WORLD OF CONCRETE®
WORLD OF MASONRY
TECHNOLOGY FOR CONSTRUCTION
hanley wood

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Questions related to specific materials, methods and services will be addressed at the conclusion of this presentation.

Learning Objectives

Upon completing this program, the participant should be able to:

1. Understand the forces that can be generated by the commonly visited disastrous forces by earthquakes, hurricanes (typhoons) and tornadoes
2. Find out how tornadoes can be almost four times as destructive as earthquakes and hurricanes
3. Understand how houses can be made fireproof
4. Recognize the principles of designing and building disaster-proof houses
5. Appreciate how easy it is to learn how they can be constructed

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SPEAKER INTRODUCTION
JOSEPH WARNES

- Civil/Structural Engineer (Registered PE in ten states)
- Construction Project Manager
  - Iran, Saudi Arabia, Romania
- ICF Home Builder in Europe
- **USAID** contractor-mentor in Romania, Russia and Poland
- Lecturer to Arab engineers on Project Management and Precast Concrete construction in the Middle East and North Africa – 10 years
- Specialist in Disaster-Resistant-Shell (**DRS**) Houses
- Concrete most of career – Lead the design of and construction of the first **all-concrete earthquake-resistant** shell house in North America in 1967 (42 years ago)
- ACI ***Concrete International*** http://www.encyclopedia.com/Concrete+International/publications.aspx?pageNumber=1
  - "***Disaster-Resistant-Shell Houses*** 5/08
  - "***Precast Concrete Connection Details for All Seismic Zones" 11/92***

ICF Builder magazine: http://www.icfmag.com/back_issues/index.html

- ***"Design and Construction of Low-Cost Disaster-Resistant Replacement Houses" 8-9/10***
- ***"Four Inch ICF Walls" 8-9/09***
  - (All available on the Internet)

DISCLAIMER

- All details, calculations and related content are provided for illustration only and are not to be used as actual designs
- The information in this presentation is for general information purposes only.
- It is not to be construed as engineering advice on a particular project and does not replace the sound engineering judgment of an engineer-of-record for any project
- All comments, recommendations and conclusions in this presentation are made for a Disaster-Resistant-Shell (DRS) reinforced concrete house which mandates the utilization of an integral cast-in-place reinforced **concrete roof** coupled with **reinforced concrete** walls by means of engineered connecting details

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INSULATED DISASTER PROOF CONCRETE HOUSES

FOR THE FIRST TIME IN THE HISTORY OF MANKIND, WE TODAY HAVE A SOLUTION TO THE AGE OLD CHALLLENGE OF BUILDING ATTRACTIVE ENERGY-CONSERVATIVE HOUSES THAT ARE COMFORTABLE AND AT THE SAME TIME SECURE FR0M DESTRUCTION BY THE SEVEREST FORCES OF NATURE

EARTHQUAKES

HURRICANES

TORNADOES

HOW TO DESIGN AND BUILD INSULATED DISASTER-PROOF REINFORCED CONCRETE HOUSES

(Copyrighted Intellectual property)

DISCUSSION TOPICS

- DISASTERS
- GUAM EXPERIENCE WITH CONCRETE HOUSES
- BOX-FRAME TECHNOLOGY
- TWO APPROACHES TO CONCRETE HOUSE CONSTRUCTION:
  - CAST-IN-PLACE WALLS PLUS ROOFS USING
    - ❑ REUSABLE CONCRETE FORMS (RCFs)
    - ❑ INSULATING CONCRETE FORMS (ICFs)
  - PRECAST INSULATED CONCRETE WALLS
    - ❑ FACTORY PRECAST
    - ❑ SITE PRECAST
      - ➢ TILT-UP
      - ➢ STACK-CAST
        - ❖ BOX-FRAME TECHNOLOGY STILL REQUIRES CIP ROOFS
- SUMMARY AND CONCLUSIONS
- WHERE TO LOOK FOR HELP

PREMISE

IT IS ACHIEVED BY BRINGING TOGETHER TWO WELL ESTABLISHED AND PROVEN TECHNOLOGIES: ONE OF BUILDING ALL-CONCRETE HOUSES USING STAY-IN-PLACE INSULATING CONCRETE FORMS (ICFs), AND/OR INSULATED PRECAST CONCRETE WALLS , PLUS THE PRACTICE OF STRUCTURALLY DESIGNING WITH FIELD-PROVEN DISASTER-RESISTANT-SHELL (DRS) BOX-FRAME TECHNOLOGY

PERFORMANCE

- This presentation is about:
- **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**

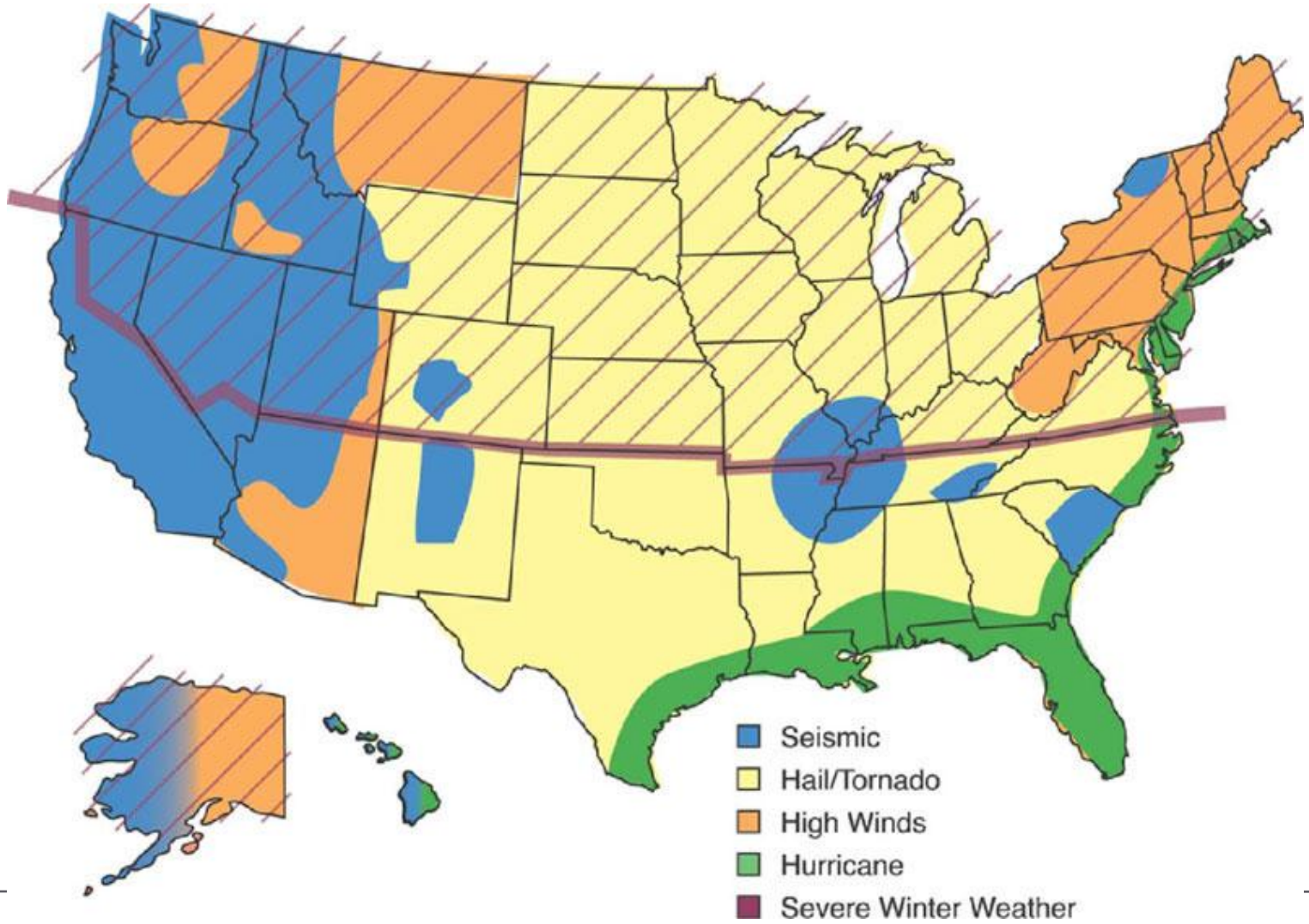
- **If the roof is not a reinforced concrete slab intimately connected to reinforced concrete walls and floors – then most of the disaster-resistant attributes are not achievable**

- **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**

NON-LATERAL FORCE-RELATED DISASTERS

FIRESTORMS

FLOODS

OTHER HAZARDS OF CONCERN -- TO INSURANCE COMPANIES

EVENT	CONCRETE HOUSES	WOOD FRAME HOUSES
Internal Gas Explosion	Little structural damage	Will burst and burn
Internal Fire	Shell will not burn	Will burn
Mold	No food for mold	Mold host
Termites	Do not eat concrete	Termite diet
Structural maintenance	Very low	High
Structural water damage	Rarely	Frequently
Varmints	No access	Accessible
Sustainability	Last for centuries	Less than a century

FIRES

Internal Origin

External origin

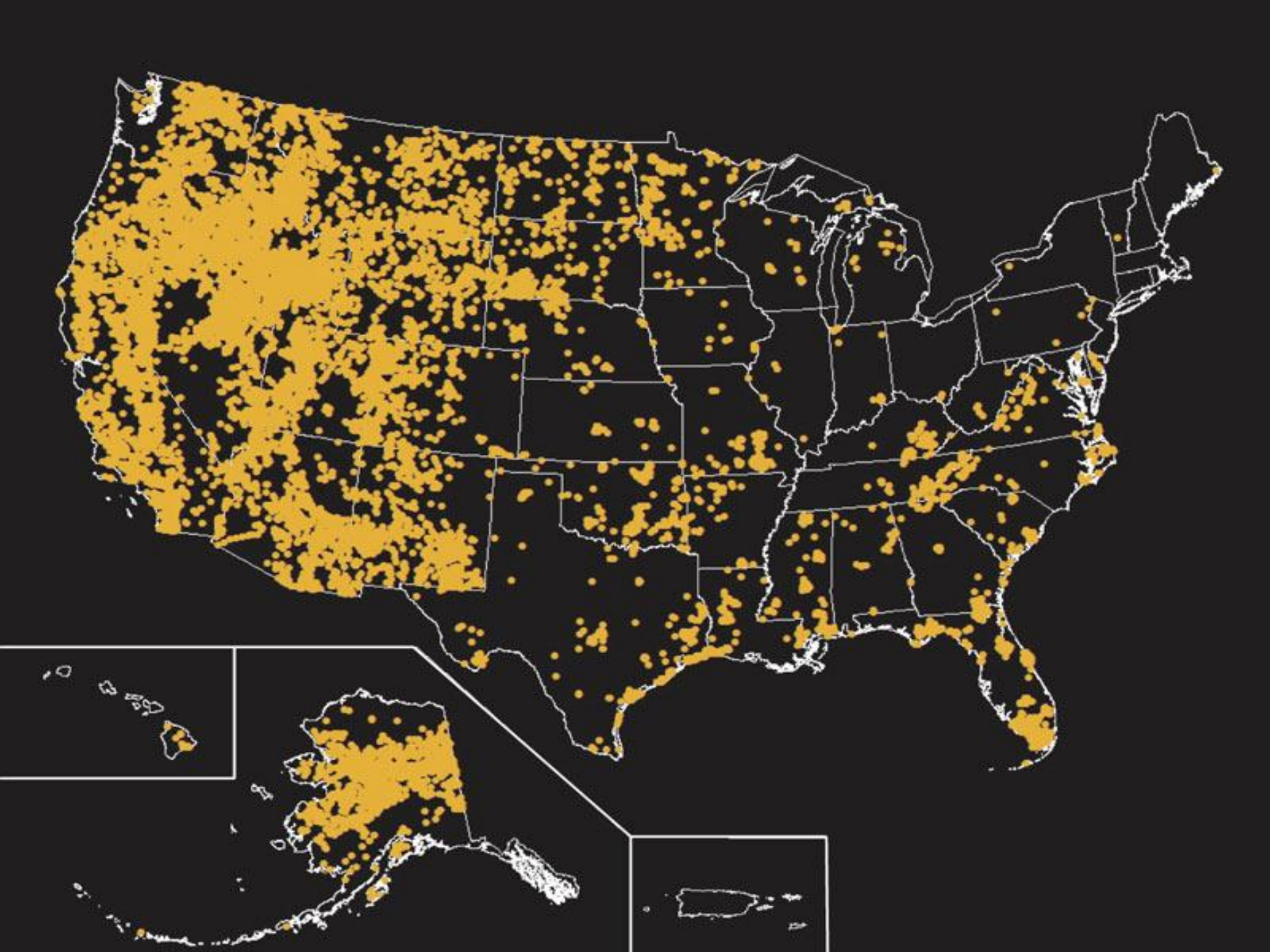
(Firestorms)

STRUCTURAL DISASTER RESISTANCE COMPARED

TYPE OF CONSTRUCTION	FIRE	CAT 5 H-CANE	RICHTER 8 E-QUAKE	CAT 3 -5 TORNADO
Total Wood Frame	None	None	Partial	None
R/C Walls & Frame Roof	None	Partial	Partial	Partial
R/C Walls & R/C Roof	Total	Total	Total	Total

BONFIRE CONSTRUCTION
U. S. and Canada

WILDFIRES & FIRESTORMS



FIRESTORMS AND WILDFIRES

- ***The map shows locations that experienced wildfires greater than 250 acres, from 1980 to 2003. (23 years) Map not to scale.***
- ***Sources: Bureau of Land Management, U.S. Forest Service, U.S. Fish and Wildlife Service, Bureau of Indian Affairs, National Park Service, and the USGS National Atlas***
- ***Particularly impacted are regions in the western United States***
- ***Few states are unaffected***

FOURMILE CANYON 2010

http://www.kdvr.com/news/kdvr-boulder-fire-victims2-txt,0,3623118.story (*Includes video)*

