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Performance Analysis of Precast Hollow Core Slab with Circle Hole Using Finite Element Method

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Abstract. The use of a hollow core slab (HCS) prestressing technology in a building is an alternative to traditional slabs or on-site casting. The advantage of HCS is that its self-weight is lighter than that of standard slabs (with the same size and thickness), reducing the total weight of a building structure. The HCS models in this study will have a thickness of 120 mm, a width of 1200 mm, varying lengths (4 m, 4.25 m, 4.5 m, 4.75 m, 5 m), and a variable number of wires (12, 14, 16). The test is performed by comparing the results of laboratory testing with the results of numerical calculations (finite element method) performed with the MIDAS FEA application. The results of the finite element method test analysis are predicted to be close to the results of the lab tests. The load capacity that can be carried by HCS utilizing the finite element method analysis (MIDAS FEA program) generated a capacity value similar to the same as the lab test results with a variance of 2% to 11%. The analytical results also demonstrate that the 4-meter HCS span is more efficient and effective than other spans when comparing the ratio between the load capacity that can be carried and the weight of the HCS itself, which is 0.856. The finite element method analysis can demonstrate the cracking of the hollow core slab in stages.

INTRODUCTION

In general, a building with a big number of floors will require a significant amount of time and money. However, the development must be completed in the shortest amount of time and at the lowest possible cost. Furthermore, it must pay attention to the quality of the materials employed so that the structure can stand on its own. It will take longer in a conventionally built building since the slab must be cast at the same time as the beams, but this is not necessary for precast concrete. As a result, it can be inferred that precast concrete is employed in building to reduce time and high expenses.

Wayss and Frytag invented precast concrete in 1906. As the name suggests, this concrete is manufactured and molded at the factory to the specifications of the project. Precast concrete is also widely employed in the construction industry, particularly in high-rise buildings, because it saves time, money, and material waste. As a result, hollow core slabs (HCS) are employed in place of traditional plates.

HCS employs a prestressing mechanism that reduces deformation caused by concentric or eccentric stresses applied in the element's longitudinal direction [1]. Furthermore, the HCS system must be capable of transferring lateral loads occurring on vertical structural members [2]. Wilhelm Siegler (Germany, 1906) was the first to use longitudinal voids in concrete slabs and has continued to develop new types of cavities to this day.

The usage of HCS reduces construction time and costs because conventional slabs require numerous phases to build formwork, then reinforcing, and finally casting. HCS is utilized in residential structures, villas, office buildings, storehouses, factories, shopping malls, parking lots, hotels, and apartments, as well as concrete and steel structural buildings.

Because HCS is manufactured in a factory, the resulting quality will be higher because the concrete is treated properly until it reaches the design life of the concrete; additionally, its production is not affected by weather, so it does not interfere with the manufacturing process or concrete quality. During construction, the material will be lifted using a tower crane. Furthermore, the voids in the HCS reduce its weight as compared to traditional plates, resulting in a lighter building structure and smaller foundation dimensions, as well as a reduction in the magnitude of the earthquake force.

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The purpose of this research is to use the finite element method to assess the precast hollow core slab under one-way loads. In this analysis, a comparison will be done between numerical calculations and laboratory test findings from company "X." The numerical analysis results are intended to be near to or equivalent to the results of laboratory tests.

The problem formulation explored in this study is whether the force obtained from the finite element technique calculation is the same as the findings of the lab test and what is the most efficient and effective slab span.

The purpose of this review was to identify the capacity obtained using the finite element method based on laboratory test findings, as well as the most efficient and effective slab span.

Scope of Problem

So that the research does not diverge too far, several constraints will be imposed to limit the difficulties that may arise, such as:

- The thickness of the plate is 120 mm.
- The plate's width is 1200 mm.
- The span used will range between 4 and 5 meters.
- The concrete used is of K-450 quality (fc' = 37.35 MPa).
- Reinforcement will use a prestressing system.
- The wire used is PC Wire 5 mm, steel grade fpu = 1670 MPa
- The constitutive model utilized in the Total Strain Crack type plate has a Brittle tension function and a Thorenfeldt compression function.
- The Von Mises type wire's constitutive model, has an initial yield stress of 1503 MPa.
- The wire's relaxation coefficient is 45.
- The curvature friction factor of wire is 0.20, while the wobble friction factor is 0.00125 (1/ft).
- Time, production, and building costs are not considered in the analysis.
- Only a vertical slab loading system in the form of a uniform load per unit area along the slab span is used in the analysis.
- The MIDAS FEA program will be used to assist with the finite element method calculation analysis.

