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Flexural Load Testing of Hollow Core Slab Systems with Added Concrete Topping

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Abstract

Hollow Core Slabs (HCS) are widely applied in multi-story buildings due to their efficiency and prestressed concrete system. The use of cast-in-place concrete topping is intended to enhance structural performance; however, sufficient composite action between the HCS and topping must be ensured. ACI 318-14 Section 16.4.4.2 specifies a minimum surface roughening depth of ¼ in. (6.35 mm) to achieve composite action between concrete elements. This study investigates the effectiveness of a reduced roughening depth of 2 mm in developing composite behavior between HCS and topping. Full-scale HCS specimens with additional toppings were experimentally tested under cyclic loading using a load-control method. Composite action was evaluated based on load response, stiffness degradation, and crack pattern observations. The experimental results demonstrate that a roughening depth of 2 mm is insufficient to develop composite action, as cracking was concentrated along the interface between the HCS and topping. These findings confirm the necessity of complying with the minimum roughening depth requirements specified in ACI 318-14.

Keywords

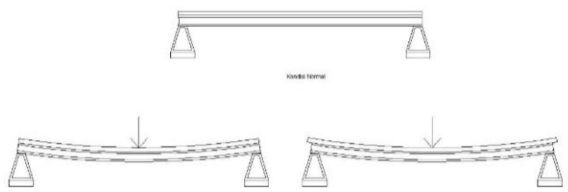
Composite action, roughing, cracking, topping

INTRODUCTION

Hollow core floor slabs are commonly used in the construction of concrete floors for multi-storey buildings. However, in many high-rise building projects, conventional cast-in-situ reinforced concrete floor systems are still widely applied. This conventional method involves multiple sequential construction stages, starting with formwork installation, followed by reinforcement placement, and finally concrete casting [10,11]. These stages require significant time, labor, and on-site coordination.

To accelerate construction progress and improve material efficiency, conventional floor slabs can be replaced with Hollow Core Slabs (HCS). Hollow core slabs are precast concrete elements containing longitudinal voids, which reduce self-weight while maintaining structural capacity. This system can be applied in various types of buildings, including residential houses, apartments, shopping centers, office buildings, hotels, parking structures, hospitals, and educational facilities [8]. Hollow core slabs are suitable for buildings with either steel structural systems or reinforced concrete structural systems [5]. The HCS units are typically manufactured using ready-mix concrete with a compressive strength of approximately K-450.

The surface roughening of the slab combined with the application of a concrete topping is intended to create a composite connection between the hollow core slab and the topping layer. Composite action occurs when two load-bearing structural components, such as a precast concrete slab and an in-situ concrete topping, are effectively bonded so that they act together under bending loads. In a fully composite system, both components deform simultaneously without slip occurring at the interface between the slab and the topping layer [1].



(a) (b)

Figure 1 Deflection of Hollow Core Slab: (a) composite condition, (b) non-composite condition

To understand the concept of composite behavior, it is first necessary to examine a non-composite slab system, as illustrated in Figure 1(b). In this condition, when the friction between the slab and the additional concrete topping is neglected, the slab and the topping independently resist portions of the applied load [4]. When the slab undergoes deformation due to vertical loading, tensile stresses develop at the bottom surface of the slab, causing elongation, while compressive stresses occur at the top surface of the topping, resulting in shortening. Consequently, a discontinuity develops at the interface between the slab and the topping. Since friction is ignored, only vertical internal forces are transferred between the slab and the topping, and no composite action is achieved.

In contrast, for a slab system exhibiting composite action, as shown in Figure 1(a), the slab and the topping act integrally to resist applied loads. In this case, the two components deform simultaneously and behave as a single structural element, resulting in improved load-carrying performance and stiffness. The composite action ensures that relative slip between the slab and the topping is minimized, allowing the system to function as a unified flexural member.

The design codes and standards adopted in this study include ACI 318 – Building Code Requirements for Structural Concrete [2] and SNI 2847 – Persyaratan Beton Struktural untuk Bangunan Gedung [3]. Additional testing and evaluation procedures follow relevant Indonesian and international standards for flexural testing and seismic performance assessment.

The problem formulation of this undergraduate thesis is to investigate the composite action developed in Hollow Core Slabs (HCS) with the addition of a concrete topping and a surface roughening depth of 2 mm in resisting applied loads.

