Preparation Technique of Experimental Specimens of Steel and Concrete Composite Slabs

Leonid Storozhenko, Grygorii Gasii, Myron Hohol, and Olena Hasii

Abstract The composite frames are used widely as the roof system for different buildings or structures as well as covering spaces as a shell. The technique of experimental investigation of steel and concrete composite space frames (SCCS frame) is compiled because it is a novel type of structure and has not sufficiently behavior investigated yet. The current investigation is aimed at prefabrication technique description. This research is a complete study of prefabrication techniques and also the strength of materials for making prototypes of the SCCS frame, which consist of steel lattice and steel and concrete composite slab (SCC slab) as well as include top and bottom chords. The research includes testing specimens of the concrete cubes and prism and reinforcement bars. It has long been known that concrete is often and widely used for slabs and surfaces in compression or bending. However, the SCC slab has another way of reinforcement than an ordinary reinforced concrete slab.

Keywords Steel · Concrete · Slab · Stress · Strain

1 Introduction

Currently, SCC structures are the widespread structure types all over the world. The SCC structures are used in various fields of building [5, 10].

This is why the investigation of the SCC structures is an important issue. The SCC slabs are a part of the SCCS frames [26]. The SCCS frame is the novel type of roof system that was designed and was patented recently. The SCCS frames consist of steel lattice and SCC slab as well as include top and bottom chords. The SCCS

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frame has the design as shown in [26]. The SCC slab plays the role of the top chord. It delivers bearing and shielding roles. The SCCS frames are used as the roof of civil and industrial buildings or structures or covering large areas as a shell.

The experimental investigating technique of SCCS frames was compiled because of its are a novel type of structure and has not yet sufficiently behavior investigated but the current investigation is aimed for prefabrication technique describe.

So, the purpose of this research is a complete the study of prefabrication technique and also the strength of materials for making samples. The research includes testing specimens of the reinforcement bars, concrete cubes as well as concrete prisms.

2 Method

The methods of experimental research, as well as theoretical research, taking into account previous research [2, 3, 5, 8, 9, 11, 13–36], are used in this study. To study the mechanical properties of materials, standard and generally accepted methods are used [4] etc.

3 Results and Discussions

3.1 The Size and Design of Experimental Specimens of the SCC Slabs

To making the SCC slab is used concrete because it has suitable mechanical properties for this structure type [25]. It has long been known that concrete is often and widely used for slabs and shells in compression or bending [19]. Nevertheless, the SCC slab has another way of reinforcement than an ordinary reinforced concrete slab [12]. Ordinary reinforced concrete slabs include reinforcement mesh that is made of steel bars that caused a significant cross-section height and total weight. Those are not suitable options for space surfaces.

That is why the SCC slabs are reinforced with meshes that are made from steel wire instead of steel bars. This method of reinforcement allows getting sufficiently homogeneous material.

Nevertheless, it caused a significant flexible thin-walled structure. That is why the SCC slab has ribs for providing rigidity. These ribs are reinforced with a few steel bars. To explorer, the stress-strained state of the SCC slab was manufactured experimental specimens (Fig. 1a).

Experimental specimens of the SCC slabs have a square shape with a side length of 1000 mm and slab thickness of 20 mm and rib height of 50 mm.

3.2 Materials of Experimental Specimens of SCC Slabs

To making the SCC slab are used steel wire meshes and a concrete mixture. There is the composition of material for concrete mixture in Table 1.

Concrete mixture was produced with concrete mixer CM-250 in the industrial department (Fig. 1b).

The steel wire meshes were made of steel wire 0.9 mm in diameter and cell size 12 mm (Fig. 2).

Steel bars 6 mm in diameter are used for reinforcement of ribs.

To prevent plain bars under tension from slipping in concrete solid, both ends of the bar are bent. In addition, reinforcement should be bent due to the design requirement.

The detailing of the bent segments is listed in design codes or acceptance specifications for construction quality.

Figure 2 illustrates bent segments that are used in the SCC slabs [6]. Figure 3 shows the dimensions and reinforcement scheme of SCC slabs.

