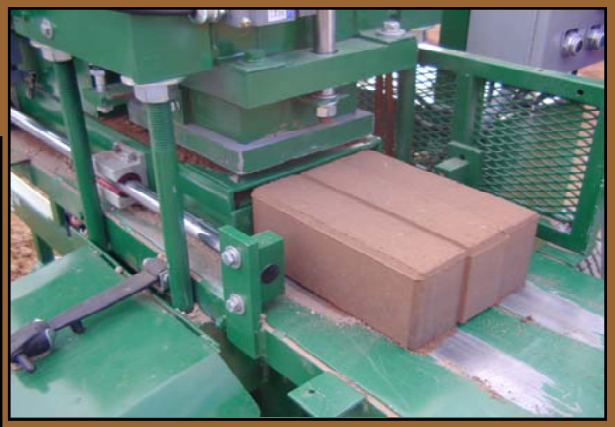
Foxfire Associates Presents…

…TerraBuilt™ *Construction System*



"…it's so simple…"

Introduction

- Historical context for earthen building
- The GreenMachine™
- Video on TerraBuilt™
- TerraBuilt™construction system
  - Soil and soil preparation
  - Production process
  - Construction system
- Testing results
- Intellectual Property
- Summary and conclusion

Photographs courtesy of Almost Heaven Habitat for Humanity Inc, Franklin, WV

Earthen Structures - A Building Tradition From 3rd Century B.C.

- Origins of contemporary compressed earth block (CEB) trace back thousands of years to molded sun-dried earth bricks ("adobe") in Iraq, Egypt, India and China.
- 60-65% of world's population live in soil based structures.
- Density and porosity problems with molded bricks reduced with compression techniques.
  - Tamp and mold techniques
  - Presses emerge in 18th century
  - Mechanical presses emerge in 20th century
  - New generation motor driven presses in 1970s-80s
- GreenMachine™ introduces dimensional accuracy to CEBs, making tongue and groove mortarless construction practical.

The GreenMachine™

- Easy to use
- Easy to transport
- Easy to maintain
- Only uses 2 ½ gallons of gasoline/day at full production
- produces 3 compressed earth blocks/minute
- dimensional accuracy of 1/64” from block to block

GreenMachine™ Specifications

- Dimensions: 81” x 55” x 70” (L x H x W)
- Track Width: 70”
- Road Clearance: 8 ¼” – 15 ¼”
- Weight: 2040 lbs.
- Engine: Honda 8 hp gas or diesel powered
- Hydraulic Pump: Barnes 2-stage 11 GPM
- Production: 3 blocks /minute; 180 blocks/hour

TerraBuilt™

The Answer To Sustainable Building

Soil and Soil Preparation

- Fundamental properties of soil for compressed earth blocks:
  - Composition or percent of gravels, sands,silts and clays
  - Plasticity or ease with which soil can be shaped
  - Compressibility or extent to which porosity can be minimized
- Stabilization – change and enhance soil properties:
  - Mechanically by compacting
  - Physically by controlling the composition mix
  - Chemically by adding cement, lime etc…

Sifting soil to remove rocks and debris

The Block Production Process

On site production of blocks

Rapid Block production -3/minute

Block Specifications

- Dimensions: 4” x 8’ x 10” (H x W x L).
- Tolerances: 1/64th inch.
- Block type: tongue & groove.
- Strength: 900- 2240 psi.
- Block weight: 20 lbs.
- Material: sub soil.
- Stabilizer: 5-8% cement.

Construction Process – Easy and Cost Effective

- No mortar used between courses.
- Doesn’t require specialized labor in most of the process.
- The main material, sub soil, is widely available in the right proportions.
- Very small proportion of Portland Cement is needed during the process.

TerraBuilt™ Wall Construction

Fannie Mae Vice President inspects, lifts and places a block into wall. Note, there is no mortar needed between the courses. This dry stack method of building is possible because of the dimensional accuracy of the tongue and groove blocks. The dimensional tolerance is less than 1/64th inch.

A Soil Block House Under Construction

Construction Details: Corners And Electrical Wiring

Soil Block House with Roof

Interior Walls

Completed Soil Block House

Cost 30% less than comparable wood frame house

TerraBuilt™ Block Tests

- **Compressive Strength** – loading a block uniformly from the top with measured force until the block breaks. Force applied is in pounds per square inch (psi).

Minimum UBC	300 psi	
Standard Adobe Block	300 psi	
TerraBuilt™ Block	900 psi	with 2% cement content
	1600 psi	with 5% cement content
	2240 psi	with 8% cement content

- **Modulus of Rupture** – loading a block across the top center while supporting it near the edges on the bottom until it breaks in half.