SAN BRUNO FIRE - 2010

FLOODS

STORM SURGES

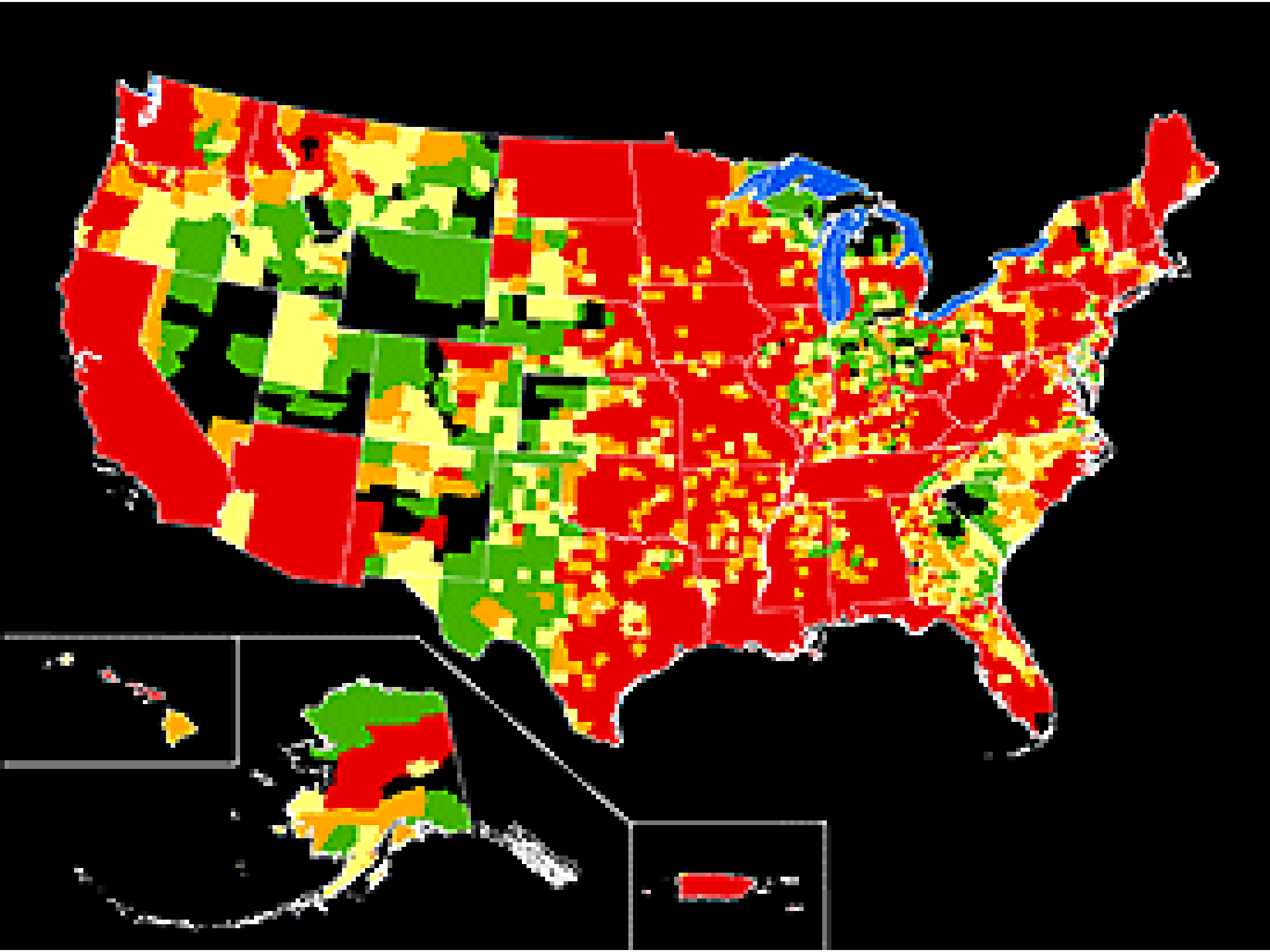
TSUNAMIS

FLOODS

U. S. FLOOD MAP

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

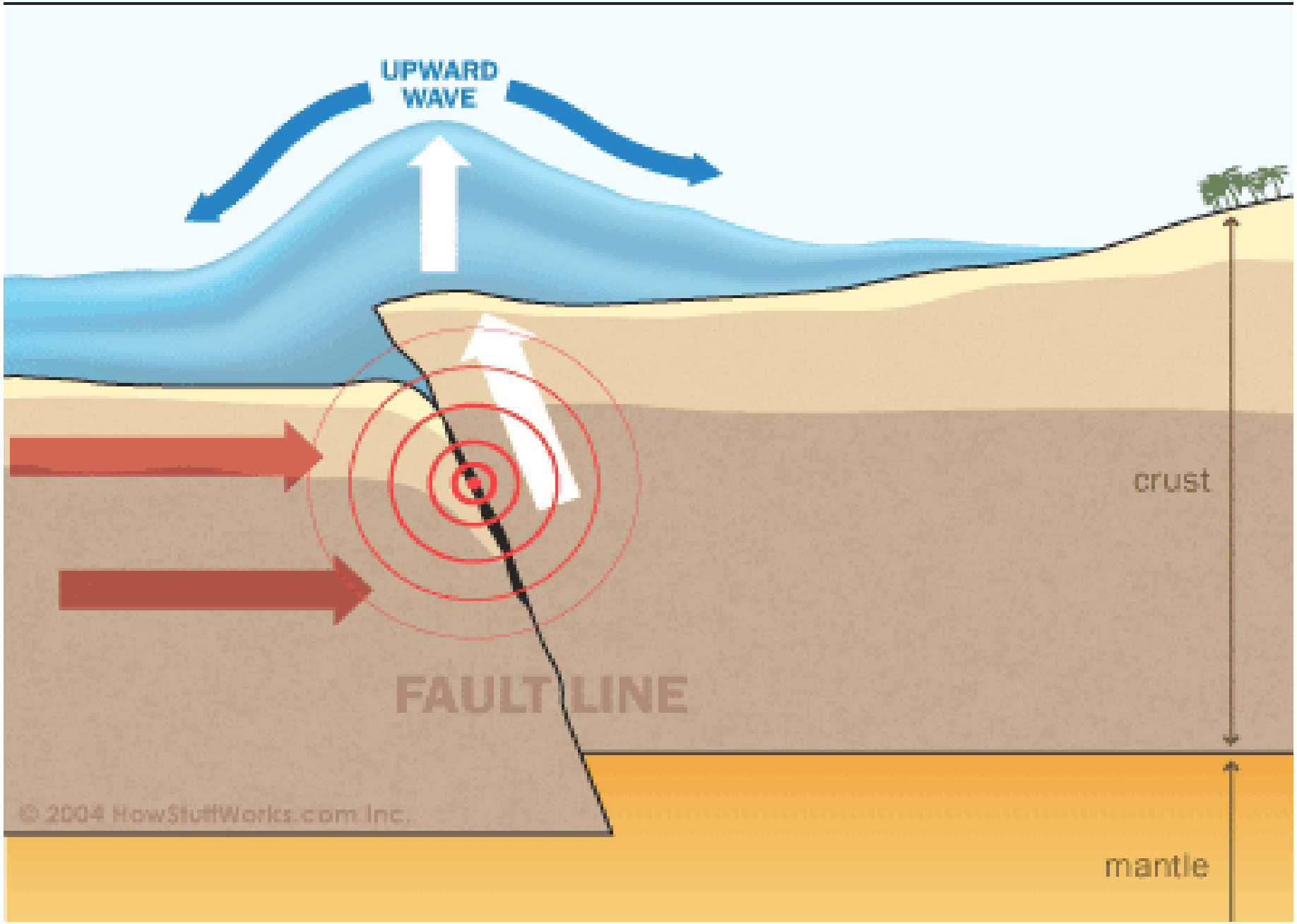
(38 YEAR PERIOD)



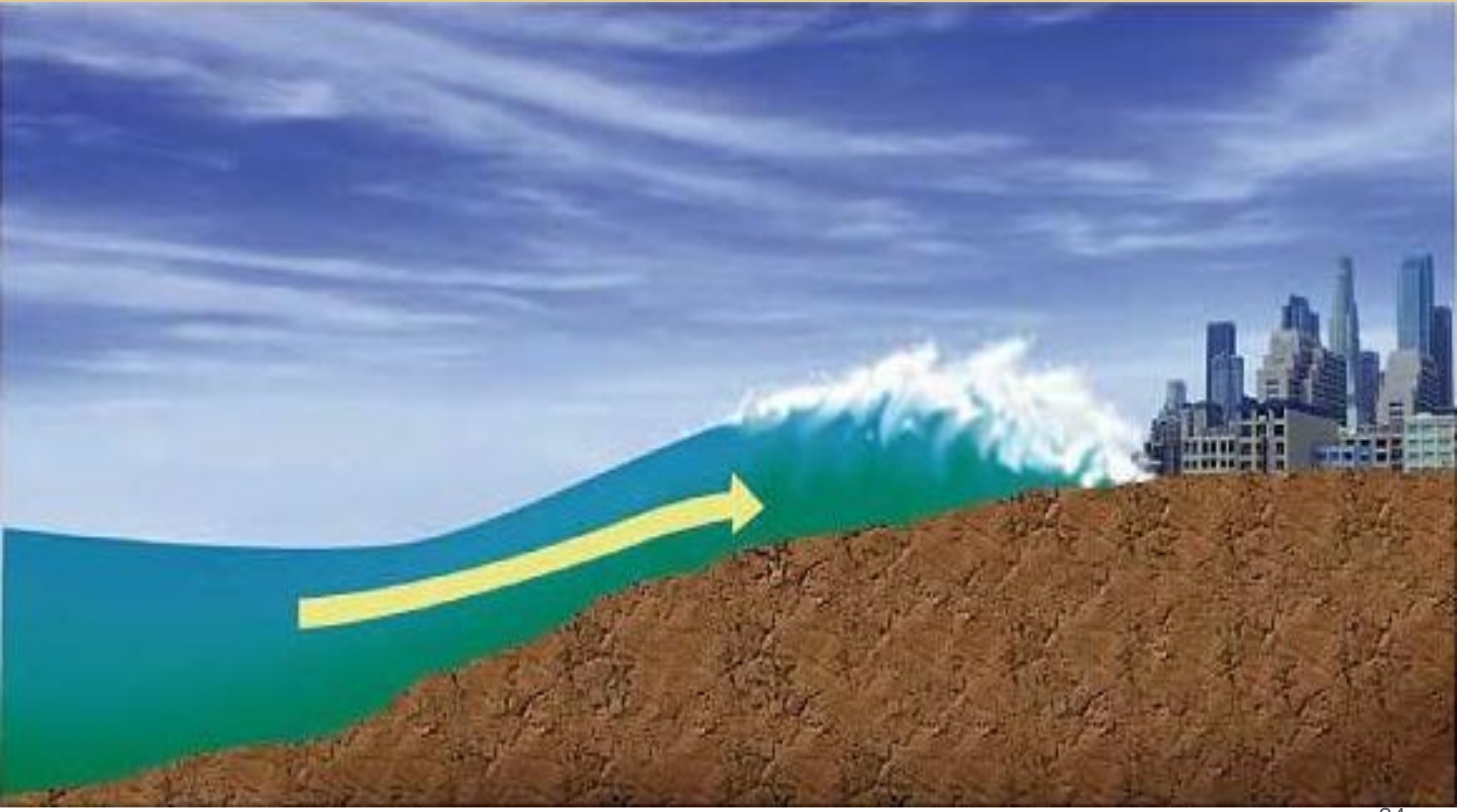
LATERAL FORCE RELATED DISASTERS

TSUNAMIS

How Tsunamis Work: Tsunamigenesis



ANATOMY OF A TSUNAMI



LATERAL FORCE RELATED DISASTERS

EARTHQUAKES

STRUCTURAL DISASTER RESISTANCE COMPARED

TYPE OF CONSTRUCTION	FIRE	CAT 5 H-CANE	RICHTER 8 E-QUAKE	CAT 3 -5 TORNADO
Total Wood Frame	None	None	Partial	None
R/C Walls & Frame Roof	None	Partial	Partial	Partial
R/C Walls & R/C Roof	Total	Total	Total	Total

EARTHQUAKES

Alaska 1964

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***

KRZYWY DOMEK

LATERAL FORCE RELATED DISASTERS

HURRICANES

HURRICANES

(Source = FEMA: ANDREW IN FLORIDA)

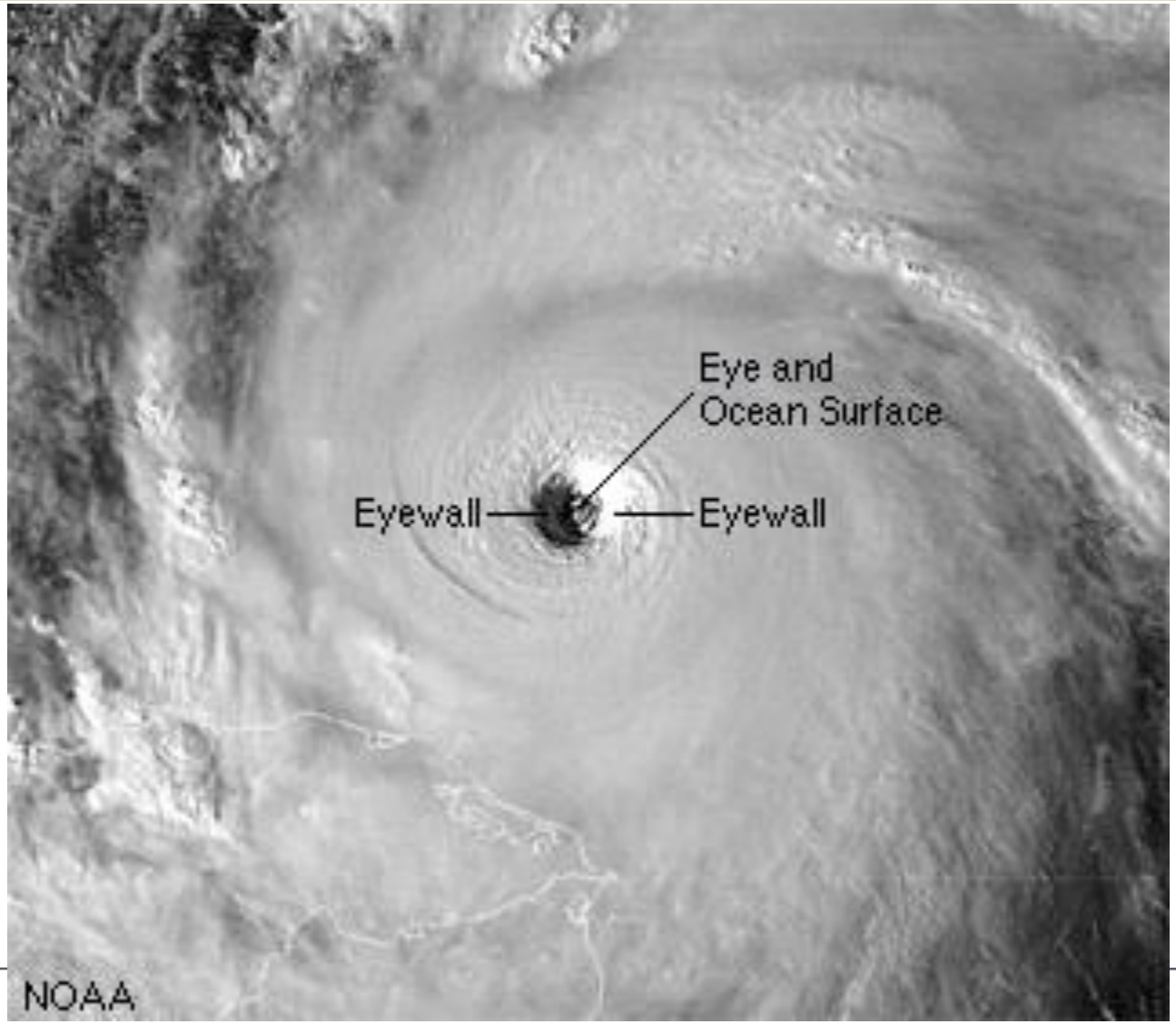
SAFFIR-SIMPSON HURRICANE SCALE –
(U. S. classification of hurricane intensity)

Category	Wind speed	Storm surge
	mph (km/h)	ft (m)
5	≥156 (≥250)	>18 (>5.5)
4	131–155 (210–249)	13–18 (4.0–5.5)
3	111–130 (178–209)	9–12 (2.7–3.7)
2	96–110 (154–177)	6–8 (1.8–2.4)
1	74–95 (119–153)	4–5 (1.2–1.5)
Additional classifications		
Tropical storm	39–73 (63–117)	0–3 (0–0.9)
Tropical depression	0–38 (0–62)	0 (0)

STORM SURGES

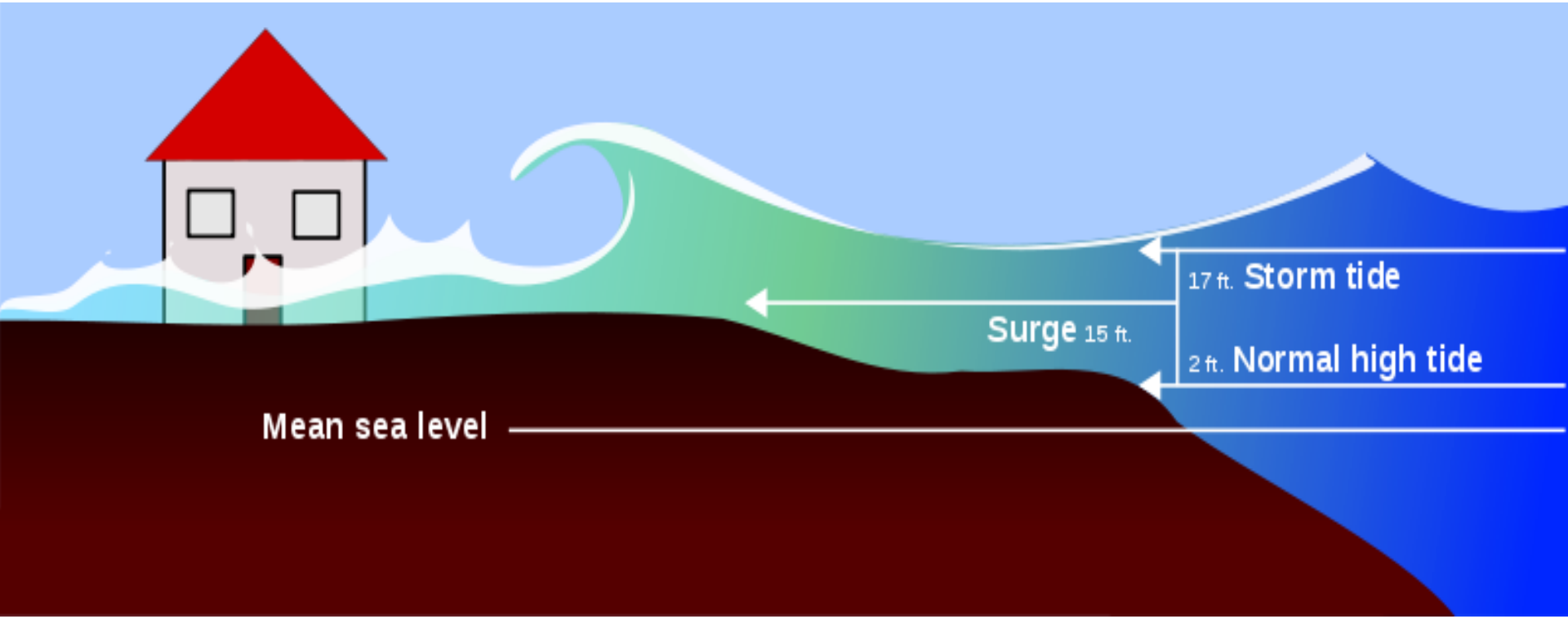
(Katrina)

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

STRUCTURAL DISASTER RESISTANCE COMPARED

TYPE OF CONSTRUCTION	FIRE	CAT 5 H-CANE	RICHTER 8 E-QUAKE	CAT 3 -5 TORNADO
Total Wood Frame	None	None	Partial	None
R/C Walls & Frame Roof	None	Partial	Partial	Partial
R/C Walls & R/C Roof	Total	Total	Total	Total

