COMPUTATIONAL SIMULATION OF COMPOSITE STEEL- CONCRETE SHEAR WALLS WITH VERTICAL STEEL ENCASED PROFILES. COMPARATIVE EVALUATION WITH EXPERIMENTAL RESULTS.

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1. ABSTRACT

Composite steel-concrete walls (CSRCW) are generated from reinforced concrete walls that are enhanced with structural steel elements. This paper, through the development of a three-dimensional finite element model by the use of the ANSYS software package, studies the mechanical properties of composite shear walls with vertical steel encased profiles and their resulting failure mode. The steel encased elements (I-shaped steel profiles) are simulated as distinct finite elements. Headed steel studs ensure the cooperation of the steel profiles and the concrete part of the composite shear wall. The contact conditions at the interface of steel and concrete of the FEM model describe the mechanical and the shear bond between the two parts of the CSRCW. The dimensions of the wall are 1 by 3 by 0.1 meters. The computational analysis has been performed using an incremental-iterative procedure. The composite shear walls with encased steel profiles are found to be more ductile than reinforced concrete walls and they have a bending failure mode. The numerical results of the finite element model are evaluated after comparison to experimental ones, from the international literature [1, 2].

2. INTRODUCTION

Structures are designed to resist vertical and horizontal loads (such as earthquake). Composite steel- concrete walls (CSRCW) are structural members that are able to resist high in-plane lateral loads at low displacement values [1, 2]. Composite shear walls are generated from reinforced concrete walls that are enhanced partially or fully encased with steel profiles, usually placed in the end of the cross section of the composite shear wall. The structural steel profiles can vary but mainly I- shaped structural steel profiles are used.

Headed shear studs ensure the composite connection between reinforced concrete and steel profile [3]. These walls are type 2- composite shear walls, according to Eurocode 8 [4, 5].

3. DESCRIPTION OF THE COMPOSITE SHEAR WALL UNDER STUDY

The composite shear wall under investigation has two I-shaped steel profiles at the both ends of the cross section. The structural steel profiles are partially encased in the concrete. The width of each profile is 7 cm and the height is 10 cm. The width of the web and the flanges is common and it is 0,7 cm. The width of the concrete varies between 0,86 and 0,93 meters. The total dimensions of the wall (without the reinforced concrete foundation) are 1 by 3 by 0.1 (width* height* depth) in meters.

The full composite connection between the steel profile and the internal reinforced concrete wall is accomplished by the use of shear studs. The shear studs are welded to the web of the steel profile [2].

4. NUMERICAL SIMULATION

A three- dimensional numerical model has been created using ANSYS Finite Element Model simulation package [6, 7]. The whole composite wall has been modeled. The element mesh of the model is shown in *Fig. 1*. The cross-section of the composite wall is depicted in *Fig. 2*.
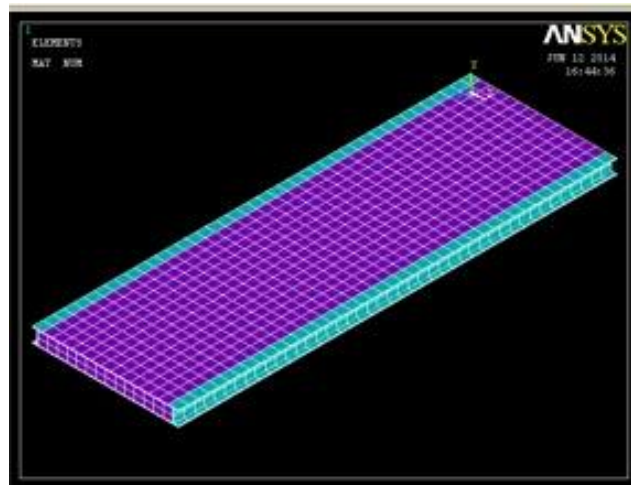

