

# EFFECTS OF SHEAR STUDS AND OPENINGS IN THE MECHANICAL PERFORMANCE OF COMPOSITE FLOOR DECK USING FINITE ELEMENT ANALYSIS

Ahmad Mahamad Al-Yacouby, Abdul Rais Abdul Rashid

Department of Civil & Environmental Engineering, Universiti Teknologi PETRONAS, Malaysia

\*E-mail: ahmad.alyacouby@utp.edu.my

## ABSTRACT

*The composite floor deck system is the most popular floor system used in the construction industry, especially in industrial structures. A composite floor deck is a floor system that consists of a steel deck bonded with concrete. The shear bond between the steel deck and concrete slab normally controls the shear capacity of a composite floor deck system. In the current construction industry, shear studs are normally used to improve the shear performance of the structure. However, the literature review shows that there were very limited studies on identifying the efficiency of these shear studs and their effects on the composite floors' mechanical performance. In addition, there were always openings for M&E equipment in the floor deck system, which needs further analysis to determine their effects on the mechanical performance of the composite floor deck system. Thus, the main objective of this study was to identify the effects of shear studs and openings on the mechanical performance of composite floor decks. The method adopted in this study was the Finite Element Analysis (FEA) using ANSYS software. The outcome of the result has shown that the presence of shear studs improves the mechanical performance of a composite floor deck while the presence of openings reduces the mechanical performance of a composite floor deck system.*

**Keywords:** composite floor deck, opening, shear studs, mechanical performance

## INTRODUCTION

A composite floor deck is defined as a floor system consisting of steel and concrete bonds to achieve high strength to withstand high pressure and load. The bond between steel and concrete is very important to ensure the floor system has high compressive strength. The bond between steel deck and concrete normally determines the load-bearing capacity of the composite deck [1]. The shear bond is mainly due to the presence of mechanical gears, which are created by the use of embossing in the deck webs during the rolling process. However, the level of shear strength between concrete and steel can also vary depending on the deck profile, steel thickness and grade, coating, as well as the deck position, i.e. normal or inverted [2]. A typical example of a composite floor deck cross-section is shown in Figure 1. The shear studs are usually welded to the metal component of the composite floor deck system. Many factors affect the strength behaviour of

the shear studs, such as the size, the arrangement, and the number of shear studs on the composite floor deck. The most widely used shear connectors in building construction are headed shear studs, typically with a diameter of 19 mm, a height of 100 mm, and a tensile strength of 450 N/mm<sup>2</sup>.

Furthermore, openings are also one of the important features of a composite floor deck system. Openings on composite floor decks are usually required for mechanical and electrical services equipment. Therefore, it is important to study the effects of these openings on the mechanical performance of the composite floor deck to identify the changes in stress and load-bearing capacity. The literature review shows that extensive research has been carried out on the progressive collapse of steel structures to develop design methods to prevent or mitigate the progressive

collapse [3]. However, there were very limited studies addressing the effects of shear studs and openings on the mechanical properties of slabs. Thus, the main objective of this paper is to study the effects of shear studs and openings on the mechanical performance of composite floor decks using the FEA method using ANSYS software. The effect of shear studs on the mechanical performance of composite floor deck systems was investigated by varying parameters such as the number of shear studs and their arrangements. Further, the effect of openings on the mechanical performance of composite floor deck systems was determined by varying the location and sizes of openings.

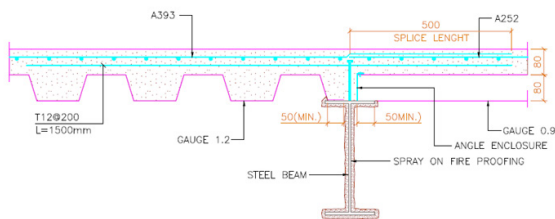


Figure 1 Typical composite floor deck cross-section

### Importance of Shear Studs in Composite Floor Deck

Shear studs are usually used in composite floor deck systems to strengthen the floor deck and to improve the load-bearing capacity of the floor deck system. Hassanin et al. [4] reported that shear connector studs are the key tool to connect the steel I-beam to the concrete slab to achieve the required bond effect. The arrangement of shear studs on the composite floor deck can be done in pairs or staggered, depending on the design requirements and specifications. There are several types of shear connectors in the construction industry, such as headed studs, perfobond ribs, t-rib connectors, t connectors, channel connectors, and rectangular-shaped collar connectors. In this project, the headed shear studs are used as the shear connectors for the composite floor deck. According to Muhit [5], this type of connector contributes to the shear transfer and prevents uplift, as it is designed to work as an arc welding electrode and simultaneously acts as the resisting connector with a suitable head after the welding.

