HOUSING - BOX and PANEL

by

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B. Arch., University of Cincinnati
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Signature of Author

Department of Architecture
May 9, 1975

Certified by

Thesis Supervisor

Accepted by

Chairman, Departmental
Committee

ARCHIVES

M.A.S.S. INST. TECH.

JUN 12 1975
The purpose of this thesis has been to do an in depth study of Housing using a system of prefabricated steel boxes and infill panels. The boxes are wholly fabricated in a factory containing all service components, stair, kitchen, bathrooms, etc. and then transported to site for erection. The infill panels, between boxes, are also partially fabricated in the factory and shipped to the site for erection. The assembly of the steel components in the factory has been designed to easily adapt to the existing Mobile Home production techniques. Using standard steel components has made it possible to address a nationwide market. The system is capable of going to at least 9 stories in height without any major changes to box and panel design.

The system does have specific limitations in planning due to the structural interdependency of box and panel. Another limiting factor is that all the mechanical elements have to be contained within the box. Even with these limitations, I feel that there is enough flexibility to design excellent living environments for people.
HOUSING
Box & Panel

GRADUATE THESIS
M.I.T.
ADVISOR:
Eduardo Catalano

William H. Soupcoff
75
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GOALS:
To develop a housing system capable of:

1) Using the existing production techniques of the Mobile Home Industry.
2) Combining on-site and factory production.
3) Appealing to a nationwide market.
4) Use for mobile homes, midrise, and highrise.
5) Use for houses and apartments up to 4 bedrooms in size.
6) Integrating with and respecting traditional American architectural character.

SYSTEM COMPARISON:

Boxes Stacked

Major Advantages:
1) Complete factory production.
2) Minimum of site labor.

Major Disadvantages:
1) Redundance of walls, ceiling, and floor.
2) Transplanting large amounts of space.
3) No variation in dimensions of room width.

Boxes Staggered

Major Advantages:
1) Minimizes redundancy of walls, floors, ceilings.
2) Transport one-half as many boxes.

Major Disadvantages:
1) Plumbing does not stack.
2) Planning difficulty due to total structural dependency of one box to another.
Major Advantages:

1) Plumbing stacks vertically.
2) Minimal shipment of air.
3) Capable of large spans between boxes.

Major Disadvantages:

1) Planning is limited because of interdependency of panel upon box.
2) Field labor needed to finish interior of panel space.

MATERIAL COMPARISON:

Concrete does not lend itself to the mass production technique of the Mobile Home Industry. Most Mobile Home factories are set to operate on a 20 min. (app.) rotation cycle time, because of concrete's long curing time. This would be prohibitive even with quick curing concrete. Also, concrete boxes address themselves to more specialized market, highrise construction, and therefore limit their application to a nationwide market.

Wood is the most common structural material in use today for fabrication of mobile home units, but it has obvious limitations in highrise construction both structurally and in meeting fire limitations.

Steel offers a nationwide market because of accessibility of standard steel sections. Steel also provides the structural capability of highrise construction. Although steel is restricted by fire limitations, it is possible to build to 9 stories in height with reasonably low fire rating requirements. (9 story steel construction = use group L-2 - 3/4 hr. fire rating of all structural members + 1 1/2 hr. fire rating on ground floor) Steel offers the designer a structural skeleton with max. planning flexibility.
FIRE CODE LIMITATIONS:
(Boca Code)

Use Group: L-2 (multi-family residential)
Construction Classification: (noncombustable construction) Type 2