Table 1 Quantities of materials per cubic meter of the concrete mixture

Material	Portland cement	Fine aggregates (sand) 1.1 mm	Water
Mixture proportions	1	1.75	0.4
Mass of material, kg	700	1225	280

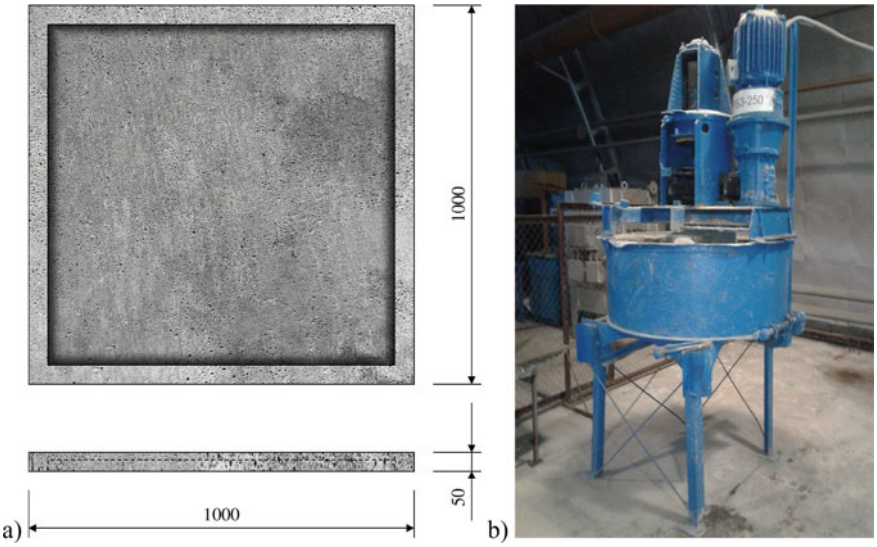

Fig. 1 The SCC slabs **a** and Concrete mixer CM-250 **b**

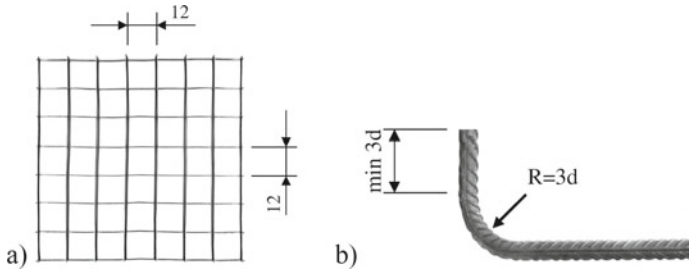

Fig. 2 Fragment of the welded wire mesh with cell size 12 mm **a** and Bent steel bar **b**

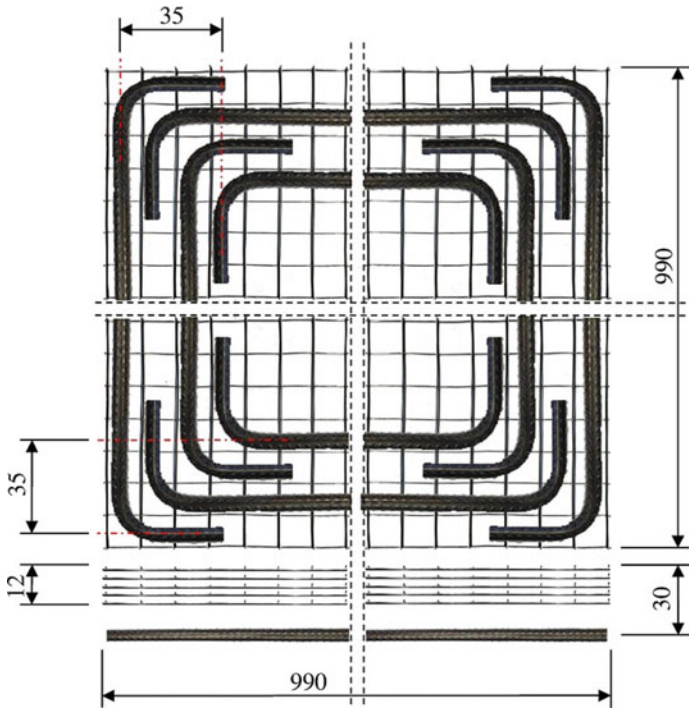

Fig. 3 Dimensions (mm) and reinforcement layout

3.3 Mechanical Properties of Materials for Experimental Specimens of SCC Slabs

The concrete strength depends on the quality of the concrete mixture, water-cement ratio, cement strength, etc. [1, 7]. Test cubes of 150 mm for obtaining the compressive strength of concrete were carried out.