### Importance of Openings in Composite Floor Deck

In the construction industry, openings in slabs are normally required for plumbing, firefighting systems, ventilation ducts, heating and air conditioning. The position and size of the required openings are usually specified in the early design stages and adjusted accordingly [6].

According to Mota and Kamara [6], a two-way slab system is divided into column and middle strips in two perpendicular directions for design. The column strip width on each side of the column centre line equals one-quarter the length of the shorter span in the two perpendicular directions. The middle strip is the strip bounded by two column strips. ACI 318 gives the following guidelines for opening sizes in different locations for slabs without beams:

1. In the area common to intersecting middle strips, openings of any size are permitted.
2. In the area common to intersecting column strips, the maximum permitted opening size is one-eighth the width of the column strip in either span.

In the area common to one column strip and one middle strip, the maximum permitted opening size is limited. Only a maximum of one-quarter of slab reinforcement in either strip may be interrupted.

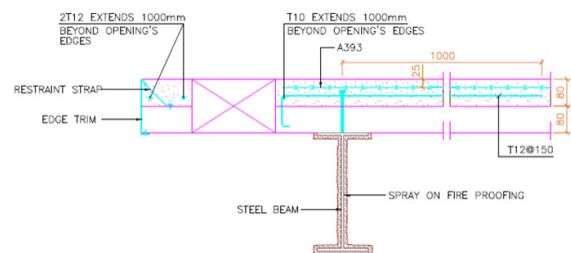


Figure 2 Typical openings provided on a composite floor deck

### THEORETICAL BACKGROUND

Composite slabs normally provide lateral restraint to steel beams to act as a diaphragm to resist horizontal actions. Thus, when shear connectors are provided in a composite floor system, the combination of forces acting on shear studs should satisfy the following equation [7]:

$$\frac{F_l^2}{P_{l,Rd}^2} + \frac{F_t^2}{P_{t,Rd}^2} \leq 1 \quad (1)$$

where,  $F_1$  is the design longitudinal force caused by composite action in the beam;  $F_t$  is the design transverse force caused by composite action in the slab, and  $P_{t,Rd}$  is the corresponding design shear resistances of the stud. According to Eurocode 4 [7], the maximum design vertical shear  $V_{t,sd}$  for the slab width,  $b$ , is limited due to the longitudinal shear resistance to  $V_{L,Rd}$  given as follows:

$$V_{L,Rd} = b d_p \left( m \frac{A_p}{b L_s} + k \right) \frac{1}{\gamma_{VS}} \quad (2)$$

where  $k$  and  $m$  (in  $N/mm^2$ ) are the ordinates at the origin, and the slope of the  $m$ - $k$  line, and  $\gamma_{VS}$  is a partial safety factor equal to 1.25. The factors  $m$  and  $k$  are obtained from standardised full-scale tests. The  $m$  and  $k$  values depend on the sheeting type and the dimensions of the slab section and are generally given by profiled steel manufacturers. For further details on the composite floor deck related papers, the reader can refer to [8]-[22].

**METHODOLOGY**

**Modelling of Composite Floor Deck**

The modelling of the composite floor deck was done using ANSYS software. The main CAD models are designed using SolidWorks software. The main model comprises of metal deck plates and concrete for the composite floor deck system. The main model is then edited to create another eight additional models of composite floor deck as follows:

1. Composite floor deck.
2. Composite floor deck with an opening.
3. Composite floor deck with shear studs.
4. Composite floor deck with opening and shear studs.
5. Composite floor deck with openings of different sizes (200 mm x 200 mm).
6. Composite floor deck with openings at different locations (Centre of the deck).
7. Composite floor deck with different numbers of shear studs (ten shear studs).
8. Composite floor deck with different shear stud arrangements.

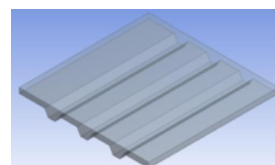
All the composite floor decks have dimensions of 1000 mm x 1000 mm. The dimension of the main opening on the composite floor deck is 120 mm x 120 mm. For the shear stud, the diameter of the head is 25 mm, and the height is 10 mm, whereas, for the leg, the dimension is 20 mm and height is 5 mm, subjected to an applied pressure of  $1 \times 10^6$  Pa. The length of the shear connector is 80 mm. The total height of the shear stud is 110 mm. Table 1 shows all the composite floor deck system components used in the ANSYS software for FEA. Table 2 shows the variables of the main components of the composite floor deck system, while the eight different models of the composite floor deck are presented in Figure 3.