EF5 TORNADO

Greensburg Kansas, 2007

http://www.kansas.com/static/slides/050507tornadoaerials/

TORNADOES

- 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"

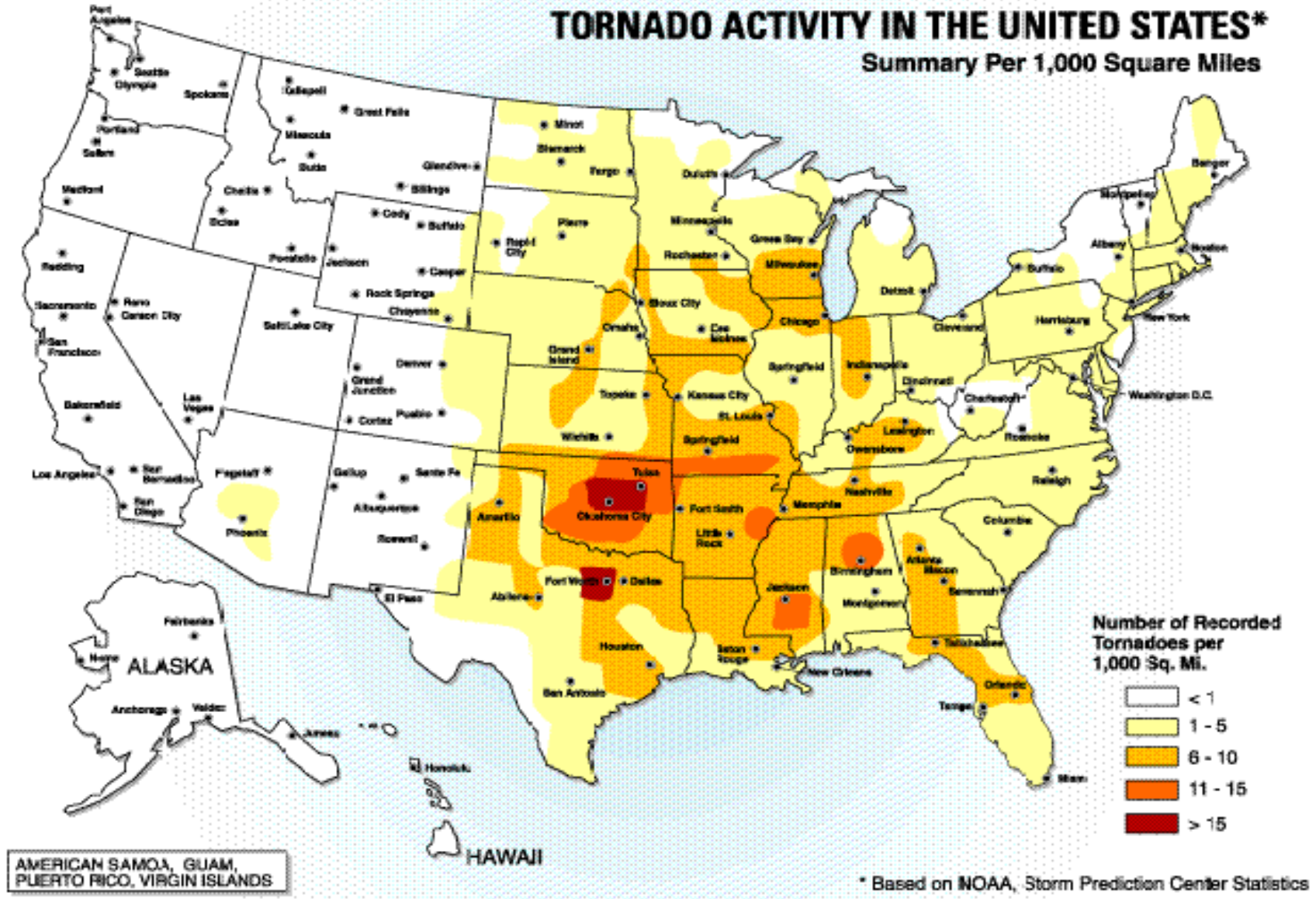


Figure I.1 The number of tornadoes recorded per 1,000 square miles

FUJITA F-SCALE FOR TORNADOES

Current designation is EF (Extended Fujita)

CATE-GORY	WIND SPEEDS mph	SUBJECTIVE DESCRIPTION
F0	40-72	GALE
F1	73-112	MODERATE
F2	113-157	SIGNIFICANT
F3	158-206	SEVERE
F4	207-260	DEVASTATING
F5	261-318	INCREDIBLE

FLAGSTAFF ARIZONA

Category EF1 (Little one) Tornado

October 2010

THE TORNADO RECORD -- USA

- 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

DESIGN OF DISASTER RESISTANT SHELLS "DRS"

ELEMENTS OF A DISASTER-PROOF HOUSE

- Must be designed and fabricated with conventional reinforced concrete as a three-dimensional shell
- Walls must be reinforced concrete made of :
  - Cast in place concrete, or can be:
  - Monolithically connected Tilt-up concrete wall panels, or
  - Monolithically connected Precast concrete wall panels
- Roofs must be a conventional cast-in-place reinforced concrete diaphragm
- Connections between roofs, walls and floors must be structurally designed so that the entire box acts as a monolithic reinforced concrete box

WOOD FRAME ROOFS VERSUS REINFORCED CONCRETE

- WHEN THE WALLS ARE REINFORCED CONCRETE AND THE ROOF IS WOOD FRAME, THE CONCRETE WALLS ARE SUPPORTED 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"

DESIGN CODES

- **Structural reinforced concrete elements (walls, roofs and floors) must be designed in accordance with standards and procedures as set forth by Building Code Requirements ACI-318 as promulgated by the American Concrete Institute**
- **Lateral load analysis must be done in accordance with the provisions of the following codes or standards:**
  - **American Society of Civil Engineers Standard 7-05**
  - **International Building Code**

BOX FRAME SHELLS (DRS)

- Based on creating a three-dimensional **BOX** by tightly connecting reinforced concrete floors, walls and roofs
- Called a **BOX FRAME** in some regions of the world
- Very successful in creating earthquake proof apartment buildings in Japan (cite Kobe experience))

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 = TYPHOONS = CYCLONES**
- **TORNADOES (ALMOST FOUR TIMES AS SEVERE AS THE ABOVE)**

STRUCTURAL CONCEPT FOR DISASTER RESISTANT HOUSE = A BOX

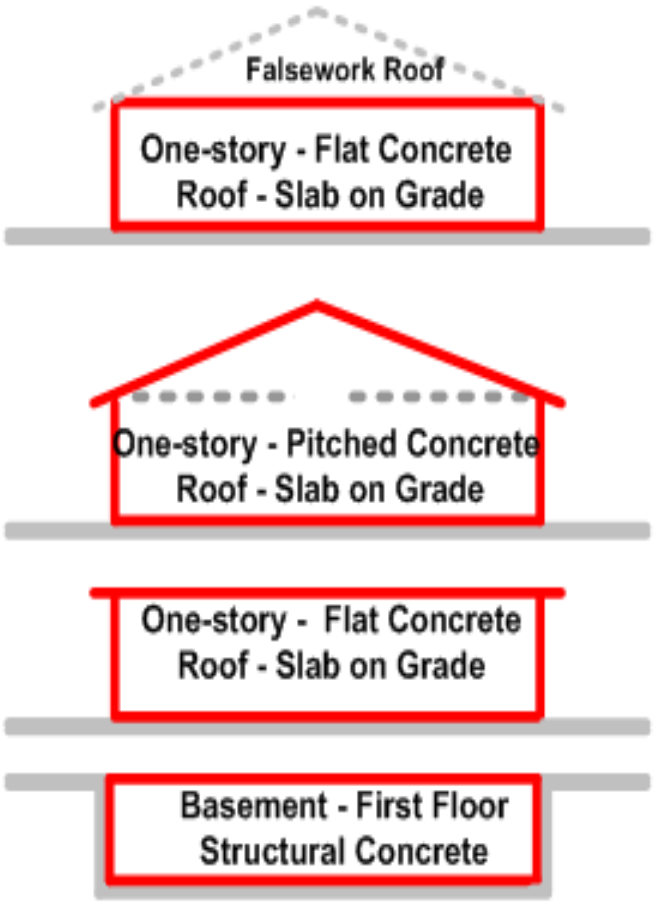
THINK “BOX”

- FOR DISASTER RESISTANCE, DO NOT THINK OF HOUSES IN TERMS OF
  - FLOORS
  - WALLS
  - ROOFS
- THINK OF WALLS, FLOORS AND ROOFS IN TERMS OF INTEGRAL PARTS OF A BOX
- ALL SUCH ELEMENTS MUST BE SECURELY CONNECTED IN SUCH A WAY AS TO EMULATE MONOLITHIC REINFORCED CONCRETE.

THINK “BOAT”
Floats over the seismic ground waves

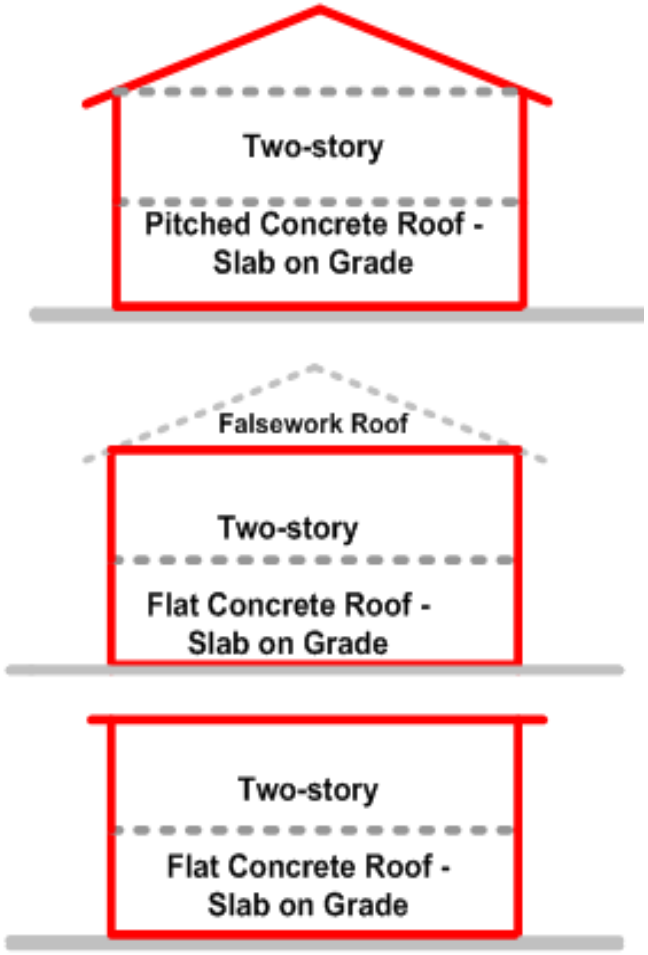
THINK AIRPLANE FUSELAGE
Resists High Winds

One Story DRS House – With or Without a Basement



- Heavy red line outlines the box-frame DRS
- For a single story house, no special details are required to achieve full tornado resistance with a structurally designed four inch wall
- Recommend structural concrete floor over basement

Two Story DRS House – With or Without a Basement



- Heavy red line outlines the box-frame **DRS**.
- For a two-story house, construct the second floor as a structural reinforced concrete diaphragm slab to stiffen all of the exterior walls.
- ·For houses with gabled concrete roofs, the end gable walls must be stiffened to achieve full tornado resistance. Possible ways to accomplish this:
  - Thicker gable wall
  - Four inch wall with built-in vertical stiffener column from ground level to the ridge
  - Second Floor R/C diaphragm slab

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

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?

Seoul
SOUTH KOREA
Yellow Sea
Pusan
JAPAN
Tokyo
Osaka
Yokohama
Shanghai
Chengdu
Wuhan
Chongqing
East China Sea
Okinawa
RYUKYU ISLANDS (JAPAN)
NAMPŌ-SHOTŌ (JAPAN)
Taipei
Taiwan
Marcus Island (JAPAN)
Hanoi
Hong Kong S.A.R.
Macau S.A.R.
Luzon Strait
LAOS
Vientiane
Gulf of Tonkin
Hainan Dao
Philippine Sea
Northern Mariana Islands (U.S.)
MARIANA TRENCH
Saipan
PARACEL ISLANDS
THAILAND
VIETNAM
Bangkok
Manila
South China Sea
Hagåtña
Guam (U.S.)
CAMBODIA
PHILIPPINES
Challenger Deep (world's greatest ocean depth, -10924 m)
Phnom Penh
Ho Chi Minh City
Gulf of Thailand
SPRATLY ISLANDS
PHILIPPINE TRENCH
FEDERATED STATES OF MIC
Koror
PALAU
Bandar Seri Begawan
BRUNEI
Kuala Lumpur
MALAYSIA
Celebes Sea
Singapore
SINGAPORE
INDONESIA
Bismarck Sea
PAPUA

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

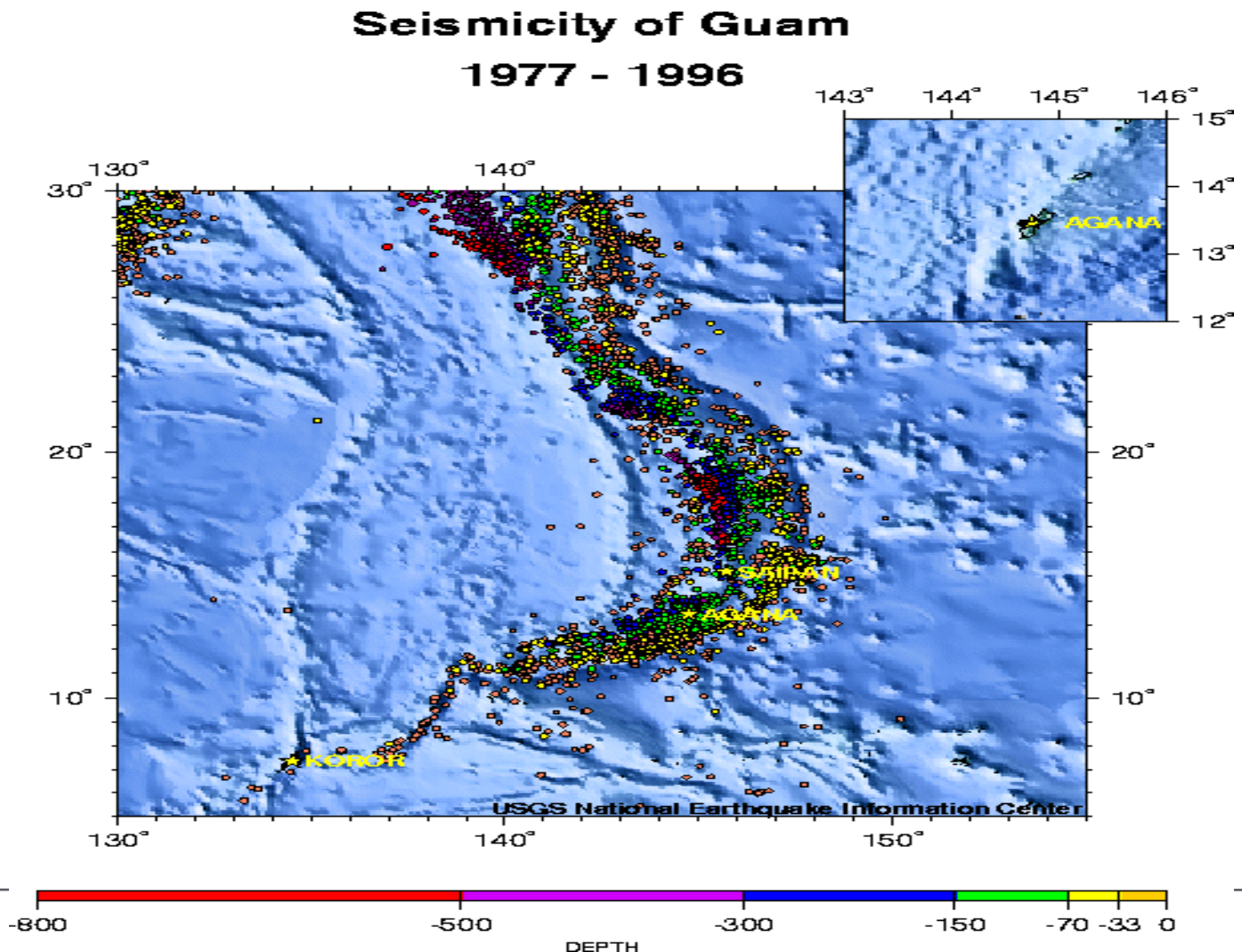
GUAM EARTHQUAKES

- “Earthquake risk in Guam is caused by the island’s proximity to the Mariana Trench, where the sub-duction of the Pacific Plate beneath the Philippine Plate occurs. This motion leads to earthquakes throughout the Mariana Island chain and north to Japan.”

Source: 1999-2009 Risk Management Solutions, Inc.

