First Progress Report
US Egypt Collaborative Research: Use of Cold-Formed Steel in Residential Housing

Project ID: 3751

Project Type: Engineering

Project Title: USE OF COLD FORMED STEEL IN RESIDENTIAL HOUSING

Principal Investigator: EGYPT: Dr Metwally Abu-Hamd, Cairo University
USA: Dr Benjamin Schafer, Johns Hopkins University

Affiliation: EGYPT: Professor of Steel Structures, Faculty of Engineering, Cairo University.
USA: Chairman, Civil Engineering Dept., Johns Hopkins University

Project Start Date: October 16, 2011
Project End Date: October 15, 2013
Project Duration: Two years

Reporting period: From: October 16, 2011 To: January 15, 2012

Date of submission: January 16, 2012

Signature of Principal Investigators:

Egypt P.I.                                                                         U.S. P.I.

Prof Dr Metwally Abu-Hamd                                                   Prof Dr Ben Schaffer
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1. Objective(s) of the reporting period, as given in the submitted grant application.

C.2 Building Archetypes Study

C.1.3 Develop home archetypes

C.2.1 Select Rural and Urban locations for archetype homes in U.S. and Egypt
2. Activities conducted since the project start date.

2.1 Selection of Conventional Home Archetypes in U.S. and Egypt:
In this part of the study, it is required to select rural and urban locations for home archetypes in U.S. and Egypt that shall be used in the research. This involved the following activities:

1. Survey of present residential building trends from available construction sector data.
2. Survey of available construction material resources.

Due to the unavailability of standard timber designs for U.S. home archetypes, it was agreed with the U.S. team to substitute additional Egyptian home archetypes to replace the U.S. archetypes as shown later in this section.

2.1.1 Present Residential Building Trends
In Egypt, it is estimated that at least 400,000 housing units are needed every year. Present construction and financial capabilities provide only about 200,000 housing units. Nearly half of this number is produced by private sector companies working in real estate and by individual owners. Typically these units are two or three bedroom units having an area between 100 and 150 m². In urban areas they take the form of 10 to 12 storey apartment buildings while in rural areas they take the form of 5 to 6 storey apartment buildings. These units are usually high-cost units that can be afforded by high income groups only.

Accordingly there is a growing gap between demand and supply in the residential housing stock for low and middle income groups. In order to help achieve this goal, the Ministry of Housing and New Urban Communities started in 2005 a 6-year national housing project to establish 500 thousand subsidized housing units in Greater Cairo area and new cities, with unit areas and prices that commensurate with the conditions of young people and below market prices. The project includes a variety of home archetype models to suit the capacities of various categories. All models have three to six storey buildings and thus are most suitable for the application of cold formed steel framing. It was decided accordingly to select the following models for this project.
2.1. Selected Home Archetypes:

1 - 63 m$^2$ Ownership Model: This model provides housing units with an area of 63 square meters per unit in 6 story buildings having either 4 or 6 flats per floor. A typical unit plan is shown in Fig. 1. The architectural drawings of this model are given in Appendix 1.

Fig. 1: Residential Units of 63 m$^2$ Flats
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2- "Build Your House" Model:
In this model, an area 150 square meters is allocated to the individual with the aim to build a residential building consisting of ground floor and two floors with an average area of 63 m² per floor.

Figure 2 shows samples of this model. The architectural drawings of this model are given in Appendix 1.

Fig. 2: Residential Units of "Build Your House"

3- Housing for Most-in-Need Citizens Lease Model:
The model aims to provide housing units with an area of 42 square meters per unit for citizens of more needs who cannot afford down payments.

Figure 3 shows samples of this model. The architectural drawings of this model are given in Appendix 1.

Fig. 3: Residential Units of "Most-in-Need" Model
2.1. Characteristics of Conventional Home Archetypes:

The selected conventional home archetypes have the following characteristics:

- **Reinforced Concrete Skeleton:**
  - The typical residential house has a 10 to 12 cm reinforced concrete slab cast in situ with a reinforced concrete footings, beams and columns.