**Table 1** Components of the composite floor deck system used in ANSYS software for FEA

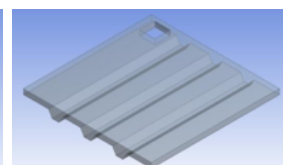
Composite Floor Deck Component	ANSYS material set up
Concrete Slab	Concrete
Shear Studs	Structural Steel

**Table 2** Characteristics of main components of composite floor deck system

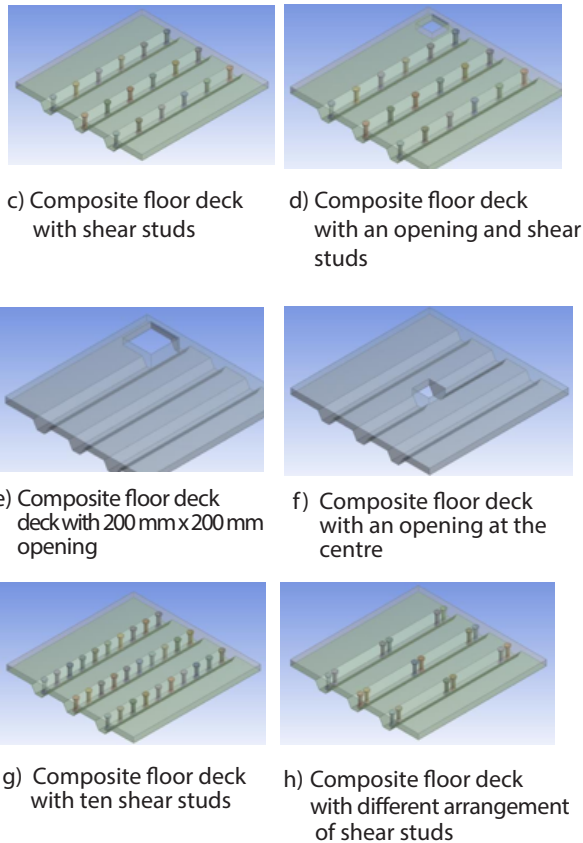
Composite Floor Slab		
Dimension	1 m x 1 m	
Shear Studs		
Number of shear studs	6	10
Arrangement of shear studs	Arranged in order on the slab	Arranged two shear studs close to each other in different locations
Opening		
Size of opening	0.12 m x 0.12 m	0.2 m x 0.2 m
Location of opening	Edge of slab	Centre of slab



a) Composite floor deck



b) Composite floor deck with opening



**Figure 3** The eight models of composite floor deck that are designed in the SolidWorks software

**Mesh Sensitivity Analysis**

Before proceeding with the model analysis, mesh sensitivity analysis was performed to ensure that mesh size is not affecting the analysis outcomes. Thus, several types of meshing were used, namely multizone meshing, inflation meshing, face meshing and edge sizing meshing. Multizone meshing is the main meshing used for the composite floor deck slab, metal deck, and shear studs.

**Analysis of the Model in ANSYS Software**

The first step of the analysis is to import the CAD model of the composite floor deck, which was designed in SOLIDWORKS software, into ANSYS software for FEA. Analysing a structure involves assessing its strength, stiffness, stability, and vibration. This study analysed the composite floor deck using the Static Structural Analysis module in ANSYS software.

**RESULTS AND DISCUSSIONS**

**Composite Floor Deck**

Figure 4 shows the variation of total deformation, maximum shear stress and the equivalent stress

developed on a normal composite floor deck, which was modelled first as the reference model. Deformation refers to modifications of the shape or size of an object due to applied forces. Deformation is usually caused by tensile and compressive forces, whereas, in total deformation, it gives a square root of the sum of the square of the x-direction, y-direction, and z-direction. Next, maximum shear stress is a small area's maximum concentrated shear force. Furthermore, equivalent stress is a scalar derivative of the shear strain energy per unit volume measured at different points in a stressed material. It helps determine the likelihood of the failure of the said material according to the Von Mises failure criteria. From the results presented in Figure 4, it can be observed that the maximum total deformation is 2.06 mm, the maximum shear stress is 383 MPa, and the maximum equivalent stress is 704 MPa.



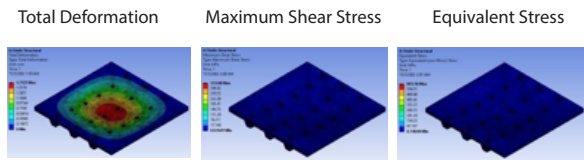
**Figure 4** Variation of total deformation, maximum shear stress and equivalent stress developed on a normal composite floor deck

Figure 5 shows the Finite Elements Results for the composite floor deck with an opening. It can be observed that the maximum total deformation, the maximum shear stress and the maximum equivalent stress are 2.09 mm, 387 MPa and 710 MPa, respectively. Moreover, for the composite floor deck with shear studs, the results presented in Figure 6 show that the maximum total deformation is 1.75 mm, followed by the maximum shear stress of 334 MPa and maximum equivalent stress of 604 MPa.