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.



MEXICO CITY BIG ONE – 8.1

(For perspective)

From the EERI Report:

- *"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."*

GUAM BIG ONE – 8.1
(By comparison)

- 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**

GUAM TYPHOONS

- **NEWS ITEM:**

"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. Saffer-Simpson Hurricane Categories)

MAINLAND USA EST. PEAK WINDS			
HURRICANE NAME	YEAR	CAT.*	PEAK WIND Mph
Ike	2008	4	145
Katrina	2005	3	140
Rita	2005	5	180
Charlie	2004	4	150
Frances	2004	3	145
Ivan	2004	4	165
Opal	1995	4	150
Andrew	1992	5	175
Hugo	1989	4	160
Camille	1969	5	190
* At point of Landfall			

GUAM ESTIMATED PEAK WINDS				
TYPHOON NAME	YEAR	S-S CAT.*	PEAK WIND Mph	TORNADO FUJITA CAT. Mph
Pongsana	2008	4	150	F2
Paka	**1997**	**Int 8**	**240**	**F4**
Omar	1992	4	150	F2
Yuri	**1991**	**Int 6**	**175**	F3
Roy	**1988**	**Int 6**	**175**	F3
Pamela	1976	5	160	F2
Olive	**1963**	**Int 7**	**185**	F3
Karen	**1963**	**Int 7**	**185**	F3
*** Saffir-Simpson Hurricane Scale**				
Int = Interpolated extension Saffir-Simpson				

TYPHOON PAKA
LARGEST EVER RECORDED

"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

PAKA RECORD

- **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

TYPHOON KAREN

- 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

DRS HOUSES IN PROGRESS

CAST IN PLACE CONCRETE WALLS (Note heavy reinforcement for wall-to-roof connection)

RCF FORMS FOR MONOLITHIC ROOF

MONOLITHIC ROOF COMPLETED

ROW OF COMPLETED DRS HOUSES

COMPLETED DRS HOUSE

HOME DEPOT
HURRICANE SHUTTERS

CAST-IN-PLACE REINFORCED CONCRETE WALLS AND WOOD FRAME ROOFS

STRUCTURAL DISASTER RESISTANCE COMPARED

TYPE OF CONSTRUCTION	FIRE	CAT 5 H-CANE	RICHTER 8 E-QUAKE	CAT 3 -5 TORNADO
Total Wood Frame	None	None	Partial	None
R/C Walls & Frame Roof	None	Partial	Partial	Partial
R/C Walls & R/C Roof	Total	Total	Total	Total

ICF WALLS & WOOD FRAME ROOF – WISCONSIN F4 TORNADO

"Concrete Home Still Standing After Tornado Strikes Stoughton, Wisconsin" (ICF Walls & Wood Frame Roof)

FROM A LOCAL NEWSPA*PER:*

"The ability of ICF homes to withstand hurricane- and tornado-force winds has long been known, but was made even more evident on August 18th when a tornado destroyed most of the homes in a Stoughton, Wisconsin neighborhood. When the air cleared, one home was still standing with almost no damage: a concrete home, currently under construction, built with insulating concrete forms (ICFs) from Reward Wall Systems."
(Tornado was minimum F-3 or possibly F-4 at times)

THE PARADIGM 60

- THE FOREGOING REPRESENTS THE TYPICAL HOME CONSTRUCTION MIND-SET OF THE ENTIRE HOUSING INDUSTRY IN NORTH AMERICA
- VERY FEW OF THE FOLLOWING HAVE GOTTEN THE MESSAGE ABOUT THE INCREDIBLE DEGREE OF ADDED HOME SAFETY PROVIDED BY STRUCTURAL REINFORCED CONCRETE WALLS PLUS ROOFS:
  - ARCHITECTS
  - ENGINEERS
  - ICF WALL FORM MANUFACTURERS & DISTRIBUTORS
  - ICF CONTRACTORS
  - GENERAL AND SPECIALTY CONTRACTORS
  - HOME INSURANCE COMPANIES
  - HOME BUYERS
  - THE PRESS
  - CEMENT MANUFACTURERS
  - REINFORCING STEEL MANUFACTURERS
  - CODE AGENCIES: LOCAL, STATE AND FEDERAL
  - READY MIX CONCRETE SUPPLIERS
  - AGGREGATE PRODUCERS
  - FEDERAL GOVERNMENT AGENCIES RESPONSIBLE FOR HOUSING SAFETY
  - APPROPRIATE TRADE ASSOCIATIONS

SURVIVING THE BIG WINDS

- NO ONE HAS CHRONICLED ANY DISASTER SURVIVAL RECORDS FOR ANY REINFORCED CONCRETE DRS HOUSES THAT HAVE SURVIVED TORNADOES ON MAINLAND NORTH AMERICA (Most likely because there may not be any)
- REINFORCED CONCRETE DRS HOUSES ON THE ISLAND OF GUAM HAVE ACTUALLY SURVIVED WITHOUT STRUCTURAL DAMAGE IN RECORDED WINDSPEEDS EQUIVALENT TO AN F4 TORNADO (TYPHOON PAKA 1997)

PERFORMANCE OF DRS HOUSES IN CONTINENTAL NORTH AMERICA

- THE ONLY KNOWN DRS CONCRETE HOUSES IN MAINLAND USA ARE IN CALIFORNIA AND TEXAS
- THE CALIFORNIA DRS HOUSES HAVE NOT YET BEEN SUBJECTED TO A TORNADO NOR A SIGNIFICANT EARTHQUAKE (ONLY A COLLISION WITH A TRUCK)
- THERE IS NO AVAILABLE INFORMATION ABOUT TORNADO PERFORMANCE OF THE TEXAS DRS HOUSES

WE HAVE ACTUAL EQUIVALENT F4 PERFORMANCE DATA FROM TYPHOON PAKA FOR DRS HOUSES ON GUAM

- According to NOAA: (http://www.outlook.noaa.gov/tornadoes/fujita.htm)
- **F4 tornado (207-260 mph)(classified as "Devastating")**

We have performance data for category F4 TORNADOES from the successful performance of thousands of DRS houses impacted by Typhoon Paka on Guam

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**
  - **An arbitrary 350 mph wind was selected for the calulations**

FOUR INCH WALLS

CONCLUSION: FOUR INCH REINFORCED CONCRETE WALLS IN A DRS DESIGN WILL WORK FOR F5 TORNADOES --- WHEN THE ROOF IS A REINFORCED CONCRETE DIAPHRAGM INTIMATELTY CONNECTED BY REINFORCING BARS TO THE WALLS

(A separate structural engineering presentation about this analysis and related calculations is available upon request)

We have architects and engineers unnessarily designing 6-inch, and even 8-inch, thick reinforced concrete walls for houses

- **The reported reason**: “Contractors request thicker walls because it is easier to pour the concrete”
- **Possible outcomes**:
- An ICF house costs more than it should
- Homebuyer pays more for the ICF house
- Ready mix concrete suppliers sell more concrete
- The ICF house doesn’t get built, resulting in loss of sales to the ready-mix and ICF form suppliers
- If the house goes to frame, homebuyer loses the advantages of fireproof and wind-proof security

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

ELEMENTS OF A STRUCTURAL BOX

- **FLOORS**

  MUST BE STRUCTUALLY DESIGNED REINFORCED CONCRETE SLABS
  - **SUSPENDED FLOORS (CAST-IN-PLACE OR PRECAST)**
  - **STRUCTURAL SLABS ON GRADE**

- **WALLS**
  - **CAST-IN-PLACE REINFORCED CONCRETE MADE WITH**
    - **REMOVABLE CONCRETE FORMS (RCFs) or**
    - **STAY-IN-PLACE INSULATING CONCRETE FORMS (ICFs)**

    OR
  - **PRECAST REINFORCED CONCRETE**
    - **FACTORY PRECAST or**
    - **SITE PRECAST**
      - **TILT-UP**
      - **STACK CAST**

- **ROOFS**

  FOR THE PRESENT, MUST BE CAST-IN-PLACE REINFORCED CONCRETE CONSTRUCTED WITH
  - **REMOVABLE (REUSABLE) CONCRETE FORMS (RCFs) OR**
  - **STAY-IN-PLACE INSULATING CONCRETE FORMS (ICFs)**

TRADITIONAL FORMS USED FOR CAST-IN-PLACE CONCRETE

- **Cast-in-place concrete involves the use of molds into which concrete is cast into the desired shape**
- **In the trade, these are called "forms"**
- **From the beginning of the use of concrete, forms have been made from different materials -- wood, plywood, metal , plastic, firberglas and others**
- **They are erected temporarily to receive the fluid concrete – then removed**
- **They are still used extensively today and are called:**
- **RCFs** – Removable or Reusable Concrete Forms

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 yearly 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*

INSULATING DISASTER-PROOF CONCRETE HOUSES

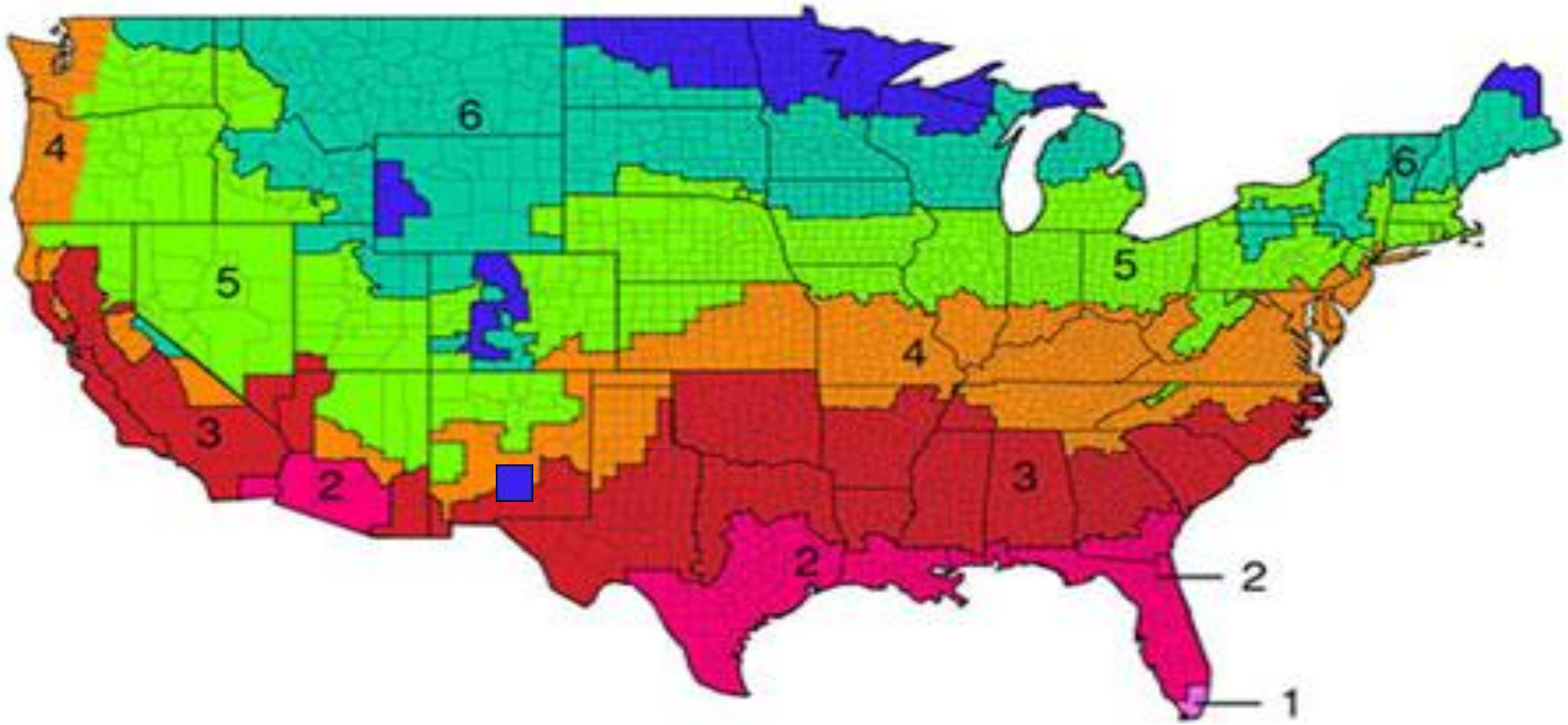
- PROCEDURES FOR INSULATING CONCRETE HOUSES THAT WERE NOT INSULATED DURING ORIGINAL CONSTRUCTION ARE NOT WELL ESTABLISHED NOR ARE THEY ECONOMICAL
- AN EFFECTIVE AND ECONOMICAL WAY TO INSULATE CONCRETE HOUSES DURING CONSTRUCTION IS TO FASTEN EXPANDED POLYSTYRENE FOAM INSULATION BOARDS DIRECTLY TO THE FLUID CONCRETE DURING FABRICATION

ENERGY CODES IN REVISION

- **INSULATION REQUIREMENTS FOR BUILDINGS, INCLUDING HOUSES, TO BE REVISED BY THE IBC IN ACCORD WITH PROPOSED NEW RECOMMENDATIONS OF ASHRAE 189***
- **CANADA MAY SEE R-VALUE REQUIREMENTS FOR WALLS AND ROOFS GO TO R-30 AND R-40**

*American Society of Heating, Refrigerating and Air-Conditioning Engineers

CANADA R-VALUES TO 30 AND 40



	ASHRAE 90.1	ASHRAE 189 (proposed)
Zone 1	R-15	R-20
Zone 2	R-20	R-25
Zone 3	R-20	R-25
Zone 4	R-20	R-25
Zone 5	R-20	R-25
Zone 6	R-20	R-30
Zone 7 & 8	R-20	R-35

USE OF INSULATING CONCRETE FORMS (ICFs) FOR CAST-IN-PLACE CONCRETE

NEW GENERATION OF FORMS FOR CAST-IN-PLACE CONCRETE

- INSULATING CONCRETE FORMS -- ICFs
- AVAILABLE FOR BOTH WALLS AND ROOFS
- INTRODUCED IN USA ALMOST TWO DECADES AGO
- THE FORMS ARE "STAY-IN-PLACE"
- THEY ARE USUALLY COATED WITH STUCCO ON THE EXTERIOR
- CONVENTIONAL DRYWALL, OR A SPECIAL SYNTHETIC COATING IS USUALLY USED ON THE INTERIOR

AN INSULATED CONCRETE HOUSE IS ACCOMPLISHED BY A SIMPLE CHANGE OF CONCRETE FORM TYPE TO AN INSULATING CONCRETE FORM (ICF)

- Cast-in-place concrete **DRS** houses shown previously on Guam were not insulated when they were built over 40 years ago because they were located in climates with moderate daily temperature swings
- Energy costs then (1960's) were relatively low compared to today
- Today houses would likely be insulated even in mild climates for comfort and especially so in more severe climates to save energy costs
- Insulated concrete houses may be achieved by simply changing the form types used in construction from RCFs to ICFs and just leaving the forms in place

INSTALLING INSULATION

- INSULATING MATERIALS LIKE EXPANDED POLYURETHANE CAN BE USED AS FORMS DURING THE CONCRETE PLACING OPERATION OR AFTER IT HAS BEEN COMPLETED
- THIS PRESENTATION DISCUSSES INSTALLATION OF INSULATION DURING PLACING OF CONCRETE
- METHODS FOR INSULATING CONCRETE STRUCTURES AFTER THEY HAVE ALREADY BEEN POURED WITH RCFs ARE BEYOND THE SCOPE OF THIS PRESENTATION
- EPS R-VALUE ABOUT 4 PER INCH THICKNESS
- PUR R-VALUE 6.0 TO 6.5 PER INCH
- (PUR = POLYISO CYANURATE)

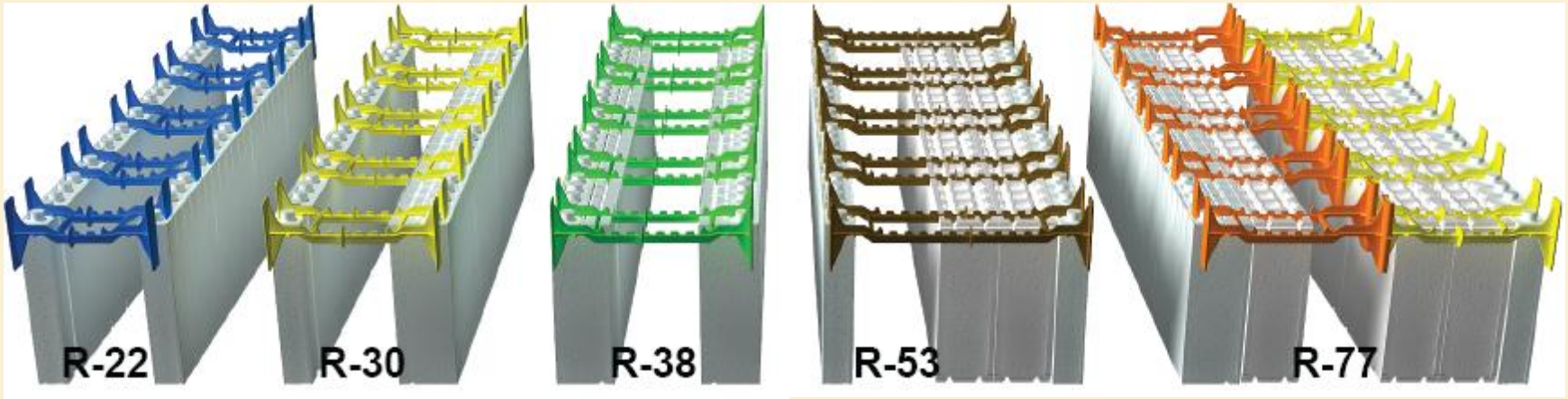
INSULATING CONCRETE FORMS

EXAMPLES OF STAY-IN-PLACE ICFs FOR CONSTRUCTION OF CAST- IN-PLACE CONCRETE HOUSES

INSULATING CONCRETE FORMS

- **Within the past couple of decades, there has evolved a specialized type of form which is intended to STAY IN PLACE**
- **Such forms provide a specialized function – that of resisting the passage of energy and sound through the insulated concrete elements– in either direction**
- **They are** called **ICF**s –
- **I**nsulating
- **C**oncrete
- **F**orms