LITERATURE REVIEW

Hollow Core Slab

Hollow-core slab (HCS) is precast concrete with a prestressed system that has continuous cavities to lower the weight of the building and is also beneficial for mechanical or electrical transmission. HCS can be used as floor or roof slabs, as well as walls and bridge decks [3]. Holes in HCS slabs contain 30% less concrete and 50% less steel than holes in standard concrete slabs [4]. The HCS prestressing system is designed to endure maximum bending and shear stresses. And, with the use of a prestressing system, the deflection that happens is intended to comply with the design plan.

Finite Element Method

According to [5], the finite element method is a numerical procedure for assessing structure and continuity. In general, the problems tackled are too complicated to be solved using traditional analytical approaches. The issue could be related to voltage analysis, heat conduction, or something else. Many simultaneous algebraic equations are produced and solved by computers, mainframes, and other computing devices in finite element calculations. The results of finite element calculations are often less precise; however, mistakes can be reduced by processing more equations.

The stress analysis method gave rise to the finite element method. The finite element method is also used to study heat transfer, fluid flow, lubrication, electric and magnetic fields, and many other problems. Buildings, electric motors, heat engines, ships, airframes, and spacecraft can all be designed using the finite element approach.

The finite element method is used to model the structure by using small interconnected elements called finite elements. Each finite element has its displacement function. Each element, including nodes, boundaries, and surfaces,

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is interconnected and connected, either directly or indirectly, with every other element over a shared interface. The behavior of a particular node in terms of the qualities of every other element in the structure can be determined by using the stress/strain properties of the material used to build the structure. The whole set of equations defines the properties of each node, resulting in a sequence of algebraic equations written in matrix notation. [6]

RESEARCH METHODS

This research was carried out in the following stages:

- Determine which cross-sectional data will be included in the review.
- Using the MIDAS FEA application, analyze the hollow core slab using the finite element approach.
- Optimizing the hole shape in the hollow core slab.
- Draw conclusions based on the findings of the finite element method and lab testing, as well as the shape of the hole in the hollow core slab.

RESULTS AND DISCUSSION

An analysis will be done on plates having a thickness of 120 mm, a width of 1200 mm, and spans ranging from 4 m to 4.25 m, 4.5 m to 4.75 m, and 5 m in this section. Roll-pins will be used to define the slab's boundary. The concrete used is of K-450 quality (f'c = 37.35 MPa). PC Wire 5 mm (fpu = 1670 MPa) was utilized for wires 12, 14, and 16. The size of the mesh utilized will be refined when creating the mesh due to the many indentations at the end of the plate. Furthermore, when the mesh is applied, the holes on the plate are separated into 24 sections, resulting in a more rounded shape of the holes.