For the case of a composite floor deck with shear studs and opening, Figure 7 shows that the maximum total deformation is 1.78 mm, followed by a maximum shear stress of 338 MPa and a maximum equivalent stress of 611 MPa.



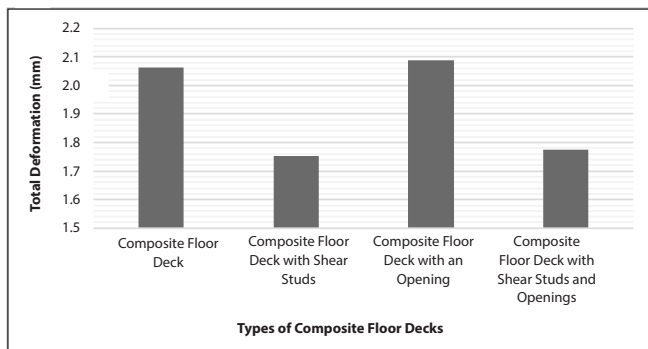
**Figure 5** The variation of total deformation, maximum shear stress, and equivalent stress for the composite floor deck with an opening



**Figure 6** Variation of total deformation, maximum shear stress, and equivalent stress for the composite floor deck with shear studs

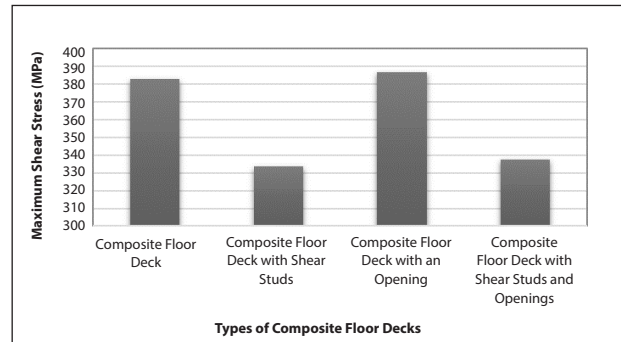


**Figure 7** Variation of total deformation, maximum shear stress, and equivalent stress for the composite floor deck with shear studs and opening



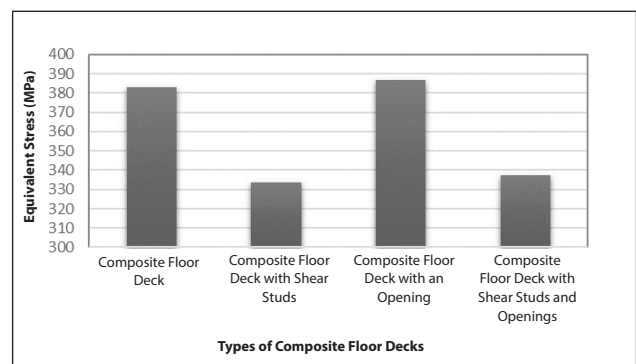
**Figure 8** Variation of total deformation for different models of composite floor deck

Figure 8 compares the total deformation of all four different models of composite floor decks. It can be observed that the composite floor deck with an opening has the highest value of total deformation. This shows that the composite floor deck with an opening has the lowest strength among all the four models investigated in this numerical simulation. The graph also shows that the second highest model in terms of total deformation is the composite floor deck, followed by the composite floor deck with shear studs and opening, and the model that has the lowest total deformation is the composite floor deck with shear studs. From the graph, one can conclude that the strength of the composite floor deck system and endurance was increased when the shear studs were present, and the strength decreased when there was an opening on the composite floor deck system. If the composite floor deck system requires an opening for construction, the presence of shear studs is essential to ensure the composite floor deck system has high strength and high endurance to avoid failure.



**Figure 9** Variation of maximum shear stress for different models of composite floor deck

Figure 9 shows the graph for the maximum shear stress of all four different models of composite floor decks. From the graph, it can be observed that the composite floor deck with an opening has the highest maximum shear stress. This shows that the composite floor deck with an opening has the lowest strength among all the four models investigated in this study. The graph also shows that the second highest model is the composite floor deck, followed by the composite floor deck with shear studs and openings, and the model that has the lowest maximum shear stress is the composite floor deck with shear studs. Generally, the higher the maximum shear stress, the higher the force and pressure need to be endured by the composite floor deck system. This indicates that the composite floor deck system strength and endurance are increased when the shear studs are present and will decrease when an opening is provided on the composite floor deck system.