- **Ceramic Tile Flooring**
  - The flooring of the conventional residential house consists of ceramic tiles fixed on top of 3 cm sand layer and 2 cm cement mortar.

- **Brick Walls**
  - The walls of conventional residential house consist of 25 cm brick walls for the exterior walls and 12 cm brick walls for interior walls. The wall finishing is plastered paint.

- **Quantities Needed for a Typical House Having Six Floors and Four Flats in Each Floor of Area 63 m² Each:**

<table>
<thead>
<tr>
<th>Item</th>
<th>Quantity</th>
<th>Unit</th>
<th>Cost</th>
<th>Cost (LE)</th>
</tr>
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<tbody>
<tr>
<td>PC for Footings (m³)</td>
<td>147.39</td>
<td></td>
<td>400</td>
<td>58955</td>
</tr>
<tr>
<td>RC for Footings (m³)</td>
<td>112.68</td>
<td></td>
<td>1200</td>
<td>135216</td>
</tr>
<tr>
<td>Skeleton (m³)</td>
<td>370.23</td>
<td></td>
<td>1400</td>
<td>518318</td>
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<tr>
<td>Brick Walls (m²/H.P.)</td>
<td>1680.00</td>
<td></td>
<td>80</td>
<td>134400</td>
</tr>
<tr>
<td>Ceramic Flooring (m²)</td>
<td>1680.00</td>
<td></td>
<td>75</td>
<td>126000</td>
</tr>
</tbody>
</table>

- **Total:** 972889

**(*) $ = 6 LE**

**Execution Time = 18 Months**
## ARCHETYPE DESIGN MATRIX

<table>
<thead>
<tr>
<th>No.</th>
<th>RC Design</th>
<th>US Steel Design</th>
<th>Egypt Steel Design</th>
</tr>
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<tbody>
<tr>
<td>1</td>
<td>63 m² Model I</td>
<td>1.1</td>
<td>1.2</td>
</tr>
<tr>
<td></td>
<td>6 Floors @ 4 flats x 63 m²</td>
<td>MB</td>
<td>MH &amp; US</td>
</tr>
<tr>
<td>2</td>
<td>63 m² Model II</td>
<td>2.1</td>
<td>2.2</td>
</tr>
<tr>
<td></td>
<td>6 Floors @ 6 flats x 63 m²</td>
<td>MB</td>
<td>MH &amp; US</td>
</tr>
<tr>
<td>3</td>
<td>42 m² Model I</td>
<td>3.1</td>
<td>3.2</td>
</tr>
<tr>
<td></td>
<td>6 Floors @ 4 flats x 42 m²</td>
<td>MB</td>
<td>MH &amp; US</td>
</tr>
<tr>
<td>4</td>
<td>Build Your Home Model:</td>
<td>4.1</td>
<td>4.2</td>
</tr>
<tr>
<td></td>
<td>Three Floors</td>
<td>MB</td>
<td>MH</td>
</tr>
<tr>
<td>5</td>
<td>7 m² Model 5.1</td>
<td>5.1</td>
<td>5.2</td>
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<tr>
<td></td>
<td>Five Floors @ 4 flats x 7 m²</td>
<td>MB</td>
<td>MH &amp; US</td>
</tr>
<tr>
<td>6</td>
<td>90 m² Model 6.1</td>
<td>6.1</td>
<td>6.2</td>
</tr>
<tr>
<td></td>
<td>5 Floors @ 4 flats x 90 m²</td>
<td>MB</td>
<td>MH &amp; US</td>
</tr>
<tr>
<td>7</td>
<td>Family Home 7.1</td>
<td>7.1</td>
<td>7.2</td>
</tr>
<tr>
<td></td>
<td>2 Floors</td>
<td>MB</td>
<td>MH</td>
</tr>
</tbody>
</table>

