Dynamic behavior of composite floor consisting profiled steel sheet and dry board under explosion load

Farhad Abbas Gandomkar[1*], Saeed Parsafar[2], Vahid Razavi Tosee[3], Negar Samimifard[4]

[1]Assisstant Professor, Department of Structure, Faculty of Civil Engineering, Jundi-Shapur University of Technology, Dezful, Iran, Farhad@jsu.ac.ir, 00986142428000
[2]Assisstant Professor, Department of Structure, Faculty of Civil Engineering, Jundi-Shapur University of Technology, Dezful, Iran, Parsafar@jsu.ac.ir, 00986142428000
[3]Assisstant Professor, Department of Structure, Faculty of Civil Engineering, Jundi-Shapur University of Technology, Dezful, Iran, Vrazavi@jsu.ac.ir, 00986142428000
[4]MSc in Structural Engineering, Department of Structure, Faculty of Civil Engineering, Jundi-Shapur University of Technology, Dezful, Iran, Samimifard.civil@gmail.com, 00986142428000

ABSTRACT

One of the kinds of structural floor systems is consisting of profiled steel sheet and dry board which connected to each other by self-drilling and self-tapping screws. The aim of this research is study on the behavior of mentioned floor under explosion load. For this purpose, effects of various parameters such as: thickness of dry board and profiled steel sheet, kind of dry board, screw spacing, boundary conditions, floor dimensions, using of double profiled steel sheet and dry board, and also weight and distance of explosive material from the center of floor, on the nonlinear dynamic behavior of the mentioned floor are studied. This study is performed by using numerical finite element method taking advantage of ABAQUS software. The research results show by varying parameters such as: thickness and kind of dry board, dimensions and boundary conditions of floor, using of double profiled steel sheet and dry board, and also distance and weight of explosive materials, significant changes are created in maximum displacement and strain energy of floor, but varying other above mentioned parameters not create important changes in them. The profiled steel sheet and dry board reach to their yield stresses under various conditions, though in many conditions they not reach to their yield stresses. The results of current research present great help to researchers and designers in identification effective and ineffective parameters on the behavior of studied floor under explosion load.

KEYWORDS

Explosion, Composite floor system, Finite element, Nonlinear dynamic analysis, PSSDB.

* Corresponding Author: Email: Farhad@jsu.ac.ir

1. Introduction

One of the structural composite floor systems is consisting of Profiled Steel Sheet (PSS) and Dry Board (DB) which connected to each other by self-drilling and self-tapping screws. This system is known as Profiled Steel Sheet Dry Board (PSSDB) and introduced by Wright and Evans in 1986 [1] and also Wright et al. in 1989 [2]. The central core of the system is PSS and DB is screwed to PSS in one layer or two layers [2]. In addition, this system may be made by two layers of the PSS and DB, which the recent system is known as Double Profiled Steel Sheet Double Dry Board (DPSSDDB) [3]. Figure 1 shows components of the PSSDB system.

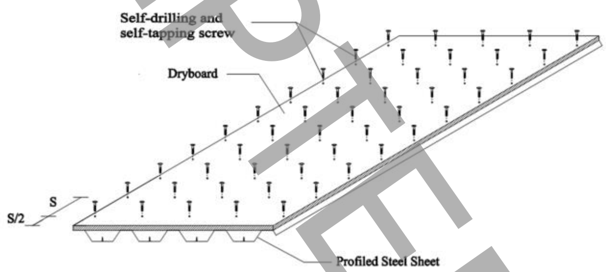

Figure 1. PSSDB system [4]

In the last decades, many studies were performed about effects of explosion load on dynamic behavior of structures. In this case, dynamic behaviors of various floor systems under explosion load were examined. In the recent studies, Iannitti et al. performed a study on the dynamic behavior of reinforced concrete slabs under explosion load [5]. Also, Abdel Wahab et al. investigated dynamic behavior of composite V shape panel under explosion load [6]. Based on accomplished studies, no research was found on revealing dynamic behavior of the PSSDB or DPSSDDB system under explosion load. Therefore, the main aim of this study is investigating dynamic behaviors of the PSSDB and DPSSDDB systems under explosion load. For this purpose, effects of various parameters such as: thickness of PSS and DB, kind of DB, screw spacing, floor dimensions, boundary conditions, using of double PSS and double DB, distance and weight of explosive materials, are evaluated on the dynamic behavior of the studied systems.