**Figure 10** Variation of equivalent stress for different models of composite floor deck

Figure 10 shows the variation of equivalent stress of all four models of composite floor decks. From the graph, it can be observed that the composite floor deck with an opening has the highest value of equivalent stress. The graph also shows that the composite floor deck with

an opening has the lowest strength among all the four models. The second highest model is the composite floor deck, followed by the composite floor deck with shear studs and openings, and the model that has the lowest equivalent stress is the composite floor deck with shear studs. The equivalent stress indicates the total stress applied on all the composite floor deck systems models investigated in this study. In this case, it can be concluded that the composite floor deck system strength and endurance are increased when the shear studs are present and will decrease when there is an opening on the composite floor deck system.

### Composite Floor Deck with Opening

This section discusses the outcomes of composite floor decks with openings. The main composite floor deck model has an opening of 120 mm x 120 mm at the edge of the deck. Two additional cases have been introduced to study the effects of openings on the mechanical performance of floor decks. The first is a composite floor deck with an opening whose dimension is 200 mm x 200 mm, and the second is the composite floor deck with an opening at the centre of the deck. As discussed in the previous section, both variables will be compared to the main composite floor deck with one opening. Figure 11 shows the variation of the maximum shear stress equivalent stress composite floor deck with a 200 mm x 200 mm opening. It can be observed that the maximum total deformation is 2.11 mm, the maximum shear stress is 391 MPa, and the maximum equivalent stress is 715 MPa. Figure 12 presents the variation of total deformation, maximum shear stress and equivalent stress of the composite floor deck with an opening at the centre. The plot shows that the maximum total deformation is 2.38 mm, followed



Figure 11 Variation of maximum shear stress equivalent stress composite floor deck with a 200 mm x 200 mm opening



Figure 12 Variation of maximum shear stress equivalent stress composite floor deck with an opening at the centre

by the maximum shear stress of 446 MPa and maximum equivalent stress of 822 MPa.

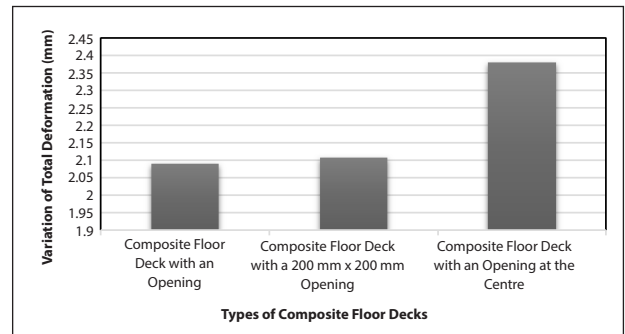


Figure 13 Variation of total deformation for different models of composite floor deck with an opening

Figure 13 shows the variation of total deformation for different models of composite floor decks with an opening. The graph shows that the composite floor deck with an opening at the centre experienced the largest total deformation. In addition, it can be observed that when comparing the main composite floor deck with an opening and the composite floor deck system with an opening at the centre, the total deformation is lower on the main composite floor deck with the opening. This indicates that the location of the opening has a major effect on the strength of the composite floor deck. The composite floor deck with an opening at the centre has very low strength due to its distance from the edges of the deck, which has a fixed support system. These problems can be solved by providing shear studs, as they may increase the strength and endurance of the composite floor deck with an opening.

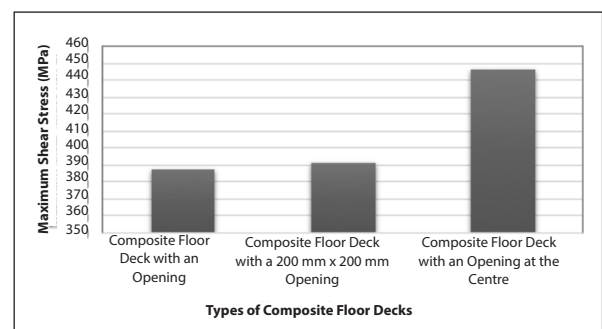


Figure 14 Variation of maximum shear stress for different models of composite floor deck an opening

Figure 14 shows the variation of maximum shear stress for different models of composite floor decks with an opening. It can be observed that the maximum shear stress was the lowest in the primary composite floor deck, with an opening recorded as 388 MPa,

while the largest shear stress was recorded as 443 MPa, corresponding to the composite floor deck with an opening at the centre. The composite floor deck with an opening at the centre has very low strength and endurance due to its distance from the edges of the deck, which has a fixed support system. These problems can be solved by providing shear studs, as they may increase the strength and endurance of the composite floor deck with openings.