The purpose of this study is to verify the composite behavior of Hollow Core Slab products manufactured by PT. BEP with a surface roughening depth of 2 mm, as well as to evaluate the load-carrying capacity of HCS systems incorporating concrete topping and surface roughening.

The objective of this final project report is to assess the effectiveness of topping-to-HCS interface strengthening through a roughened surface connection with a depth of 2 mm.

The scope and limitations of this study are defined as follows: the HCS specimen used is type HCS 250.07.18, the topping thickness is limited to 100 mm, the roughness depth at the HCS–topping interface is fixed at 2 mm, and the number of test specimens is limited to one unit.

Previous studies on Hollow Core Slabs (HCS) have demonstrated that precast hollow core slabs are structural elements with continuous longitudinal voids that significantly reduce self-weight while utilizing high-strength concrete and steel materials. One notable experimental study investigated the flexural behavior of prestressed precast hollow core slabs strengthened with CFRP layers. The flexural test results showed that the proposed strengthening method reduced cracking by up to 12.5% compared to unstrengthened HCS specimens and significantly reduced shear forces in prestressed hollow core slabs [6].

Based on these findings, the present study focuses on strengthening the interface between HCS and the concrete topping using a surface roughening method. This research aims to evaluate the resulting composite action and to determine the structural performance of the HCS–topping system when surface roughening is applied at the interface.

RESEARCH SIGNIFICANCE

This study provides experimental evidence on the effectiveness of surface roughening as an interface treatment to achieve composite action between hollow core slabs (HCS) and cast-in-place concrete topping. By evaluating the structural response, deflection behavior, strain distribution, and cracking patterns under cyclic flexural loading, this research contributes to a better understanding of the interaction mechanism between precast HCS elements and additional topping layers.

The findings of this study are expected to support engineers and practitioners in assessing the feasibility of using surface roughening with a depth of 2 mm as a method for improving composite performance in hollow core slab floor systems. Furthermore, the results can serve as a reference for precast concrete manufacturers and designers in optimizing construction methods, enhancing structural performance, and reducing construction time through the use of precast floor systems.

In addition, this research provides baseline experimental data that can be used for comparison with numerical simulations, such as finite element modeling, in future studies. The outcomes are also intended to contribute to the development and evaluation of design recommendations related to composite action in hollow core slab systems with concrete topping.

METHODOLOGY

This methodology describes the experimental procedure employed to conduct a two-point loading flexural test on a Hollow Core Slab (HCS) specimen with an additional concrete topping. The tested slab specimen has a width of 1,200 mm, a length of 6,000 mm, and a thickness of 250 mm, and is supplemented with a concrete topping layer with a thickness of 100 mm.

The specimen is supported using pinned–pinned boundary conditions. Rubber pads are placed at the support locations to ensure uniform load distribution and to reduce stress concentration at the supports. The loading configuration applied in this test is a two-point loading system, with a maximum applied load of 50 kN.

The primary objective of this loading scheme is to determine the maximum shear capacity developed at the interface between the Hollow Core Slab and the concrete topping. The load is applied incrementally and continuously until failure of the test specimen occurs.

A. CASE STUDY

The measuring instruments used in this experimental study include strain gauges for strain measurement and Linear Variable Differential Transformers (LVDTs) for displacement measurement. Three LVDTs are installed during the test. LVDT 1 is placed at the midspan on the underside of the slab to control the stroke during loading, while LVDT 2 and LVDT 3 are installed at one-third of the span from the left and right sides on the underside of the slab, as illustrated in Figure 2.

The testing equipment includes an MTS actuator, which functions as the loading device to apply force to the Hollow Core Slab (HCS). The load is applied gradually until failure of the HCS specimen occurs. A spreader beam is used as an auxiliary loading device to transform the initially concentrated load produced by the MTS actuator into a uniformly distributed load. In this study, the spreader beam consists of a rectangular steel plate with dimensions of 17.5

× 37.5 cm. Additionally, a transverse beam is employed to convert the uniformly distributed load from the spreader beam into a two-point loading configuration with adjustable spacing. The transverse beam used in this study consists of a square steel plate with dimensions of 10 × 10 cm.