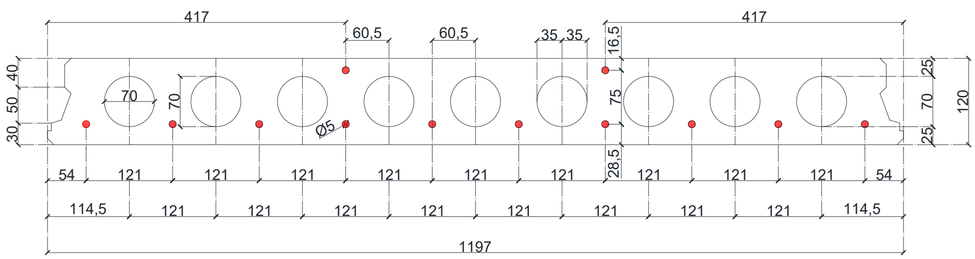

FIGURE 1. Example of Hollow Core Slab With 12 Wire

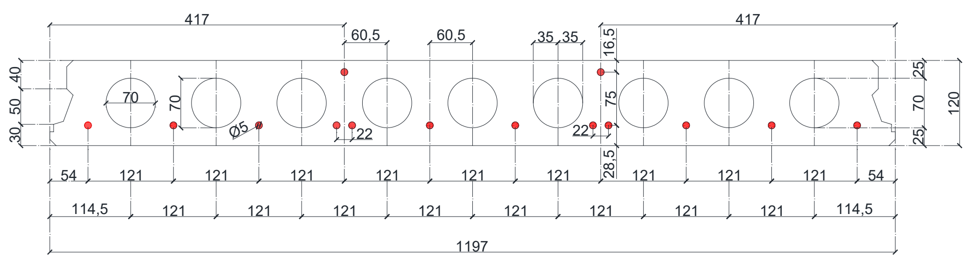

FIGURE 2. Example of Hollow Core Slab With 14 Wire

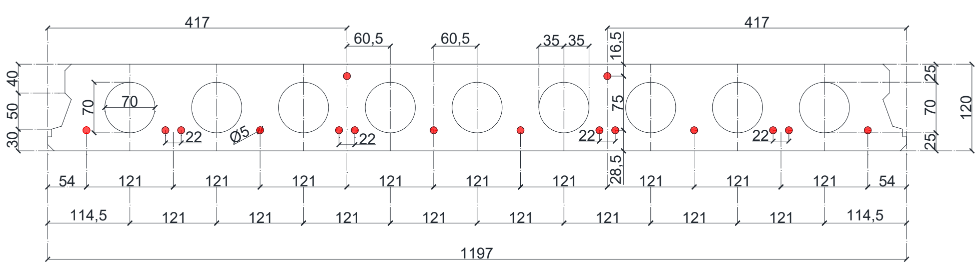

FIGURE 3. Example of Hollow Core Slab With 16 Wire

TABLE 1. Sample

HCS Code	Span (m)	Number of Wires	Element	Node
H11	4	12	134076	132604
H12	4	14	131427	133515
H13	4	16	141095	137353
H21	4.25	12	142377	141371
H22	4.25	14	143519	142517
H23	4.25	16	144838	143840
H31	4.5	12	151515	149096
H32	4.5	14	152815	150400
H33	4.5	16	154852	152441
H41	4.75	12	155721	158543
H42	4.75	14	157179	160005
H43	4.75	16	158405	161235
H51	5	12	164551	166087
H52	5	14	166564	168104
H53	5	16	168111	169655

Analysis Results of a Hollow Core Slab with a Circular Cross Section Using Prestress Force

With the use of the MIDAS FEA tool, an analysis of HCS utilizing prestress force with a round cross area was obtained.