FIRE RESISTANCE RATINGS FOR TYPE 2 CONSTRUCTION

<table>
<thead>
<tr>
<th>Structural Elements</th>
<th>2A</th>
<th>2B</th>
<th>2C</th>
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<tbody>
<tr>
<td>Fire Walls</td>
<td>2 hr.</td>
<td>2 hr.</td>
<td>2 hr.</td>
</tr>
<tr>
<td>Fire Divisions</td>
<td>1 1/2</td>
<td>1 1/2</td>
<td>1 1/2</td>
</tr>
<tr>
<td>Fire Enclosure of Exitways, Lifts, Exitway Hallways, and Stairways</td>
<td>2</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>Shafts other than Stairways</td>
<td>2</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>Exitway Access Hallways and Vertical Separation of Tenant Spaces</td>
<td>3/4</td>
<td>3/4</td>
<td>0</td>
</tr>
<tr>
<td>Columns, Girders, Trusses (other than roof trusses) and Framing</td>
<td>1 1/2</td>
<td>3/4</td>
<td>0</td>
</tr>
<tr>
<td>Structural Members supporting Walls</td>
<td>1 1/2</td>
<td>1 1/2</td>
<td>1 1/2</td>
</tr>
<tr>
<td>Floor Construction including beams</td>
<td>1 1/2</td>
<td>3/4</td>
<td>0</td>
</tr>
</tbody>
</table>

HEIGHT LIMITATIONS AND FLOOR AREA LIMITATIONS

<table>
<thead>
<tr>
<th>L-2 (multi-family residential)</th>
<th>9st. -100'</th>
<th>4st. -50'</th>
<th>3st. -40'</th>
</tr>
</thead>
<tbody>
<tr>
<td>Max. Floor Area</td>
<td>22,800</td>
<td>15,000</td>
<td>9,600</td>
</tr>
</tbody>
</table>

*Note:
There is a sq. ft. area/floor reduction as building goes above first floor. The chart on the following page indicates these reductions.
### AREA LIMITATION ADJUSTMENTS

<table>
<thead>
<tr>
<th></th>
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<th></th>
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<tbody>
<tr>
<td>1</td>
<td>none</td>
<td>22,800</td>
<td>none</td>
<td>15,000</td>
</tr>
<tr>
<td>2</td>
<td>none</td>
<td>22,800</td>
<td>none</td>
<td>15,000</td>
</tr>
<tr>
<td>3</td>
<td>5%</td>
<td>21,660</td>
<td>20%</td>
<td>12,000</td>
</tr>
<tr>
<td>4</td>
<td>10%</td>
<td>20,520</td>
<td>20%</td>
<td>12,000</td>
</tr>
<tr>
<td>5</td>
<td>15%</td>
<td>19,400</td>
<td>30%</td>
<td>10,500</td>
</tr>
<tr>
<td>6</td>
<td>20%</td>
<td>18,240</td>
<td>40%</td>
<td>9,000</td>
</tr>
<tr>
<td>7</td>
<td>25%</td>
<td>17,100</td>
<td>50%</td>
<td>7,500</td>
</tr>
<tr>
<td>8</td>
<td>30%</td>
<td>15,960</td>
<td>60%</td>
<td>6,000</td>
</tr>
<tr>
<td>9</td>
<td>35%</td>
<td>14,820</td>
<td>70%</td>
<td>4,500</td>
</tr>
</tbody>
</table>

*PROTECTED NONCOMBUSTABLE CONSTRUCTION: (Boca Code 905.62)*

When of 3/4 hr. protected noncombustable (type 2-B) construction, multi-family dwellings (use group L-2) may be increased to 9 stories or 100' in height when separated not less than 50' from any other building on the lot and from interior lot lines, the exitways are segregated in a fire area enclosed in a continuous fire wall of 2 hr. fire resistance and the first floor is not less than 1 1/2 hr. fire resistive construction.

**Note:**

Two buildings, while being separated by 50', can be linked by a corridor or passage that is properly treated with 2 fire resistant construction.

**Notes:**

1. **FIRE RETARDANT PLYWOOD** is considered noncombustable and can be used in Type 2 construction.
2. Floor joists and/or ceiling joists need only be fire proofed from bottom and not from top.
3. **FIRE WALLS** must be continuous and extend from foundation to 2'-8" above roof line.
DECISION:

Upon completion of comparative analysis of preceeding building systems and structural materials, I have chosen to study a system of steel boxes and infill panels.

Box is a constant 12' width measured from center line of steel columns.

Panel is a variable which can change dimension from 10' - 28' in width.

All wet core elements plumbing walls are prefabricated in factory and installed into box. Therefore, only the vertical connection from one plumbing wall to next is necessary in field. (assuming plumbing stacks)

It is possible to run plumbing horizontally in ceiling space but this is discouraged because of possible intervention with mechanical heat ducts or pipes.