2. Methodology

Results of current study obtain from numerical finite element method, implemented by ABAQUS software. The option of CONWEP is utilized to apply the explosion load on the surface of DB. In the current study, explosion load is applied on the system in various weight and distance from center of DB. First, modal analysis performed on all structural models of the studied systems, to extract their natural frequencies. Second, for the all structural models, Rayleigh coefficients calculated by the first and fourth natural frequencies of the structural models and also damping ratio of 1.1% which measured by Gandomkar et al. [7] for the studied system. Third, nonlinear dynamic time history analysis performed on the structural models.

3. Results and discussion

Due to the main objective and the sub objectives of the study, 28 structural models were simulated to show the effects of various parameters on the dynamic behavior of system under explosion load. These models were verified by the study of Gandomkar et al. [5]. A model is considered as a base model with 0.8 mm thickness of PSS, 18 mm thickness of DB (Plywood), 200 mm screw spacing, 2385 mm width, 2800 mm length, and both ends simply supports, under loading of 10 kg TNT as explosive material with 2 m distance of TNT from the center of DB. For this model, time history of strain energy, time history of displacement at the center of DB and also von Mises stress contour are shown in Figures 2, 3 and 4.

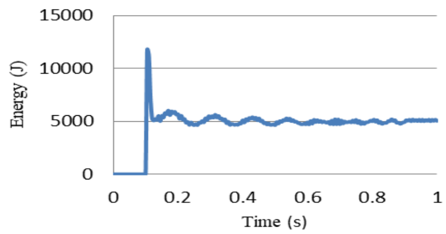

Figure 2. Time history of strain energy in the base model

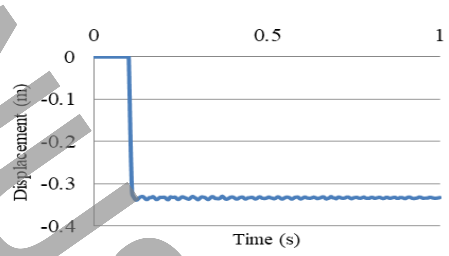

Figure 3. Time history of displacement at the center of DB in the base model

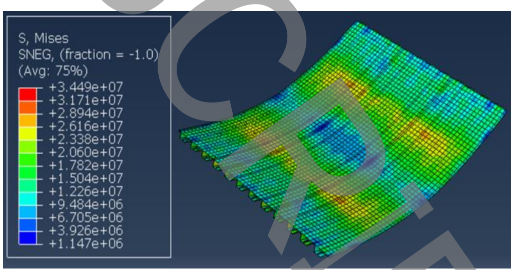

Figure 4. von Mises stress contour in the base model

The explosion load applies on the system in time of 0.1 second. According to Figure 2 and 3, it is shown a gap in time of 0.1 second. After that, meaningful changes can be seen in strain energy and displacement time histories, and so free vibration behavior of studied system is shown after the time of 0.1 second. By using Figure 4 can extracted maximum von Mises stresses in PSS and DB. These stresses compare with the yield stresses of PSS and DB materials to show their yielding.

