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Behavior Study of Three-Side-Supported Floor Deck Sytem Slab

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ABSTRACT

The purpose of this research is to observe the ultimate strength between conventional slab and floor deck supported at three side, the other side was not supported, and subjected to monotonic loading at the center of the slab. This research used four slabs, two conventional slabs, one Alkadeck type floor deck, and one ISD type floor deck. Slabs were casted in size of 1800x1600mm with 120mm thickness. Conventional slabs were reinforced in two way, using ϕ10 with space of 100mm in negative moment area. While floor deck system slabs were using M6 wire mesh in positive moment area. Load speed was 0,03mm/s. Load was centered to 200x200mm steel plate at the center of the slab. The results found that floor deck system slab decrease flexural strength by 51.6% for Alkadeck and 61.62% for ISD, but increase ductility by 99.32% for Alkadeck and 64.86% for ISD. Steel Strain gauge showed that at floor deck system slab, the steel deck was more brittle and had longer strain hardening compared with steel bar in conventional slab. While on Concrete strain gauge, concrete at floor deck system slab showed sudden increasement in strain before it fails.

Keywords: Floor deck, two way slab, three-side-supported, deflection, strain
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1. INTRODUCTION

The field of construction is an area with high technological developments, the need for strong and efficient design and practical installation techniques, making many parties compete to create an innovation to answer the challenge. One of the trending developments is the use of steel in Building construction. Besides being used as beams and columns, steels are also used in slab systems. Generally, slabs use steel bars as their reinforcement. In addition to the shape of such slab, there is also a slab form where a corrugated steel sheet serves as its tensile reinforcement and then the concrete is casted on it to form a composite steel slab. Composite steel slab is known in various names including floor deck, steel deck, bondek, smart deck, metal deck, etc, in this study we named it floor deck.

Compared to conventional slabs where reinforcement are covered by concrete in the negative moment area to withstand the tensile force due to moment, at the steel sheet on floor deck system is poured by concrete on positive moment area so that if the slab is not properly cleaned it will easily slip, due to the form of a bumpy floor deck causing reduced area of concrete at the tensile area. This study aims to find out how big the difference between the strength of two-way slab with three supported beams and one unsupported end if made conventionally and using floor deck.

When a slab is loaded to failure, yield lines form in the most highly stressed areas and these develop into continuous plastic hinges. As described above, these plastic hinges develop into a mechanism forming a yield line pattern [1]. Flexural failure is a failure caused by flexural moments, the indication can be observed from the pattern of cracks that occur when the slab are subjected to its ultimate load, the crack pattern for each slab with three supported ends can be considered like half of crack pattern with four supported ends[4]

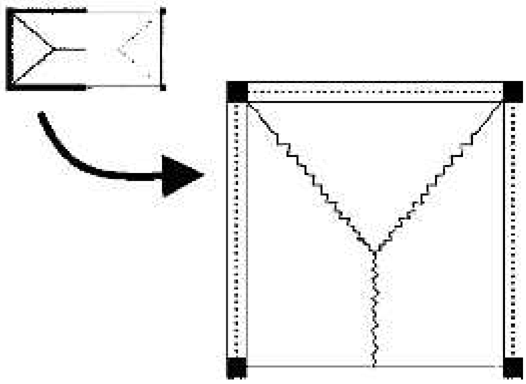
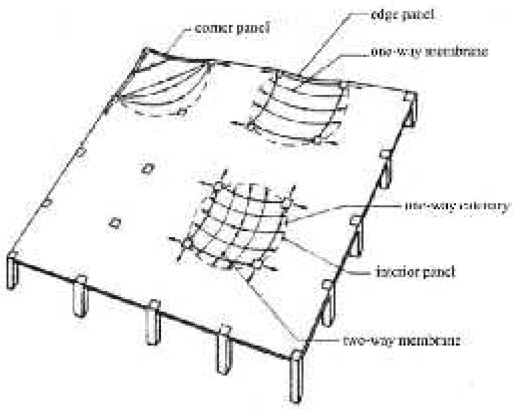


Fig. 1. The example of Flexural crack pattern of two-way slab with three supported ends