This is what insulating concrete wall forms typically may look like for cip



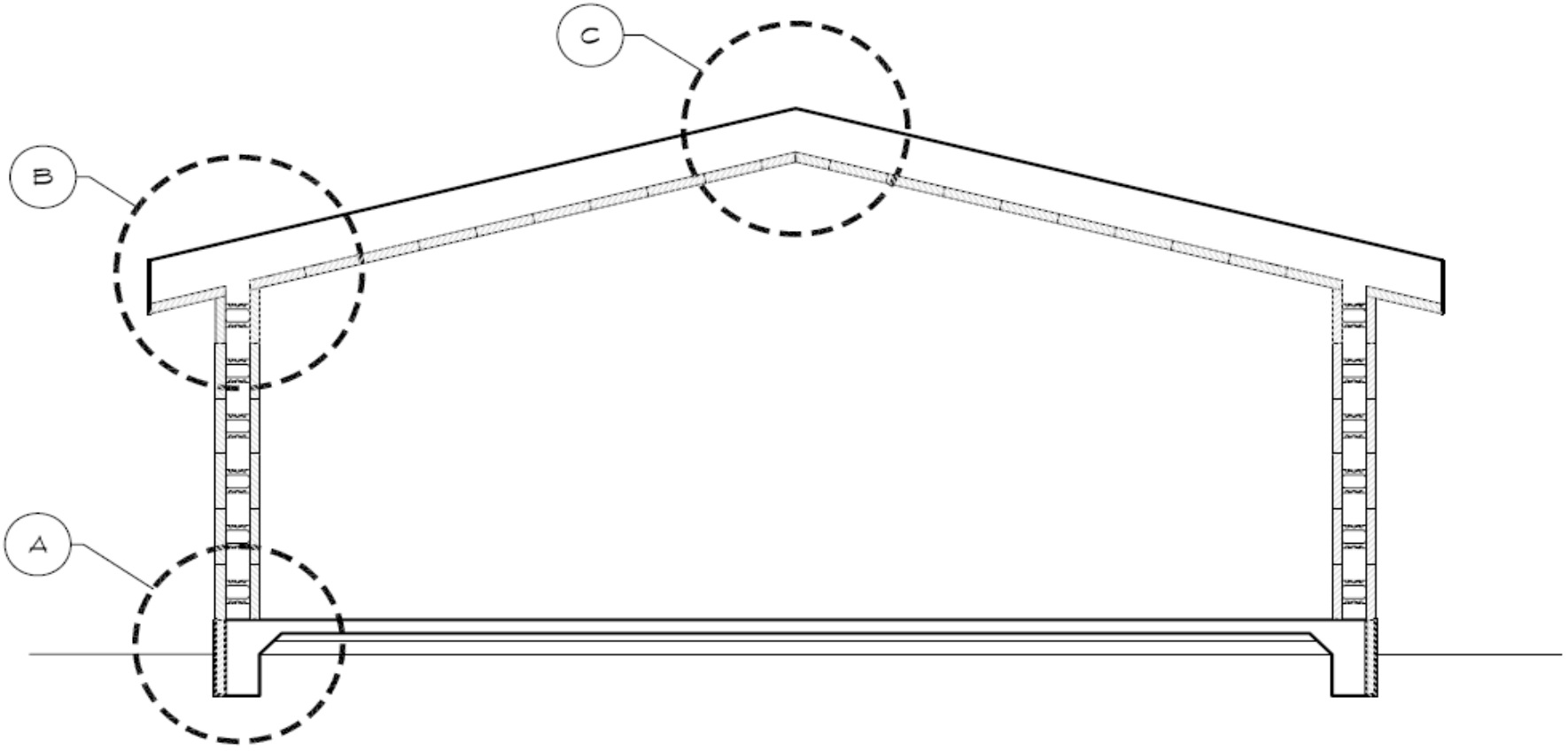
DRS CONCRETE HOUSES MADE WITH ICF FORMS

- Structural concrete design and construction techniques would essentially be the same for either type of formwork (RCFs or ICFs)
- Reinforcing bar specs would be the same
- Placing concrete in forms would be unchanged
- The only change would be techniques in erecting and bracing the forms, and
- The insulating forms would stay in place and not be removed or reused – thus eliminating a separate operation

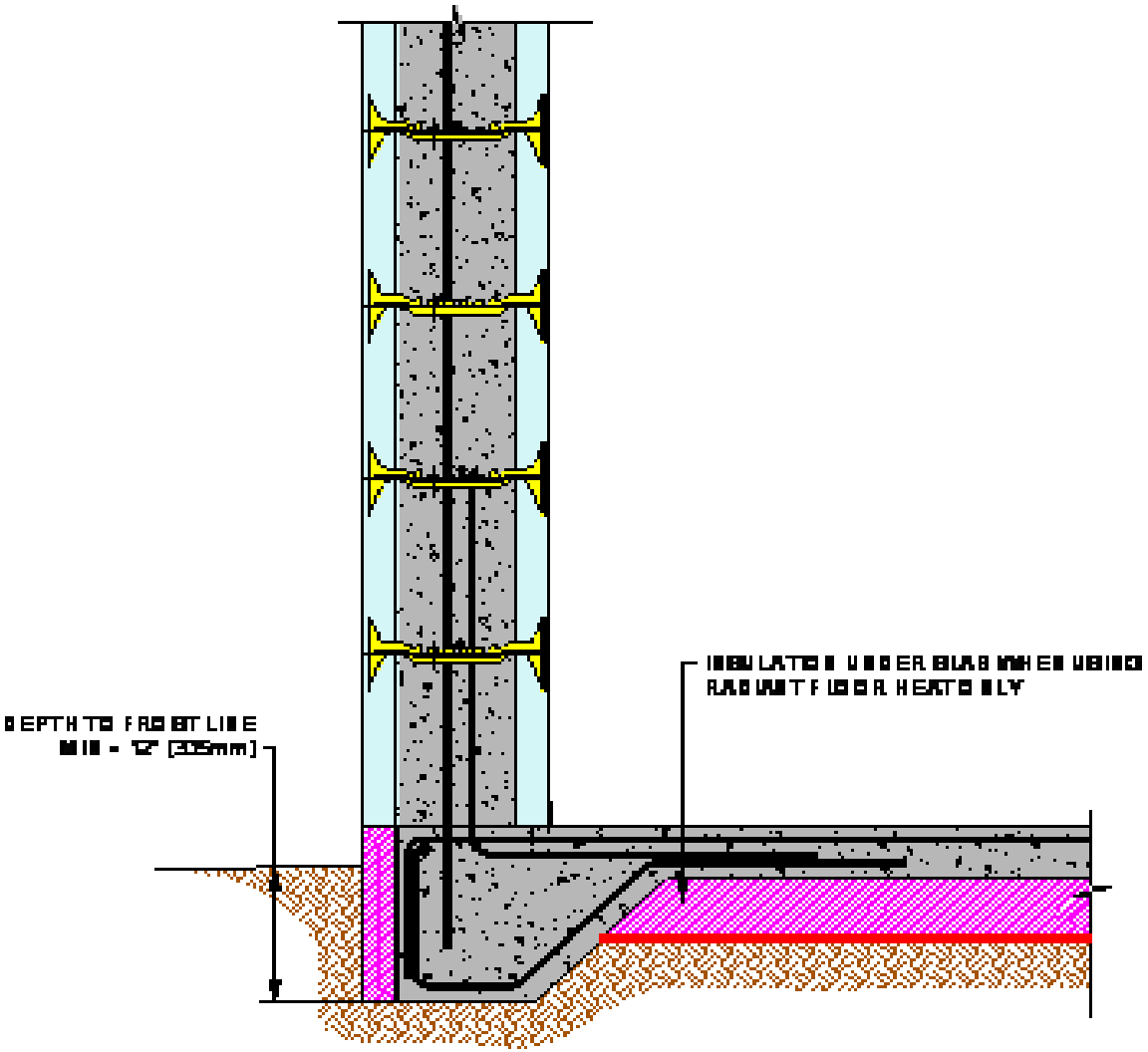
FEATURES OF INSULATING CONCRETE FORMS –WHEN USED FOR A BUILDING SHELL

- **Resist the passage of heat energy --**
  - **From inside to outside – when COLD outside**
  - **From outside to inside – when HOT outside**
  - **(Eliminate "Heat Bridges")**
- **Impede the transmission of sound**
- **Maintain the temperature of the concrete more constant – avoiding large temperature expansion and contraction swings**
- **Impenetrable to passage of**
  - **Animals (Mice, moles, rats etc.)**
  - **Insects (Termites, ants, centipedes, cockroaches etc)**
  - **Molds, dry rot, bacteria**

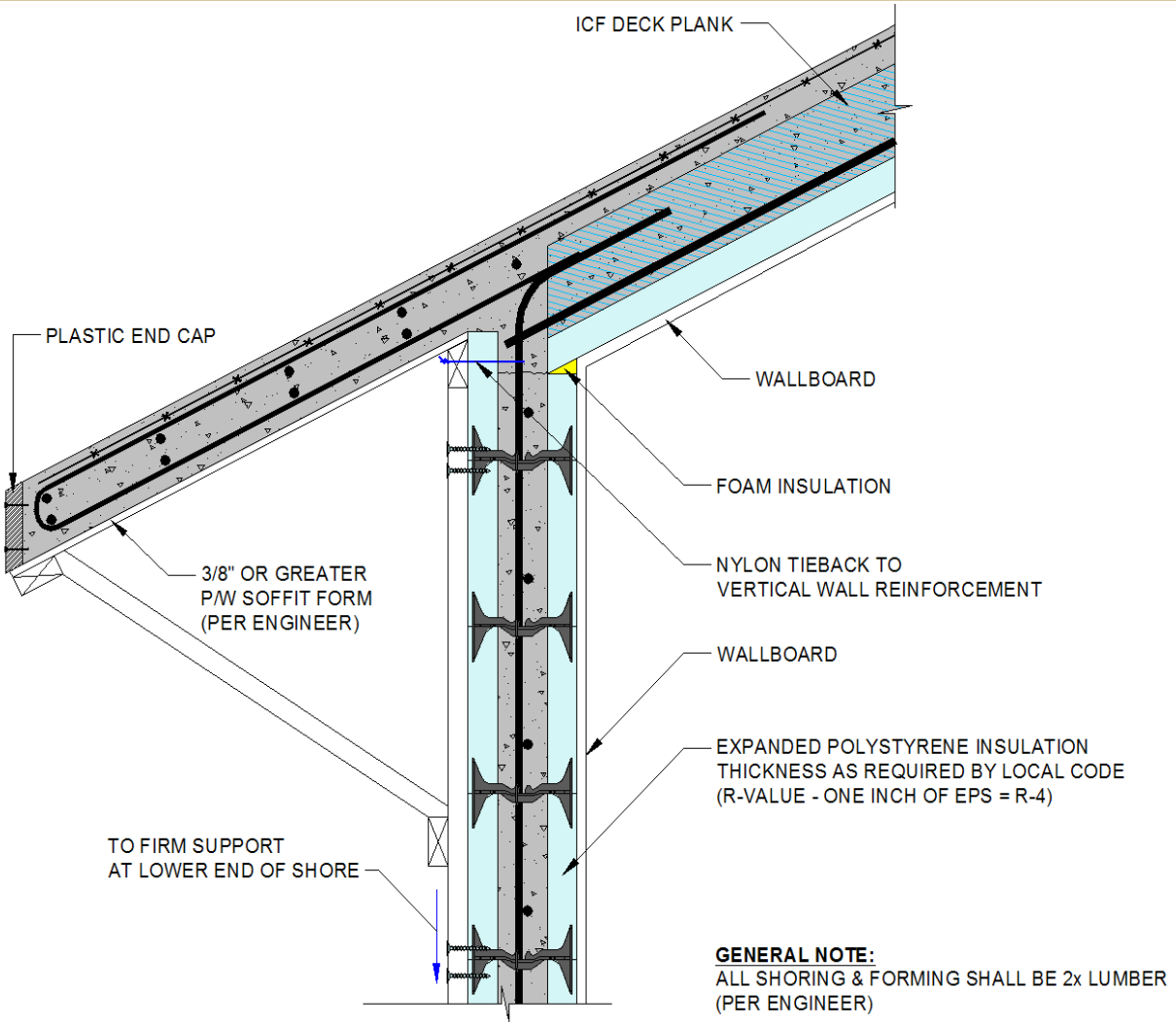
CROSS-SECTION DETAILS OF DISASTER-RESISTANT ICF SHELL



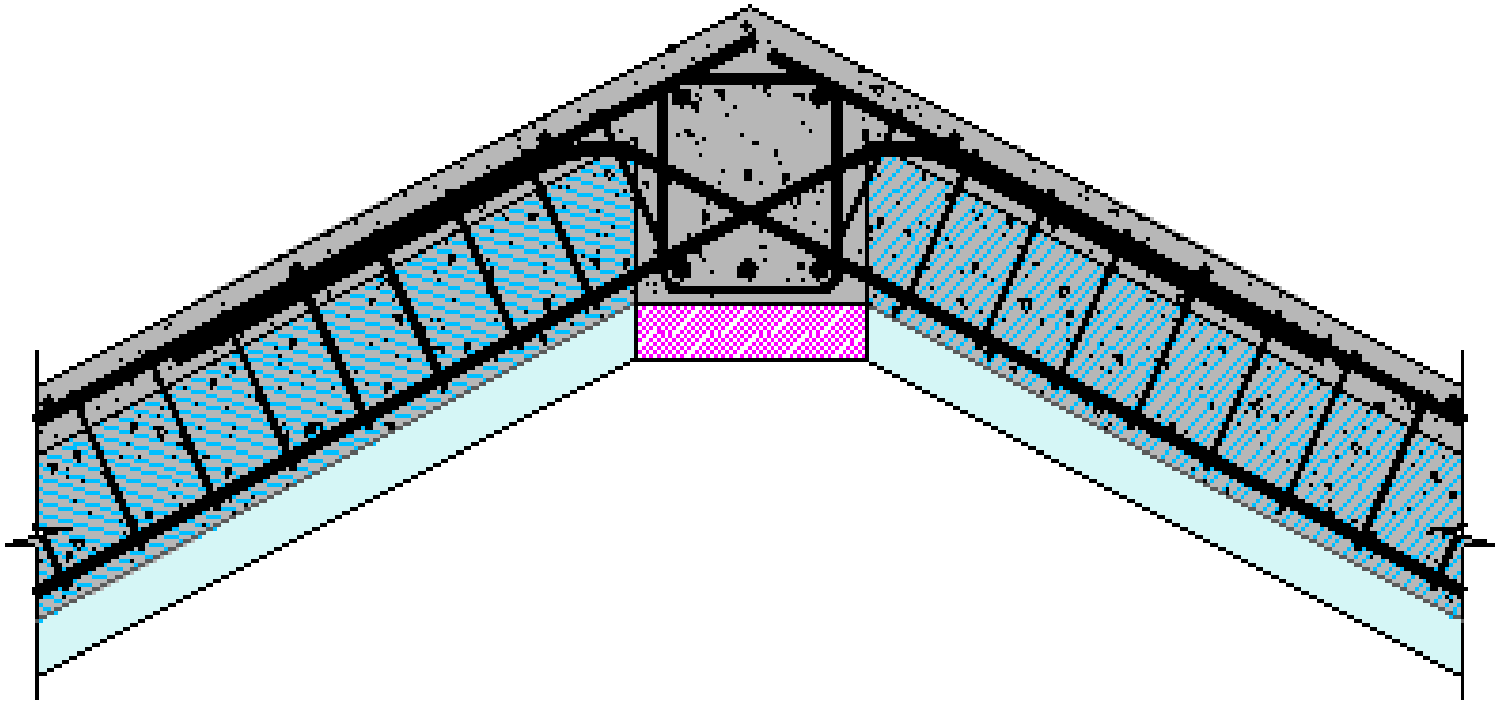
DETAIL A- DRS Floor-to-Wall Detail — Using ICF Wall Forms