Plumbing wet wall may be located freely in box according to design.
**CONSTANT**

The Box, which will be considered the CONSTANT element, is wholly fabricated in the factory. Because factory production is almost 1/2 the cost of field labor, it is desirable to do as much work as possible in the factory. For this reason all services (bathrooms, kitchens, etc.) will be factory installed in box in order to minimize field labor.

Components
- bathrooms
- kitchens
- stair
- mechanical room
- furnace
- washer
- dryer
- hot water heater

**VARIABLE**

The INFILL PANEL, which will be considered the VARIABLE element, is partially fabricated in the factory. Because of the need to make structural and mechanical connections, the ceiling of the floor panel will be erected after it has been placed and bolted to adjoining boxes. All interior partitions will also be partially prefabricated in factory, shipped to site, erected, and finished by field labor.

Components
- non-service areas
  - living room
  - family rooms
  - bedrooms
- storage
- decks
- 2-story spaces
- pitched roofs
BOX:

Box Structure is based on a 12' and 6' structural bay, measured to centerline of column. By combining these 2 bay sizes, various size boxes can be fabricated, ranging from 18' to 66' in length.

Boxes 67 feet in length are max. allowable by highway transportation limitations.

Most Common box lengths:

- Townhouses 24' to 42'
- Lowrise Apartments 24' to 42'
- Highrise Apartments
  - single loaded 24' to 30'
  - double loaded 42' to 60'
INFILL PANEL:

Panel Structure is based on a constant 12' and 6' width. Panel lengths variable and may be 12', 14', 16', 24', 26', and 28'.

Panels stacked horizontally during transportation.
SITE:

SITE PREPARATION:
1. Install all ground services (ele., plumbing, sewage, etc.)
2. Build forms and pour foundation levers.
3. Set and bolt foundation column cap.

PREPARE FOUNDATIONS:
1. Set and bolt closure beams.
2. Erect masonry block wall between piers.
3. Place and bolt infill bearing beams.

PANEL ERECTION:
1. Place floor infill panel.
2. Bolt floor panel to beam.

BOX ERECTION:
1. Connect box to foundation cap.
2. Bolt box to floor panel.
3. Connect air ducts between box and floor panel.
4. Connect electrical lines.
5. Connect plumbing to ground services.

SITE ERECTION
FINISH WORK:
1. All interior finishes in the infill zone to be completed.
2. Exterior facia strip placed at floor joints.
3. Roof flashing connections.
4. Site work.
   a. landscaping
   b. parking
   c. lighting
   d. etc.

SECOND FLOOR ERECTION:
1. Place and connect floor panel to boxes.
2. Connect mechanical ducts.
3. Connect plumbing wet wall between first floor box and second floor box.
4. Install interior wall partitions in infill area between boxes. (first floor)
5. Install exterior wall infill on first floor.
PLAN

12'

2' 2' 2' stair opening

12'

16' 16'

ELEVATION

4'

9'

8'

6'

openings in beam for mech.

scale: 3/8" = 1'

BOX STRUCTURE
Floor Beams

- FB-1: 7'-8" (alternate) and 12"
- FB-2: 5'-8" and 10"
- FB-3

Floor Joists

- FJ-1: alternate joists
- FJ-2: 16" and 8"
- FJ-3
- FJ-4

Ceiling Beams

- CB-1: 7'-8"
- CB-2: 5'-8"
- CB-3

Ceiling Joist

- CJ-1

scale 3/8" = 1'

BEAMS & JOISTS (BOX)
Panel Beams

PB-1 6'

PB-2 1'

mechanical opening in box

Panel Joists

RJ-1 11' 8"

RJ-2 13' 8"

RJ-3 15' 8"

RJ-4 23' 8"

RJ-5 25' 8"

RJ-6 27' 8"

Scale: 3' 8" = 1'

INFILL PANEL COMPONENTS
12" drywall
vapor barrier
3 batt insulation
1/2 exterior plywood
1/2 plywood sheathing
air duct
1/2 asbestos panel
4" x 4" steel ceiling beam
8" floor joist
4" ceiling joist
carpet
3/4" plywood subfloor
8" x 4" floor beam
electrical conduit
2" rigid insulation

concrete block infill
metal parapet
3 ply built-up roof
2" rigid insulation
panel joist

wood blocking
1.2"plywood
1.2 asbestos facia
8x4 steel beam

DETAILS 1&2
Plan Panel
Panel air supply.