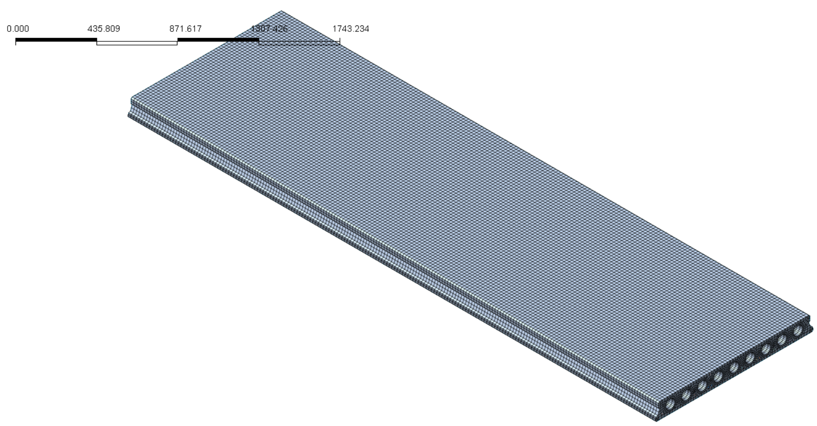

FIGURE 4. Isometric Hollow Core Slab View

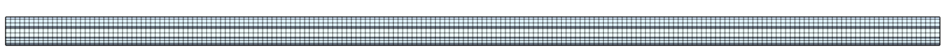

FIGURE 5. Side View of Hollow Core Slab

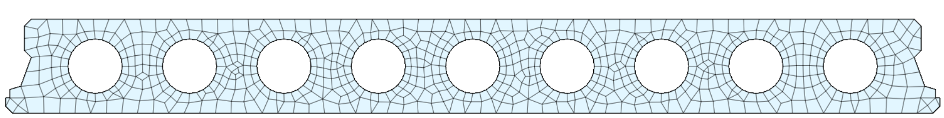

FIGURE 6. Hollow Core Slab Cross Section

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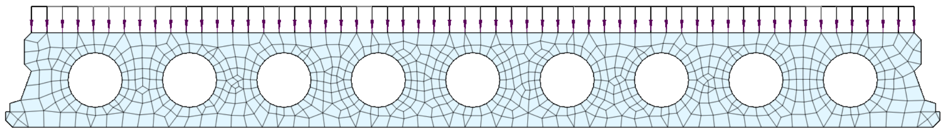


FIGURE 7. Load On Hollow Core Slab

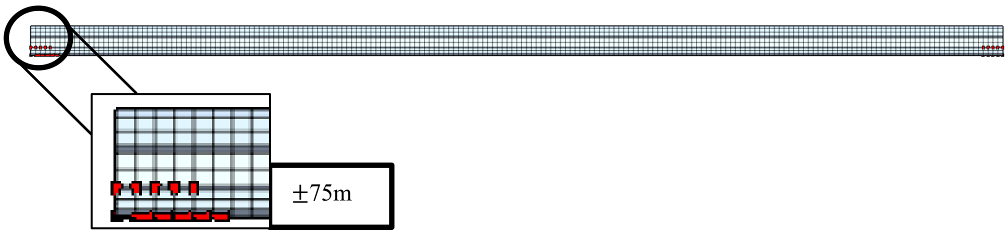
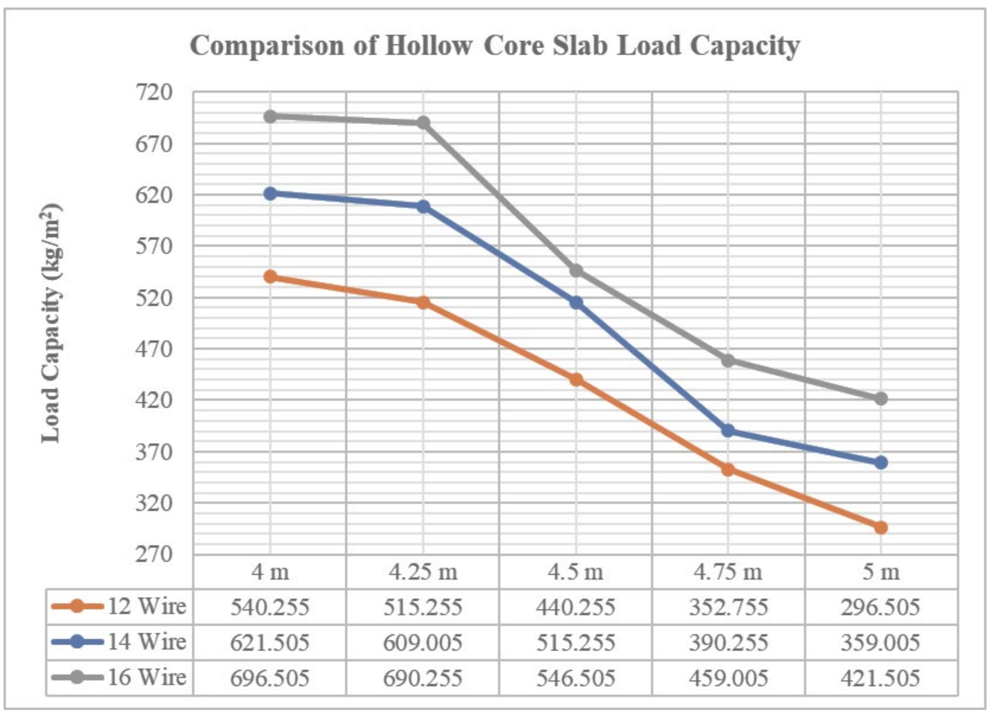


FIGURE 8. Boundary On Hollow Core Slab

The following study is a recapitulation of the load capacity and displacement of the hollow core slab based on the results of the previous analysis.