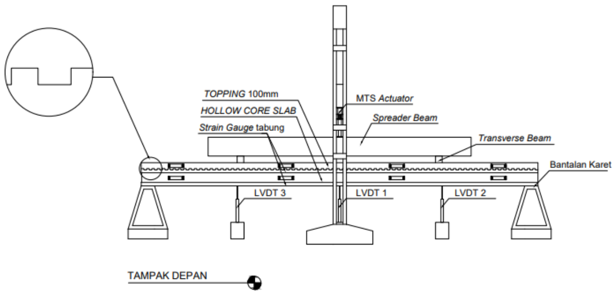


Figure 2 LVDT Position

Support beams are installed at both ends of the HCS specimen to act as the slab supports. Strain gauges are used to measure strain (deformation), while LVDTs function as sensors that convert movement or vibration into measurable data. All measurement data are recorded and processed using an HBM Data Acquisition (DAQ) System, which captures the deflection response of the HCS slab during loading. The recorded data are subsequently transferred to a laptop for documentation and analysis, as shown in Figure 2.

Based on the method of data acquisition, the data used in this study consist of secondary data. These data are not obtained directly from the test object but are sourced from data previously collected by another party. The secondary data were obtained from PT. Beton Elemenindo Perkasa (BEP) and include geometric specifications and material properties of the HCS and the concrete topping.

The surface roughening used to form the connection between the slab and the topping is applied along the transverse direction of the slab. The roughening process is performed while the slab is still in a wet condition to facilitate surface treatment and to prevent cracking, which could reduce concrete quality if the roughening were carried out after the slab had fully hardened.

The concrete topping is added after the roughened surface of the HCS has dried sufficiently. A topping layer with a thickness of 100 mm is cast on the top surface of the slab. The purpose of adding the topping is to increase the effective thickness of the HCS, thereby enhancing its load-carrying capacity and improving shear resistance at the interface.

RESULTS AND DISCUSSIONS

The technical specification data of the Hollow Core Slab (HCS) used in this study consist of a prestressed concrete slab with specified concrete strength and PC-wire properties, as illustrated in Figure 3. Detailed information regarding these specifications is presented in Table 1.

Additional variables related to concrete strength and PC-wire properties are presented separately in tabulated form.

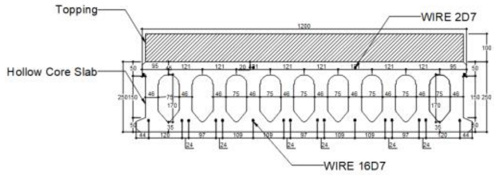


Figure 3 Specification Technis Hollow Core Slab

A. SPECIFICATION

The loading mechanism is conducted using displacement control, where the applied displacement is monitored based on the maximum displacement measured by the LVDT system. Prior to the commencement of the laboratory test, all measuring instruments and loading devices are installed on the test specimen and verified to be in proper working condition. The displacement cycles are then input into the LVDT readout system or data logger.

The test is carried out by applying displacement cycles incrementally, starting from the smallest displacement and gradually increasing to larger displacement levels. Displacement readings are continuously recorded until failure of the test specimen occurs, at which point the specimen is considered to have reached its ultimate load capacity.

Throughout the testing process, the crack patterns developed in the specimen are carefully observed at each displacement cycle. The crack patterns are documented by marking the observed cracks directly on the specimen surface using a marker or drawing tool to provide a visual record of crack propagation and failure behavior.

Table 1 Specification Technis Hollow Core Slab

No	Variabel	Value
1	Span (L)	6.000 mm
2	Width (B)	1.200 mm
3	Thickness of Slab HCS	250 mm
4	Thickness of Topping	100 mm
5	Resitrain	sendi-sendi
6	Concrete Young Modulus	27.805,57 Mpa

B. DEFLECTION

Based on the results presented in Figure 5, the field cyclic load test on the Hollow Core Slab (HCS) with an additional concrete topping, conducted using the load control method over three loading cycles, indicates that the maximum load was achieved during the third loading cycle. The maximum recorded load was 48 tons, corresponding to a displacement of 66.49 mm.

The relationship between deflection and time was obtained from three Linear Variable Differential Transducers (LVDTs) installed on the Hollow Core Slab (HCS). The maximum deflection recorded by LVDT 1 was −66.490 mm, while the maximum deflection recorded by LVDT 2 was −11.070 mm, and that recorded by LVDT 3 was −45.500 mm. The deflection–time relationship is presented in Figure 4.