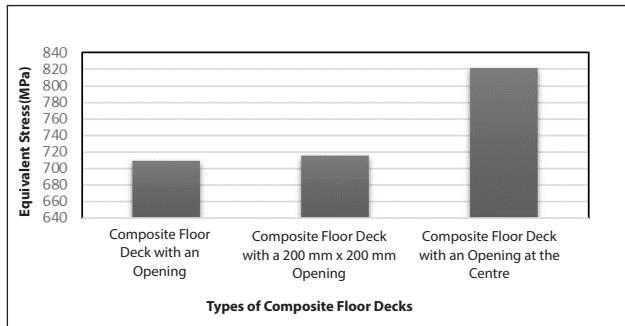


Figure 15 Variation of the equivalent stress for different models of composite floor deck with an opening

Figure 15 shows the variation of the equivalent stress for different models of composite floor decks with an opening. The graph shows that by comparing the main composite floor deck with an opening and the composite floor deck with a 200 mm x 200 mm opening, the equivalent stress is lower on the main composite floor deck with the opening. It can be concluded that the size of the opening has effects on the strength and endurance of the composite floor deck. The larger the size of the opening, the lower the strength and endurance of the composite floor deck. Moreover, comparing the main composite floor deck with an opening and the composite floor deck system with an opening at the centre, one can observe that the later has experienced higher equivalent stress. This indicates that the location of the opening is critical, as it significantly affects the strength and endurance of the composite floor deck.

### Composite Floor Deck with Shear Studs

This section presents and discusses the FEA results of composite floor decks with shear studs. The main composite floor deck has six shear studs, and the arrangement of shear studs is in order. The parametric study of shear studs consists of two different scenarios. The first case consists of a composite floor deck with ten shear studs; the second one is a composite floor deck with a closely arranged shear studs. Both cases

will be compared to the main composite floor deck with shear studs.

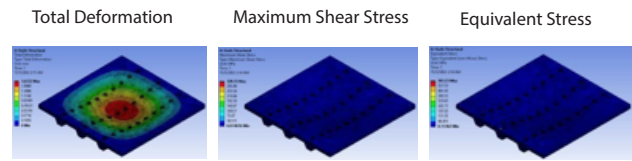


Figure 16 Variation of total deformation, maximum shear stress, equivalent stress composite floor deck with ten shear studs

Figure 16 shows the variation of total deformation, maximum shear stress, and equivalent stress for composite floor deck with ten shear studs. Generally, it can be observed that the maximum total deformation recorded is 1.67 mm, the maximum shear stress is 329 MPa, and the maximum equivalent stress is 593 MPa.

Similarly, for the composite floor deck with a different arrangement of shear studs, Figure 17 shows the results generated from ANSYS software for the composite floor deck with different arrangements of shear studs. It can be observed that the maximum total deformation is 1.72 mm, the maximum shear stress is 347 MPa, and the maximum equivalent stress is 632 MPa.

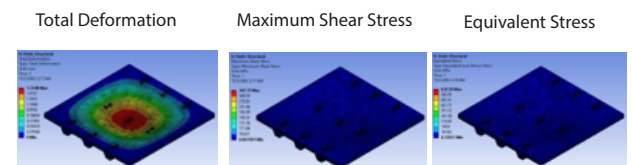
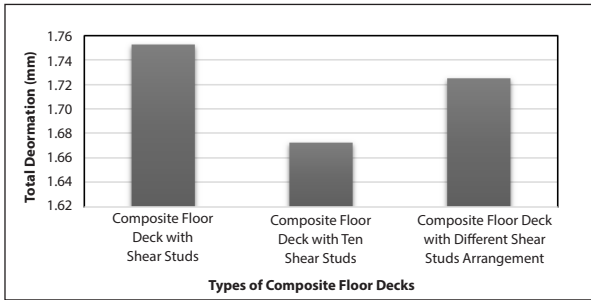


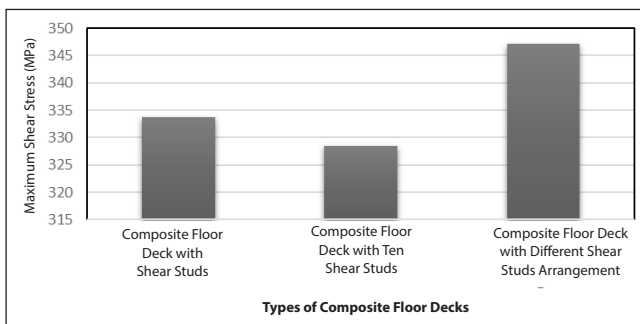
Figure 17 Variation of total deformation, maximum shear stress and equivalent stress of composite floor deck with different arrangement of shear studs

Figure 18 shows the variation of the total deformation for different models of composite floor decks with shear studs. From the graph, it can be observed that the composite floor deck with shear studs experienced the more considerable total deformation, recorded as 1.75 mm, followed by the composite floor deck with different shear studs' arrangement, while the model with ten shear studs experienced the lowest deformation (1.67 mm). It can be concluded that the number of shear studs affected the strength of the composite floor deck. Generally, the larger the number of shear studs, the higher the strength and endurance of the composite floor deck. In addition, it can be observed that by comparing the main composite floor deck with shear studs and the composite floor deck with different arrangements of shear studs, the total deformation is higher on the primary composite floor