	4 m	4.25 m	4.5 m	4.75 m	5 m
12 Wire	540.255	515.255	440.255	352.755	296.505
14 Wire	621.505	609.005	515.255	390.255	359.005
16 Wire	696.505	690.255	546.505	459.005	421.505

FIGURE 9. Comparison of Hollow Core Slab Load Capacity

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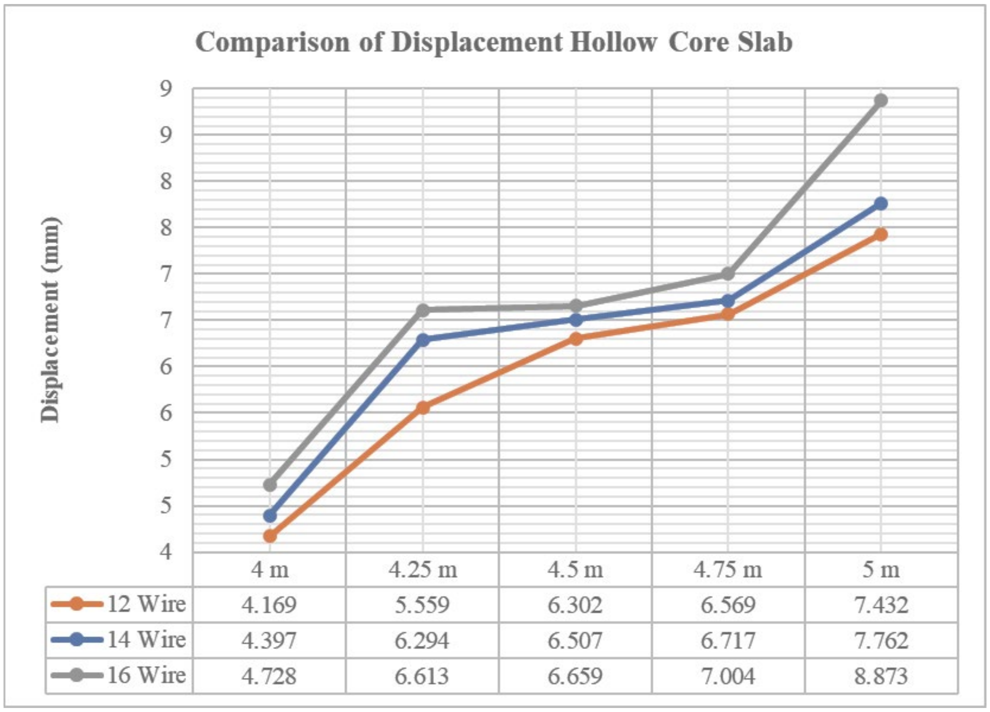