**KEY:**
- **US:** US Team
- **MA:** Metwally Abu-Hamd
- **MB:** Mohammed Badr
- **MH:** Maged Hanna
Locally Available Construction Material Alternatives:

Available Cold Formed Steel Sections in Egypt:

Cold formed steel sections suitable for use in residential housing are available in Egypt as ready to deliver sections of Channel with or without lip and Sigma sections through some local fabricators such as Alexform Company as shown in Figures 4 to 7. Other ways to produce such sections are available since the cold forming process is easy.
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Fig. 5: Cold Formed Channel with Lip Sections
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Fig. 6: Cold Formed Channel without Lip Sections
Fig. 7: Cold Formed Sigma Sections
Alternative Material for Floors and Walls: In order to develop a novel solution to the residential housing problem, it is not sufficient to just implement non-conventional structural systems such as the cold formed steel framing as proposed in this study. It is equally important to employ non-conventional materials that provide added advantages such as ease and speed of execution in addition to savings in costs.

One example of such material was the use of Glass Reinforced Concrete (GRC) for floors and walls.

**Definition:**
Glass Fiber Reinforced Cement or GRC is a composite with alkaline resistance fiber acting as reinforced elements randomly distributed throughout a mixture of cement and silica sand. The fiber material used is Alkali-resistant glass (ARG) fibers which contain about 20% of zirconia which is necessary for resistances to alkaline.

The GRC composite is a concrete like material that combines the flexural and tensile strength of glass fiber with the compressive strength of cement mortar. GRC is a high modules' fiber composite material that displays an associated high tensile, impact strength.

The blend of glass fiber with cement and sand mix creates a thin concrete like material that displays some very useful and interesting properties:

- lightweight
- high impact strengths
- high tensile; flexural strengths
- moldability
- fire resistance
- sound reduction properties
- low water penetration
- high resistance to crack development
- vandal resistance

**Uses of GRC**
Since the introduction of GRC in the late 1960s, extensive ad well proven design parameters regarding loading, fixing, and handling etc. have been established. GRC is used principally...
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GRC presents architects and engineers with a material from which the most ambitious designs can be created. It can be molded to form modern futuristic designs or to replicate traditional historic features. GRC can be painted, faced with fine aggregates, colored or simply left with a natural white or grey, smooth or textured finish.

Thin section GRC 'sprayed' panels provides a cavity for insulation and electrical, mechanical, communications ducting.

Application and advantages of GRC panels are highlighted below:

- ability to reproduce fine surface details – ideal for simulated stone or slate
- lightweight – thus reducing transport and erection cost
- ability to be molded into completed shapes – especially for building renovations or restoration work
- reduce loading on building due to lightweight – leads to reduction in structural and foundation cost

GRC cladding panels can be designed as wall units, window wall units, spandrels, mullions, column coverings, cornices. Shapes can be designed to suit modular planning of building. GRC is especially suited as fascia panels, sunscreens, roofing and interior feature panels.

GRC panels can be produced with a face mix of conventional concrete with decorative aggregates. A wide range of surface finishes may be achieved using exposed aggregate face mixes, color pigment, white cement, tile surface. In terms of creative architectural design, the architect/designer can choose from deep reveals to complex rectilinear and curvilinear shape, such as short radius curves, wide sweeping arcs or 90 degrees angles. GRC offers the architect/designer wide latitude for free architectural expression.

GRC is used to produce beautiful architectural moldings and features. Whilst often cast with thicknesses in excess of 12 mm, these products remain easy to handle and erect, and presents to the architect or engineer an unrivalled freedom for creative design. Using glass fiber, GRC does not suffer from corrosion of the reinforcement.

