The Innovative Precast Light Gauge Steel Wall System Combined with Cellular Concrete

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***Abstract*-- In many countries around the world, wood is the preferred construction material. The use of wood in construction depends on availability, cost, and several other factors. In North America and many other parts of the world, for residential construction, wood studs are placed usually at 16" to carry the structural loads and the walls are finished with drywall. This form of construction has its limitations when it comes to its use in commercial and high rise construction. Many building codes around the world do not allow the use of wood frame construction for structures taller than 6 storeys. Moreover, this form of construction does not provide the sense of a permanent structure for the residents, and is also prone to environmental damage especially due to moisture. One solution that addresses most of these concerns is the innovative light gauge steel wall system that utilizes steel studs connected to form a steel frame to carry the structural loads. In this technology, recent developments have taken place to develop and utilize cellular concrete as a filler material to produce precast panels for mass construction. In this paper, this innovative technology is introduced and some typical applications in India and around the world are presented. A brief summary of on-going research in Canada is also presented.**

***Index Terms*—Light gauge steel wall, cellular concrete, precast panels.**

I. Introduction

THERE are various technologies and materials available for construction of walls for residential and commercial structures. Wood is one such material that has been used for decades for residential and commercial structures across the world. According to the American wood council [1], wood frame construction is a flexible system that allows buildings to heat and cool, and provides a comfortable environment for the occupants. However, applications of this form of construction are confined by Building code design restrictions in many countries and its limitations include: limited load carrying capacity, non-availability of lumber locally, the need to season the lumber and keep it protected during construction, low resistance to moisture, mold growth, and termites, and variability in strength and quality of timber.

Most of the limitations of wood mentioned above can be overcome by using steel. Steel has been used in the North American construction industry for more than 150 years [2]. Canadian Sheet Steel Building (CSSBI) further states that cold formed steel when compared to wood framing is light weight, easy to handle, economical and has a more consistent quality [2]. Due to the recyclability of steel as compared to wood, light gauge steel (LGS) can also be considered a more environmentally friendly construction material. According to a publication on Swedish Institute of Steel Construction [3], 41 growing trees are used to build a wooden house, but only six junk cars to build a steel house. Further benefits of using LGS over wood frame include non-combustibility and year-round constructability [4]. Use of LGS is also becoming popular owing to depletion of timber resources and low productivities associated with reinforced concrete structures [5].

In this paper, the innovative LGS framing system is briefly introduced and some of the recent applications in India, US, and Canada are highlighted. Recently concluded research work focused on developing a sustainable cellular concrete mix to be used as an in-fill with the LGS system is also presented.

II. Light Gauge Steel Wall System

The LGS wall system comprises of a network of steel members connected to form a frame. The studs are connected to a top and bottom track to form a frame (Figure 1) and may depending on the load conditions, may also have bracing. The various sections used for LGS frames are cold formed and have standard geometric properties. The flange width, lip length, inside radius, and thicknesses are defined by CSSBI [6]. The thickness of the sections typically ranges between 0.87 to 2.5 mm. Typical geometric and section properties of some selected sections are given in Tables 1 and 2. As indicated in Table 2, when following CAN/CSA-S136-01 for design, steel shall have a minimum yield strength of 230 MPa for design thicknesses less than or equal to 1.146 mm and 345 MPa for design thicknesses greater than or equal to 1.438 mm [6].

Table 1. Geometric properties of selected LGS sections (source: CSSBI, 2005 [6])

Section	Flange width (mm)	Lip length (mm)
S125	31.75	4.775
S162	41.28	12.70
S200	50.80	15.88
S250	63.50	19.05
S300	76.20	19.05

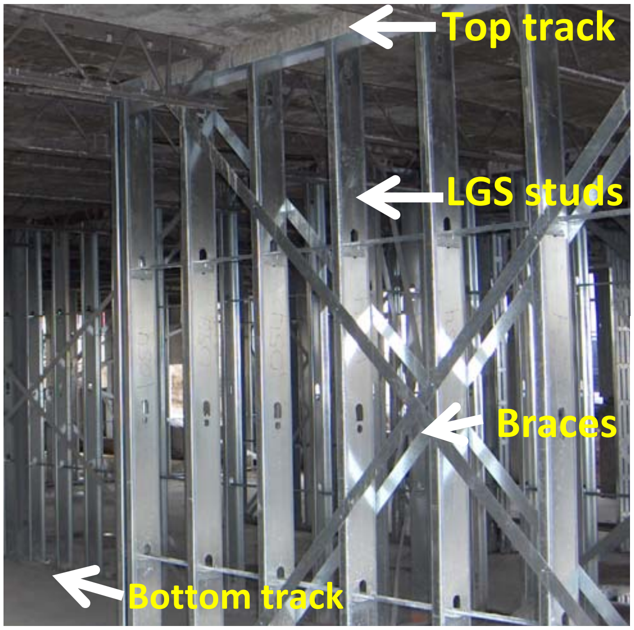

Figure 1. Different components in a typical LGS frame

Table 2. Geometric and section properties of typical LGS sections (source: CSSBI, 2005 [6])

