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COMPARISON OF DESIGN, COST AND DURATION OF LGS AND SCIP CONSTRUCTION WITH CONVENTIONAL RC CONSTRUCTION

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Abstract: The research work presented in this paper was planned to have a comparison between "Cold Roll Light Gauged Steel (LGS)", "Structural Concrete Insulating Panel (SCIP)" and conventional "Reinforced Concrete (RC)" constructions. The basis of comparison was decided to be structural design, structural analysis, construction detailing, project cost and construction scheduling for three types of systems. A school building, consisting of three classrooms, assumed as unit scale for comparison, was designed, estimated and scheduled for three types of construction. Commercial software was used for analysis and design purposes. Microsoft Excel was used for cost estimation while planning & scheduling was carried out with the help of management software. Comparison of three structures after analysis and design dictates that LGS and SCIP constructions result in economical dimensions of structural members having less depth of footing as compared to conventional RC construction. LGS construction costs almost half while that of SCIP construction is almost 0.65 times to that of conventional RC construction. It was also studied that cold-roll technology took 27 days for completion, SCIP 25 days while conventional method completed in 52 days for the same structure. Cold-roll structural steel is 98% recyclable with 60% industry recycling rate while conventional construction is 50% recyclable with 0% industry recycling rate. On the other hand, SCIP construction does not has much recycling value as compared to LGS and conventional RC constructions.

Keywords: Recycling, Cold-roll, Insulating panel, Conventional concrete

1. Introduction

With the increasing complexity of projects and decreasing time frames to complete them, cost, seismic factors as well as energy crisis throughout the world, need for innovative information on materials has been increased a lot. Time has passed when the space available for construction was in excess. At present, structural engineers must accommodate large number of people in very less space. For this purpose, they must work for multi-story constructions associated with factors like stronger design, higher cost etc. To make the construction optimum in every sense, there is a need to get rid of traditional services and turn towards the advanced technologies [1]. In steel construction, there are two main families of structural members. One is the familiar group of hot- rolled shapes and members built up of plates. The other, less familiar but of growing importance, is composed of sections, which are cold formed from steel sheets, strip, plates, or flat bars in roll-forming machines or by press brake or bending brake operations. These are called cold-formed steel structural members [2]. The thickness of steel sheets or strips generally used in cold-formed steel structural members ranges from 0.0149 in. (0.4 mm) to about 0.256 in. (6.4 mm). Steel plates and bars as thick as 1 in. (25 mm) are molded successfully into structural shapes. Since 1946, the use and the development of thin-walled cold-formed steel construction in the United States have been accelerated by the issuance of various editions of the ''Specification for the Design of Cold-Formed Steel Structural Members'' issued by "American Iron and Steel Institute (AISI)" [3]. The earlier editions of the specifications were based largely on the research sponsored by AISI at Cornell University under the direction of George Winter since 1939. It has been revised subsequently to reflect the technical developments and the results of continuing research [4].

SCIP consists of high-performance composite building panels used in floors, walls and roofs of residential and light commercial buildings. These panels are fabricated in factory and shipped to the construction site, where these are quickly assembled to form a tight, energy-efficient building envelope [5]. SCIP is a simple composite sandwich panel. Generally, SCIP is made by sandwiching a core of rigid foam plastic insulation between two structural skins, though many different variations (based on facing and core materials) are included in the blanket definition. SCIP is currently made with a variety of structural skin materials, including oriented strand board (OSB), treated plywood, fibre-cement board (cementitious), and metal. However, virtually any bondable material could be used as a facing. Core materials are typically expanded polystyrene (EPS), extruded polystyrene (XPS), or polyurethane but other rigid insulation can be used as well. Facings and core materials are bonded by structural adhesives. These variables allow for panels to be optimized to the specific needs of any project. SCIP is typically available in thicknesses ranging from 4 ½ inches (108 mm) to 12¼ inches (311 mm). Walls are commonly between 4 to 6 inches (102 to 152 mm) and roof panels are generally thicker, often up to 12 inches (305 mm) depending on climatic conditions [6].