In Ukraine as in all over the world, the cube strength is used as the main index of concrete strength.

A compression test of concrete cubes is an easy way to obtain concrete strength. On top of that, the strength is measured is quite accurate.

Moulds are used to making concrete cubes. No voids must be in the concrete mixture during the moulds are filled. A vibrating table to concrete mixture compaction in moulds was used.

The load-carrying capacity of the table is about 300 kg. All cubes moulds that were filled simultaneously were accommodated on the vibrating table. The vibration was adjusted to 2000 vibrations per minute.

The concrete cubes are taken out from moulds after 24 h and for curing, it put in water. The concrete cubes are tested after 28 days of curing. For the test are used the compression testing machine PG-125.

To fail the concrete cubes, the load is applied gradually 130 kg/cm^2 per minute.

The compressive strength of concrete is obtained according to [4]. The average value of the mechanical properties of concrete cubes is 17.86 MPa.

The concrete prisms to determine the prism strength are tested.

Concrete prisms were manufactured by the same technique as concrete cubes are used, except moulds. Before, prisms testing on side surfaces had been set strain gauges. Strain gauges set on the side surfaces of prisms with clue BF-2.

The average value of the mechanical properties of concrete prisms is 16.30 MPa. The stress–strain curves based on the testing results are mapped (Fig. 4).

Reinforcement strength was obtained by tests of specimens of 600 mm length with press PM-500.

However, the strengths of different specimens, despite that they were of the same type, were different. It was due to the inherent variability of reinforcement materials. The stress–strain curves of steel bars, which were used for reinforcing experimental specimens of SCC slabs, were obtained from tension tests, in which the loads are monotonically applied without any unloading until the bars fail in a short time.

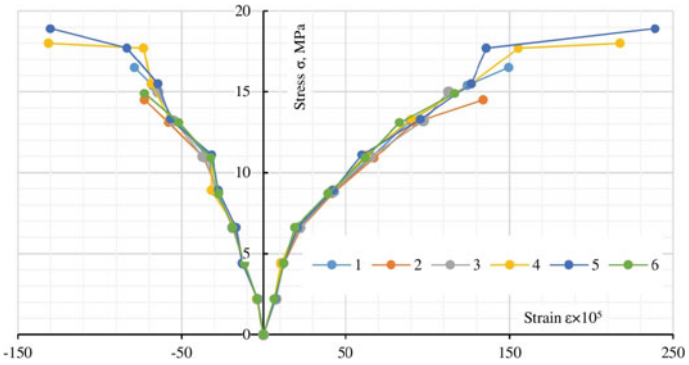

Fig. 4 The stress–strain curves for concrete prisms

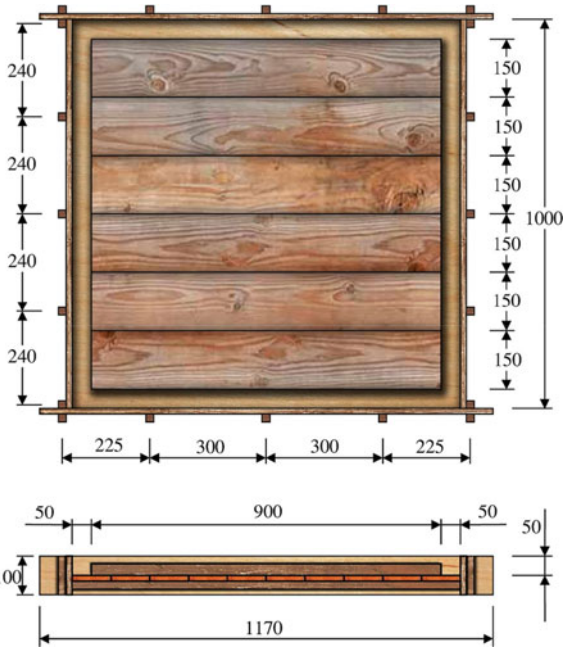

Fig. 5 Timber moulds for slab manufacture

Therefore, measured strength with a certain degree of confidence was taken as the strength of reinforcement. The degree of confidence is more than 95%. The average strength is 279.74 MPa.