Fig. 1: Finite element mesh

The concrete part of the wall has been modelled using Solid65 finite element. This element has eight nodes and has the ability to crack in tension and to crush in compression. The options for nonlinear material property, large plastic deformation and element birth and death attributes have been selected. The non-linear material simulation of the ANSYS software program has been used (William-Warnke yield criterion) [6]. The failure surface of the concrete is defined by five strength input parameters. The shear transfer coefficients for an open crack and for a closed crack were 0,3 and 1 respectively. The stress relaxation coefficient was equal to the default value of 0,6. The characteristic yield stress in compression has been determined at 65,6 MPa and the modulus of elasticity at 38,68 GPa. The ultimate tensile stress has been determined at 7 MPa. The density of the reinforced

concrete has been determined at 2500 Kgr/m^3. The Poisson ratio for concrete has been assumed as 0,2 [7, 8, 9].
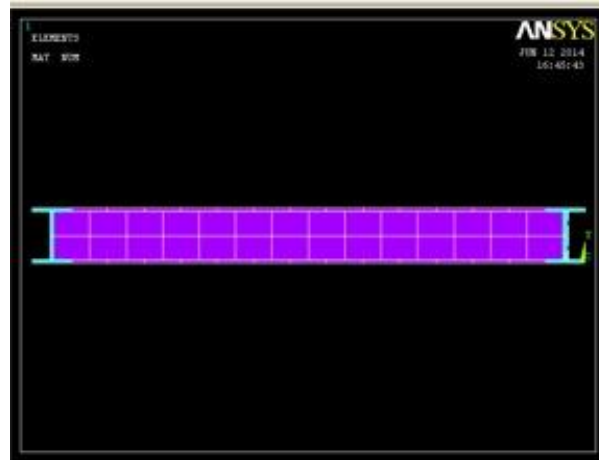

Fig. 2: Cross-section

The constitutive material law selected for steel has been bilinear elastoplastic-strain hardening using the von Mises stress yield criterion. Steel has been assumed to be homogenous [7, 9, 10]. The yield stress for the steel in tension has been determined at 355 MPa and the modulus of elasticity at 210 GPa. The density of steel has been determined at 7850 Kgr/m^3. The Poisson ratio for steel has been assumed as 0,3. The material law is depicted in *Fig. 3*.

The contact elements overlay the elements used for the simulation of the steel profile and the concrete wall [6, 10]. The contact status has been modeled as always bonded in order the relative slip at the steel- concrete interface to be deemed negligible. This option is selected to ensure a full composite connection. The friction, which develops in the steel-concrete interface, has been taken into consideration with a constant friction coefficient of 0,3. ANSYS uses the Coulomb friction model, which is adequate for our problem [6, 9, 10]. The composite shear wall has been assumed as a cantilever beam, so fixed boundary conditions have been applied at the base nodes of the composite shear wall, as shown in *Fig. 4*.
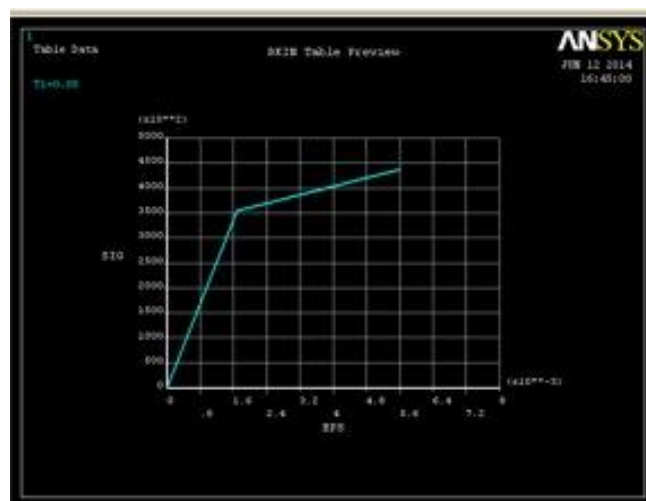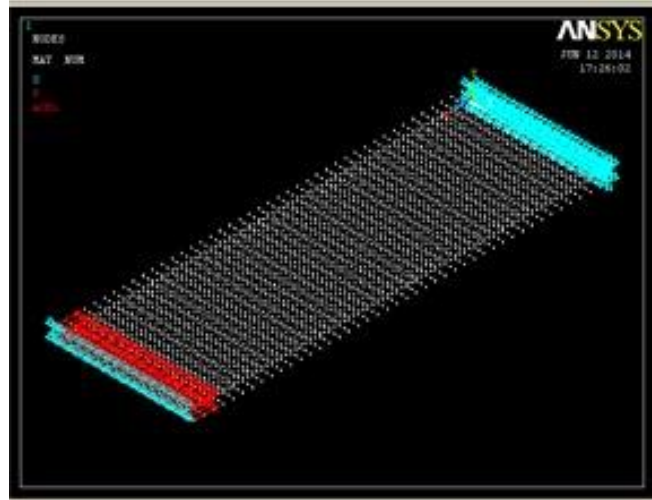