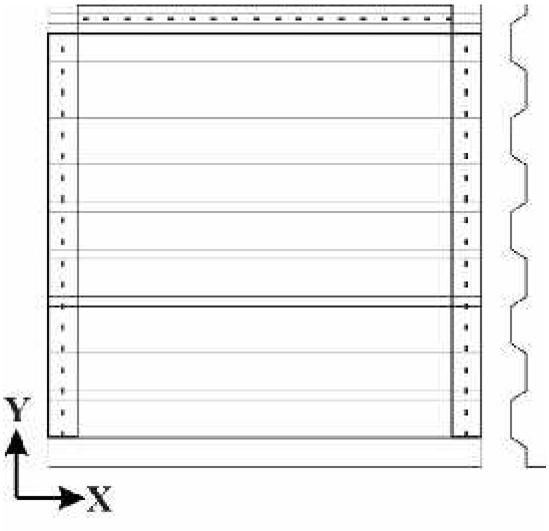
Properties of the floor deck system slab have a different display failure with conventional slabs. Flexural failure of the floor deck system slab can be categorized into two types:

1. Flexure-yielding, is a condition where floor deck is flexed and even torn due to flexural moment exceeding its capacity.
2. Flexure-crushing, is a condition where floor deck has a high reinforcement ratio so that it is stiff in holding the deflection but the concrete receives too much load so that at the point of loading the concrete has been crushed or slip from floor deck.[3]

Figure 2 (a) shows that the deflection of the tensile force on the slab with three supported ends is greater in the direction of supports on each side than the direction of support only on one side [2]. Therefore, the floor deck slabs will be placed with the corrugated portion in X way as in Figure 2 (b), this situation happened because the inertia of the cross section in that direction is greater.



(a)



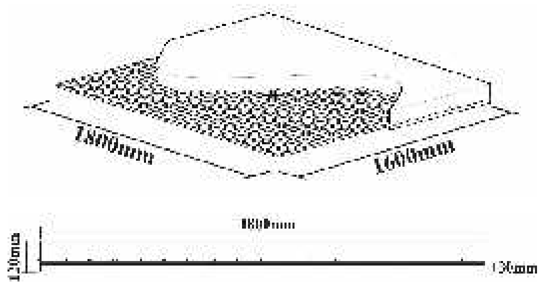
(b)

Fig. 2. (a) Tensile membrane behavior of a floor slab (b) the position of the floor deck system slab

In this research, four slabs were used; two conventional slabs, one Alkadeck type floor deck and one ISD type floor deck. The striking difference between the two floor deck types is the geometry of the cross section and also the protrusion feature that serves as the embossment. Slabs were casted in size of 1800x1600mm with 120mm thickness. The conventional slabs were given a two-way reinforcement using ϕ10 with space of 10cm in the tensile area, while the floor deck slab is given M6 wire mesh on top. Two Linear Variable Differential Transformer (LVDT) were placed at center of the slab and at unsupported end to record the amount of deflection that occur, and strain gauge installed in steel and concrete in X and Y way to obtain strain. The slab was subjected to monotonic loading at a rate of 0.03mm/s then load cell will record the load centered to 200x200mm steel plate at the center of the slab.

2. Methodology

A. Sample



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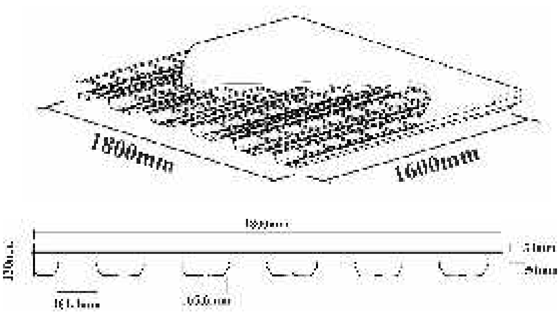