3.4 Preparation of Experimental Specimens of SCC Slabs

For experimental specimens preparation was used timber moulds (Fig. 5). Preparation of experimental specimens of SCC slabs includes 4 steps. The first step was to set moulds on a vibrating table. Then were put reinforcement bars and welded wire meshes in mould and concreting.

4 Conclusions

The fabrication technique of experimental specimens of steel and concrete composite slabs is described. The mechanical properties of materials are obtained by testing. The strengths of concrete and steel bars are determined. The average value of the mechanical properties of concrete cubes is 17.86 MPa. The failure load N is from 384 to 430 kN. The average value of the mechanical properties of concrete prisms

is 16.30 MPa. The failure load N is from 331 to 427 kN. The average strength of the reinforcement is 279.74 MPa. This strength is sufficient for the structures under study. thus, the proposed technology for the production of concrete mix is acceptable. It allows you to get a durable material. This also applies to fittings. The adopted reinforcement provides the necessary rigidity and strength of the slab ribs. The technology of concreting samples is quite simple to manufacture and does not require special equipment, which makes it cost-effective.

References

1. Alvarez Rabanal FP, Guerrero-Muñoz J, Alonso-Martinez M, Martinez-Martinez JE (2016) Bending and shear experimental tests and numerical analysis of composite slabs made up of lightweight concrete. J Eng. 2016:Article ID 6819190. https://doi.org/10.1155/2016/6819190
2. Charif A, Mourad SM, Khan MI (2016) Flexural behavior of beams reinforced with steel bars exceeding the nominal yield strength. Latin Am J Solids Struct 13(5):945–963
3. Dass G, Talwar M (2017) Review paper on Ferrocement in construction. Int J Adv Res Comput Sci 8(4):384–386
4. DSTU B V.2.7–224:2009 (2010). Betony. Pravyla Kontroliu Mitsnosti
5. Gasii GM (2014) Technological and design features of flat-rod elements with usage of composite reinforced concrete. Metal Min Ind 4:23–25
6. Gu X, Jin X, Zhou Y (2016) Basic Principles of Concrete Structures. Springer, Berlin
7. Hedaoo NA, Gupta LM, Ronghe GN (2012) Design of composite slabs with profiled steel decking: a comparison between experimental and analytical studies. Int J Adv Struct Eng 4(1):1–15
8. Fawzi NM, Jalawi A (2020) Quality control of production lightweight ferrocement plate using sustainable materials. Key Eng Mater 857:10–14
9. Kaish ABMA, Jamil M, Raman SN, Zain MFM, Nahar L (2018) Ferrocement composites for strengthening of concrete columns: a review. Constr Build Mater 160:326–340
10. Leon RT, Perea T, Rassati GA, Lange J (2011, February) Composite construction in steel and concrete VI. American Society of Civil Engineers
11. Liu B, Zhang Z, Zhang M, Wang X (2019) Experimental study of the mechanical performance of corrugated steel plate-concrete composite structures. Int J Steel Struct 19(3):733–746
12. Lysenko E F (1981) Armocementnye konstrukcii: ucheb. Vishcha shkola.
13. Madadi A, Eskandari-Naddaf H, Shadnia R, Zhang L (2018) Digital image correlation to characterize the flexural behavior of lightweight ferrocement slab panels. Constr Build Mater 189:967–977
14. Madadi A, Eskandari-Naddaf H, Shadnia R, Zhang L (2018) Characterization of ferrocement slab panels containing lightweight expanded clay aggregate using digital image correlation technique. Constr Build Mater 180:464–476
15. Madadi A, Tasdighi M, Eskandari-Naddaf H (2019) Structural response of ferrocement panels incorporating lightweight expanded clay and perlite aggregates: experimental, theoretical and statistical analysis. Eng Struct 188:382–393
16. Mughal UA, Saleem MA, Abbas S (2019) Comparative study of ferrocement panels reinforced with galvanized iron and polypropylene meshes. Constr Build Mater 210:40–47
17. Murali G, Amran M, Fediuk R, Vatin N, Raman SN, Maithreyi G, Sumathi A (2020) Structural behavior of fibrous-ferrocement panel subjected to flexural and impact loads. Materials 13(24):5648
18. Naderpour H, Eidgahee DR, Fakharian P, Rafiean AH, Kalantari SM (2020) A new proposed approach for moment capacity estimation of ferrocement members using group method of data handling. Eng Sci Technol Int J 23(2):382–391