Fig. 3: Material law for steel

Fig. 4: Support and loading conditions

The vertical load has been applied at full value of 100 kN, as static forces, at the higher nodes (3 m) of the numerical model [2]. The horizontal load was applied in displacement increments (substeps) until failure [1, 2]. The support and loading conditions coincide with those of the international literature [2].

The analysis performed is transient with ramped loading [6]. ANSYS uses the Newton-Raphson method as an incremental-iterative solution process [6, 8, 9]. Both the normal and the tangential stiffness matrix are updated after iteration [6, 10]. The convergence procedure is force-based and thus considered absolute [6, 7, 8].

5. NUMERICAL RESULTS

The following *Fig. 5* to *9*, present the computational results. In *Fig. 5* the deformed shape of the composite shear wall under maximum load is depicted.
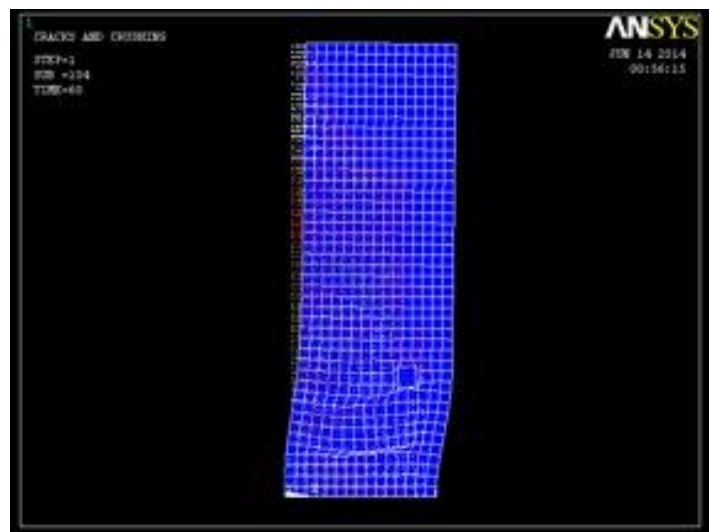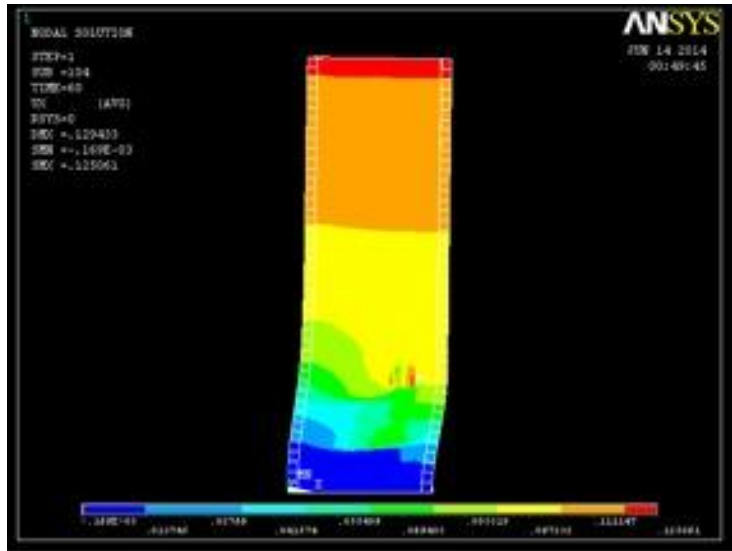

Fig. 5: Deformed shape

Fig. 6: Horizontal displacement [m]

