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Defining Structural Behavior of Cold–Formed Steel in FilledWalls and Light Weight Concrete with Increasing Frame Types

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ABSTRACT

An innovative model of structuring light cold-formed steel is that it has provided the situation for supplying quality in building and performance and optimized the use of steel industry, and decreased the performance time. In these structures, cold-formed steel has been used to form structure. That is one of the innovative methods of filling free spaces (gaps) in cold-formed steel frames are utilizing light weight foam concrete. The purpose of the present paper is to define the effect of filling light weight concrete (LWC) and the increase in the numbers of frames that exist in structural behavior in filled walls cold–formed steel structure system. The wall with one span frame and five span frames made of cold–formed steel sections and filled with light weight concrete (LWC)has been modeled using ABAQUS software and finite elements method and also has been analyzed through push over non-linear static.

To increase the number of spans from one to five, ductility strength raise due to increase in degree of indeterminacy. Five span frames bear much more ultimate loads than one span frames, but ultimate displacement is much more in one span frames. With respect to the obtained results, in filled light weight concrete led to reduction in the lateral drift, remarkable increase in ductility, and increase in lateral resistance in one and five span frames.

KEY WORDS: Cold–Formed Steel, Light weight concrete (LWC), Seismic Behavior, Filled Walls.

INTRODUCTION

Lightening structural buildings using light weight cold-formed steels, led to resistance of building against earthquake due to making use of light weight materials or reduction of structural building items. In the present paper, the inner sides of cold–formed steel walls have been filled with various light weight concrete in one and five span frames. Due to lightening, lateral enjoyed at least 20percent reduction and regarding to, structurally consumed materials reduced up to 50 percent, too, [1].Structural modeling has been analyzed through finite elements method and ABAQUS software.

Main or Load Bearing Elements of Cold- Formed Steel Structures

The main structures of light weight cold–framed steels which have been simulated in the present paper and have structural load bearing, have been composed of U, C thin–walled sections as following:

Stud plays the role of pillar / column in the structure and runner which is the manual of studs. The geometric properties of cold-framed steel sections modeled in this paper have been displayed in figure 1, [2]. The height of frame is 3000mm and the width of it is 600 mm.

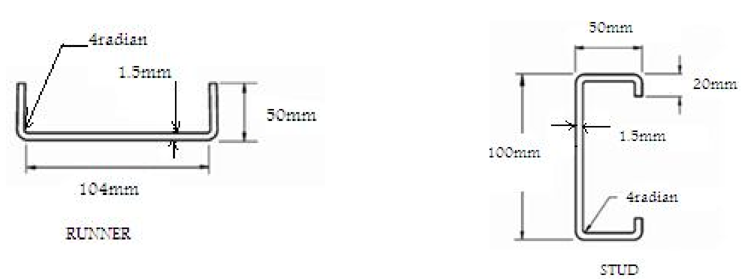

Figure 1: Runner, Stud sections in the analyses

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Introducing Analytic Models

The properties of considered models to analyze finite elements using ABAQUS software have been shown in table 1. The model number 1 has been considered to compare the results of the analyses and existing laboratory observations. The variable parameter in this paper is various 1, 2, light weight concreteand the numbers of frame spans which are one span and five span.

Table 1: the properties of analytic frame samples formed of cold–framed steel in ABAQUS

Properties of analytic model	Model number
laboratory sample Of Ten span frame filled with plain concrete	ABA[1]-C[2]-10S[3]
Bare one span frame	ABA-B[4]-1S
One span frame filled with type one plain concrete	ABA-LWC[5].NO1-1S
One span frame filled with type two plain concrete	ABA-LWC.NO2-1S
five span frame filled with type one plain concrete	ABA-LWC.NO1-5S
five span frame filled with type two plain concrete	ABA - LWC. NO2 - 5S
Bare five span frame	ABA – B - 5S

The properties of concrete and cold-framed steelmaterials

Usual compressive strength of 28 day concrete which has been used as controlled analytical model was 28 mega Pascal. The properties of various kinds of used light – weight concrete to fill frame in analysis of finite elements included, number one light weight concrete (LWC.NO1) which its density was 1106.3 kilogram/mm, 12000 mega Pascal elasticity module and ultimate compressive strength which was 6.4 mega Pascal, number 2 light weight concrete (LWC. NO2) which its density was 735.2 kg/mm, 7500 mega Pascal elasticity module and 2.7 mega Pascal ultimate compressive strength.Poisson's ratio of concrete was considered 0.2. Cold form steel density (CFS1), elasticity module, ultimate compressive strength, and Poisson's rate in the analysis of finite elements has been considered 785 kg/mm, 210000 mega Pascal, 370 mega Pascal, and 0.3, respectively, [3] [4] [5] [6] [7] [8].