It has been observed that a hesitation is found especially in developing countries in adoption of new technologies. In this document, attempt is made to convince the stakeholders in this regard by concluding some results based on comparison of design, cost and duration of LGS and SCIP construction with RCC conventional construction. For this purpose, a school building was assumed as unit scale consisting of three class rooms each of size 18' x 24' (5.5m x 7.32 m) and a veranda of size 6' x 24' (1.83 m x 7.32 m) with total covered area of building as 1664 ft2 (54.6 m2) and bearing capacity of soil 0.75 ton/ft2 (8 ton/m2). Three technologies were applied on this unit scale for comparison in terms of design, cost, and scheduling.

2. Analysis and structural design

2.1 Design parameters

Following loads were taken for computation of forces applied on the structure:

1) Dead load (Self and finish Load)
2) Live load (UBC 97: Ch 16)
3) Seismic/earthquake load (UBC 97, ASCE 7-10)
4) Wind load (UBC 97, ASCE 7-10)

2.2 Seismic parameters

Following parameters were used for seismic design as per UBC 97 and ASCE 7-10:

1) Earthquake Zone = 4
2) Near source factor, Na = 1.5 & Nv = 2.0
3) Importance factor, I = 1
4) Ductility factor = 8.5
5) Soil type = SD
6) CT value = 0.03
7) Rw in X direction = 8.5
8) Rw in Z direction = 8.5

2.3 Wind parameters

Following parameters were used for wind in the structural design as per UBC 97 and ASCE 7-10:

1) Exposure category = B
2) Importance factor, I = 1
3) Basic wind speed = 70 mph
4) Windward coefficients:
5) Cp = 0.8 Windward & Cp = 0.5 Leeward
6) Side Walls = 0.7 outward

2.4 Analysis and design of RC structure

E-tab 13.1.3 software, developed by "Computer System Incorporation (CSI)" University of Berkeley USA, was selected for analysis and design of RC structure. Authenticity and credibility of the software is well tested and is accepted worldwide. Also, CSI is pioneer in the application of "Finite Element Method" through computers. ACI 318-02 and guidelines were used for structural strength and serviceability adequacy. UBC-97 [7] guidelines were used for design loads. Ultimate Stress Design (USD) method was adopted for design [8]. Figures 01 & 02 represent some steps in the design of RC structure by E-tab 13.1.3 software.

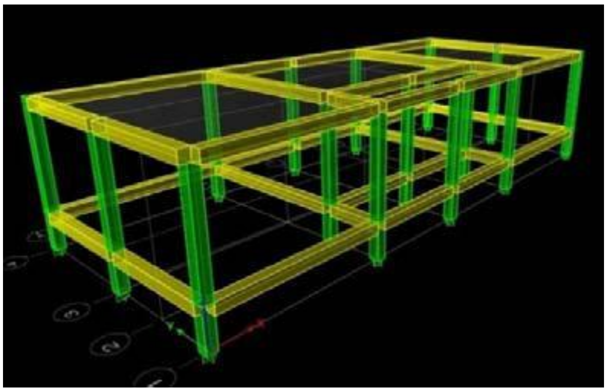

Fig. 01. Geometry

2.3 Analysis and design of LGS structure

For analysis and design of LGS structure, SAP2000 software was selected. SAP2000 has integrated ability to analyse and design cold formed steel structures. Raft foundation for the structure was designed with the help of SAFE. AISI LRFD-96 (American Iron and Steel Institute) and UBC-97 guidelines were followed for structural design and serviceability of LGS structural design and serviceability of LGS of LGS structure by SAP2000 are shown in Figures 03 & 04.