Minimum UBC	50 psi	
Standard Adobe Block	50 psi	
TerraBuilt™ Block	95 psi	with 2% cement content
	150 psi	with 5% cement content
	170 psi	with 8% cement content

Structural Test: Compressive Strength

- Kleinfelder Lab tested TerraBuilt™ wall (96”H x 50”W) with cast-in-place, reinforced concrete bond beam per ASTM standard E 72.

- Compressive Strength – top surface of test wall uniformly loaded to design load or failure; lateral and vertical deflections or movements measured.
- A total of 5,670 pounds per square inch incrementally and uniformly applied to top wall surface.
- Results: Under maximum load applied, no significant deflections occurred. Load designed to simulate three times worst case roof load. Ultimate wall failure calculated to be over 200,000 pounds, far exceeding any normal roof load.

Structural Tests: Lateral Load and Shear Strength

- **Lateral Load** - center face of test wall uniformly loaded to design load or failure. A force of 700 pounds applied over full width of wall at its mid span, and top load simulating roof loads also applied.
- **Results**: a 4½" measurable deflection occurred in wall. After load removed, wall returned to normal without block or bond bean failure. Loads far exceeded 120mph wind load required by code without structural failure.

- **Shear Strength** – test wall point loaded in plane of wall from its edge to design load or failure. A total of 2,000 pounds of forces loaded over a one square foot area at top edge of wall to induce slippage. Resistance to shear with and without added roof loads were measured.
- **Results**: No movement of the TerraBuilt™ wall occurred up to the design load.

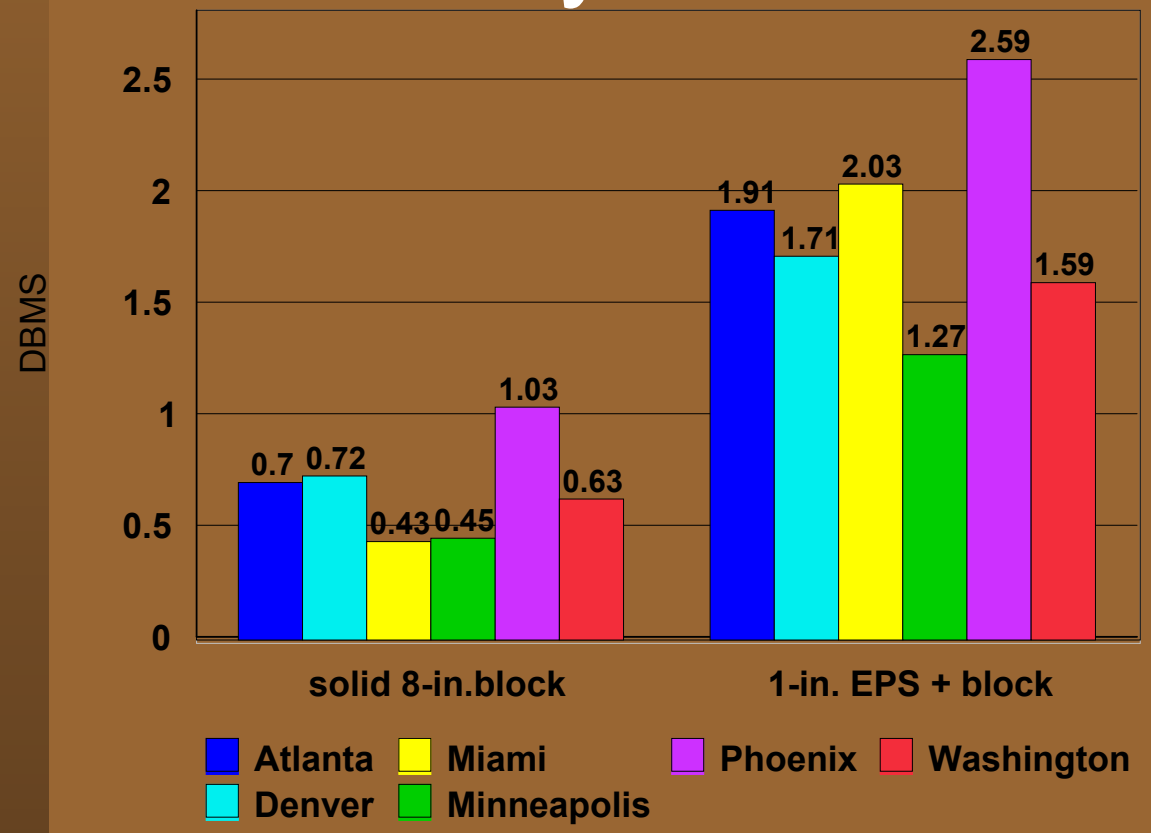
Thermal Performance Test of TerraBuilt™ Wall

- Oak Ridge National Laboratory (ORNL) conducted dynamic energy performance analysis of TerraBuilt™ wall.
- In six considered US locations, a TerraBuilt™wall with one inch of insulation performed better than equivalent R-6.8 wood-frame wall.
- The insulated TerraBuilt™ wall performed better by an average factor of 1.84 than a wood frame wall in all six considered locations.