12" panel joist
panel beam
12" x 4" panel closure beam
4" metal stud
carpet
3/4" plywood subfloor

3" batt insulation
12" plywood
column cap beyond

SECTION
scale 3 4" = 1'
DETAILS 4 & 5

metal stud plate
interior wall

34 1/4"
12"
1/2" shim space
panel joist
panel end beam

1/2" ext. plywood
1/2" asbestos facia
neoprene gasket

exterior panel
wall infill panel
1/2" drywall
steel column
3" batt insulation

1/2" asbestos panel or 12" exterior plywood over 1/2" plywood sheathing

double stud at panel joint
MECHANICAL STUDY

The following study is primarily made for individual or combined lowrise housing units, but the principles are valid for analyzing the heating needs for most small building structures. This study is directed at quickly analyzing and calculating where and how heat is lost from a house. Upon determining where and how heat is being lost, "Rule of Thumb" estimates can be used for determining amount of BTU/Hr. heat loss. This information can be used in comparing different types of fuel, to size and pick individual furnace and boiler types, or to be combined with other house loads to determine loads for a central heating system.

DEFINITIONS:

BTU (British Thermal Unit) is the heat or energy needed to raise one pound of water 1° Fah.

U-Coefficient is the number of BTU/Hr. that pass through one square foot of wall, floor, roof, etc., when temperature difference between inside and outside is 1° Fah.

COSTS:

If costs were not an important factor in determining which fuel to use for heating, most builders and users would pick Electricity, Gas, Oil, and Coal, in that order. Electricity has the advantages of instantaneous response, individual thermostatic control, and metering, no combustable parts, being clean, and being quiet. The other fuel sources need combustable parts; also Oil and Coal are not only dirty but need large storage areas.

Because cost is many times the decision maker in determining the type of fuel to be used, it is important to know the relative efficiencies of the four major fuels and their costs/unit.

<table>
<thead>
<tr>
<th>FUEL</th>
<th>HEAT/UNIT</th>
<th>EFFICIENCY</th>
</tr>
</thead>
<tbody>
<tr>
<td>Electricity</td>
<td>3.41 BTU/watt</td>
<td>95 - 100%</td>
</tr>
<tr>
<td>Gas</td>
<td>1,052 BTU/cub. ft.</td>
<td>70 - 80%</td>
</tr>
<tr>
<td>Oil</td>
<td>141,000 BTU/gal.</td>
<td>70 - 80%</td>
</tr>
<tr>
<td>Coal</td>
<td>14,600 BTU/lb.</td>
<td>65 - 75%</td>
</tr>
</tbody>
</table>
COSTS: (Continued)

In order to make a rough cost comparison of the various fuel types, one only needs to know the amount of energy (BTU/Hr.) to heat a building and the cost of each fuel source in a given locale.

Formula:

\[
\frac{\text{BTU/Hr. (needed heat house)}}{\text{BTU's (per unit) x efficiency}} = \text{UNITS/Hr. x COST/UNIT} = \$/\text{Hr.}
\]

Example:

given: 1 gallon of Oil = 141,000 BTU

given: efficiency of fuel = 75%

assume: 40¢ per gallon

assume: 100,000 BTU/Hr. needed to heat house

\[
\frac{100,000 \text{ BTU/Hr.}}{141,000 \text{ BTU/gal} \times 75\% \text{ efficiency}} = .95 \text{ gal/Hr.} \times 40\text{¢ gal.} = 38\text{¢/Hr.}
\]

Note:

By computing for each fuel, one can quickly compare fuel costs.
DESIGN CRITERIA:

HEAT LOSS EXAMPLE

Objective: Determine BFUH Loss thru Building

Assumptions:
1. Area - New England
2. Calculate for worst condition - nighttime
3. Design temperatures: 70° activity areas 66° sleeping areas 64° storage areas
4. Insulating glass (1/4" air space)
5. Wood door (1 1/2" solid)
## 1st Floor Heat Loss