Simulation model and analysis

In order to three dimensional simulations in ABAQUA software, a kind of model needed to be considered that supplied the behavior of concrete. The model which solved much the problem of concrete modeling was plasticity failure model which had the capability of investigating reinforced concrete having various loadings (uniform and temporary).[9] This model was continuum type and has been based on the plasticity of failure model of concrete.The selection of appropriate coppering has had defining effects during program application. A concrete element coppering (rectangular shape) has been conducted by 3 dimensional solid element, and 8 nodes (C2D&R).

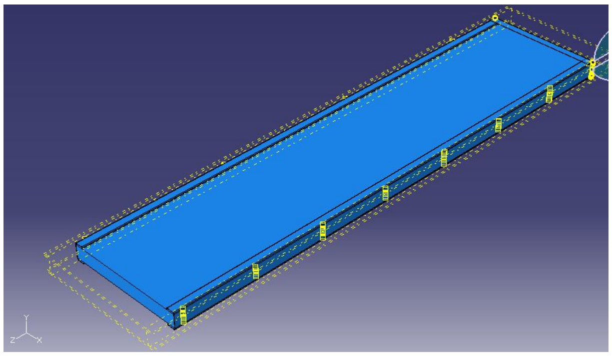

Figure 2: studs in contact with concrete

The loads pushed on the given model were lateral and gravity ones. The gravity load has been imposed on beams and beginning the analysis was constrained on the models in a stable state. Software automatically considered the weight of the elements. The distribution of lateral loads was increasing and based on 2800 standard, the pattern of focused load has been used.

In order to stop out of plate constrained force to thin filled elements and to prohibit local deformity due to out of plate constrained force, connections needed be designed in a way that between

[1]ABAQUS
[2]Concrete
[3]Span
[4]Bare
[5]Light Weight Concrete

member forces transferred in an internal plate way. [10] In this model the situation of hinged support at the end of column has been operated due to displacement restriction. The hinges of concrete elements to cold-formed steel, the slips between them have been considered.The coefficient of slip friction was μ = 0.25.

In order to stop structural and nonstructural elements failure against extreme displacement, the relative lateral displacement of a floor did not have to exceed definite limit. Regarding to the relative lateral displacement of a floor had to be limited. Based on 2800 code of practice third edition maximum relative lateral displacement of structure would be defined as follow:

$$\Delta \leq 0.02h \qquad (1)$$

Where h was the height of the floor. In the analysis, in order to find out the exact behavior of given structure $\Delta \leq 0.035h$ has been considered. The analysis has been conducted in push over non linear static. In order to control structural behavior using force-displacement figure, displacement control has been utilized.

Computerized modeling results of experimental sample in NAHB institute

In order to compare the obtained analytical results and laboratory observations, the sample ten span frame analyzed using finite elements software and similar to laboratory situation, and the displacement–force figure has been obtained.With respect to the comparison of maximum obtained base shear, the obtained results demonstrated that the shear was approximately 8.8% which was acceptable, [11].

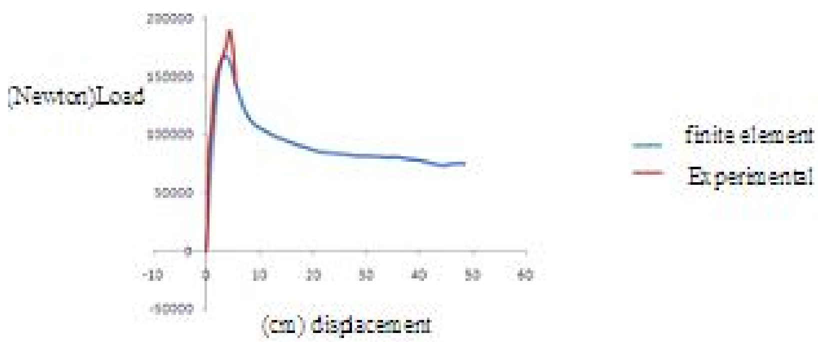

Figure 3: the comparison of sample load-displacementfigures in laboratory and finite elements analysis

The obtained results of in filled concrete cold–formed steel analysis using displacement–force figures

Non analytic static represented all behavior of structure. Non linear behavior of concrete in filled walls depended greatly on materials' nonlinear behavior, strain-stress curve and tension of strain, environmental effects, cracking, softening due to relative displacement, and hardening. The analytical one span and five span samples load-displacementfigures has been displayed in accordance to defined properties. As it is presented, all analytic models incurred yield area and the amount of energy absorption and the area under load-displacementcurve are differentiated from one another and only the ABA–B–5S and ABA–B–1S sample have behaved linearly without in filled concrete in which the capacity of bearing is very trivial with respect to the rest of samples. The comparison of figure 4 and 5showed that the effect of in filled concrete is more remarkable in the increase of lateral strength of wall.