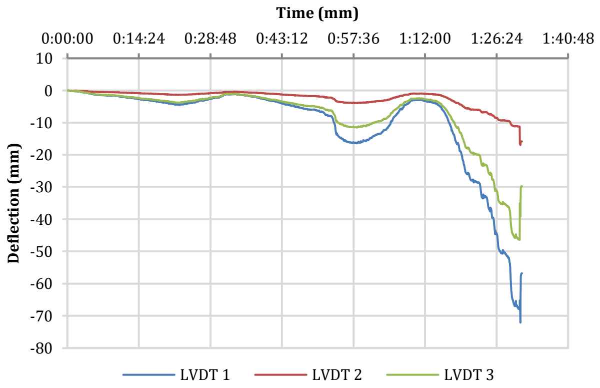


Figure 4 Deflection–Time Relationship

The load–deflection relationship of the Hollow Core Slab (HCS) was obtained using data from three Linear Variable Differential Transducers (LVDTs) installed on the HCS, along with cyclic load data applied to the specimen through three repeated loading cycles. The load–deflection relationship is presented in Figure 5.

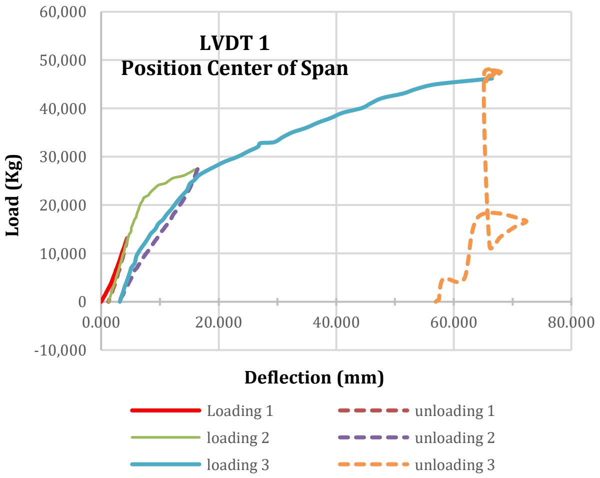


Figure 5 Load–Deflection Relationship

The loading pattern applied to the Hollow Core Slab (HCS) is shown in Figure 6. The peak load of the first loading cycle reached 13,140 kg, followed by a peak load of 27,440 kg in the second loading cycle, and a peak load of 47,885 kg in the third loading cycle.

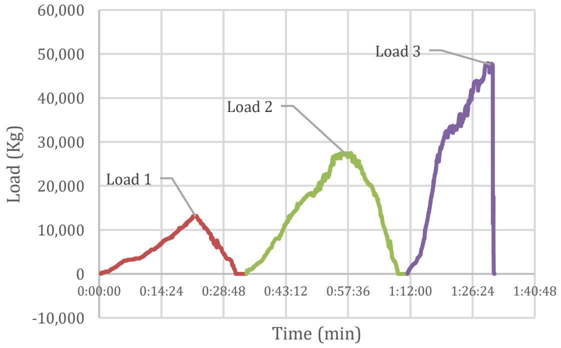


Figure 6 Load–Time Relationship

Table 2 Summary of Maximum Deflection at Each LVDT under Peak Load

Parameter	Loading 1	Loading 2	Loading 3
Peak Load (kg)	13,140	27,440	47,885
LVDT 1 (mm)	−4.410	−16.410	−66.490
LVDT 2 (mm)	−1.330	−3.910	−11.070
LVDT 3 (mm)	−3.770	−11.510	−45.500

C. STRESS & STRAIN

As shown in Figure 7, a total of eight strain gauges were installed on the slab specimen. The strain gauges with odd numbers (Strain Gauges 1, 3, 5, and 7) were installed on the concrete topping, while the strain gauges with even numbers (Strain Gauges 2, 4, 6, and 8) were installed on the Hollow Core Slab (HCS).