Design Thickness (mm)	Inside Radius (mm)	Minimum yield strength (MPa)
0.879	1.942	230
1.146	1.808	
1.438	2.157	345
1.811	2.717	
2.583	3.875	

Studs and tracks when used as structural members can be used for floor, ceiling joists, axial load-bearing wall and curtain walls. These members are selected based on the loads they will be required to carry as well as wall and floor thicknesses called for in the building design [7]. Based on the design, the various sections are chosen for the top and bottom track, studs, and the braces. These frames can be pre-assembled according to the shop drawings. The shop drawings are normally used for submission to the Architect and Engineer of Record for their approval/comments before it is sent to the shop for fabrication. Each wall panel is assembled in the shop and then shipped to the site. Figure 2 shows a typical facility where the frames are being assembled, stored and then shipped.

Figure 2. Typical production facility for manufacturing the LGS wall panels in Navi Mumbai (relocated to Bangalore)

Conventionally, these LGS frames are received on site and a series of frames are then assembled, interconnected and then erected on the foundation. Figure 3 shows the use of LGS frames in a six-storey high-rise building. In this structure, a dry wall (also called wall board, plaster board or gypsum board) finish was specified.

Figure 3. Assembling of LGS frames for high rise construction, West Town, 2007

In many countries around the world, the dry wall finish is unacceptable and there is a requirement to have something more permanent. In such situations, concrete has been used as an in-fill in combination with the LGS system. This entire system can then be used as a load bearing wall. Figure 4 shows such a wall. Since, these LGS wall panels are usually precast and then shipped to the sites, it becomes imperative to use low density concrete or cellular light weight concrete (CLC). Many a times the LGS walls are constructed by using a combination of CLC and dry wall. Figure 5 shows a typical section of a wall where CLC provides the exterior finish and dry wall serves as the interior finish.

Figure 4. LGS system with a concrete in-fill being placed on site

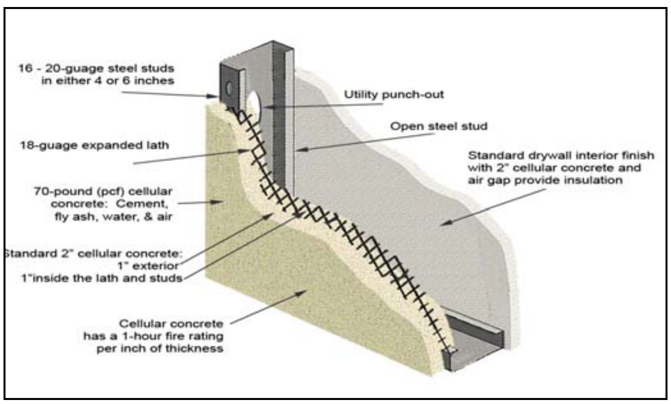

Figure 5. Typical LGS wall section where a combination of CLC and dry wall are used

III. Typical Applications

The LGS system is a flexible construction system and can be used for hospitals, high-rise buildings, gas stations/petrol pumps, commercial buildings, and customized buildings. Other than main stream mass housing and infrastructure development projects, the LGS wall system is also being used for modular buildings –retail outlets, ATM kiosks, modular washrooms, modular cabins, site offices, modular street furniture -bus queue shelters, and LED displays. Due to the flexibility in this LGS system, the steel frame can be customized to meet the requirements of a project. The system is also compatible for township projects, IT parks, malls, and multi-storied apartment buildings. Some of the applications of this system in US, Canada, and India are shown in Figures 6 through 10.

Figure 6. Hospital in Valsad, Gujarat

Figure 7. Customized Construction (Club house and dining hall building, Gujarat, India, 2006)

Figure 8. Commercial building in Belmont, USA (during construction)

Figure 9. Commercial building in Belmont, USA (after construction)

Figure 10. Apartment building in Vancouver, Canada

IV. On-Going Research

As described in previous sections, the LGS wall system is becoming popular for a wide range of applications. For various reasons, many of these applications necessitate a concrete wall finish. However, the use of regular concrete would impede the use of the LGS technology when used for precast construction due to high density of concrete and issues associated with economically handling and transporting such heavy panels. A research project was initiated at the Department of Civil Engineering at the British Columbia Institute of Technology in Canada to develop a light weight cellular concrete mix that could be used as an in-fill with the LGS system. The cellular concrete mix was required to have the following characteristics: target density 1200-1800 Kg/m^3, low permeability, low shrinkage, early-strength, good finish on form stripping, thermal and sound insulative properties, and ability to insert nails. The key mechanical property of concrete is usually the compressive strength, however, in this system since the structural loads are carried by the steel frame, concrete just becomes a filler material. The cellular concrete would be expected to have a low compressive strength, but would still confine the studs and change its structural behavior. However, the effect of this confinement on the axial load carrying capacity of the studs had to be quantified and hence led to this research project.