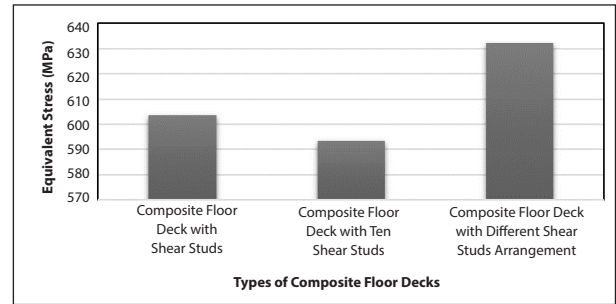
**Figure 18** Variation of the total deformation for different models of composite floor deck with shear studs

deck with shear studs. This indicates that the arrangement of shear studs significantly influences the strength of the composite floor deck. The arrangement of shear studs must be studied in more detail to get the most efficient arrangement for composite floor deck systems' maximum strength and endurance.



**Figure 19** Variation of maximum shear stress for different models of composite floor deck with shear studs

Figure 19 shows the variation of maximum shear stress of all three different models of composite floor decks with shear studs. The comparison of the results between the main composite floor deck with shear studs and the composite floor deck with ten shear studs shows that the maximum shear stress is higher in the primary composite floor deck with shear studs. It can be concluded that the number of shear studs does affect the strength and endurance of the composite floor deck. The greater the number of shear studs, the higher the strength and endurance of the composite floor deck. However, the arrangement of shear studs must be further studied in more detail to get the most efficient arrangement of shear studs for the maximum strength and endurance of the composite floor deck system.



**Figure 20** Variation of equivalent stress on different models of composite floor deck with shear studs

Figure 20 shows the variation of equivalent stress on different models of composite floor decks with shear studs. From the comparison of the graph, one can observe that the composite floor deck with different shear studs' arrangement has experienced the most considerable equivalent stress of 633 MPa, followed by the composite floor deck with shear studs with 604 MPa, and the composite floor deck with ten shear studs, with 594 MPa. This indicates that the number of shear studs and their arrangement significantly impact the equivalent stress of the floor deck.

### CONCLUSIONS

In this paper, a parametric study was conducted to study the effects of shear studs and openings on the mechanical performance of composite floor decks using ANSYS software. The FEA results obtained from the numerical simulations are the total deformation, the maximum shear stress and the equivalent stress of the composite floor decks. The following concluding remarks can be drawn based on the parametric study:

1. The composite floor deck with shear studs has the best performance as its total deformation is only 1.75 mm, the maximum shear stress is 334 MPa, and the equivalent stress is 604 MPa, which is 4% lower than the composite floor deck with openings which has a total deformation of 2.1 mm, maximum shear stress of 387 MPa and equivalent stress of 710 MPa.
2. The composite floor deck with 100 mm x 100 mm opening has better performance as the total deformation was 2.1 mm, the maximum shear stress is 387 MPa, and the equivalent stress is 710 MPa which is lower than the composite floor deck with 200 mm x 200 mm opening that experienced a total deformation of 2.1 mm, maximum shear stress of 391 MPa and equivalent stress of 715 MPa.

3. The composite floor deck with an opening at the corner has better performance as the total deformation is 2.1 mm, maximum shear stress is 387 MPa, and equivalent stress of 710 MPa which is 6.5% lower than the composite floor deck with an opening at the centre that has experienced a total deformation of 2.38 mm, maximum shear stress of 4461 MPa and equivalent stress of 822 MPa.
4. The composite floor deck with ten shear studs has better results as the total deformation is 1.6722 mm, the maximum shear stress is 323 MPa, and the equivalent stress is 593 MPa which is 2.4% lower than the composite floor deck with six shear studs that have a total deformation of 1.75 mm, maximum shear stress of 334 MPa and equivalent stress of 604 MPa.
5. Generally, a floor deck with a higher number of shear studs has comparatively higher strength as compared to the case with a lower number of shear studs and the composite floor deck with shear studs arranged very close to each other and has a considerable distance with another two shear studs, which has higher strength than the shear studs that are arranged in order.

#### ACKNOWLEDGEMENT

The authors would like to express their gratitude to the Yayasan Universiti Teknologi PETRONAS for funding this study entirely through the Yayasan Universiti Teknologi PETRONAS (YUTP-FRG 015LC0-95, 015LC0-133) grants.