The results uncovered by decreasing thickness of Plywood as DB from 18 mm to 12 mm, maximum displacement increased by 76.35% and maximum strain energy decreased by 29.29%. In addition, by increasing thickness of PSS from 0.8 mm to 1.0 mm, maximum displacement decreased by 5.63% and maximum strain energy increased by 0.6%. Also, the results showed varying kind of DB changed maximum displacement and strain energy of the system, greatly. Furthermore, by reducing screw spacing from 200 mm to 100 mm maximum displacement of system decreased by 2.69%. Also, by increasing screw spacing from 200 mm to 300 mm, maximum displacement of floor system increased by 2.29%. Moreover, when screw spacing increased from 200 mm to 300 mm, maximum strain energy of the system reduced by only 1.78%. The results revealed by increasing width of the system from 795 mm to 3975 mm, maximum displacement decreased by 22.14% and maximum strain energy increased by 364.13%. Also, by increasing length of system from 2000 mm to 3200 mm, maximum displacement and strain energy increased by 62.37% and 41.27%, respectively. The results showed varying supports of system from Pin-Pin in two sides of system (perpendicular on length of system) to Pin-Roller, maximum displacement and strain energy increased by 165.48% and 13.21%, respectively. On the other hand, by changing supports from Pin-Pin to four pin supports in four sides of system, maximum displacement decreased by 30.56% and maximum strain energy increased by 61.44%. In addition, by converting PSSDB system to DPSSDDB system, maximum displacement not changed much, but maximum strain energy reduced by 45.63%. Also, by varying supports in both ends of DPSSDDB system, maximum displacement and strain energy changed by 36.28% and 23.02%, respectively. Furthermore, it was shown by changing distance of TNT from center of DB from 2 m to 14 m, when weight of TNT was constant and equal to 10 kg, maximum displacement decreased by 77.08% and maximum strain energy reduced manifold. In the end, the results revealed by increasing weight of TNT from 10 kg to 30 kg, when distance of TNT from center of DB was constant and equal to 2 m, maximum displacement and strain energy increased by 253.86% and 33.34%, respectively.

By comparing the von Mises stresses of PSS and DB with their yield stresses, it was uncovered unknown effects of studied parameters on conditions of yielding PSS and DB.

4. Conclusion

This paper investigates nonlinear dynamic behaviors of the PSSDB and DPSSDDB systems under explosion load by using numerical finite element method. The results are extracted from ABAQUS software. Effects of changing various parameters such as: thickness of DB and PSS, kind of DB, screw spacing, boundary conditions, floor dimensions, distance and weight of explosive load, and also using of double PSS and double DB, are investigated on mentioned behaviors. The results of study show changing thickness of DB, kind of DB, floor dimensions, boundary conditions, weight and distance of explosive load, and also using of double PSS and double DB, have considerable effects on varying displacement and strain energy of the system. On the other hand, changing screw spacing and thickness of PSS have not much effect of their changes. Based on the sub objectives of this study, the PSS and DB reach to their yield stresses in some of conditions, but not reach in some other conditions.

5. References

[1] H. Wright, H. Evans, Profiled steel sheeting for the replacement of timber flooring in building renovation, SERC Grant GR/D/76875, in, United Kingdom, 1986.
[2] H. Wright, H. Evans, C. Burt, Profiled steel sheet/dry boarding composite floors, Structural Engineer, 67 (1989) 114-120.
[3] F. Sharafi, F.A. Gandomkar, Fundamental natural frequency in structural composite floor constructed of two profiled steel sheet and two dry board, in: 4th International Congress of Civil, Architecture and Urban Development, Shahid Beheshti University, Iran, 2016 (in persian).
[4] F.A. Gandomkar, Determining comfort level of profiled steel sheeting dry board floor system, Ph.D Thesis, National University of Malaysia, 2012.
[5] G. Iannitti, N. Bonora, G. Curiale, S. De Muro, S. Marfia, A. Ruggiero, E. Sacco, S. Scafati, G. Testa, Analysis of reinforced concrete slabs under blast loading, Procedia Structural Integrity, 9 (2018) 272-278.
[6] M. Abdel Wahab, S. Mazek, M. Abada, M. Abdel Shafy, Blast hazard impact on V-shape composite panel performance, Journal of Engineering Science and Military Technologies, 2(2) (2018) 90-99.
[7] F.A. Gandomkar, W.H. Wan Badaruzzaman, S.A. Osman, A. Ismail, Experimental and numerical investigation of the natural frequencies of the composite profiled steel sheet dry board (PSSDB) system, Journal of the South African Institution of Civil Engineering, 55(1) (2013) 11-21.