The research project was divided into two phases: first, a cellular concrete mix was developed that could be used in combination with the LGS system keeping in mind the practical aspects of construction and in the second phase, a scaled down version of the walls was tested for its axial capacity under quasi-static loading. In the first phase, various methods of producing light weight concrete was considered including use of light weight aggregates, polystyrene beads, use of special air entraining agents, and using foaming agents. Fresh properties including slump, air content, fresh density, homogeneity, finish, thermal properties, free shrinkage, and strength gain were recorded for more than 30 mixes.

Production of CLC using a foaming agent:

Figures 11 and 12 show the production of foam using a foaming agent and addition of this foam with the control concrete mix. Amongst the various methods used to produce light weight concrete, use of a foaming agent is being proposed for future studies.

Figure 11. Foam being produced using a foaming gun

Figure 12. Foam being added to the control concrete mix

Density, slump, and compressive strength:
From this phase, three mixes were selected with densities ranging between 1300 and 2100 Kg/m^3 and were considered for the second phase. To make the concrete mixes more sustainable, high volumes of Class F fly-ash (meeting the specifications of ASTM classification) was used as a replacement for cement. Different proportions of fly-ash were used with the maximum replacement at 50%. The use of fly-ash reduced the density of concrete and also reduced the water demand in concrete increasing the slump. Mixes with fly-ash produced flowing concrete and omitted the need for any external vibration. The lightest concrete mix considered for further testing was approximately 1300 Kg/m^3 with roughly 40% of air voids. Cylinders were cast for performing compressive strength tests according to ASTM C 39 [8] and were cured in ambient conditions to simulate in-situ conditions. At the time of writing this article only 7 days strength was available for the lightest CLC mix and was approximately 3 MPa. This compressive strength is expected to increase with time since the mix has high volumes of fly-ash and further tests are planned at 28 and 56 days of curing.

Free Plastic shrinkage:
When using concrete as an in-fill with the LGS system, there have been some prior field observations made suggesting the potential for cracking due to shrinkage. In this research project, the CLC mix was compared to a higher density control concrete mix and the length change of prisms was monitored according to ASTM C 157 [9]. In Figure 13, the change in length vs. time for four different CLC specimens is presented. It can be seen that the average length change for the specimens at 28 days is 0.01255" (0.3 mm) as compared to an average of 0.0078" (0.2 mm) at 24 days for the control concrete mix. An envelope for all the readings for the control mix is shown in the figure for clarity. Even though this roughly represents a 60% increased potential for shrinkage in the CLC mix, the overall shrinkage in both concrete types is low. This needs further investigation.

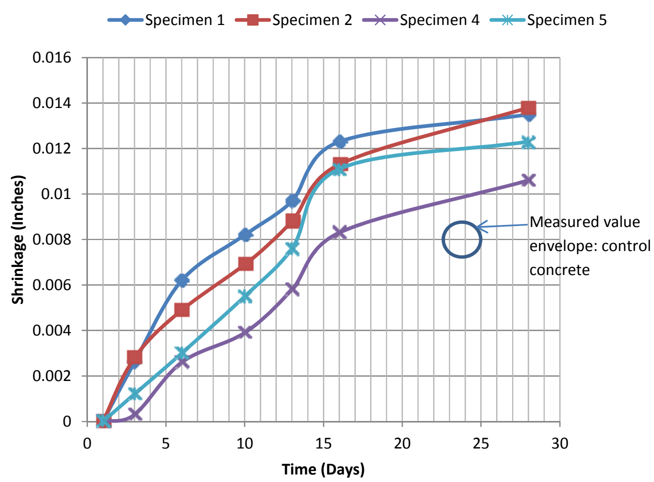

Figure 13. Free shrinkage test: length change vs. time

Due to the confinement offered by the concrete, the steel studs are expected to perform differently and possibly offer enhanced load carrying capacity. Figure 14 shows a structural test being performed on a fully instrumented specimen. Test results are currently being analyzed.

Figure 14. Structural test on a fully instrumented wall constructed with the LGS system and CLC in-fill

V. Concluding Remarks

The LGS wall system offers a lot of flexibility in construction and can be used for a wide range of applications including modular residential and commercial structures. Concrete can be used in combination with the LGS system and can be cast-in-situ or poured at a precast facility. The compressive strength recorded of the lightest CLC mix is very conservative and can be optimized by reducing the amount of concrete flow by reducing the w/cm ratio. The potential for the CLS mix to crack under restrained conditions needs to be investigated. The LGS systems when combined with light weight cellular concrete can potential offer increased structural capacity due to confinement. Scaled down structural wall specimens are being studied in an on-going research project where test results will be confirmed with FEM modeling.

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