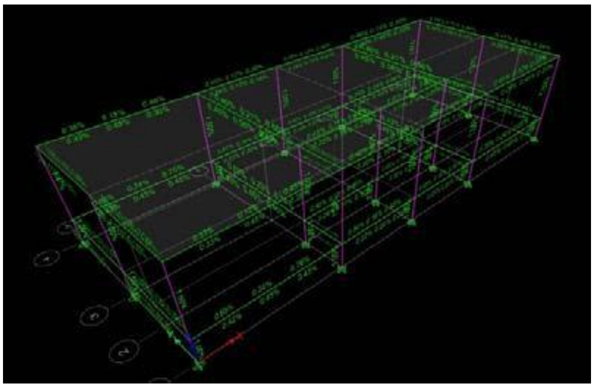

Fig. 02. Design results of longitudinal reinforcement

2.4 Analysis and design of SCIP structure

SCIP behaves as shell element with layers of different materials. SAP2000 has an integrated ability to analyse multilayer shell elements also. Raft foundation for the structure was designed with the help of SAFE software. ACI 318-02 and

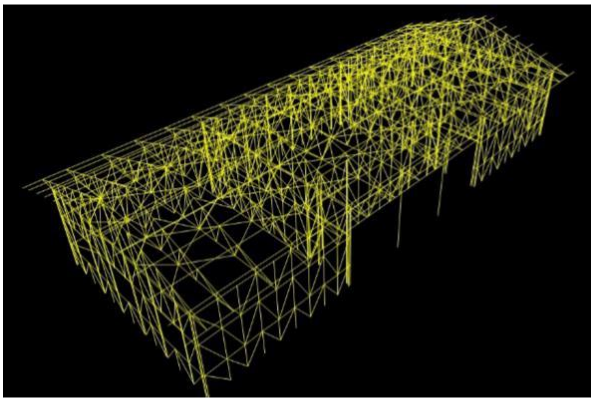

Fig. 03. Geometry

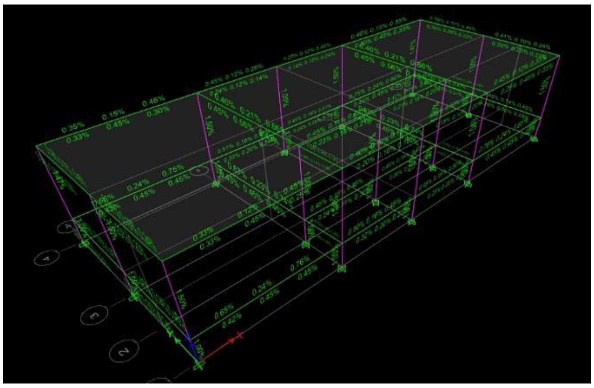

Fig. 04. Design results

UBC 97guidelines were followed for structural design and serviceability of SCIP structure.

The flexural capacity, shear capacity and axial load capacity of structural components is evaluated in accordance with ACI 318-08. The structural capacity of each component is summarized in Table 01, while different design steps during modelling by SAP2000 are shown in Figures 05 & 06.

Table 1: Structural component capacity

Bending moment (Ton-m/m)		Shear force (Ton/m)	Compression force (Ton/m)	Tension force (Ton/m)
Positive	Negative			
0.8	0.8	13	81	10
1.6	1.6	21.8	88	21
1.2	-	8.8	-	-
1.2	1.2	22	237	15