FIGURE 10. Comparison of Hollow Core Slab Displacement

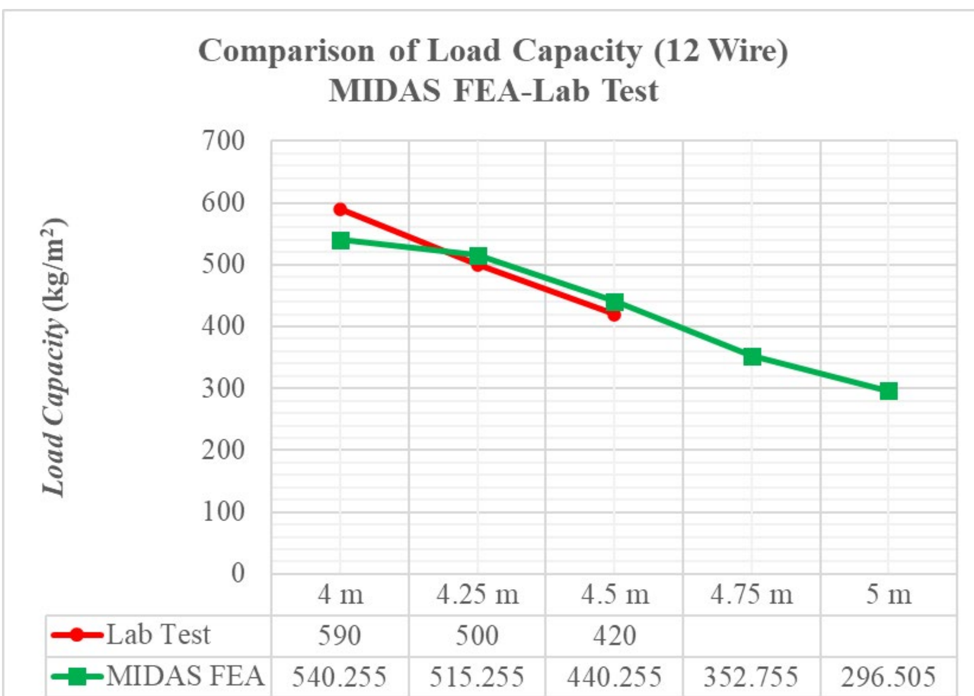

FIGURE 11. Comparison of Load Capacity MIDAS FEA – Lab Test (12 Wire)

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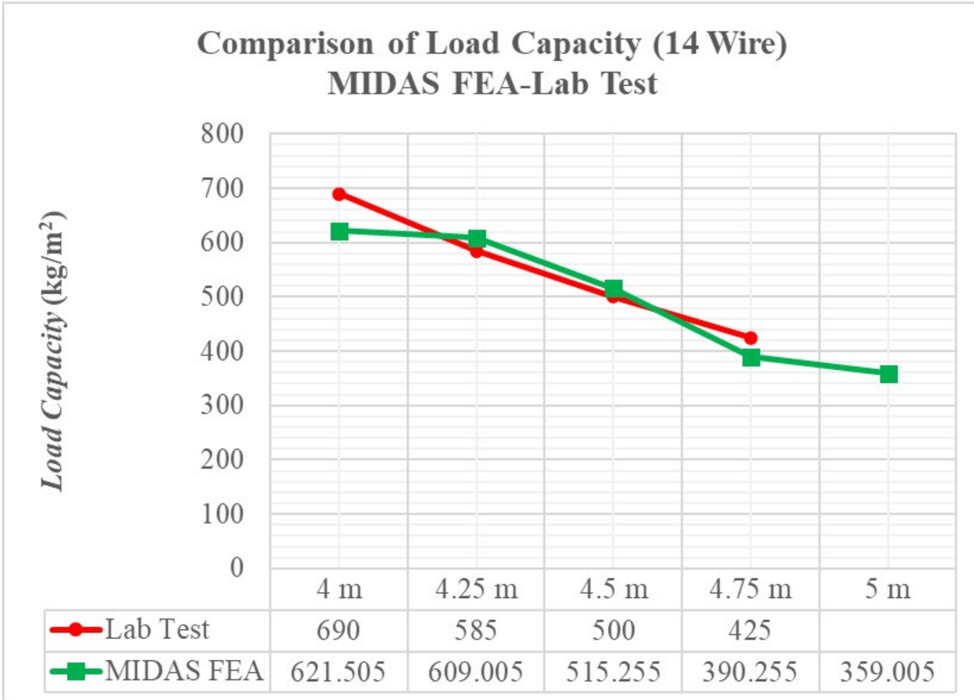

FIGURE 12. Comparison of Load Capacity MIDAS FEA – Lab Test (14 Wire)