#### REFERENCES

- [1] R. Tremblay, C. A. Rogers, P. Gignac, and G. Degrange, "Variables affecting the shear-bond resistance of Composite Floor Deck Systems," *The 16th International Specialty Conference on Cold-Formed Steel Structures*, Orlando, Florida, pp. 663-676, 2002.
- [2] M. -H. Shen, K. -F. Chung, A.Y. Elghazouli, and J.-Z. Tong, "Structural behaviour of stud shear connections in composite floors with various connector arrangements and profiled deck configurations," *Engineering Structures*, vol. 210, p. 110370, 2020.
- [3] J. Huo, H. Wang, L. Li, and Y. Liu, "Experimental study on impact behaviour of stud shear connectors in composite beams with profiled steel sheeting," *Journal of Constructional Steel Research*, vol. 161, pp. 436-49, 2019.
- [4] A. I. Hassanin, H. F. Shabaan, and A. I. Elsheikh, "The Effects of Shear Stud Distribution on the Fatigue Behavior of Steel-Concrete Composite Beams," *Arabian Journal for Science and Engineering*, vol. 45, pp.8403-8426, 2020.
- [5] A. Shariati, M. Suhatriil, N. H. Ramlisulong, and M. Shariati, "Various types of shear connectors in composite structures: A review," *International Journal of the Physical Sciences*, vol. 7, no. 22, 2012.
- [6] M. C. Mota, and M. Kamara, "Floor Openings in Two-Way Slabs," *Concrete International-Detroit*, vol. 28, no. 7, p.33, 2006.
- [7] *Eurocode 4: Design of composite steel and concrete structures — Part 1-1: General rules and rules for buildings*, The European Union, 2004.
- [8] S. V. Bhise, and U. L. Deshpande, "Finite Element Analysis of Composite Concrete Slab With Profiled Steel Decking For Different Shear Spans," *International Journal of Engineering Applied Sciences and Technology*, vol.4, no.3, pp. 342-348, 2019.
- [9] M. D. Rambo-Roddenberry, W. S. Easterling, T. E. Cousins, S. M. Holzer, T. M. Murray, and K. B. Rojiani, "Behavior and Strength of Welded Stud Shear Connectors," *Virginia Polytechnic Institute and State University*, 2002.
- [10] M. D. Rambo-Roddenberry, "Behavior and strength of welded stud shear connectors," Ph.D dissertation, Dept. Civil Eng., Virginia Polytechnic Institute and State University, 2002.
- [11] W. S. Easterling, D. R. Gibbings, and T. M. Murray, "Strength of Shear Studs in Steel Deck on Composite Beams and Joists," *Second Quarter 1993*, pp. 44-55, 2003.
- [12] M. El-Shami, S. Mahmoud, and M. Elabd, "Effect of floor openings on the capacity of composite space trusses," *Journal of King Saud University*, 2016.
- [13] D. Huakun, W. Xintang, and W. Jianping, "Study of mechanical performance of a new type of fabricated composite floors," *IOP Conference Series: Earth and Environmental Science*. vol. 153 no. 5, 2018.
- [14] S. S. Kalamkar, and A. R. Akhare, "Analytical Study on Behaviour of Composite Slabs with Profiled Steel Decking," *International Journal of Engineering Research*, vol. 5, no. Special 3, pp. 654-657, 2016.

- [15] P. A. Langarudia, and M. Ebrahimnejad, "Numerical study of the behaviour of bolted shear connectors in composite slabs with steel deck," *Structures* vol. 26, pp. 501-515, 2020.
- [16] M. Majeed, P. Kumar, and S. Chaudhary, "Shear Stud Connectors in Steel-Concrete Composites: A Review, 2012."
- [17] J. Mikula, and J. Szolomicki, "Numerical modelling of RC floor slab," *IOP Conference Series: Materials Science and Engineering*, vol. 586, no. 1, p. 012031, 2019.
- [18] T. Molken, J. Dobrić, and B. Rossi, "Shear resistance of headed shear studs welded on welded plates in composite floors," *Engineering Structures*, vol. 197, p. 109412, 2019.
- [19] O. Mirza and B. Uy, "Effects of the combination of axial and shear loading on the behaviour of headed", *Engineering Structures*, vol. 32, no. 1, pp. 93-105, 2010.
- [20] N. Rehman, D. Lam, X. Dai, and A. F. Ashour, "Experimental study on demountable shear connectors in composite slabs," *Journal of Constructional Steel Research*, vol. 122, pp. 178-189, 2016.
- [21] C. Topkaya, J. A. Yura, and E. B. Williamson, "Composite Shear Stud Strength at Early Concrete Ages," *Journal of Structural Engineering*, ASCE, vol. 130, no. 6, pp. 952-960, 2004.
- [22] C. Xu, and K. Sugiura, "FEM analysis on failure development of group studs shear," *Engineering Failure Analysis*, vol. 35, pp. 343-354, 2013.