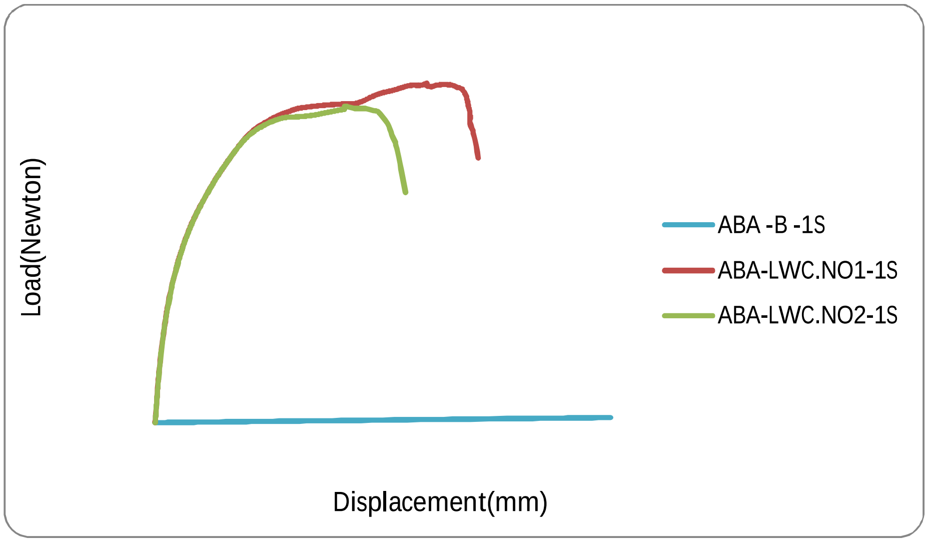

Figure 4: the comparison of displacement–force figures in ABA–LWC.NO1-1S, ABA–B–1S, ABA–LWC.NO2–1S

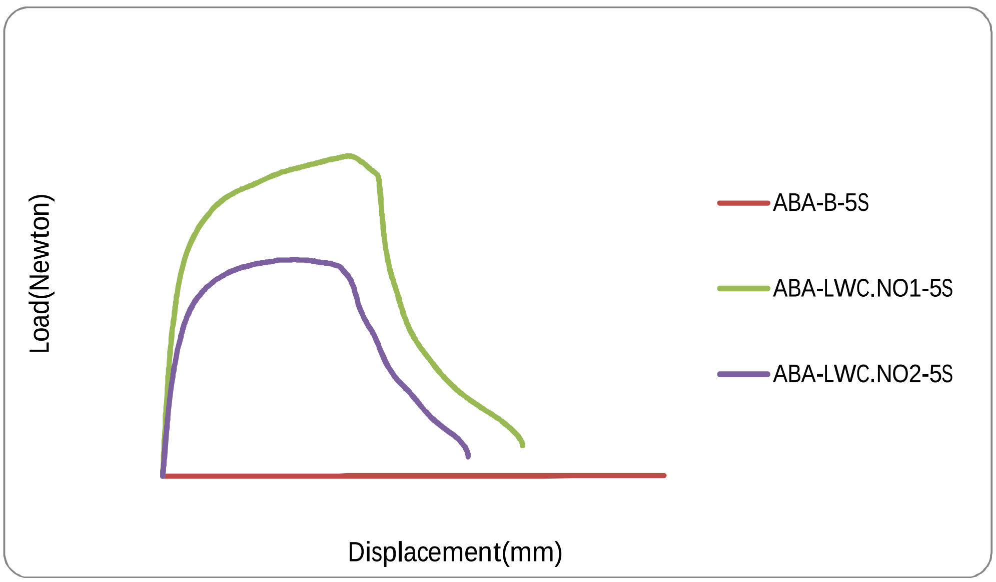

Figure 5: the comparison of displacement–force curve in ABA–B – 5S, ABA–LWC.FC2 –5S, ABA–LWC. FC1–5S

As it is clear the whole capacity of a structure depended upon strength capacity and deformation of each members of a structure. The comparison of concrete in filled frame and concrete unfilled frame demonstrated that filling walls with concrete increased the surface under displacement–force curve which presented energy absorption capability and traced increasing effect in lateral strength of analytic models.

