peak Winds

<table>
<thead>
<tr>
<th>NAME</th>
<th>YEAR</th>
<th>CAT.*</th>
<th>WIND Mph</th>
<th>S-S PEAK</th>
<th>TORNADO</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pongsana</td>
<td>2008</td>
<td>4</td>
<td>150</td>
<td>150</td>
<td>F2</td>
</tr>
<tr>
<td>Paka</td>
<td>1997</td>
<td>Int 8</td>
<td>240</td>
<td>150</td>
<td>F4</td>
</tr>
<tr>
<td>Omar</td>
<td>1992</td>
<td>4</td>
<td>150</td>
<td>150</td>
<td>F2</td>
</tr>
<tr>
<td>Yuri</td>
<td>1991</td>
<td>Int 6</td>
<td>175</td>
<td>150</td>
<td>F3</td>
</tr>
<tr>
<td>Roy</td>
<td>1988</td>
<td>Int 6</td>
<td>175</td>
<td>150</td>
<td>F3</td>
</tr>
<tr>
<td>Pamela</td>
<td>1976</td>
<td>5</td>
<td>160</td>
<td>150</td>
<td>F2</td>
</tr>
<tr>
<td>Olive</td>
<td>1963</td>
<td>Int 7</td>
<td>185</td>
<td>150</td>
<td>F3</td>
</tr>
<tr>
<td>Karen</td>
<td>1963</td>
<td>Int 7</td>
<td>185</td>
<td>150</td>
<td>F3</td>
</tr>
</tbody>
</table>

* Saffir-Simpson Hurricane Scale

Int = Interpolated extension Saffir-Simpson

### Mainland USA Estimated Peak Winds

<table>
<thead>
<tr>
<th>NAME</th>
<th>YEAR</th>
<th>CAT.*</th>
<th>WIND Mph</th>
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</thead>
<tbody>
<tr>
<td>Ike</td>
<td>2008</td>
<td>4</td>
<td>145</td>
</tr>
<tr>
<td>Katrina</td>
<td>2005</td>
<td>3</td>
<td>140</td>
</tr>
<tr>
<td>Rita</td>
<td>2005</td>
<td>5</td>
<td>180</td>
</tr>
<tr>
<td>Charlie</td>
<td>2004</td>
<td>4</td>
<td>150</td>
</tr>
<tr>
<td>Frances</td>
<td>2004</td>
<td>3</td>
<td>145</td>
</tr>
<tr>
<td>Ivan</td>
<td>2004</td>
<td>4</td>
<td>165</td>
</tr>
<tr>
<td>Opal</td>
<td>1995</td>
<td>4</td>
<td>150</td>
</tr>
<tr>
<td>Andrew</td>
<td>1992</td>
<td>5</td>
<td>175</td>
</tr>
<tr>
<td>Hugo</td>
<td>1989</td>
<td>4</td>
<td>160</td>
</tr>
<tr>
<td>Camille</td>
<td>1969</td>
<td>5</td>
<td>190</td>
</tr>
</tbody>
</table>

* At point of Landfall

* Saffir-Simpson Hurricane Scale

Int = Interpolated extension Saffir-Simpson
“On Tuesday December 16th 1997, with peak winds of **240 mph** the highest wind speeds ever recorded over land, swept across the island of Guam.”

*Wind velocity equivalent to a Category F4 tornado”*

“Approximately 1500 structures (most of them residential) were completely destroyed and another 10,000 were damaged leaving an estimated 5000 homeless. Damage estimates were around $645 million (2007)”

**No** known damage to the thousands of **DRS** reinforced concrete houses
Typhoon Paka proved by actual experience that DRS reinforced concrete box frames could withstand wind velocities equivalent to a Category EF4 tornado without structural damage.

The high winds of Paka were present for about six hours – as compared to a tornado which passes through a given location in only a few minutes.
HISTORY OF THE DEVELOPMENT OF DRS BOX FRAME HOUSES ON GUAM
One of the more intense typhoons to strike Guam was typhoon Karen, which passed over the southern part of the island in 1962. Wind gusts estimated near 185 mph destroyed 95% of all homes on the island.

Guam governor appealed to President Kennedy for assistance.

JFK enlisted the help of Henry Kaiser and Kaiser Cement company.

With guidance from structural engineer Alfred A. Yee, Kaiser developed the prototype for a DRS house and began building in 1963.
THIS IS THE FIRST DELIBERATELY DESIGNED DRS HOUSE IN THE WORLD – 1963 – ON THE ISLAND OF GUAM
THOUSANDS OF DRS CONCRETE HOUSES BUILT THIS WAY ON GUAM SINCE 1963
TYPICAL CONSTRUCTION OF CONCRETE HOUSES ON GUAM IN 1963 (NON-INSULATED)
GUAM HOUSE DETAILS

- Four inch thick tilt-up reinforced concrete walls
- Cast-in-place monolithic reinforced concrete flat roof
- Florida-style hurricane shutters
- Designed as “box-frame” with walls tied securely to the reinforced ribbed floor slab and to the roof slab
- Structural engineer Yee says: “You can almost imagine a giant picking these boxes up and dropping them on the ground with no damage”

- (Insulation was not considered necessary on Guam at that time - 1963)
Preparing for Ribbed Structural Concrete Floor Slab – On Grade
FORMS FOR FOUR INCH TILT-UP CONCRETE WALLS
FABRICATED TILT-UP WALL PANELS
RCF FORMS FOR CIP ROOF
CAST-IN-PLACE R/C ROOF
(NON-INSULATED)
2008 Comments by the Structural Engineer Alfred A. Yee