<table>
<thead>
<tr>
<th>Space</th>
<th>Item</th>
<th>Area</th>
<th>U-Coeff.</th>
<th>ΔT</th>
<th>Heat Loss</th>
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<tbody>
<tr>
<td>Living</td>
<td>Wall</td>
<td>135 sq. ft.</td>
<td>.091</td>
<td>70</td>
<td>860</td>
</tr>
<tr>
<td></td>
<td>Glass</td>
<td>106</td>
<td>.65</td>
<td>70</td>
<td>4,800</td>
</tr>
<tr>
<td></td>
<td>Roof</td>
<td>168</td>
<td>.10</td>
<td>70</td>
<td>1,000</td>
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<tr>
<td></td>
<td>Infiltration</td>
<td>4,200 cu. ft.</td>
<td>0.018</td>
<td>70</td>
<td>5,300</td>
</tr>
<tr>
<td></td>
<td>Slab Edge</td>
<td>20 lin. ft.</td>
<td>248TU/FT</td>
<td></td>
<td>480</td>
</tr>
<tr>
<td></td>
<td><strong>Sub Total</strong></td>
<td></td>
<td></td>
<td></td>
<td><strong>11,340 BTU/H</strong></td>
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<tr>
<td>Kitchen-Dining</td>
<td>Wall</td>
<td>318 sq. ft.</td>
<td>.091</td>
<td>70</td>
<td>2,000</td>
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<tr>
<td></td>
<td>Glass</td>
<td>60</td>
<td>.65</td>
<td>70</td>
<td>2,750</td>
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<tr>
<td></td>
<td>Infiltration</td>
<td>2,700 (2) cu. ft.</td>
<td>0.018</td>
<td>70</td>
<td>1,000</td>
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<tr>
<td></td>
<td>Slab Edge</td>
<td>42 lin. ft.</td>
<td>24 BTU/FT</td>
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<td><strong>Sub Total</strong></td>
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<td></td>
<td></td>
<td><strong>12,550 BTU/H</strong></td>
</tr>
<tr>
<td>Den</td>
<td>Wall</td>
<td>278 sq. ft.</td>
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<td>70</td>
<td>1,800</td>
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<tr>
<td></td>
<td>Slabs</td>
<td>46</td>
<td>.65</td>
<td>70</td>
<td>2,100</td>
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<td></td>
<td>Infiltration</td>
<td>1,150 (1.5) cu. ft.</td>
<td>0.018</td>
<td>70</td>
<td>870</td>
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<tr>
<td></td>
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<td>36 lin. ft.</td>
<td>24 BTU/FT</td>
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<td></td>
<td></td>
<td><strong>6,990 BTU/H</strong></td>
</tr>
<tr>
<td>Utility</td>
<td>Wall</td>
<td>54</td>
<td>.091</td>
<td>64</td>
<td>320</td>
</tr>
<tr>
<td></td>
<td>Glass</td>
<td>-</td>
<td>-</td>
<td></td>
<td>-</td>
</tr>
<tr>
<td></td>
<td>Infiltration</td>
<td>43 (.5)</td>
<td>0.018</td>
<td>64</td>
<td>240</td>
</tr>
<tr>
<td></td>
<td>Slab Edge</td>
<td>6</td>
<td>24 BTU/FT</td>
<td></td>
<td>144</td>
</tr>
<tr>
<td></td>
<td><strong>Sub Total</strong></td>
<td></td>
<td></td>
<td></td>
<td><strong>704 BTU/H</strong></td>
</tr>
<tr>
<td>Stair</td>
<td>Wall</td>
<td>100</td>
<td>.091</td>
<td>70</td>
<td>640</td>
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<tr>
<td></td>
<td>Glass</td>
<td>27</td>
<td>.65</td>
<td>70</td>
<td>1,200</td>
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<tr>
<td></td>
<td>Infiltration</td>
<td>1,200 (1)</td>
<td>0.018</td>
<td>70</td>
<td>1,500</td>
</tr>
<tr>
<td></td>
<td>Roof</td>
<td>72</td>
<td>.10</td>
<td>70</td>
<td>510</td>
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<tr>
<td></td>
<td><strong>Sub Total</strong></td>
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<td></td>
<td></td>
<td><strong>3,850 BTU/H</strong></td>
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## 1st FLOOR HEAT LOSS (cont!)