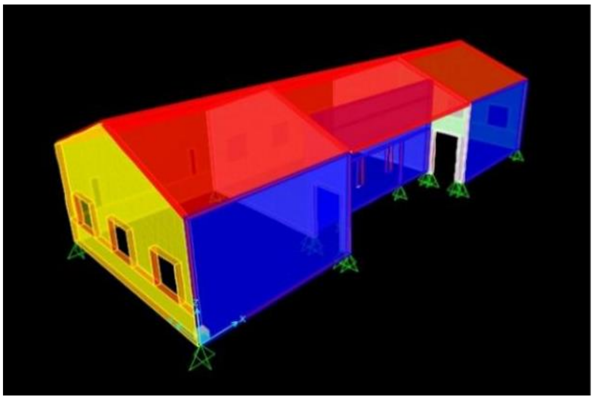

Fig. 05. Geometry

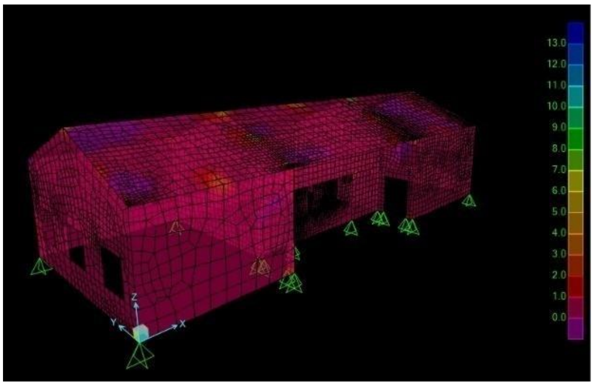

Fig. 06. Vmax diagram of structure (ENVMAX)

Table 02 exhibits detailed comparison of design outputs for three technologies It can be observed from Table 2 that the depth of footing for RC structure is 58.33% more as compared to that for LGS and SCIP structures. It means that there is much saving in excavation for foundations in case of new techniques i.e., LGS & SCIP techniques, as compared to conventional RC technique. Similarly, size of plinth and roof beams is 12" x 15" for RC structure. For LGS structure, plinth and roof track consist of single C section of size C90 mm x 40 mm x 1.0 mm. For SCIP structure, there are no plinth or roof beams, it simply be composed of walls of 7" thick layer comprising 3" thick polymer and two layers of 2" thick shotcrete. In SCIP structure, walls are simply used for load bearing, no special cladding, column box or corner studs are used. On the other hand, in LGS technology, the cladding, column box, and corner studs consist of a single, double and triple C section of C90 mm x 40 mm x 1.0 mm respectively while the RCC frame consists of all column of size 12" x 12".

3. Cost estimation

The cost estimation for 3 types of constructions was carried out in detail. The schedule of rates for RC building was taken from "Pakistan Institute of Cost and Contracts (PICC)" and "Market Rate System (MRS) 2014 [10]". The unit cost for LGS and SCIP structures was taken from "National Engineering Services Pakistan (NESPAK) Limited". A comparison of construction costs estimated for the construction of same building by three technologies is shown in Fig. 07.

The total cost of constructing the same facility by RC, LGS and SCIP techniques was found to be 28922, 14390 and 18736 USD respectively. It means that LGS technique is 45.5% cheaper than RC while 17.65% cheaper than SCIP techniques. On the other hand, SCIP is 33.88% cheaper than conventional RC techniques.

4. Planning and scheduling

Planning and scheduling of three structures was carried out with the help of Primavera P6, software. Construction work was divided into activities and durations were estimated by the outputs of allocated resources. It is clear from Figure 8 that duration for constructing the same facility by RC, LGS and SCIP techniques is 52, 27, and 25 work days respectively. It means that SCIP technique is 51.92% more time saving than RC while 7.4% than LGS techniques. On the other hand, LGS is 48 % cheaper than conventional RC techniques.