“The Dededo Houses have been in existence for 30 plus years and they have gone through many heavy typhoons that make Katrina look like only a rainstorm. ” (They survived Typhoon Paka without damage)

“They have gone through earthquakes of Richter Scale 8.1, but the Dededo Houses did not even suffer any cracking”

“Of the thousands of (sic – DRS concrete shell) houses we built, not a single bit of damage was ever recorded from typhoons or seismic action”
CONTEMPORARY (2008)
CAST-IN-PLACE
CONCRETE DRS
HOUSES
ON GUAM
MONOLITHIC ROOF COMPLETED
ROW OF COMPLETED DRS HOUSES
HOME DEPOT
HURRICANE SHUTTERS
CAST-IN-PLACE REINFORCED CONCRETE WALLS AND WOOD FRAME ROOFS
<table>
<thead>
<tr>
<th>TYPE OF CONSTRUCTION</th>
<th>FIRE</th>
<th>CAT 5</th>
<th>RICHTER 8</th>
<th>CAT 3 -5</th>
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<tbody>
<tr>
<td>Total Wood Frame</td>
<td>None</td>
<td>None</td>
<td>Partial</td>
<td>None</td>
</tr>
<tr>
<td>R/C Walls &amp; Frame Roof</td>
<td>None</td>
<td>Partial</td>
<td>Partial</td>
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<td>R/C Walls &amp; R/C Roof</td>
<td>Total</td>
<td>Total</td>
<td>Total</td>
<td>Total</td>
</tr>
</tbody>
</table>
ICF WALLS & WOOD FRAME ROOF – WISCONSIN F4 TORNADO
So what about an F5 Tornado?

- **F5 tornado (261-318 mph) (classified as “Incredible”)**

  - In the absence of field information about the structural performance of concrete DRS houses in an F5 tornado, we made a comprehensive structural analysis of a hypothetical DRS house to see if four inch R/C walls would also work under F5 tornado winds.

- A small uncomplicated DRS house was studied (in order to reduce the analysis work).

- An arbitrary 350 mph wind was selected for the calculations.
CONCLUSION: FOUR INCH REINFORCED CONCRETE WALLS IN A DRS DESIGN WILL WORK FOR F5 TORNADOES --- WHEN THE ROOF IS A REINFORCED CONCRETE DIAPHRAGM INTIMATELY CONNECTED BY REINFORCING BARS TO THE WALLS

(A separate structural engineering presentation about this analysis and related calculations is available upon request)
TWO GENERALLY ACCEPTED
METHODS AVAILABLE FOR
CONSTRUCTING DRS REINFORCED
CONCRETE HOUSES:

CAST-IN-PLACE WALLS AND ROOFS
OR
TILT-UP OR FACTORY PRECAST WALLS
WITH CIP ROOFS
INSULATION WAS NOT USED ON ORIGINAL GUAM DRS HOUSES

- Because of its moderate temperatures, Guam construction practices did not call for insulation for their concrete houses 45 years ago
- Little demand for heat, much demand for A/C
- There are no energy resources on the island
- All energy must be imported, mostly by tanker
- Construction of reinforced concrete houses with stay-in-place ICF forms instead of removable concrete forms on Guam would likely:
  - Reduce energy demand per house by about half
  - Make the houses more comfortable
  - Reduce temperature change-related stresses in the concrete
INSULATION IS IMPORTANT TODAY FOR ENERGY CONSERVATION AND COMFORT

- FOR MOST REGIONS TODAY, INSULATION IS A NECESSITY FOR ENERGY CONSERVATION AND COMFORT

- UNTIL RECENT YEARS, (PRESENTER’S OPINION) THE LACK OF A PRACTICAL AND ECONOMICAL SYSTEM FOR INSULATING CONCRETE HOUSES HAS POSSIBLY BEEN THE MOST IMPORTANT DETERRENT AGAINST THE GROWTH IN THE USE OF REINFORCED CONCRETE IN SINGLE FAMILY HOUSES
EXAMPLES OF STAY-IN-PLACE ICFs FOR CONSTRUCTION OF CAST- IN-PLACE CONCRETE HOUSES
CROSS-SECTION DETAILS OF DISASTER-RESISTANT ICF SHELL

TRANSVERSE BUILDING SECTION

[One-Story House on Grade]
DETAIL A- DRS Floor-to-Wall Detail — Using ICF Wall Forms
Detail B --- DRS Wall to Pitched Roof --- ICF CIP Wall Forms plus ICF Roof Plank Forms

- ICF Deck Plank
- Plastic End Cap
- 3/8" or greater P/W soffit form (per engineer)
- Wallboard
- Foam insulation
- Nylon tieback to vertical wall reinforcement
- Wallboard
- Expanded polystyrene insulation thickness as required by local code (R-value - one inch of EPS = R-4)
- To firm support at lower end of shore

**General Note:**
All shoring & forming shall be 2x lumber (per engineer)
C - DRS Ridge (Deep Beam) Detail
–ICF Roof Plank Forms
Structural Plans

Foundation/Grade Beam Plan

Floor Framing Plan
Structural Section & Elevation

Transverse Building Section
[One-Story House on Grade]

Longitudinal Elevation
Conclusions

• All-Concrete House can Resist Highest Tornado Winds

• Other “Hard-Shell” Structural Systems can Resist Tornados Too

• ICF System for an All-Concrete Building is Cost-Effective

• Wood Roof Systems Problematic, Even for EF-3 Tornados

• Wood Roof Anchorage to Walls Must be Addressed in the IRC
Thank You!
Any Questions?

DISASTER RESISTANT HOUSING (DRH) WEBSITE ADDRESS:

http://www.tornadoproofhouses.com