The maximum load has been found equal to 342,6 kN. The maximum horizontal displacement has been calculated equal to 125,061 mm, as shown in *Fig. 6*. The latter value was measured when the maximum load bearing capacity has been achieved.
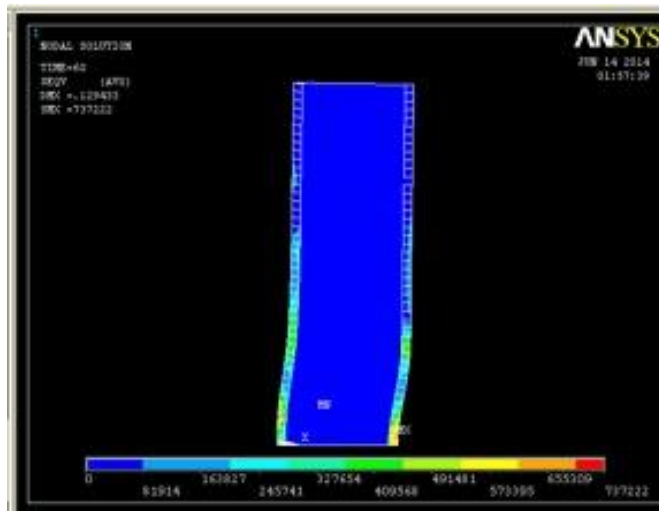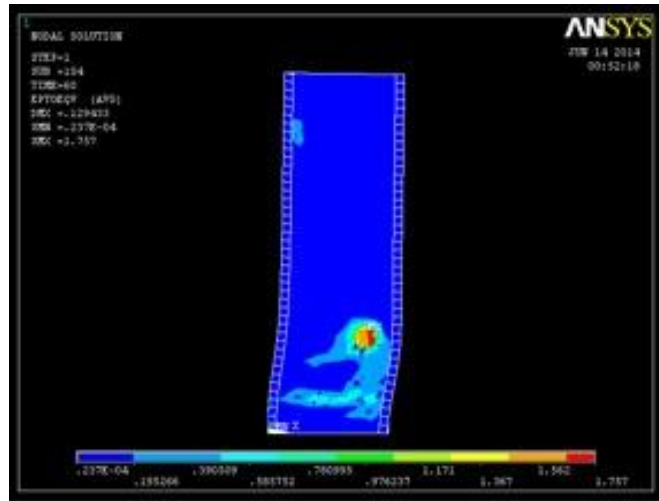

Fig. 7: Von Mises stresses [kPa]

Fig. 8: Von Mises strains [m]

The von Mises stresses and strains are depicted in *Fig. 7* and *Fig. 8,* respectively. The concrete has crushed in the compression zone and the steel has yielded in the tension zone.

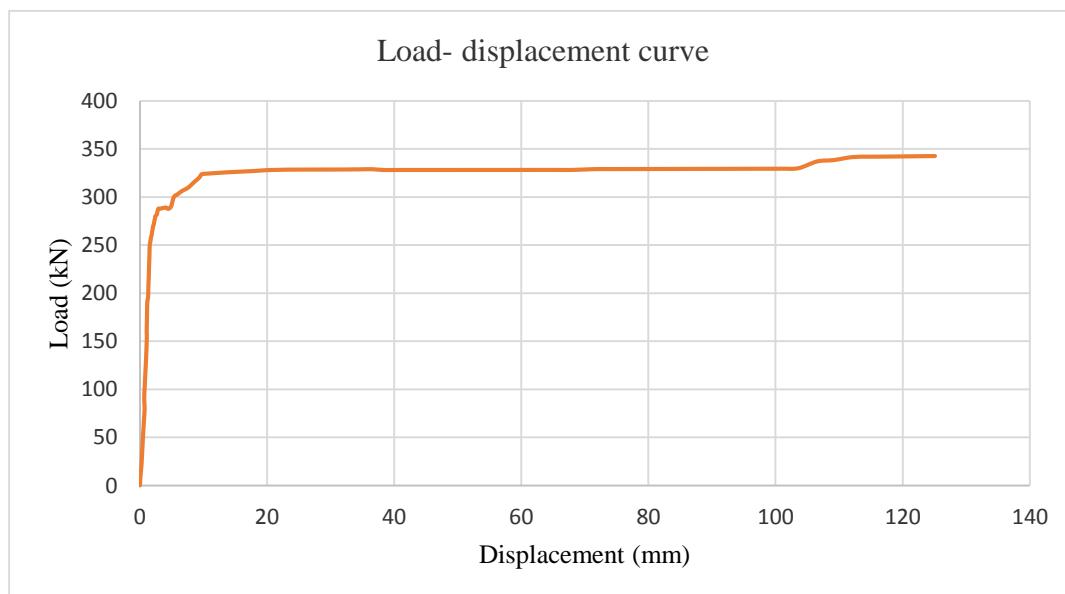The load-horizontal displacement curve of the composite shear wall is plotted in *Fig. 9*.