In number 1 and 2 light weight concretes, number one light weight concrete contained more under curved surface and as a result had more ductilitydue to more tension strength. The height of the walls in led to increase in wall shear strength in five span frames. Therefore five span frames bore much more ultimate force than one span frames. On the other hand, ultimate displacement of one span frames was much more than five span frames. It was because of bending deformationin one span frames were more than bending deformation in five span frames and also bending deformation was greater than shear deformation.

Ductility ratio

Ductility factors were obtained based on the following equation (2): [10]

$$\mu_{\Delta} = \frac{\Delta_u}{\Delta_y} \tag{2}$$

In the above mentioned equation, Δ_y and Δ_u are boundary points in displacement–force figure, which indicates the first point in yielding (plastic hinge) and ultimate point in analytic increasing stages.

In table2 the relation of modeled frames deformation has been noted using equation 2. The obtained numbers using displacement–force figures indicates that number 1 light weight concrete in filled wall has greater ductility ratio than number 2 light–weight concrete. Regarding to high tension strength, Plain concrete has less ductility ratio and it can be concluded that in light–weight, cold–formed steel using light–weight concrete leads to increase in more deformation/ductility.

Table2: the ratio of ductility in analytic frames

Properties of modeled sample	Deformation /ductility as yielding point(mm)(Δ_y)	Deformation/ ductility as ultimate strength (Δ_u) (mm)	Ductility ratio ($\mu_{\Delta} = \frac{\Delta_u}{\Delta_y}$)
ABA-C-10	22.5	51.5	2.2
ABA–LWC.NO1–1S	4.5	64.8	14.4
ABA–LWC.NO2–1S	5.9	40.5	6.8
ABA–LWC.NO1–5S	2.9	34.6	11.9
ABA–LWC.NO2–5S	4.2	58.5	6.7

Elastic stiffness

Using obtained displacement – force figures from ABAQUS program, the structural stiffness can be calculated based on following equation: [12]

$$k = \frac{F_y}{\Delta_y} \tag{3}$$

Stiffness based on table3 is as follow for analytic models:

Table3: analytic frames stiffness

Properties of modeled sample	Ultimate strength F_u (KN)	Displacement boundary yielding (mm) (Δ_y)	Force boundary yield (F_y)(KN)	Stiffness ($k = \frac{F_y}{\Delta_y}$) N/mm
ABA–C–10 S	168.1	22.5	159.1	7071.1
ABA–LWC.NO1–1S	29.4	4.5	24.01	5335.6
ABA–LWC.NO2–1S	27.3	5.9	22.3	3749.5
ABA–B–1S	0.45	100	0.45	4.5
ABA–LWC.NO1–5S	576.3	2.9	487.6	168122.4
ABA–LWC.NO2–5S	391.1	4.2	336.5	80107.8
ABA–B–5S	1.3	100	1.3	13.5

Regarding to displacement–force analytic samples and the calculation of samples stiffness, it can be concluded that using light–weight concrete leads to increase in frame stiffness. Based on obtained numbers in table, it can be concluded that between two kinds of light weight concretes, having filled the walls with number one light weight concrete includes more stiffness or the concrete with greater strength leads to greater stiffness, in other words.

Conclusion

The present paper has investigated the effect of in filled light–weight concrete regarding to strength, ductility, and stiffness of this kind of structure in five and one span frames. Based on these two types of wall in filled light – weight concrete has been considered.In filled and non filled/ hollow wall figures indicated that using concrete has increased under curved area of force–displacement that in turn led to strain increase, energy absorption capacity increase, ductility increase, and structure strength increase. The obtained results indicated that: due to increase indefinite degree, ductility ratio increased with the raise in the number of frames. In five span frames, shear strength of wall elevated, thus five span frames bore much more ultimate force than one span frames. Ultimate deformation in one span frames is higher, and also bending deformation in them is much more than shear deformation because of bending deformation in one span frames rather than five span frames.

Having higher tension strength in number one light–weight concrete, they contained higher displacement and ultimate force. Calculating ductility ratio, it was observed that using in filled light–

weight concrete led to increase in ductility ratio. Due to greater tension strength in number one light–weight concrete, the ductility ratio in number one light–weight concrete was higher than number two light–weight concrete.Based on the obtained results, wallsthat had been filled with number one light–weight concrete enjoyed greater stiffness regarding to higher strength compared two types of light–weight concretes.

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