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<th>FOYER</th>
<th>WALL</th>
<th>74 sq. ft.</th>
<th>x .091</th>
<th>x 70</th>
<th>480</th>
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<tr>
<td></td>
<td>GLASS</td>
<td>12</td>
<td>x .65</td>
<td>x 70</td>
<td>550</td>
</tr>
<tr>
<td></td>
<td>DOOR</td>
<td>26</td>
<td>x .49</td>
<td>x 70</td>
<td>900</td>
</tr>
<tr>
<td></td>
<td>INFILTRATION</td>
<td>400 (1) cub. ft.</td>
<td>x 0.018</td>
<td>x 70</td>
<td>510</td>
</tr>
<tr>
<td></td>
<td>SLAB EDGE</td>
<td>8 lin. ft.</td>
<td>x 24 BTU/FT</td>
<td></td>
<td>194</td>
</tr>
<tr>
<td><strong>sub total</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>2,634 BTU/HR</td>
</tr>
</tbody>
</table>

1st floor total Heat Loss/Hr. 37,868 BTU/H
### 2ND FLOOR HEAT LOSS

<table>
<thead>
<tr>
<th>SPACE</th>
<th>ITEM</th>
<th>AREA</th>
<th>U-COEFF</th>
<th>ΔT</th>
<th>HEAT LOSS</th>
</tr>
</thead>
<tbody>
<tr>
<td>BED 1</td>
<td>WALL</td>
<td>255 sq. ft.</td>
<td>x .091</td>
<td>x 68</td>
<td>1,550</td>
</tr>
<tr>
<td></td>
<td>GLASS</td>
<td>41</td>
<td>x .65</td>
<td>x 68</td>
<td>1,300</td>
</tr>
<tr>
<td></td>
<td>ROOF</td>
<td>250</td>
<td>x .10</td>
<td>x 68</td>
<td>1,700</td>
</tr>
<tr>
<td></td>
<td>INFILTRATION</td>
<td>1,900 (1.5)cub. ft.</td>
<td>x 0.018</td>
<td>x 68</td>
<td>3,500</td>
</tr>
<tr>
<td></td>
<td><strong>sub total</strong></td>
<td></td>
<td></td>
<td></td>
<td><strong>8,050 BTU/H</strong></td>
</tr>
<tr>
<td>BED 2</td>
<td>WALL</td>
<td>210 sq. ft.</td>
<td>x .091</td>
<td>x 68</td>
<td>1,300</td>
</tr>
<tr>
<td></td>
<td>GLASS</td>
<td>37</td>
<td>x .65</td>
<td>x 68</td>
<td>1,600</td>
</tr>
<tr>
<td></td>
<td>ROOF</td>
<td>170</td>
<td>x .10</td>
<td>x 68</td>
<td>1,150</td>
</tr>
<tr>
<td></td>
<td>INFILTRATION</td>
<td>1,250 (1.5)cub. ft.</td>
<td>x 0.018</td>
<td>x 68</td>
<td>2,250</td>
</tr>
<tr>
<td></td>
<td><strong>sub total</strong></td>
<td></td>
<td></td>
<td></td>
<td><strong>6,300 BTU/H</strong></td>
</tr>
<tr>
<td>MASTER BED</td>
<td>WALL</td>
<td>270 sq. ft.</td>
<td>x .091</td>
<td>x 68</td>
<td>1,700</td>
</tr>
<tr>
<td></td>
<td>GLASS</td>
<td>54</td>
<td>x .65</td>
<td>x 68</td>
<td>2,400</td>
</tr>
<tr>
<td></td>
<td>ROOF</td>
<td>300</td>
<td>x .10</td>
<td>x 68</td>
<td>2,050</td>
</tr>
<tr>
<td></td>
<td>INFILTRATION</td>
<td>2,850 (1.5)cub. ft.</td>
<td>x 0.018</td>
<td>x 68</td>
<td>5,300</td>
</tr>
<tr>
<td></td>
<td><strong>sub total</strong></td>
<td></td>
<td></td>
<td></td>
<td><strong>9,450 BTU/H</strong></td>
</tr>
<tr>
<td>BATHS</td>
<td>WALL</td>
<td>78 sq. ft.</td>
<td>x .091</td>
<td>x 70</td>
<td>550</td>
</tr>
<tr>
<td></td>
<td>GLASS</td>
<td>18</td>
<td>x .65</td>
<td>x 70</td>
<td>850</td>
</tr>
<tr>
<td></td>
<td>ROOF</td>
<td>72</td>
<td>x .10</td>
<td>x 70</td>
<td>540</td>
</tr>
<tr>
<td></td>
<td>INFILTRATION</td>
<td>580 (1) cub. ft.</td>
<td>x 0.018</td>
<td>x 70</td>
<td>750</td>
</tr>
<tr>
<td></td>
<td><strong>sub total</strong></td>
<td></td>
<td></td>
<td></td>
<td><strong>2,690 BTU/H</strong></td>
</tr>
</tbody>
</table>