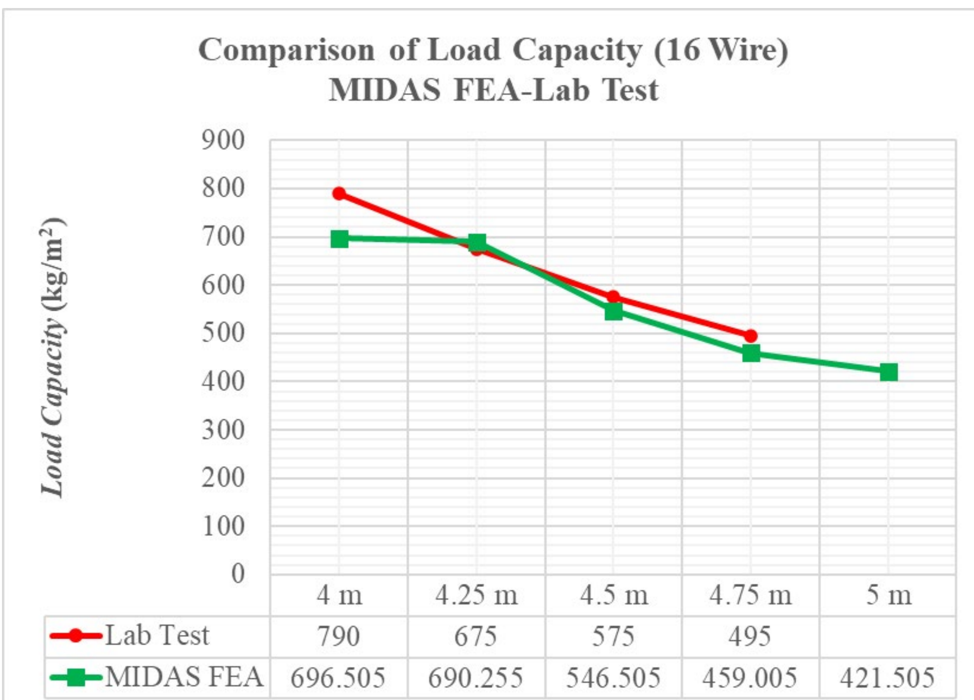

FIGURE 13. Comparison of Load Capacity MIDAS FEA – Lab Test (16 Wire)

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TABLE 2. Capacity And Ratio of Hollow Core Slab

HCS Code	Lab Test Load Capacity (kg/m^2)	MIDAS FEA Load Capacity (kg/m^2)	Load Capacity Difference (%)	Ratio (Load Capacity/Total)
H11	590	540.255	8.431	0.829
H12	690	621.505	9.927	0.844
H13	790	696.505	11.835	0.856
H21	500	515.255	3.051	0.823
H22	585	609.005	4.103	0.842
H23	675	690.255	2.260	0.855
H31	420	440.255	4.823	0.805
H32	500	515.255	3.051	0.823
H33	575	546.505	4.956	0.830
H41	-	352.755	-	0.778
H42	425	390.255	8.175	0.790
H43	495	459.005	7.272	0.810
H51	-	296.505	-	0.756
H52	-	359.005	-	0.780
H53	-	421.505	-	0.800

CONCLUSION

The following conclusions can be taken based on the results of the FEM analysis performed with the MIDAS FEA program:

- The capacity of the hollow core slab examined using the finite element method (MIDAS FEA) produces a capacity value that is similar to the results of the lab test, ranging from 2 to 11 percent.
- The analytical results demonstrate a growing trend: the more wires there are, the greater the capacity that the hollow core slab can carry.
- There is a downward trend; the greater the span of the hollow core slab, the less capacity that can be carried.
- In phases, the MIDAS FEA program can simulate the crack process in the hollow core slab.

REFERENCES

1. E. G. Nawy, Beton Prategang: Suatu Pendekatan Mendasar (Erlangga, Jakarta, 2001).
2. I. Imran and S. J. Pantazopoulou, "Slab-Wall Connections Under Lateral Forces," in ACI Structural Journal-1992, vol. 89, no. 5, pp. 515-527
3. D. R. Buettner and R. J. Becker, PCI Manual for the Design of Hollow Core Slabs (PCI Journal, Chicago, 1998).
4. J. H. H. Fellinger, Shear and Anchorage Behaviour of Fire Exposed Hollow Core Slabs (DUP Science, Delft, 2004).
5. R. D. Cook, D. S. Malkus and M. E. Plesha, Concepts and Applications of Finite Element Analysis (John Wiley & Sons, New York, 1989).
6. D. L. Logan, A First Course in the Finite Element Method (Brooks/Cole, United States, 2002).

https://doi.org/10.24912/ijaste.v1.i1.105-112