The following Figures show some data about GRC floor and wall panels available in Egypt.
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Problems Encountered and Resolutions

Description of problems encountered:
None

Description of actions taken to resolve the problems:
NA
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4. Implementing Teams:

4.1 Egypt Team

1. Prof Dr Metwally Abu-Hamd

2. Prof Dr Mohammed Ragaee Badr

3. Dr. Maged Tawfick Hanna

4. U.S. Team

1. Prof Dr Ben Schaffer

2. Dr. Li Zhanjie
<table>
<thead>
<tr>
<th>Task/Activities</th>
<th>Start</th>
<th>End</th>
<th>Duration (Days)</th>
<th>% Completed</th>
<th>Working Days</th>
<th>Days Complete</th>
<th>Remaining Days</th>
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<tbody>
<tr>
<td>1.1 Develop Library of Optimal Shapes</td>
<td>M1</td>
<td>M12</td>
<td>225+135</td>
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<tr>
<td>1.2 Develop 'dual' system for walls and floors</td>
<td>M4</td>
<td>M24</td>
<td>360+270</td>
<td></td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>1.3 Develop home archetype</td>
<td>M4</td>
<td>M6</td>
<td>90</td>
<td></td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>1.4 Develop full framing solution for archetype home</td>
<td>M10</td>
<td>M18</td>
<td>270</td>
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<td></td>
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<tr>
<td>1.5 Demonstrate flexibility of 'dual' framing system</td>
<td>M19</td>
<td>M23</td>
<td>135</td>
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<td></td>
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<tr>
<td>1.6 Price estimates for building archetypes study</td>
<td>M10</td>
<td>M15</td>
<td>180</td>
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<tr>
<td>2.1 Selection of rural and urban locations in U.S. and Egypt</td>
<td>M1</td>
<td>M3</td>
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<td>2.2 traditional framing (U.S. timber, Egypt concrete)</td>
<td>M4</td>
<td>M6</td>
<td>90</td>
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<td>2.3 conventional cold-formed steel framing</td>
<td>M7</td>
<td>M12</td>
<td>180</td>
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<tr>
<td>2.4 novel 'dual' system cold-formed steel framing</td>
<td>M13</td>
<td>M18</td>
<td>180</td>
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<td></td>
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<td>2.5 Environmental Impact and Sustainability assessment</td>
<td>M4</td>
<td>M21</td>
<td>360</td>
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<td>2.6 Sensitivity Analysis</td>
<td>M13</td>
<td>M24</td>
<td>360</td>
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Science and Technology Development Fund

Established by the presidential decree number 218 for the year 2007

Annex 3: Logical Framework Matrix

<table>
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<th>Project Title: Use of Cold Formed Steel in Residential Housing</th>
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<tr>
<td>Project ID:</td>
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<tr>
<td>Principle Investigator: Prof Dr Meftawy Abu-Hamd (Egypt) &amp; Prof Dr Benjamin Schafer (USA)</td>
</tr>
</tbody>
</table>

### Activity description

<table>
<thead>
<tr>
<th>Goal (Overall Objective)</th>
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<tbody>
<tr>
<td>Increasing residential housing building capacity by using cold formed steel framing.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Performance Indicators</th>
</tr>
</thead>
<tbody>
<tr>
<td>Increase of the share of steel framed buildings in newly built homes up to 30% of the total building market.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Means of Verification</th>
</tr>
</thead>
<tbody>
<tr>
<td>Analysis of relevant governmental and private sector statistics.</td>
</tr>
<tr>
<td>Market survey of building contractors.</td>
</tr>
<tr>
<td>Monitoring of building sector activities</td>
</tr>
</tbody>
</table>

### Assumptions

<table>
<thead>
<tr>
<th>1. Continued market demand for more residential housing.</th>
</tr>
</thead>
<tbody>
<tr>
<td>2. Newly developed cold formed steel framing systems shall be more affordable to people and financially profitable to building contractors.</td>
</tr>
</tbody>
</table>

| 1. People and building contractors have the ability to use the developed building designs once proven beneficial to both. |
Activity Description

2.1. Development of typical steel framing building systems using locally available cross-sections

2.2. Developing new non-proprietary steel framed systems using novel optimized cross-section shapes and new dual system for load bearing and lateral resistance.