*Rule of Thumb:*

Net Heat Loss x 1.6 = Furnace Capacity

2nd Floor Total Heat Loss/Hr. = 26,490 BTU/H

TOTAL NET HEAT LOSS = 64,358 BTU/H

*1.6 x NET = 102,000 BTU/H

FURNACE CAPACITY
HEATING DUCT DISTRIBUTION
scale 1/8" 1'

BOX

PANEL

air ducts

joists

m. shaft

m. shaft

stair opening
PLANNING:
components
apartments
townhouses
### Minimum Room Areas (FHA standards)

#### Separate Room Areas

<table>
<thead>
<tr>
<th>Room Type</th>
<th>0 Bedroom</th>
<th>1 Bedroom</th>
<th>2 Bedroom</th>
<th>3 Bedroom</th>
<th>4 Bedroom</th>
</tr>
</thead>
<tbody>
<tr>
<td>Living</td>
<td>160 sq. ft</td>
<td>160 sq. ft</td>
<td>170 sq. ft</td>
<td>180 sq. ft</td>
<td></td>
</tr>
<tr>
<td>Dining</td>
<td>100</td>
<td>100</td>
<td>110</td>
<td>120</td>
<td></td>
</tr>
<tr>
<td>Kitchen</td>
<td>60</td>
<td>60</td>
<td>70</td>
<td>80</td>
<td></td>
</tr>
<tr>
<td>Bedroom (primary)</td>
<td>120</td>
<td>120</td>
<td>120</td>
<td>120</td>
<td></td>
</tr>
<tr>
<td>Bedroom (secondary)</td>
<td></td>
<td></td>
<td>80</td>
<td>80</td>
<td>80</td>
</tr>
<tr>
<td>Others (den, family, etc.)</td>
<td>80</td>
<td>80</td>
<td>80</td>
<td>80</td>
<td></td>
</tr>
<tr>
<td>Foyer</td>
<td>25</td>
<td>25</td>
<td>25</td>
<td>25</td>
<td></td>
</tr>
</tbody>
</table>

#### Combined Room Areas

<table>
<thead>
<tr>
<th>Room Combination</th>
<th>200 sq. ft</th>
<th>200 sq. ft</th>
<th>220 sq. ft</th>
<th>230 sq. ft</th>
</tr>
</thead>
<tbody>
<tr>
<td>Living and Dining Area</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Living and Dining Room</td>
<td>240</td>
<td>240</td>
<td>260</td>
<td>270</td>
</tr>
<tr>
<td>Living and Dining and Bedroom</td>
<td>240</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Living and Bedroom</td>
<td>190</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Kitchen and Dining Room</td>
<td>150</td>
<td>150</td>
<td>160</td>
<td>180</td>
</tr>
<tr>
<td>Living and Dining and Kitchen</td>
<td>260</td>
<td>270</td>
<td>290</td>
<td>310</td>
</tr>
</tbody>
</table>