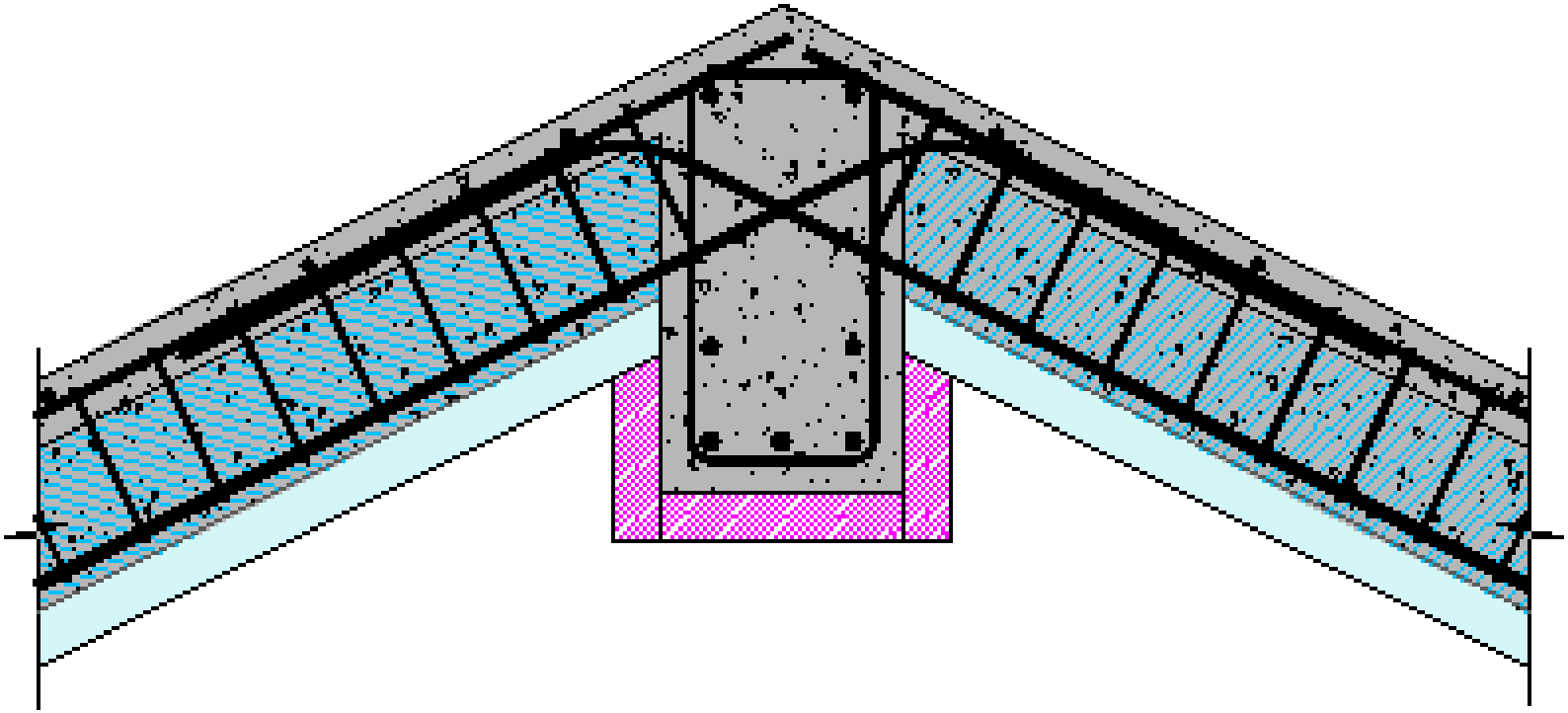
Detail B --- DRS Wall to Pitched Roof -- ICF CIP Wall Forms plus ICF Roof Plank Forms



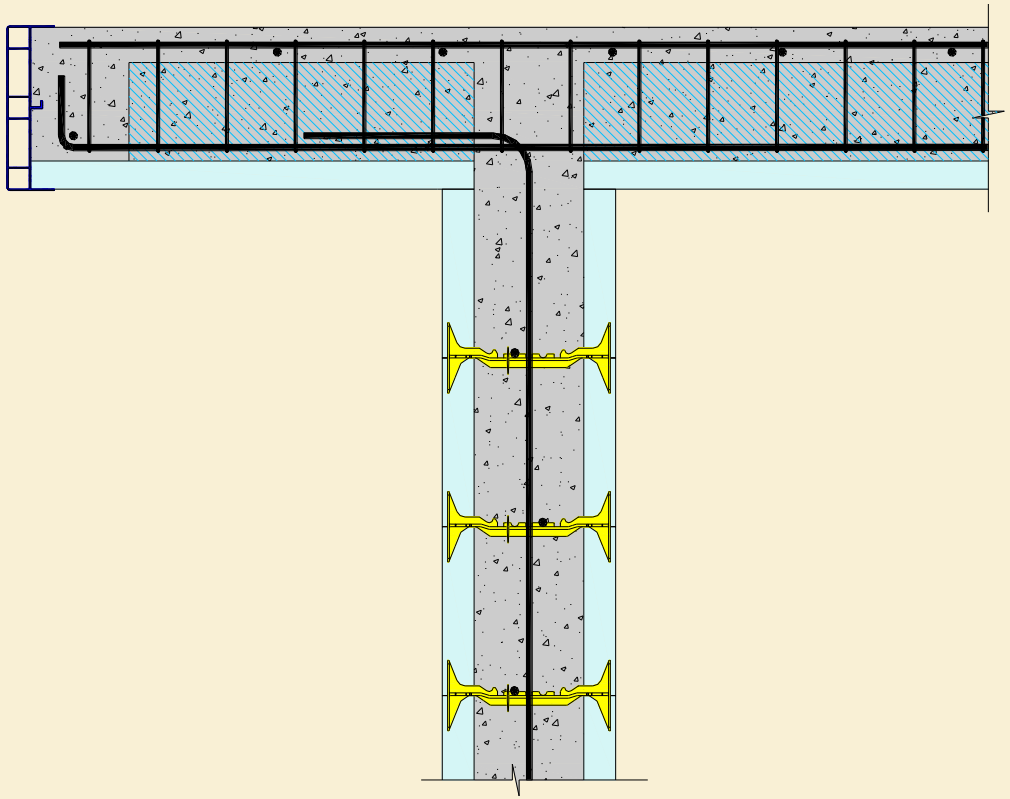
Detail C - DRS Ridge (Shallow Beam)
ICF Roof Plank Forms



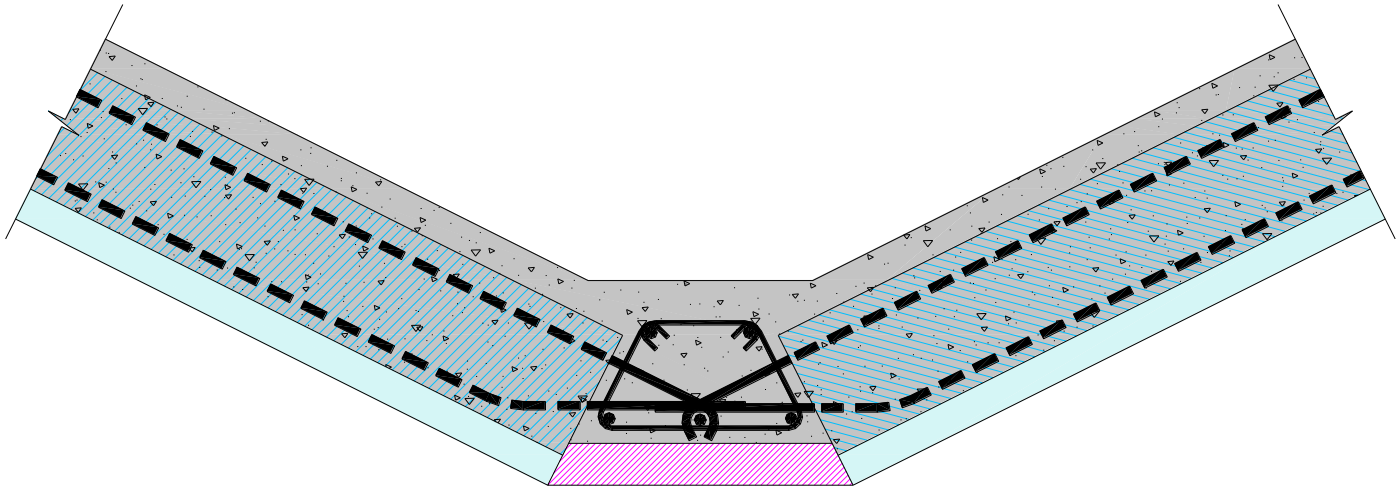
C - DRS Ridge (Deep Beam) Detail –ICF Roof Plank Forms



FLAT ROOF DRS Wall-to-Roof Detail With Overhang ICF Wall Forms & ICF Roof Forms



DRS Valley Beam Detail
ICF Roof Plank Forms



TYPICAL STEPS IN CONSTRUCTION OF A SLAB-ON-GRADE INSULATED DRS HOUSE

- This project in Romania in eastern Europe required four feet deep foundations for frost considerations. (Frost line at 4 feet) An inverted foundation was chosen to save cost. (special details by request)
- For this project, the following sequence was followed:
- A trencher was used to excavate neat foundation walls. Foundation may be insulated with EPS.
- Concrete was poured with careful attention to accurate grading of the concrete surface. Note vertical rebars used to tie down the DRS walls to the foundation and floor slab.

Top of Foundation Carefully Leveled with Laser

First Course of ICF Block

Forms Halfway Erected
Note Door and Window Bucks

Job-Fabricated Scaffolding and Bracing

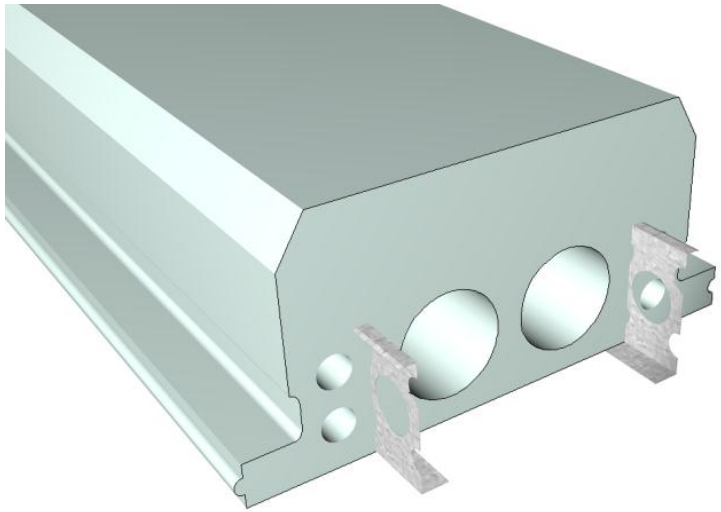
Factory Made Scaffolding and Bracing

Wall Forms Completed
Pouring Concrete in Wall Forms

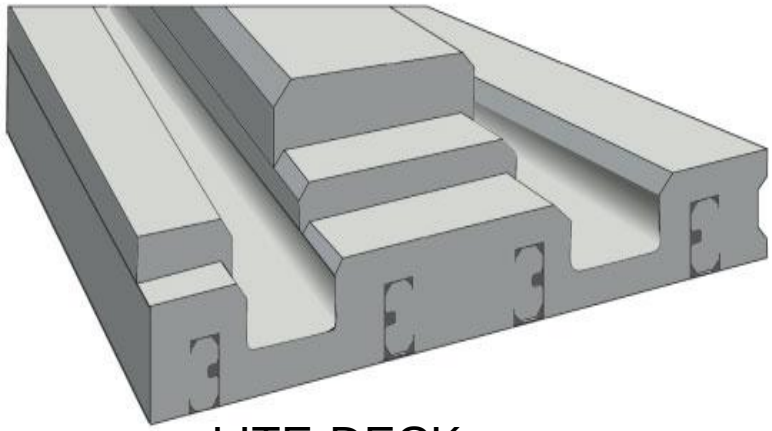
Walls completed-
Begin setting ICF Roof Planks

ICF FORMS FOR ROOFS

TYPICAL ICF ROOF DECK PLANKS

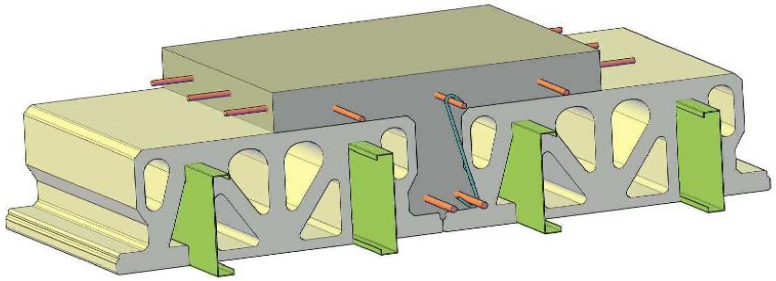


INSUL-DECK, QUAD-DECK, PLASTBAU



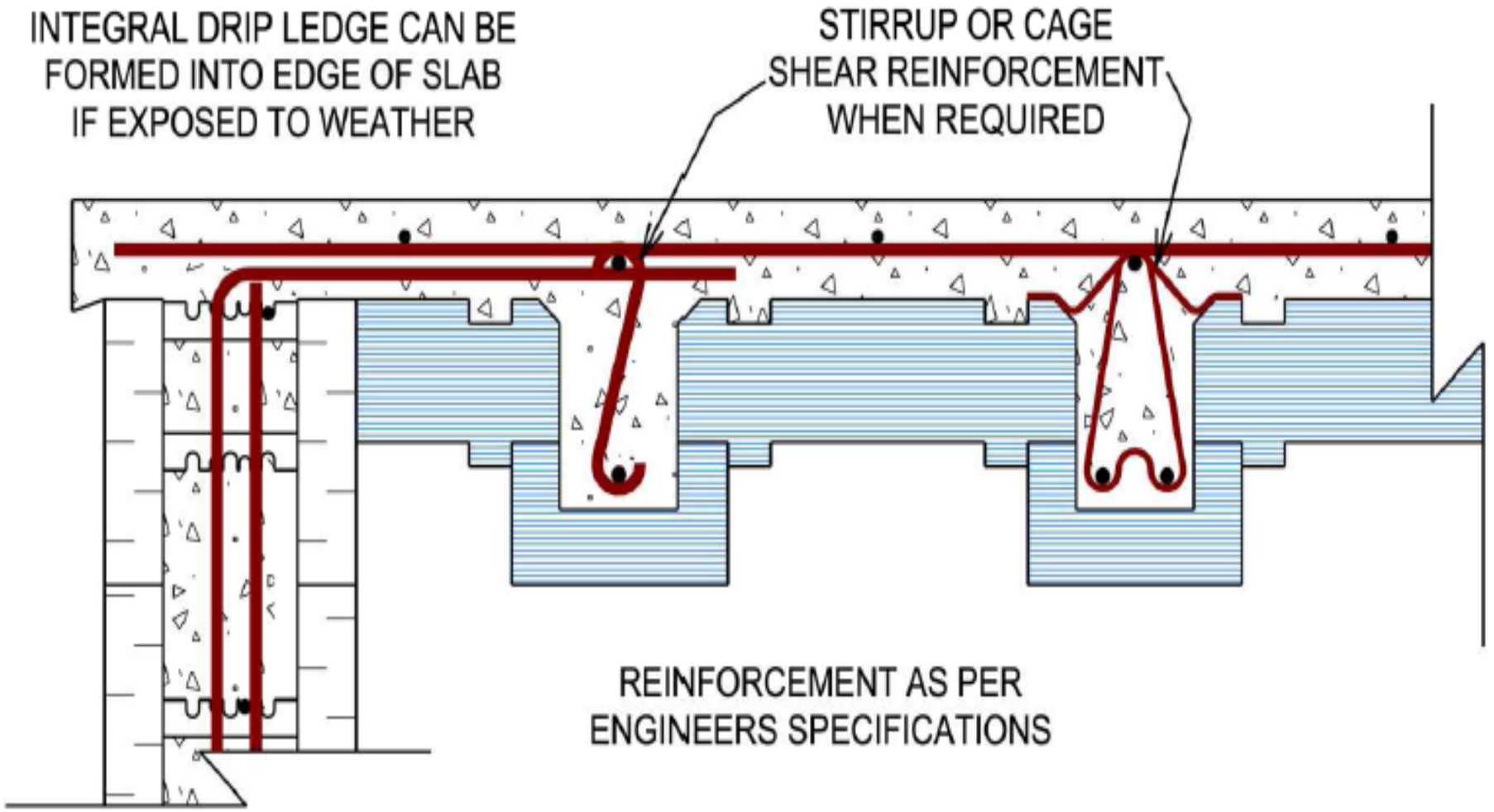
LITE-DECK

BUILD-DECK



AM-DECK

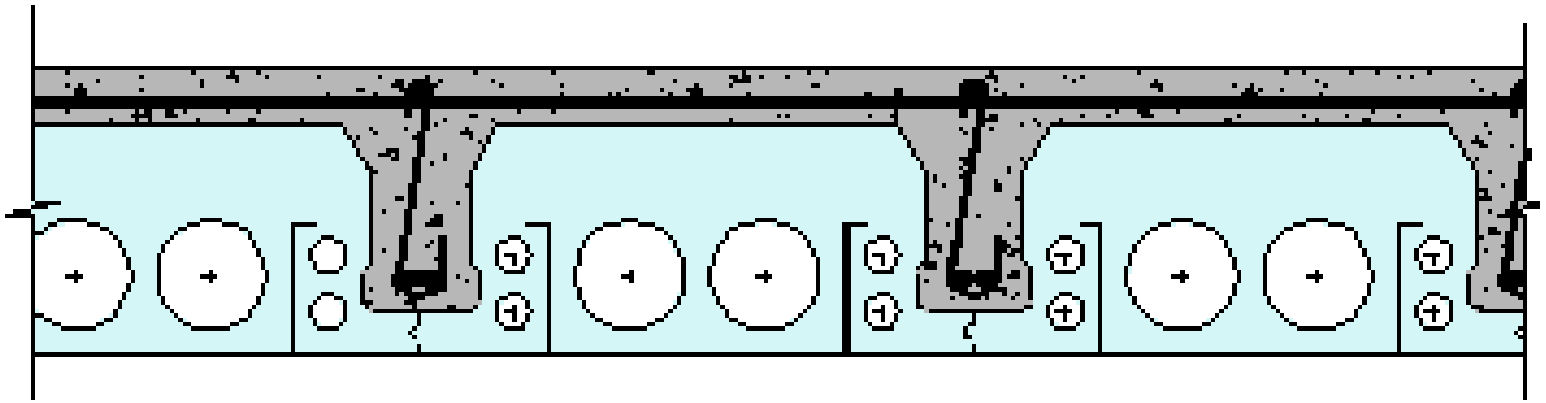
Logix “FORTRUSS” Deck Plank Forms (Introduced in 2010)