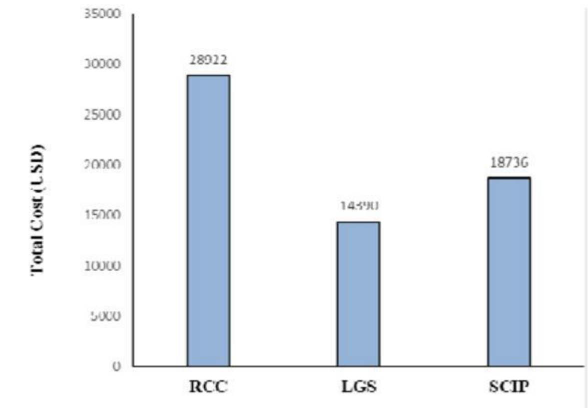

Figure 7: Estimated cost of construction for 3 technologies

Table 02: Comparison of design outputs for three technologies

Sr. No.	RCC structure		LGS structure		SCIP structure	
1	Beam sizes		Tracks		Layer thickness	
	Plinth beams	12" x 15" (30 x 37.5 mm)	Bottom track	C90mm x 40mm x 1.0mm	7" thick layer comprises of 3" thick polymer and two layers of 2" thick shotcrete	
	Sill beam	No sill beam	Sill track	C90mm x 40mm x 1.0mm	7" thick layer comprises of 3" thick polymer and two layers of 2" thick shotcrete	
	Lintel beams	9" x 9" (30 x 37.5 mm)	Lintel track	C90mm x 40mm x 1.0mm	7" thick layer comprises of 3" thick polymer and two layers of 2" thick shotcrete	
	Roof beams	12" x 15" (30 x 37.5 mm)	Roof track	C90mm x 40mm x 1.0mm	7" thick layer comprises of 3" thick polymer and two layers of 2" thick shotcrete	
2	Columns		Studs		Corners	
	All columns are of same size	12" x 12" (30 x 3o mm)	Cladding column	C90mm x 40mm x 1.0mm	No corner column	
			Box section	C90mm x 40mm x 1.0mm		
			Corner studs	C90mm x 40mm x 1.0mm		
3	Foundation		Foundation		Foundation	
	Single column footing		Raft		Raft	
	Thickness	12" (30 mm)	Size	62' x 25'4"	Size	62' x 25'4"
			Thickness	5"	Thickness	5"
4	Roof		Roof		Roof	
	RCC slab 6" (15 mm)		Material used cold roll C-sections for both truss members and purlins		Material used 7" thick layer comprises of 3" thick polymer and two layers of 2" thick shotcrete	
			Spacing between trusses	Shall not be more than 4'		
			No of trusses	17		
5	Expansion coefficient					
	Bricks	5.5 (10^{-6} m/m K)	Doesn't expand on heating and contract on cooling		Doesn't expand on heating and contract on cooling	
	Concrete	9.8 (10^{-6} m/m K)				
6	Earthquake resistance					
	More susceptible		Earthquake-proof against 9 degrees		Earthquake-proof against 9 degrees	

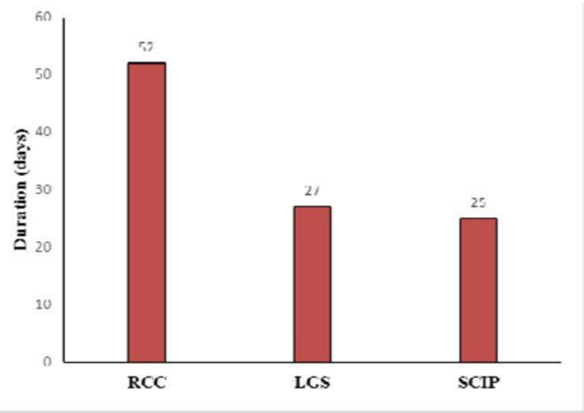

Figure 8: Durations of construction for 3 technologies

5. Conclusions & Recommendations

5.1 Conclusions

1) LGS and SCIP constructions results in economical dimensions of structural members, especially having less depth of footing as compared to conventional RC construction.

2) There is much saving in excavation for foundations in case of new techniques i.e., LGS & SCIP techniques, as compared to conventional RC technique.

3) LGS and SCIP construction is cheaper than RC construction. The costs of LGS & SCIP constructions are half and 0.65 times as compared to that of conventional construction.

4) With the SCIP and LGS technology, we can build a structure mush faster than conventional construction.

5) Cold roll structural steel is 98% recyclable and has 60% industry recycling rate while conventional construction is only 50% recyclable and has 0 % industry recycling rate. On the other hand, SCIP has not much value of recycling.

6) LGS is a lighter structure with stronger connections resulting in less seismic forces. SCIP structure also consist of light weight insulation in between two layers of concrete which reduces its weight resulting in less seismic forces, whereas in conventional concrete due to massive weight of the structure seismic forces are dominant.

5.2 Recommendations

LGS & SCIP technologies are recommended in place of conventional RC construction. These are not only earthquake proof but also more economical, time saving and recyclable. However, LGS construction is cheaper as compared to SCIP construction.

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