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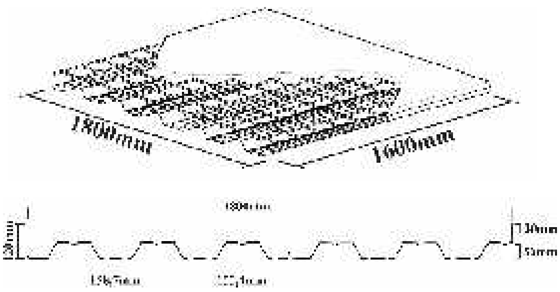


(c)

Fig. 3. (a) Conventional Slab (b) Alkadeck type floor deck (c) ISD type floor deck

a. Conventional Slab (Nr)

Conventional slabs were casted in size of 180x160cm with 12cm thickness, using 25MPa concrete and given a two-way reinforcement using ϕ10 in tensile area with Space of 10cm and concrete cover for around 3cm.

b. Floor Deck

Planning of this composite slab follows the standards listed in ISO 1729-2015 [5]. Floor deck slab are casted in size of 1800x1600mm with a 120mm thickness counted from the bottom part of the slab, using 25MPa concrete, and using M6 wire mesh with space 3cm from top of the slab. Floor deck steel sheet thickness is 0.75mm with grade of G-550. The striking difference between the two floor deck types is the geometry and also the protrusion feature that serves as the embossment.

B. Setup

The slabs were supported on three sides and one unsupported end, two LVDT were positioned at center of the slab and at unsupported end of the slab. At the center of the slab a 200x200mm steel plate with Load Cell to record the load were placed.

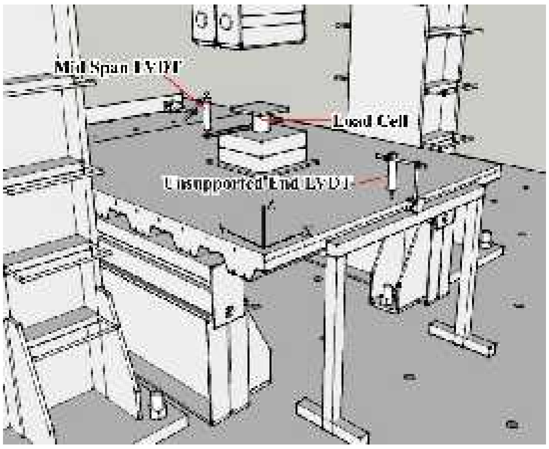
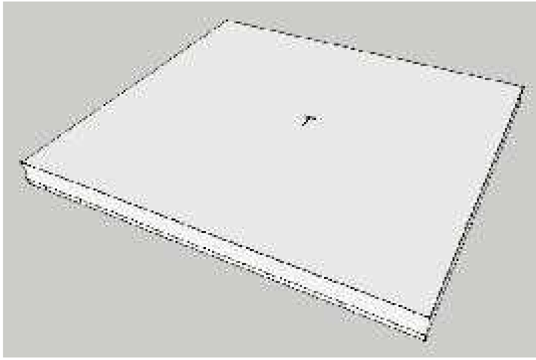
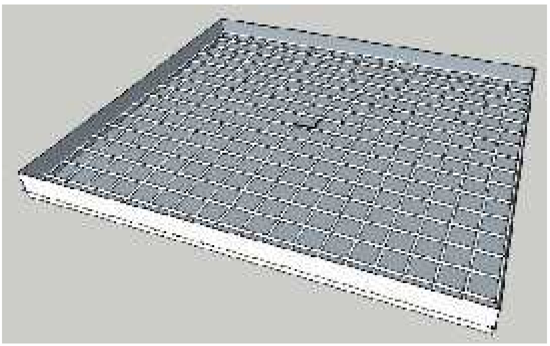


Fig. 4. Setup

For every slab there were four strain gauge, two for steel in X and Y way, and two for concrete in positive moment area, in X and Y way.