Performance Indicators

1. Newly built houses implement developed systems.

2. Construction times are reduced considerably.

3. Building contractors strongly support the developed systems.

Means of Verification

1. Monitoring of building sector activities.


3. Questionnaire in building fairs and workshops.

Assumptions

1. Locally available materials and construction methods produce affordable designs in terms of economic, environmental and sustainability aspects.

2. Society is made aware of the benefits of the developed systems through successful marketing.
3.1. Comparative study between reinforced concrete houses and developed typical cold formed steel houses in Egypt.

3.2. Comparative study between wood houses and developed typical cold formed steel houses in USA.

3.3. Comparative study between reinforced concrete houses and newly developed cold formed steel houses in Egypt.

3.4. Comparative study between wood houses and newly developed cold formed steel houses in the USA.

3.5. Building a demonstration model of one of the developed designs.

Performance Indicators

1. Newly built houses implement developed systems.
2. Construction times are reduced considerably.
3. Building contractors strongly support the developed systems.

Means of Verification

1. Monitoring of building sector activities.
3. Questionnaire in building fairs and workshops.

Assumptions

1. Newly developed cold formed steel framing systems shall be more affordable to people and financially profitable to building contractors.
2. Building of the demonstration model shall be financed totally by private sector building contractors (see annex 6).
<table>
<thead>
<tr>
<th>Activity Description</th>
<th>Performance Indicators</th>
<th>Means of Verification</th>
<th>Assumptions</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>4- Activities</strong></td>
<td><strong>I. Indicators:</strong></td>
<td>1- Survey of present residential building trends from building contractor data.</td>
<td>1- Availability of typical layout designs presently used in residential housing.</td>
</tr>
<tr>
<td>4.1. Selection of typical design layouts presently used in residential buildings.</td>
<td>i. Satisfaction of housing needs</td>
<td>2- Survey of social housing needs in selected urban and rural locations.</td>
<td>3. Availability of data related to construction material resources and present construction methods.</td>
</tr>
<tr>
<td>4.2. Identify locally available construction materials and construction methods.</td>
<td>ii. Compliance with local building codes and regulations.</td>
<td>3- Survey of available construction material resources</td>
<td>4. Existing facilities at Cairo University and Johns Hopkins University are sufficient to perform the needed design work.</td>
</tr>
<tr>
<td>4.3. Select the structural systems appropriate to each design location.</td>
<td>iii. Sustainability of structural systems and construction methods to be executed at the specified urban/rural location.</td>
<td>4- Review of developed design against design codes.</td>
<td></td>
</tr>
<tr>
<td>4.4. Perform structural design and cost analysis of conventional (wood in USA and concrete in Egypt), typical cold formed steel framing, and newly developed steel framing systems.</td>
<td><strong>II. Means</strong></td>
<td>5- Survey of material and labor cost for executing the developed designs.</td>
<td></td>
</tr>
<tr>
<td>4.5. Assess sustainability and environmental impact of developed designs.</td>
<td>i. At the project stage all the required design work shall be performed by the project staff using mostly the available facilities at Cairo University (EGYPT) and Johns Hopkins University (USA).</td>
<td></td>
<td></td>
</tr>
<tr>
<td>4.6. Perform detailed comparisons among developed building designs.</td>
<td>ii. At the implementation stage, training courses and workshops shall be arranged to familiarize practicing engineers and building contractors with the developed systems.</td>
<td></td>
<td></td>
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<tr>
<td>4.7. Analyze results to arrive at appropriate recommendations for different design situations.</td>
<td></td>
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Appendix I

Architectural Drawings of Home Archetypes
القوط (1-1)