19. Nervi PL (1965) Aesthetics and Technology in Building. Harvard University Press, Cambridge
20. Patil SS, Gaidhankar DG, Kulkarni MS (2020) Ferrocement panels under flexure by partial replacement of cement With marble powder. IJITEE 9(8):255–260
21. Shaaban IG, Shaheen YB, Elsayed EL, Kamal OA, Adesina PA (2018) Flexural characteristics of lightweight ferrocement beams with various types of core materials and mesh reinforcement. Constr Build Mater 171:802–816
22. Shaheen YB, Abusafa HM (2017) Structural behavior for rehabilitation ferrocement plates previously damaged by impact loads. Case Stud Constr Mater 6:72–90
23. Shaheen YB, Etman ZA, Gomaa O (2019) Structural behavior of thin ferrocement plates with and without stiffeners subjected to compression loading. Asian J Civil Eng 20(2):237–260
24. Soman M, Mohan J (2018) Rehabilitation of RC columns using ferrocement jacketing. Constr Build Mater 181:156–162
25. Storozhenko LI, Tymoshenko VM, Nyzhnyk OV, Gasii GM, Murza SO (2008) Research and Design of Composite Steel and Concrete Space Structural Designs. ASMI, Poltava
26. Storozhenko LI, Gasii GM, Gapchenko SA (2015) Space Steel and Concrete Grid-Gable Roofs. ASMI, Poltava
27. Wang W, Song J, Hou M, Liu G, Wang W (2019) Experimental study and numerical simulation of replaceable corrugated steel plate-concrete composite shear walls. Soil Dyn Earthq Eng 127:105827
28. Yang Y, Liu R, Huo X, Zhou X, Roeder CW (2018) Static experiment on mechanical behavior of innovative flat steel plate-concrete composite slabs. Int J Steel Struct 18(2):473–485
29. Yardim Y (2018) Review of research on the application of ferrocement in composite precast slabs. Periodica Polytech Civil Eng 62(4):1030–1038
30. Leshchenko MV, Semko V (2015) Thermal characteristics of the external walling made of cold-formed steel studs and polystyrene concrete. Mag Civil Eng 60(8):44–55. https://doi.org/10.5862/MCE.60.6
31. Kochkarev D, Azizov T, Galinska T (2018) Bending deflection reinforced concrete elements determination. In: MATEC Web of Conferences, vol 230. https://doi.org/10.1051/matecconf/201823002012
32. Korobko B (2016) Investigation of energy consumption in the course of plastering machine's work. Eastern-Eur J Enterp Technol 4(8–82):4–11. https://doi.org/10.15587/1729-4061.2016.73336
33. Loburets AT, Naumovets AG, Senenko NB, Vedula YS (1997) Surface diffusion and phase transitions in strontium overlayers on W(112). Zeitschrift Fur Physikalische Chemie 202(1–2):75–85. https://doi.org/10.1524/zpch.1997.202.part_1_2.075
34. Pavlenko A, Koshlak H (2015) Design of processes of thermal bloating of silicates. Metall Min Ind 7(1):118–122
35. Pichugin SF (2018) Reliability estimation of industrial building structures. Mag Civil Eng 83(7):24–37. https://doi.org/10.18720/MCE.83.3
36. Popova AV, Kremenetsky VG, Solov'ev VV, Chernenko LA, Kremenetskaya OV, Fofanov AD, Kuznetsov SA (2010) Standard rate constants of charge transfer for nb(V)/Nb(IV) redox couple in chloride-fluoride melts: experimental and calculation methods. Russ J Electrochem 46(6):671–679. https://doi.org/10.1134/S1023193510060121