(a)



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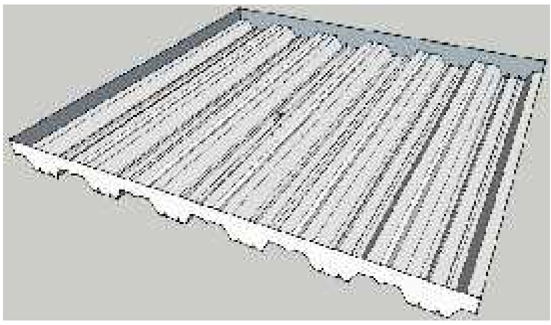


(c)

Fig. 5. Strain Gauge position (a) concrete in X and Y way, (b) reinforcements in X and Y way, (c) at the bottom part of corrugated floor deck steel plate in X and Y way

3. RESULT AND DISCUSSION

a. Concrete Attributes

Attribute	Value (Mpa)
Compressive strength (f'c)	24,57
Modulus of Elasticity (Ec)	23010,18
Flexibility strength	3,73

b. Steel Attributes

Attribute	Value(Mpa)
Yield Strength	331,84
Ultimate Strength	472,82

c. Load-deflection graph

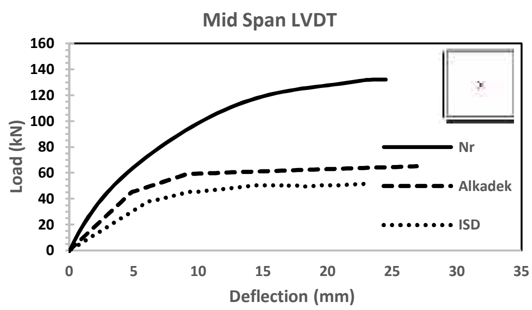


Fig. 6. Load-deflection graph at center of slab

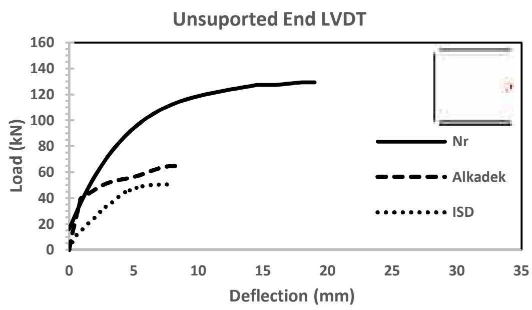


Fig. 7. Load-deflection graph at unsupported end

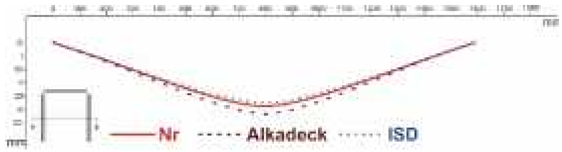


Fig. 8. X-X way slab

Fig. 9. Y-Y way slab

The results showed that conventional slab could carry higher load compared to floor deck slab before finally failed. Conventional slab failed at 132,02kN, Alkadeck failed at 65,10kN (50, 68% lower than conventional slab), and ISD failed at 51,64kN (60,88% lower than conventional slab). At center of the slab, deflection occurred at conventional slab and floordeck slab was similar, around 22,07mm to 26,89mm, but at unsupported end, there was a different behavior between conventional slab and floor deck slab. Conventional slab's deflection at unsupported end was almost as many as deflection happened at center of slab, around 19mm, while floordeck's deflection at unsupported end was not as many as conventional slab, only around 8,21mm for Alkadeck (about 43,24% to conventional slab) and 7,6mm for ISD (about 40% to conventional slab).

For conventional system slab, deflection occurred at the unsupported side was almost as much as deflection occurred at middle span. This condition happened due to inertia of the conventional slab was equal at entire area of the concrete.

Meanwhile, for floor deck system slab, due to the shape of the wavy floor deck caused the difference in inertial concrete at the bottom and the top of the floor deck slab. This difference caused the force distribution due to the deflection occurring at the middle of the slab to be reduced. In addition, wider area of concrete at the bottom of floor deck area increased the stiffness of the slab. Deflection Comparison is showed in figure 10 and figure 11.