TYPICAL ICF ROOF DECK FORMS

- AVAILABLE IN SECTIONAL OR FULL SPAN LENGTHS
- STRUCTURAL CONCRETE DESIGN IS BASED ON ORDINARY REINFORCED CONCRETE TEE-BEAMS PER THE ACI CODE. NO COMPLICATED CODE OR DESIGN REQUIREMENTS
- TOP FLANGES OF THE TEE BEAMS DOUBLE AS THE ROOF DECK SLAB AND ACT AS A STRUCTURAL DIAPHRAGM TO ACCOMMODATE LATERAL FORCES

Typical Section Through ICF Roof Deck Forms for Flat or Pitched Roof
(Ordinary CIP Concrete Tee-Beams)

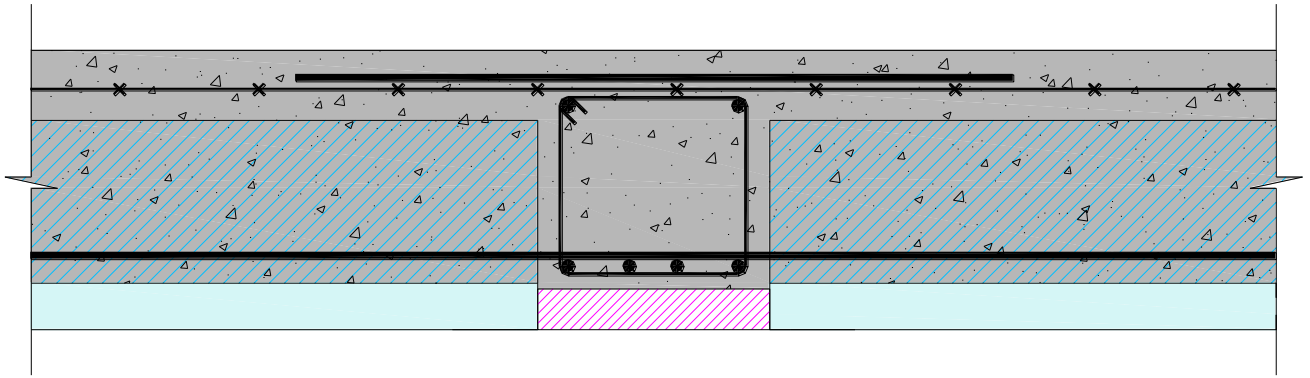


ICF Roof Planks in Place for a Flat Roof

View of roof forms in a flat roof configuration -- Rebars in Place

INTEGRAL IMBEDDED BEAM

Poured at the same time as the Deck



Composite Roof Beam Formed to Pour at Same Time as the Deck

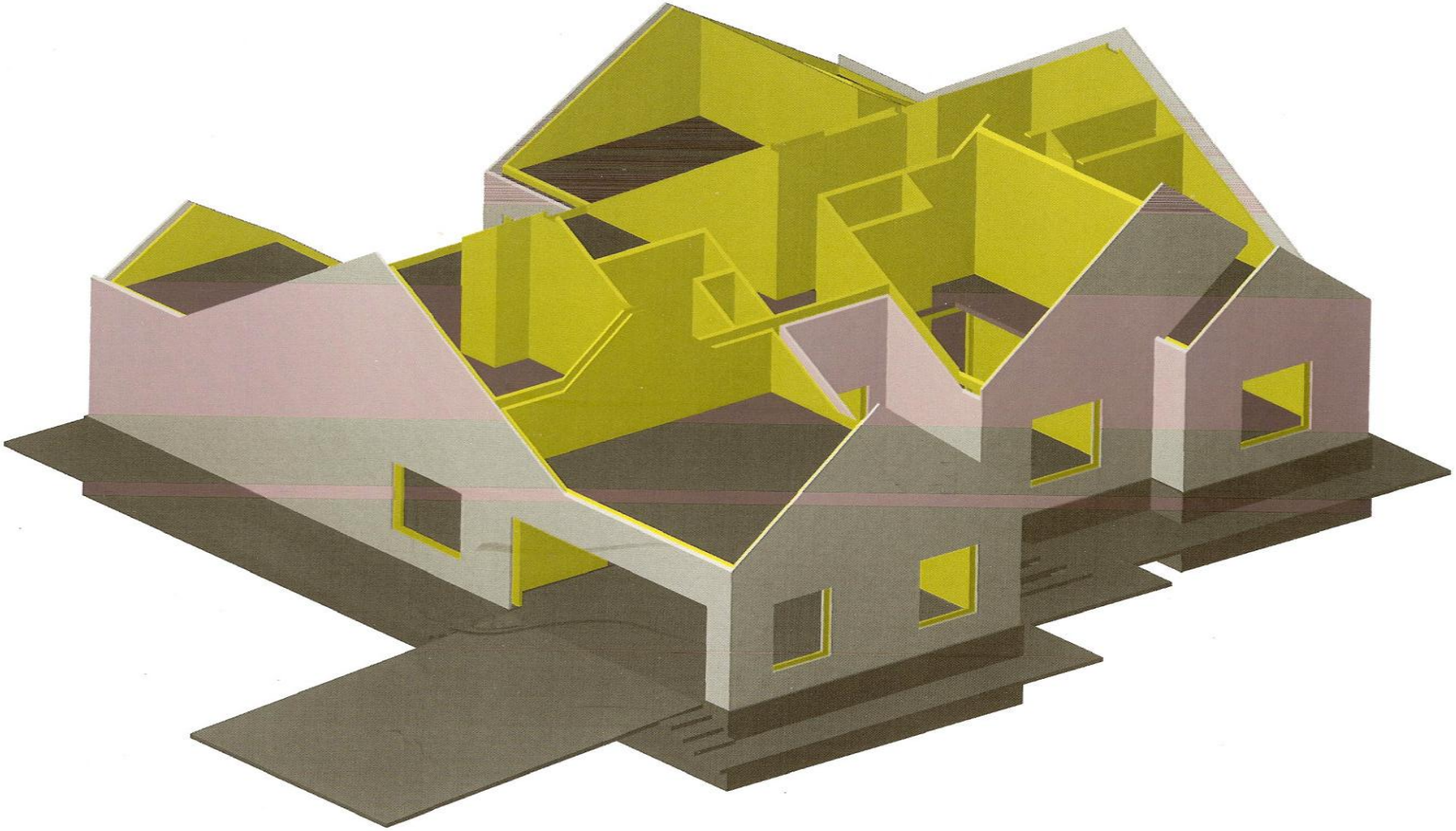
Placing Roof Deck Concrete

How to Build a Pitched Concrete Roof Using Insulated Concrete Planks

- Procedure is not complicated for the type of house just illustrated
- Beams and girders are imbedded in the deck assembly and are poured at the same time as the deck
- Using prefabricated rebars and assemblies, on this project the total time from the beginning of setting and shoring deck forms until the concrete was placed was **FIVE DAYS** !

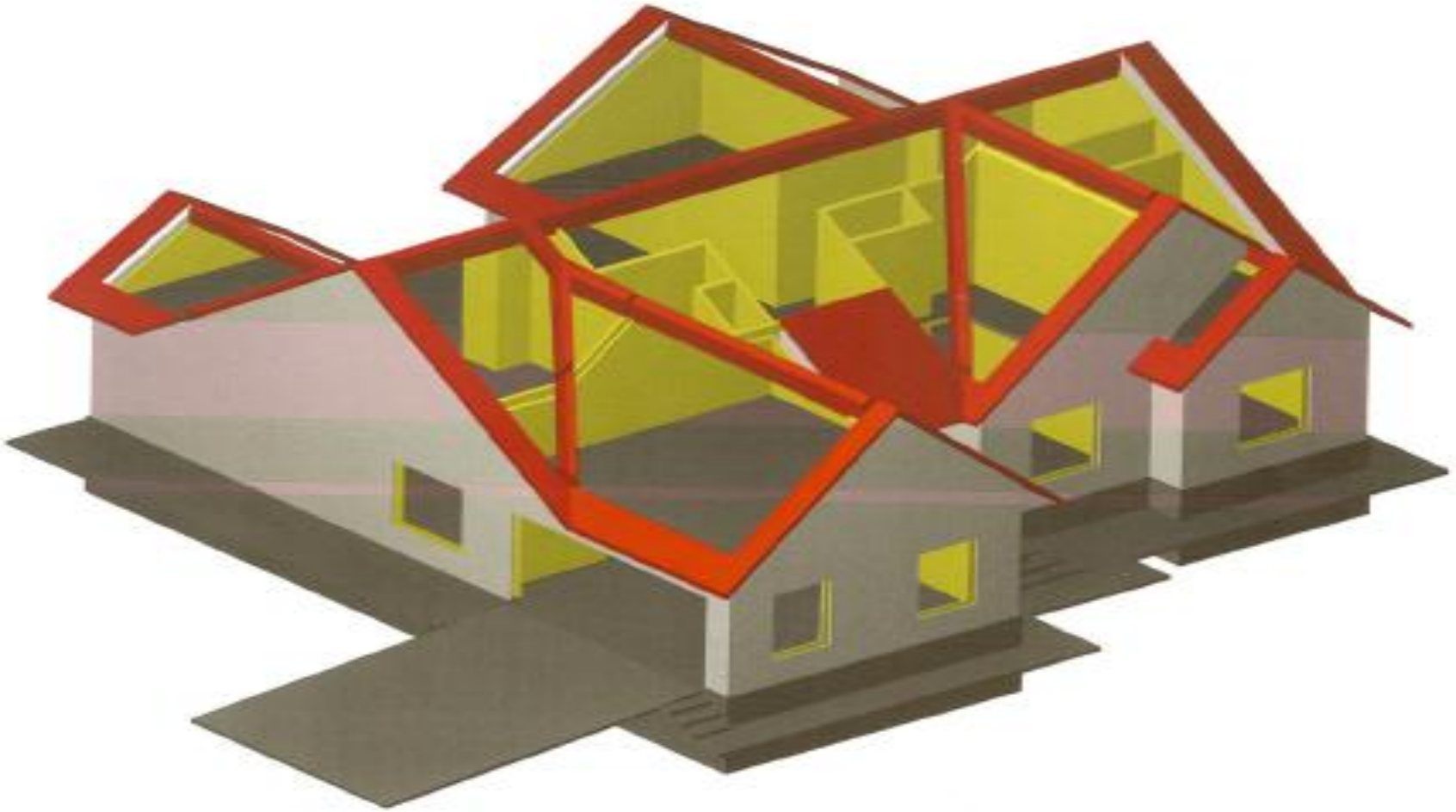
USING ICF PLANK FOR A PITCHED ROOF

Step One: All ICF Concrete Walls Completed to Roof Line



Step Two: Form and Shore Ridge and Valley Beams (Add columns if required)

Step Three: Form and Shore Overhangs and Eaves



Step Four: Install ICF Roof Planks = Ready for Concrete

ICF DECK FORMS USED FOR A PITCHED ROOF

CONCRETING A PITCHED ICF ROOF

SUMMARY

- SINGLE FAMILY CONCRETE HOUSES DESIGNED ACCORDING TO DRS PRINCIPLES AND CONSTRUCTED WITH FOUR INCH THICK R/C WALLS CAN SURVIVE MAXIMUM CATEGORY F5 TORNADOES
- PROOF:
  - UP TO CATEGORY F4 TORNADOES = ACTUAL RECORDS
    - THOUSANDS OF DRS HOUSES HAVE SURVIVED THIS MAGNITUDE OF WIND WITHOUT DAMAGE ON THE ISLAND OF GUAM
  - CATEGORY F5 TORNADOES
    - NO EXAMPLES WERE FOUND, BUT WIND CALCULATIONS SHOW STRUCTURALSURVIVABILITY WITHOUT DAMAGE

CONCLUSION

- FOR THE FIRST TIME IN THE HISTORY OF MANKIND, WE TODAY HAVE A SOLUTION TO THE AGE OLD CHALLENGE OF BUILDING ENERGY-CONSERVATIVE HOUSES THAT ARE COMFORTABLE AND AT THE SAME TIME SECURE FROM DESTRUCTION BY SOME OF THE MOST DEVASTATING FORCES OF NATURE
- IT IS ACHIEVED BY BRINGING TOGETHER TWO WELL ESTABLISHED AND PROVEN TECHNOLOGIES: ONE OF BUILDING ALL-CONCRETE HOUSES USING STAY-IN-PLACE INSULATING CONCRETE FORMS (ICFs) AND/OR INSULATED PRECAST CONCRETE WALLS , PLUS THE PRACTICE OF STRUCTURALLY DESIGNING WITH FIELD-PROVEN DISASTER-RESISTANT-SHELL (DRS) TECHNOLOGY

THE POINT ?

- THOUSANDS OF REINFORCED CONCRETE HOUSES ON GUAM HAVE STOOD UP TO DISASTROUS WINDS AND EARTHQUAKES WITHOUT DAMAGE
- WHY ARE WE STILL BUILDING HOUSES IN NORTH AMERICA WITH WOOD FRAMES AND TRUSSES IN DISASTER-PRONE REGIONS OF MAINLAND USA -- OR ANYWHERE ELSE IN THE WORLD? -- WHEN WE ALREADY HAVE THE ANSWER?

BOTTOM LINE

PREDICTION:

INSULATED DISASTER-PROOF CONCRETE HOUSES WILL REPLACE WOOD FRAME CONSTRUCTION IN NORTH AMERCICA OVER THE NEXT 50 YEARS

Q&A EXPERTS

- Kenneth A. Luttrell
  - California registered structural engineer
  - Former president of the Structural Engineers Association of California
  - Specialist in earthquake and wind design codes
  - Chairman of both SEAOC Seismic and of the Wind committees
- Bill Juhl
  - CEO of Amvic Pacific, an ICF forms distributor
  - Involved with more than 200 ICF construction projects in the southwest
  - Teaches ICF technology in the colleges
  - Presents a bi-monthly “nuts and bolts” all-day seminar for contractors

WHERE TO LOOK FOR HELP

HELP FOR INTERESTED PERSONS

- **WORLD OF CONCRETE – At least 12 prominent North American ICF producers have exhibits in the North Hall – Visit every one – talk to the most senior representative of each. You will learn a number of ideas. These exhibitors are listed in the WOC program and in the next slide**
- **NATIONAL ASSOCIATION OF HOME BUILDERS – NAHB Two seminars for ICF contractors – hbi.org**
- **PRODUCERS AND DISTRIBUTORS OF ICF FORMS**
  - **Instruction manuals**
  - **Formal training by some – seminars and courses**
  - **Help on the job site**
- **MAGAZINES – *'ICF Builder'* and *'Concrete Homes'* – Also In the North Hall**
- **BOOKS – Check the PCA & ICFA exhibits and the book store at WOC**
- **VARIOUS CONSULTANTS**

SUGGESTED WORLD OF CONCRETE EXHIBITS TO VISIT

- **ICF DISTRIBUTORS**
  - Integraspec N165
  - *QuadLock* N1023
  - Reward N1445
  - Nudura N1813
  - *LiteForm* N1951
  - Logix N2051
  - ARRX N562
  - Fox Blocks N1113
  - BuildBlock N1654
  - AMVIC N1819
  - *Greenblock* N2015
  - *InsulDeck* N2362
  - **PUBLICATIONS**

ICF Builder magazine **N957**

Concrete Homes magazine **Check with PCA**

Concrete Construction magazine **Hanley Wood booth**

- **INDUSTRY ASSOCIATIONS**

Insulating Concrete Forms Association

Portland Cement Association **C4213**

Tilt-Up Concrete Association **C4637**

MAXIMIZE YOUR TIME AT MINIMUM EXPENSE

- Company senior people are here at the exhibits
- You don’t need an appointment
- They are receptive – They are anxious to talk with you about their products
- Fewer interruptions – phones, secretaries, etc.
- You are already here – no extra travel cost
- They are concentrated at WOC – at considerable cost to them
- The only opportunity to get that many experts together in one spot over the entire year.