Figure 7 Crack Patterns Observed in the Test Specimen

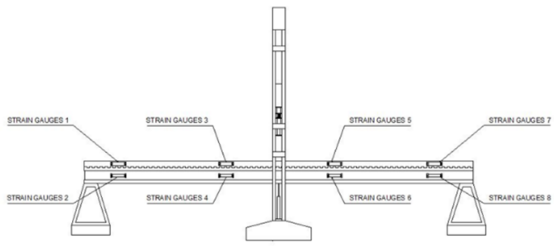


Figure 8 Placement of Strain Gauges on the Specimen

Based on the results presented in Figure 9, it can be observed that the strain recorded at the third peak load represents the highest strain value, with a magnitude of 0.027542 measured at Strain Gauge 6. Furthermore, Figure 9 indicates that at the second and third peak loads, the calculated stresses exceeded the material strength of the test specimen, which is 35 MPa. In contrast, during the first peak load, the stress level remained below the material strength, i.e., less than 35 MPa.

The results presented in Table 3 also indicate that the Hollow Core Slab (HCS) specimen exhibited partial composite action with the concrete topping. This conclusion is supported by the observation that certain regions of the HCS did not act integrally with the topping when the third peak load was applied. Specifically, Strain Gauge 2 failed at the interface between the HCS and the topping during the third peak load, indicating a loss of composite action at that location. In addition, Strain Gauges 5 and 6 also exhibited separation of composite action at the third peak load, as indicated by positive strain readings (+), suggesting differential behavior between the HCS and the topping layers.

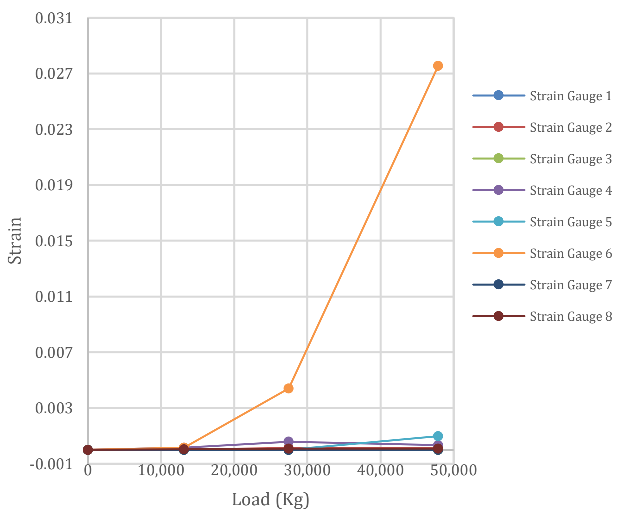


Figure 9 Strain – Load Relationship

Table 3 Summary of Stress Distribution in the Test Specimen

Strain Gauge	Peak Load 1 (MPa)	Peak Load 2 (MPa)	Peak Load 3 (MPa)
Strain Gauge 1	−4.403	−15.293	−21.318
Strain Gauge 2	0.463	3.707	3.244
Strain Gauge 3	−16.683	−46.343	−70.673
Strain Gauge 4	4.403	15.988	9.269
Strain Gauge 5	−12.513	−22.244	27.11
Strain Gauge 6	4.171	122.576	765.812
Strain Gauge 7	−0.463	−0.232	−1.622
Strain Gauge 8	0.927	2.317	2.317

During the first and second loading stages, the test specimen still exhibited composite action in all of its components, as indicated by the strain distribution diagram shown in Figure 11. However, during the third loading stage, separation occurred in the test specimen, resulting in the strain distribution diagram shown in Figure 10.

When the hollow core slab (HCS) and the additional concrete topping do not act compositely, the flexural stress distribution develops separately within each component, as shown in Figure 10. In contrast, when composite action is achieved, the HCS and the concrete topping behave as a single monolithic section, resulting in a unified flexural stress distribution over the entire cross section, as illustrated in Figure 11.