Fig. 9: Load-displacement curve

6. COMPARISON-CONCLUSIONS

The results of the proposed finite element simulation have been compared with numerical and experimental ones from the international literature [1, 2].
- The composite shear wall under study has a bending failure mode.
- The ultimate load capacity of the composite wall is 333,1 kN (numerical)/ 357,3 kN (experiment) and the maximum horizontal displacement is 117,9 mm (numerical)/ 115,1

mm (experiment) in the international literature. The equivalent outcomes in the current study are 342,6 kN and 125,061 mm respectively.

- No significant slip at the interface of the reinforced concrete wall and the structural steel profile has been measured during the numerical analysis, as expected.

- The load–displacement curves produced by the numerical approach of the problem are in close agreement with the load–displacement curves produced during the numerical study performed before the experiment [1, 2]. The experimental curves produced during the experiment [2], are also in agreement with the proposed numerical simulation.

- The load- displacement curves produced from cyclic loading during the experiment cannot be directly compared with the outcomes of the proposed numerical model. Nevertheless, the load- displacement curves of the current numerical analysis can be used as the envelope of the hysteretic curves. The authors, in future research study, aim to implement sinusoidal cyclic loading in the model.

- The proposed three-dimensional numerical model, for the type 2 composite shear wall (CSRCW), is simple to build (approximately 1 hour) and demands little computational time to run (approximately 3 hours). The model can be used as an effective design tool for steel and composite structures.

- Concrete has been modelled with smeared reinforcement for simplicity reasons. Smeared reinforcements produce accurate results, very close to models with discrete reinforcement [11].

7. REFERENCES

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ΥΠΟΛΟΓΙΣΤΙΚΗ ΠΡΟΣΟΜΟΙΩΣΗ ΣΥΜΜΙΚΤΩΝ ΤΟΙΧΩΜΑΤΩΝ ΜΕ ΕΓΚΙΒΩΤΙΣΜΕΝΑ ΣΕ ΣΚΥΡΟΔΕΜΑ ΜΕΤΑΛΛΙΚΑ ΠΡΟΦΙΛ. ΣΥΓΚΡΙΤΙΚΗ ΑΞΙΟΛΟΓΗΣΗ ΜΕ ΠΕΙΡΑΜΑΤΙΚΑ ΑΠΟΤΕΛΕΣΜΑΤΑ.

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ΠΕΡΙΛΗΨΗ

Τα σύμμικτα τοιχώματα (τύπου CSRCW) αποτελούνται από τοίχωμα οπλισμένου σκυροδέματος στο οποίο έχουν εγκιβωτιστεί μερικώς ή πλήρως μεταλλικά προφίλ. Η παρούσα εργασία., μέσα από τη δημιουργία ενός τρισδιάστατου προσομοιώματος σύμμικτου τοιχώματος με χρήση πεπερασμένων στοιχείων, αποσκοπεί στην μελέτη των μηχανικών χαρακτηριστικών και της μορφής αστοχίας τέτοιων δομικών μελών. Τα μεταλλικά προφίλ μορφής διπλού ταυ μοντελοποιούνται ως διακριτά στοιχεία ενώ οι σύνδεσμοι διάτμησης σαν στοιχεία επαφής, που καθορίζουν τη σύμμικτη λειτουργία σκυροδέματος και χάλυβα. Ταυτόχρονα, ο μηχανικός και διατμητικός δεσμός στη διεπιφάνεια επαφής περιγράφεται με τα στοιχεία επαφής. Το τοίχωμα έχει διαστάσεις 1 επί 3 επί 0,1 μέτρα. Η υπολογιστική ανάλυση είναι μη-γραμμική και κάνει χρήση της μεθόδου αυξήσεων-επαναλήψεων. Τα σύμμικτα τοιχώματα είναι πιο πλάστιμα από τα τοιχώματα οπλισμένου σκυροδέματος. Τα αποτελέσματα της υπολογιστική ανάλυσης συγκρίνονται με αντίστοιχα πειραματικά, από τη διεθνή βιβλιογραφία.