d. Load-strain graph

i. Steel

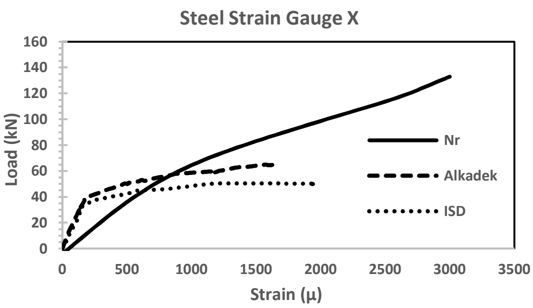


Fig.10. Steel Load-Strain graph in X way

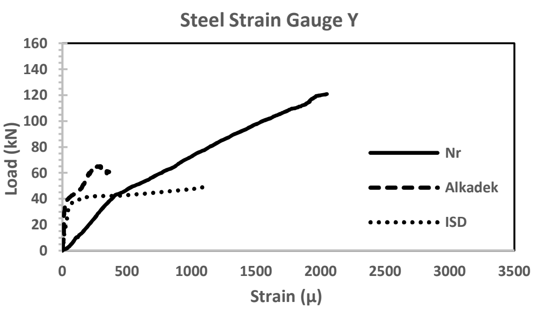


Fig. 11. Steel Load-Strain graph in Y way

According to Figure 10. Reinforcement in conventional system slab yielded due to maximum tensile strain of steel reach about 3000µ (more than 2500µ as the yield limit).

On the other hand, at floor deck system slabs, strain occurred at middle span was around 1600µ for Alkadeck and 2000µ for ISD. The steels was not yielded because they didn't reach 2500µ. This condition indicated that slip happened at interface between concrete and floor deck.

Conventional slab steel graphs, in X and Y way, was more sloping compared to floordeck steel graph. This condition showed that conventional slab elastic area was wider than floordeck steel. Reinforcement continued to stretch slowly as the load increases, and floordeck steel had plastic area that was more steep and longer strain hardening area. This condition made floordeck system slab can collapse suddenly due to floor deck characteristic which is brittle. Visually, center of floor deck slab began to bend at 35 – 40kN. After that, strain occurred quickly.

ii. Concrete

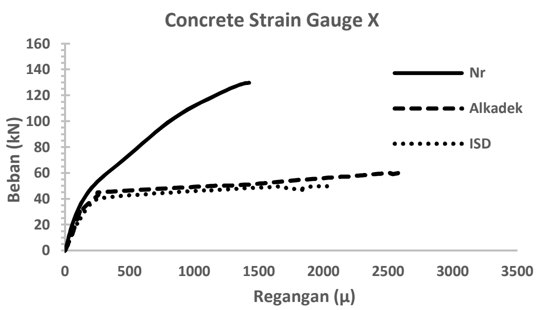


Fig. 12. Concrete Load-Strain graph in X way

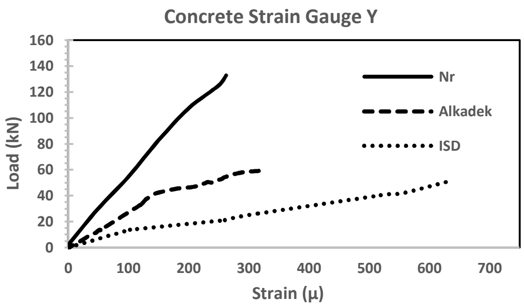
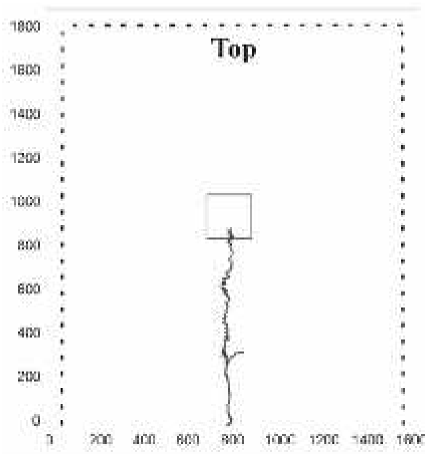