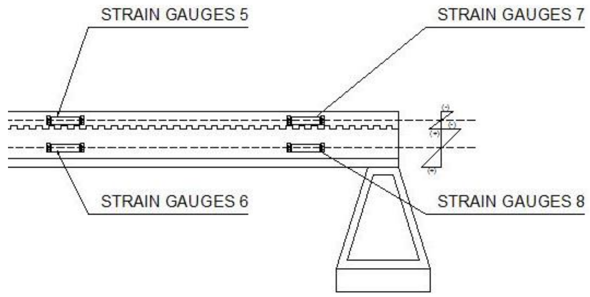


Figure 10 Non-Composite Action Observed in the Test Specimen

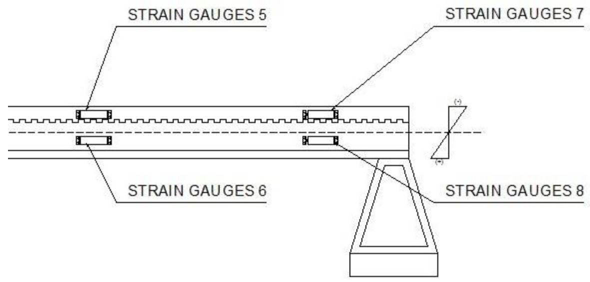


Figure 11 Composite Action Observed in the Test Specimen

CONCLUSIONS

This study aimed to evaluate the effectiveness of surface roughening with a depth of 2 mm in developing composite action between hollow core slabs (HCS) and cast-in-place concrete topping. The evaluation was carried out through an experimental two-point cyclic flexural load test, focusing on deflection behavior, strain distribution, crack patterns, and interface performance.

The field-testing results demonstrate that surface roughening with a depth of 2 mm does not produce composite action between the structural elements. This conclusion is supported by the observed cracking pattern in the hollow core slab (HCS), where cracks developed at the interface between the HCS and the concrete topping during the field test.

For future research, it is recommended to utilize numerical modeling using the finite element method to obtain data that could not be captured through experimental testing. Such analysis can also serve as a comparative study between connections with adequate surface roughening and those that do not meet the required roughening criteria.

REFERENCES

[1] Adityo, E., Katni, D., & Nursandah, A. (2020). Kajian Metode Struktur Pelat Konvensional terhadap Pelat Pracetak Segmental dan Pelat Bondek Ditinjau dari Segi Waktu, Biaya dan Struktur. Agregat, 5(1), 387–395. https://doi.org/10.30651/ag.v5i1.4977

[2] American Concrete Institute. (2014). Building Code Requirements for Structural Concrete (ACI 318-14). In American Concrete Institute.

[3] Badan Standarisasi Nasional Indonesia. (2013). SNI 2847:2013 Persyaratan Beton Struktural untuk Bangunan Gedung. In Badan Standarisasi Nasional Indonesia.

[4] Bekkos, R., & Kanestrøm, M. N. (2021). Tensile capacity of hollow core slabs subjected to concentrated edge loads. Norwegian University of Science and Technology.

[5] Buettner, D. R., & Becker, R. J. (1998). Manual for the Design of Hollow Core Slabs. Precast/Prestressed Concrete Institute, 1–141.

[6] Elgabbas, F., El-Ghandour, A. A., Abdelrahman, A. A., & El-Dieb, A. S. (2010). Different CFRP strengthening techniques for prestressed hollow core concrete slabs: Experimental study and analytical investigation. Composite Structures, 92(2), 401–411. https://doi.org/10.1016/j.compstruct.2009.08.015

[7] Imran, I Firdaus, F., Sangadji, S., & HarTono, W. (2017). Analisis Perbandingan Efisiensi Penggunaan Hollow Core Slab (HCS) Dibandingkan dengan Pelat Konvensonal in Situ Pada Proyek Pembangunan Gudang Ciwastra Bandung. E-Jurnal MATRIKS TEKNIK SIPIL, 1418–1426. https://103.23.224.239/matriks/article/view/36920.

[8] Hasan, M., Saidi, T., Sarana, D., & Bunyamin. (2022). The strength of hollow concrete block walls, reinforced hollow concrete block beams, and columns. Journal of King Saud University - Engineering Sciences, 34(8), 523–535. https://doi.org/10.1016/j.jksues.2021.01.008

[9] Johnson, T., & Ghadiali, Z. (1972). Load Distribution Test on Precast Hollow Core Slabs With Openings. J Prestressed Concr Inst, 17(5), 9–19. https://doi.org/10.15554/pcij.09011972.9.19

[10] Meleka, N. N., Tayel, M. A., & Heiza, K. M. (2017). Behavior of Precast Prestressed Hollow Core Slabs With Openings: Experimental Study. ERJ. Engineering Research Journal, 40(4), 325–329. https://doi.org/10.21608/erjm.2017.66358

[11] Sofyan, M., Rokhman, A., & Irlan, A. O. (2019). Analisis Perbandingan Metode Desain Pelat Beton Konvensional Terhadap Slab Steel Deck Komposit. Forum Mekanika, 8(1), 36–42. https://doi.org/10.33322/forummekanika.v8i1.428