Calculation of Thermal Performance

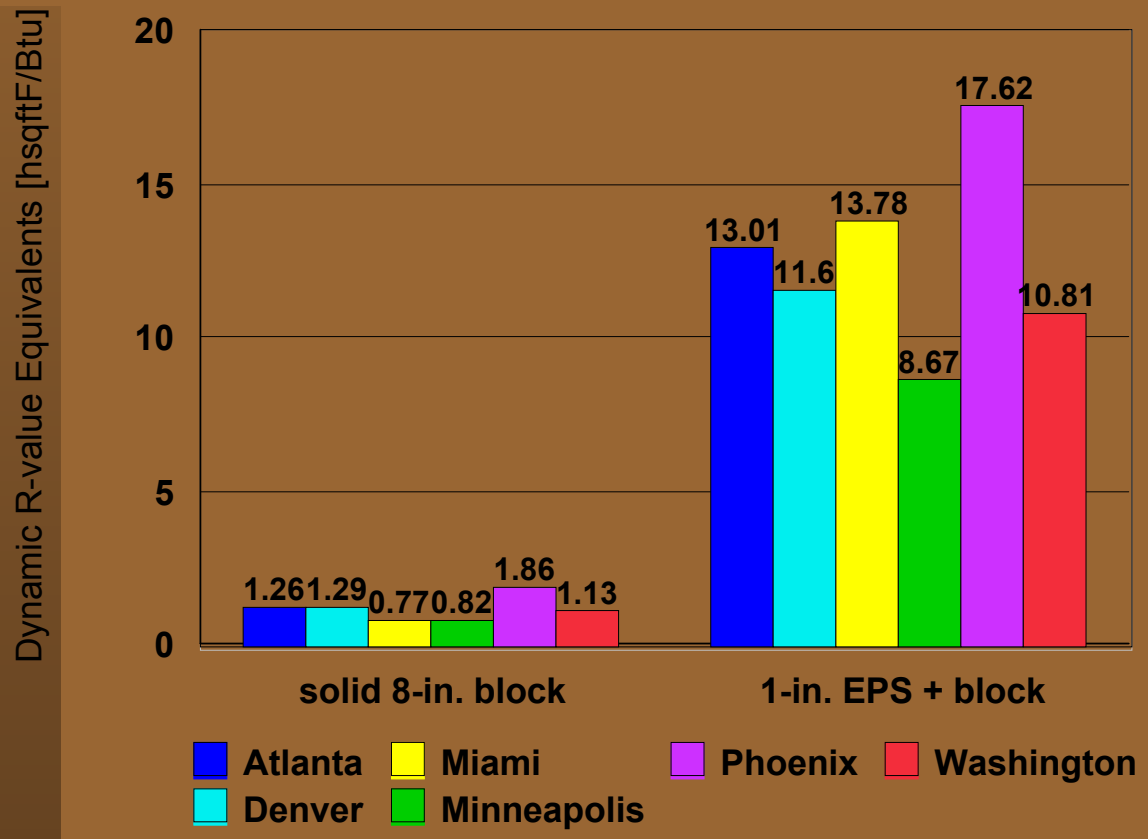
- **ORNL's new measure of thermal dynamic performance is Dynamic Benefit for Massive Systems (DBMS).**
- **DBMS is a function of the material configuration and climate conditions.**
- **Dynamic wall R-value equivalent (DRE) is calculated by comparing energy demands of light weight wall to energy demands of massive wall (DRE=DBMS x steady state R-value).**
- **DRE has no physical meaning – it should be understood only as answer to question: *"What wall R-value should a house with wood frame walls have to obtain the same space heating and cooling loads as a similar house containing massive walls?"***

Dynamic Benefit for Massive Systems (DBMS)-Values for TerraBuilt™ Wall System



Source: Oak Ridge National Laboratory's Building Technology Center

Dynamic R-Value Equivalents (DRE) for TerraBuilt™ Wall System



Source: Oak Ridge National Laboratory's Building Technology Center

Patent and Trademark Rights for GreenMachine™ and TerraBuilt™

- **The GreenMachine™ is patented (#6,302,675) with a further patent pending.**
- **The US Patent and Trademark Office has approved the trademark GreenMachine™ and TerraBuilt™.**

Value and Benefits

- Thermal mass benefit
- Dimensionally accurate CEBs
- Onsite CEB production
- Dry stack construction
- Sound attenuation
- Local raw materials
- Non-combustible
- Structural integrity
- Strong and durable
- High quality
- Cost effective
- Lower maintenance costs
- Lower life cycle cost
- Environmentally friendly

TERRABUILT™

THE ANSWER TO SUSTAINABLE BUILDING

Thank You!

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