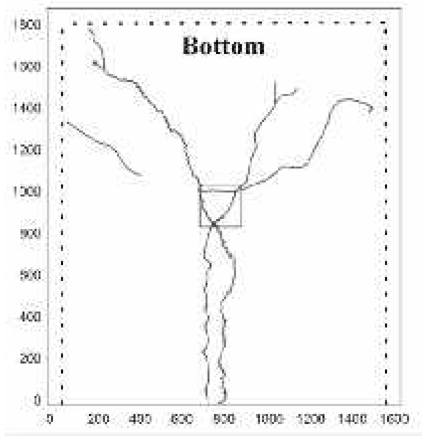
Fig. 13. Concrete Load-Strain graph in Y way

According to Figure 12 Concrete in conventional system slab didn't sustain compressive failure due to maximum compressive strain of concrete didn't reach 3500µ. The maximum compressive was around 1450µ for conventional slab, 2600µ for Alkadeck, and 2000µ for ISD.

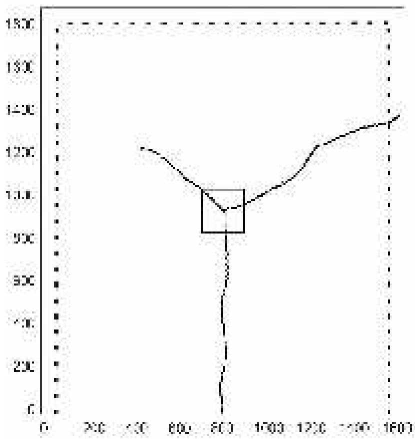
For concrete in Y way, stiffness in conventional slab was higher than floor deck system slab. While for Concrete in X way, at first all sample have same behavior. By the time load reaches 35 – 40kN, when floordeck slab began to collapse, concrete at floordeck system slab experienced a lot of strain increasing. This condition shows that in 35 – 40kN, strain occured quickly

e. Crack Pattern





(a)



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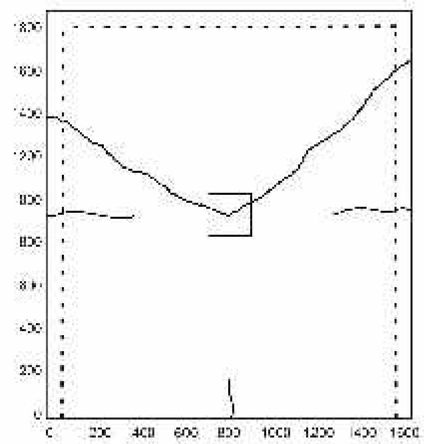

(c)

Fig. 14. Crack pattern at (a) Normal Slab, (b) Alkadeck type, (c) ISD type

Crack pattern happened at conventional and floor deck system slab was like general crack pattern happens at slab supported on three side, like Y shaped with line perpendicular with unsupported side of the slab. Floor deck slab's Crack pattern could be only observed from above because the bottom side is covered by steel sheet. At the bottom of slab, steel sheet "deflect" at the middle of the slab and the concrete was slipped from the floor deck.

The Type of failure happened was bending failure. Crack began at center of the lower side of slab, spread to unsupported side. Next, crack spread to compressive part to the direction of loading. After that, the cracks branched to the thinner part of slab. Thinner parts of the slab meant concrete was on the top part of floor deck.

Fig. 15. Interface failure between concrete and steel

Based on Figure 15 showed that concrete was slipped from steel due to floor deck's embossment. The embossment couldn't prevent interface failure. Floor deck was failed to transfer tensile stress from steel to concrete.

4. CONCLUSIONS

The results of the research showed that floor deck system slabs decrease flexural strength by 51,61% for Alkadeck and 61,62% for ISD, because inertia of the plane is reduced due to corrugated slab shape at the bottom of the slab. Even though floor deck decrease flexural strength but the ductility is increased by 99,32% for Alkadeck and 64,86% for ISD, because the concrete is slipped from the steel deck made it deflected more freely. Y-Y showed that at floor deck system slab, deflection happened at the middle span was not transferred to the unsupported end as many as conventional slab did. Steel Strain gauge graph showed that at floor deck system slab, steel deck was more brittle and had longer strain hardening compared with steel bar in conventional slab. While on Concrete strain gauge, concrete at floor deck system slab showed sudden increasement in strain before it failed, made it hard to observe cracks during the failure moment of the floor deck system slab.

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