WORLD OF CONCRETE®
WORLD OF MASONRY
TECHNOLOGY FOR CONSTRUCTION
hanley wood

SUPPLEMENTAL TOPICS

- STUCTURAL ANALYSIS FOR F5 TORNADO
- DETAILS FOR INSULATED PRECAST AND TILTUP WALLS
- LOWER COST INVERTED FOUNDATIONS FOR HEAVY LOADING
- INVERTED FOUNDATION
- PROTOTYPICAL SUPER-INSULATED DISASTER-PROOF HOUSE NEARING COMPLETION

STRUCTURAL ANALYSIS FOR F5 TORNADO

- **Because we could not find any records about the performance of existing all-concrete DRS houses having been subjected to the forces of an F5 tornado anywhere , a structural analysis was made of a SMALL RESIDENTIAL STRUCTURE WITH FOUR INCH REINFORCED CONCRETE WALLS AND A T-BEAM REINFORCED CONCRETE ROOF SLAB**
  - **Subjected to Maximum California seismic loads AND**
  - **F5 (350 mph) tornado winds**
- *(Structural calculations are available for inspection).*

Prefabricated Concrete

WALLS:

- Tilt-up
- Factory Precast

DRS WALLS WITH CONCRETE ROOFS

- **TILT-UP**
  - Single-family houses
    - DOCUMENTED: Guam, California CCH
    - UNDOCUMENTED: Mainland North America
  - Multi-Family
    - See Redwood City slide

- **FACTORY PRECAST**
  - UNDOCUMENTED: Single-family houses
  - Multi-Family -- See PCI websites, Japan (Kobe)

APARTMENT BUILDINGS
REDWOOD CITY CA

REDWOOD CITY PRODUCTION RECORD

YEAR	1969	1971	1972*
BUILDING	Marshall Towers # 4	Broadway II	Casa de Redwood
Number of apt units	112	123	136
Number of stories	7	7	7
Number of panels			
Wall	729	685	600
Floor	328	297	340
Total	1,057	982	940
Number of working days			
Fabrication	44	24	29
Erection	21	16.5	15.5

*Included Penthouse

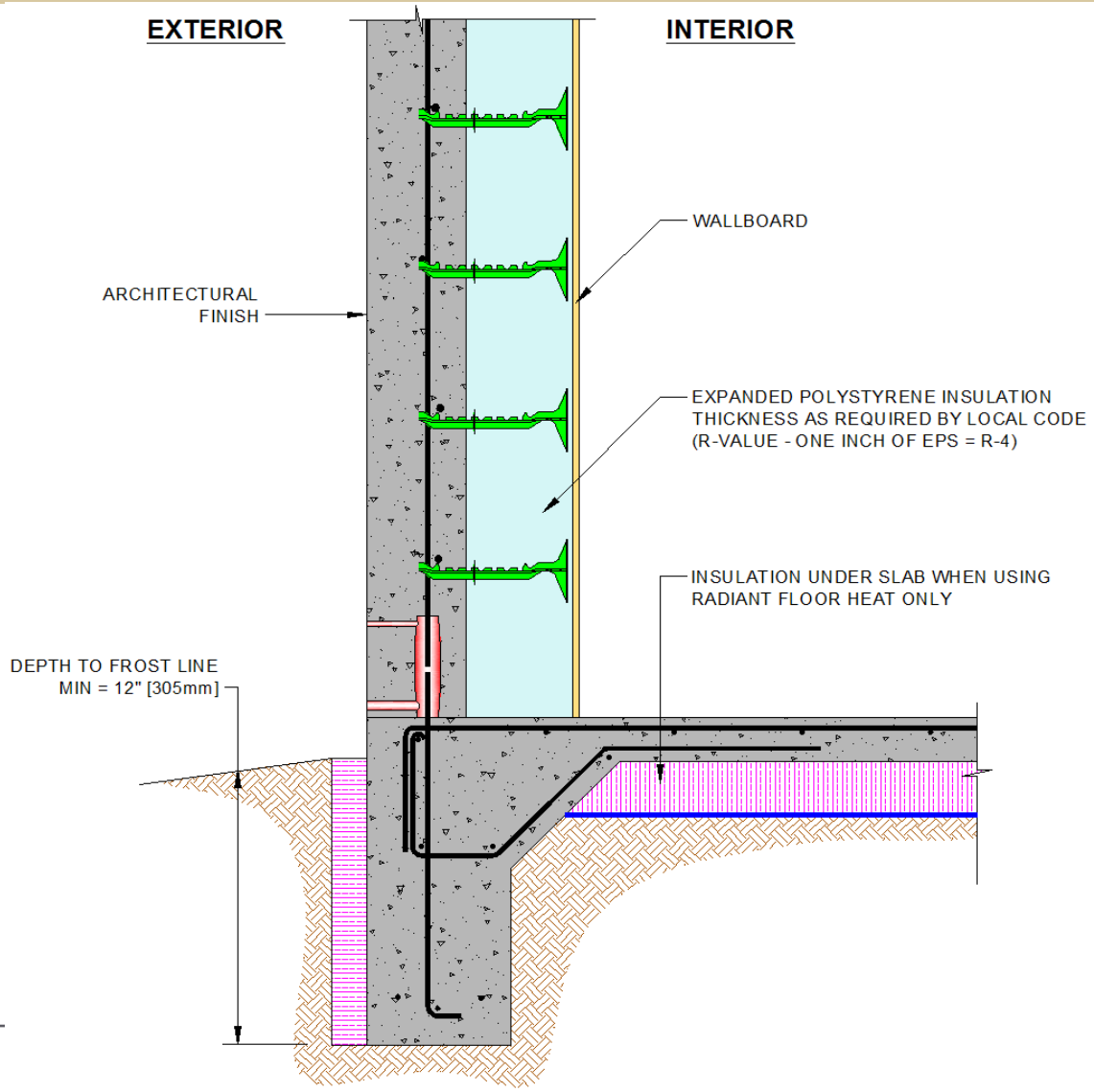
ICF WALL INSULATION FOR P/C & T/U

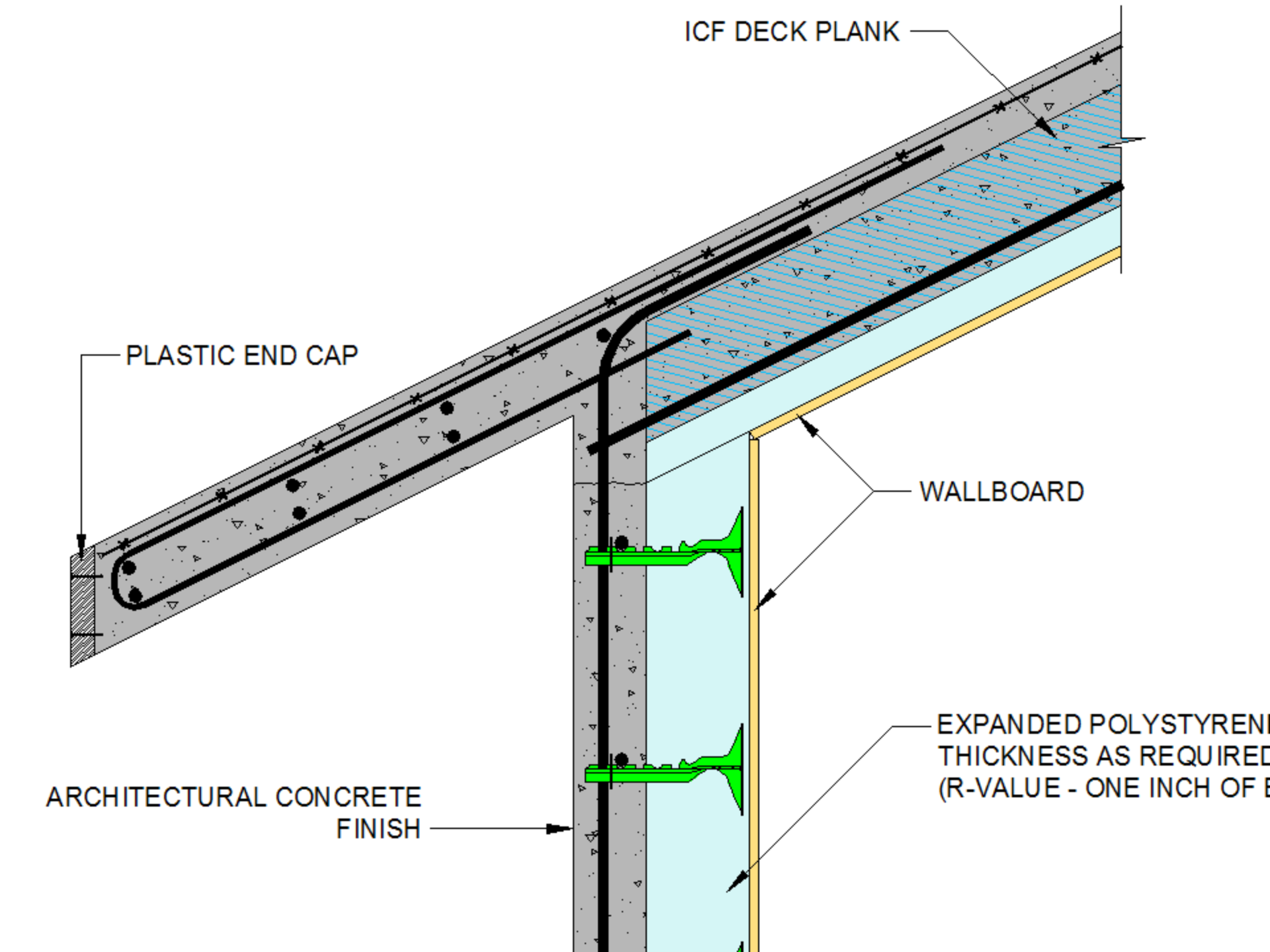
- STACK CASTING SYSTEM TAKEN TO COLORADO
- COMPETED SUCCESSFULLY AGAINST WOOD FRAME APARTMENTS
- DEVELOPED METHOD OF INSULATING THE WALLS

INSULATED PRECAST/TILTUP CONCRETE WALLS

- THE PROCEDURE IS THE SAME AS FOR CAST-IN-PLACE CONCRETE IN ICF OR RCF FORMS
- EXCEPT THAT THE INSULATED WALLS WILL BE PREFABRICATED BEFORE ERECTION
- WALL UNITS CAN BE PREFABRICATED IN AN OFFSITE FACTORY AND DELIVERED BY TRUCK
- OR, THEY CAN BE PREFABRICATED ON SITE AND TILTED UP
- IN EITHER CASE, A CRANE IS REQUIRED.

INSULATED PRECAST CONCRETE WALL CONNECTION TO FOUNDATION

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WALLBOARD
EXPANDED POLYSTYRENE
THICKNESS AS REQUIRED
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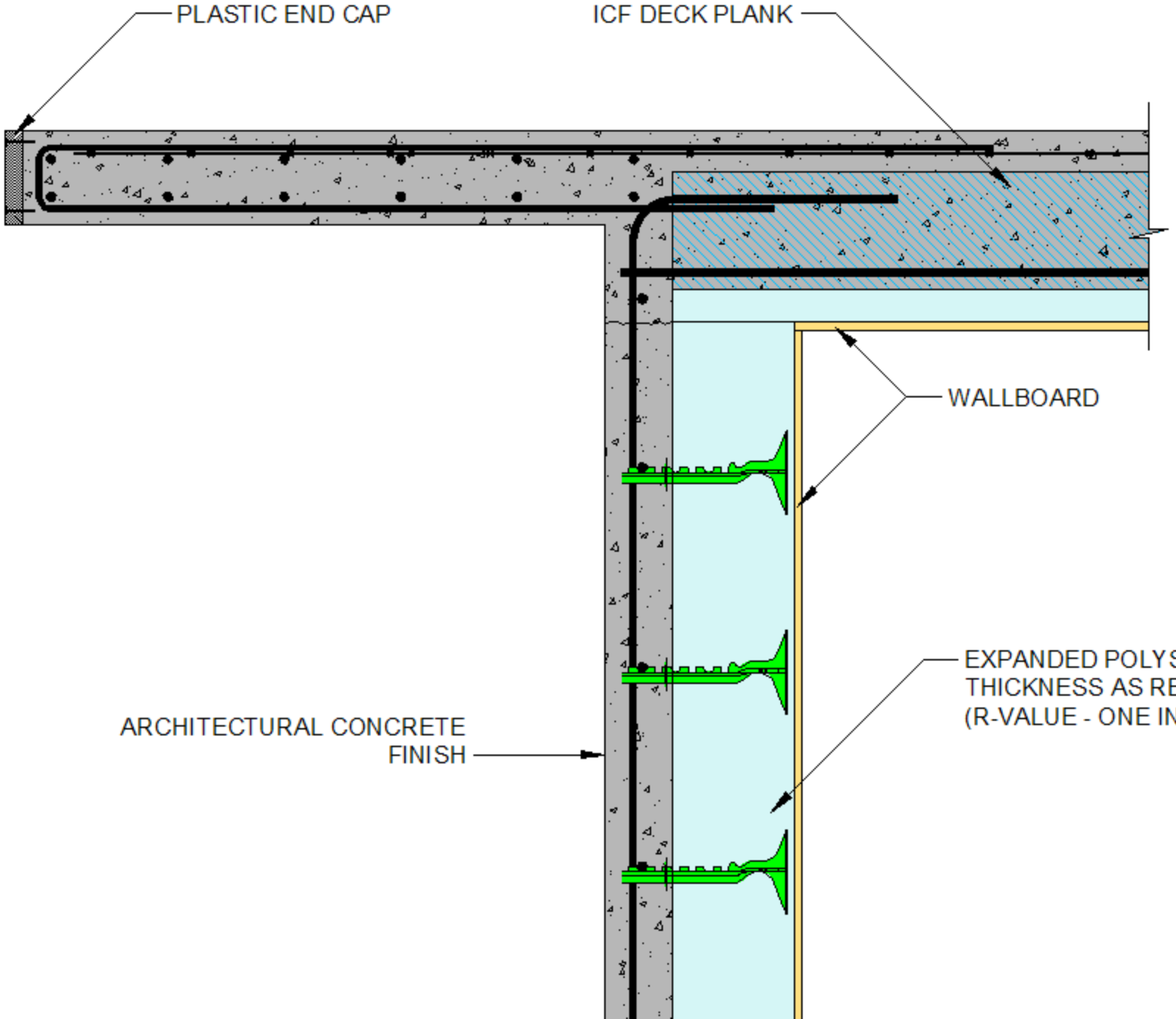
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COSTS IN GENERAL

- In Canada and the United States, experience would suggest that the cost of an ICF/DRS tract house would be a toss-up with a wood frame tract house in its present stage of development
- Wood frame tract houses have a centuries-long history in the housing market and have essentially matured in the methods, materials, labor and management techniques being used
- By comparison, ICF/DRS tract house construction has a history of not much longer than a decade
- Construction practices for ICF/DRS are yet on the low end of the learning curve and are still evolving

COST CONSIDERATIONS

- **Side-by-side comparisons are scarce and generally have not been done under meticulously controlled construction management conditions by a single large-scale tract homebuilder**
- **The presenter believes a realistic representation of cost awaits construction of a hundred wood frame tract houses and a hundred ICF/DRS houses built by the same reputable homebuilding contractor in the same locale and in the same optimum construction period.**
- **The International Brotherhood of Carpenters are actively training frame carpenters in ICF techniques**

CONSTRUCTION TIME CONSIDERATIONS

- **THE PRESENTER BELIEVES:**
- **It may be possible to construct an ICF/DRS house in as much as 25% less time than a frame house.**
- **In severe climates, an ICF/DRS house can be closed in much quicker**
- **Interior work can proceed in relative comfort all during winter weather with only a small heating requirement – even a wood stove (Electrical, plumbing, painting, communications, dry-walling, cabinetry, painting, floor coverings, appliance installation, etc.)**
- **This is based upon actual experience**

IMPACT OF ICFs

- **UNTIL THE INTRODUCTION OF ICFs A LITTLE OVER FIFTEEN YEARS AGO:**
- **(PRIOR TO THE INTRODUCTION OF ICF DESIGN AND CONSTRUCTION TECHNIQUES) NO PRACTICAL NOR COST-COMPETITIVE METHOD HAD YET BEEN DEVISED TO INSULATE CONCRETE HOUSES**