#### Other Room Areas

<table>
<thead>
<tr>
<th>Room Type</th>
<th>100 cub. ft</th>
<th>100 cub. ft</th>
<th>140 cub. ft</th>
<th>180 cub. ft</th>
<th>200 cub. ft</th>
</tr>
</thead>
<tbody>
<tr>
<td>Storage (interior)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Storage (at least 1/3 interior)</td>
<td>150 cub. ft</td>
<td>150 cub. ft</td>
<td>200 cub. ft</td>
<td>250 cub. ft</td>
<td>300 cub. ft</td>
</tr>
<tr>
<td>Closet (primary bedroom)</td>
<td>5 lin. ft</td>
<td>5 lin. ft</td>
<td>5 lin. ft</td>
<td>5 lin. ft</td>
<td></td>
</tr>
<tr>
<td>Closet (secondary bedroom)</td>
<td>3</td>
<td>3</td>
<td>3</td>
<td>3</td>
<td></td>
</tr>
<tr>
<td>Linen</td>
<td>1'-6&quot; lin. ft</td>
<td>1'-6&quot; lin. ft</td>
<td>1'-6&quot; lin. ft</td>
<td>1'-6&quot; lin. ft</td>
<td>1'-6&quot; lin. ft</td>
</tr>
</tbody>
</table>

#### Number of Bathrooms

<table>
<thead>
<tr>
<th>Income Category</th>
<th>1</th>
<th>1</th>
<th>1 1/2-2</th>
<th>2</th>
<th>2 1/2</th>
</tr>
</thead>
</table>
**STAIR DESIGN**

**F/F = 9'-0"
= 108"**

Assume: riser @ 6 3/4"
108/6.75 = 16 risers

Rule of Thumb: 2r + t = 24" to 25"
2(6 3/4") + t = 24" to 25"
t = 10 1/2" to 11 1/2"

16 risers @ 6 3/4"
14 treads @ 11"

Railing Height @ 2'-8"
EXTERIOR SIDING

Exterior finish for all lowrise construction to be 1/2" exterior grade plywood over 1/2" plywood sheathing.

Finish: natural

WINDOWS

Anodized Aluminum
Color - dark brown
Operable windows: casement awning

Glass:

Insulating glass - Double (1/4" air space)
U-coefficient = 0.65

Note:

Bottom window of type 2 and 3 may be replaced by ventilating grill for fancoil or through the wall airconditioning unit.

WINDOWS (Lowrise)
DOORS & CLOSETS

EXTERIOR DOORS:

INTERIOR DOORS:

CLOSET DOORS:

CLOSETS
EXTERIOR SIDING:

1/2" or 3/4" Corspan asbestos panels bolted to heavy gauge metal studs (sheet ).

Finish: stone gray
Properties:
  Density: 100 lbs/cub. ft.
  Tensile Strength: 1200 psi
  Squareness of cut: 1/8" in 24"
  Length variance: +1/8"
  Width variance: ±1/8"
  Weight: 1/2" = 4.7 lbs/sq. ft.
  3/4" = 7.0 lbs/sq. ft.
  Max. length = 15 feet
  Safe span: 1/2" = 4 feet
  3/4" = 5 feet

WINDOWS:

Anodized Aluminum
  Color: black
  Operable windows: casement

GLASS:

Insulating glass: Double (1/4" air space)
  U-coefficient = 0.65

*Note:

Bottom window of type 2 used for ventilating grill for through the wall unit or fan coil.

WINDOWS & DOORS (Highrise)
APARTMENTS

TYPES:

Apt. 1
430 sq ft

Apt. 2, 2a
2 - 590 sq ft
2a - 520 sq ft

Apt. 3, 3a
3 - 660 sq ft
3a - 580 sq ft

Apt. 4, 4a
4 - 860 sq ft
4a - 790 sq ft

Apt. 5, 5a
5 - 930 sq ft
5a - 860 sq ft

Apt. 6, 6a
6 - 1440 sq ft
6a - 1370 sq ft

Apt. 6b
1230 sq ft
APT. COMBINATIONS
APT. COMBINATIONS

Structure

Panel
Box

1st Floor

3

6

2nd Floor

3a

6a

3rd Floor/same
APT. COMBINATIONS
APT. COMBINATIONS
FACTS:
2 acres
44 units
40 parking

SITE PLAN
scale 1: 40'
Townhouse 1
Total - 1040 sq ft
Townhouse 2
Total - 1385 sq ft
Townhouse

Total - 1370 sq ft.
Townhouse 3
Total 1440 sq ft
Townhouse
Total-1550 sq ft
Townhouse
Total - 1685 sq ft
Townhouse

Total - 2000 sq ft
TOWNHOUSE CLUSTER