Structural Engineering and Mechanics, *Vol. 89, No. 6 (2024) 627-634*
https://doi.org/10.12989/sem.2024.89.6.627

Assessment of structural behavior of reinforced concrete slab ceiling under full load test in a residential complex project

Jaffar A. Kadim[a], Oday A. Abdulrazzaq*, Abdulamir A. Karim[b] and Aqeel H. Chkheiwer[c]

Department of Civil Engineering, College of Engineering, Basrah University, Al-Basrah, Republic of Iraq

(*Received March 23, 2023, Revised March 21, 2024, Accepted March 22, 2024*)

Abstract. This research deals with the process of conducting a reinforced concrete slab loading test of a Residential Complex Project at the Shatt Al Arab District which is located in southern Iraq. The purpose of the test which represents a destructive test is to evaluate the structural behavior of the slab condition state during and after the examination of the test process in order to ascertain the ability of the slab ceiling to withstand the loads generated during the use of the building. The test was carried out accordant to ACI 437.2-13 code. The reason for this test is the postponed 8 years of building project construction. Concrete blocks were used to simulate and conduct a loading test of 30-tons for 3 days. The central point has been installed to measure the slab deflection that occurred during the test. The results showed that both the total deflection and residual deflections were lesser than the permissible values according to the ACI 437.2-13, the RC slab behavior was mainly linear structural behave, and that the purpose of the examination was achieved. Finally, a new method was introduced to the assessment of the slab condition at the support which is found in good condition.

Keywords: compression loading test; destructive test; load distribution; RC slab ceiling; residual deflection; slab deflection

1. Introduction

The load test of RC structures member is extensively used as the final decision for the strength assessment of existing and new structures. This test may be undertaken under many conditions such as:

a- The soundness (integrity) of a structure member is in inquiry;
b- The materials test results are not satisfied the project material test requirement.
c- After extreme loads;
d- If the structure will be used for a new function; and,
e- To evaluate the strengthening and retrofitting of a structure.

The strength and behavior of a structure member through the load test may be evaluated using different ways which means the applied standards of the load test both acceptance limits and procedures are critical to show the engineering conclusion in the strength estimation and to ensure the structure is to be out of construction problems when planned it to be used. The American Concrete Institute (ACI) addresses in-situ load testing in two standards; ACI 318 (Building Code Requirements for Structural Concrete) (2014) adopts a monotonic (24-hour) load test and ACI 437.2 (Code Requirements for Load Testing of Existing Concrete Structures) (2013) which adopts both the cyclic load test (CLT) and a modified version of the monotonic (24-hour) load test. ACI 437.2-13 is referenced by ACI 562 (Code Requirements for Evaluation, Repair, and Rehabilitation of Concrete Buildings) (2013). In this paper, the ACI 437.2-13 is used for the RC loading test which relates to conducting a loading test of a roof of the third floor of one building in Shatt Al-Arab District, Basra, Iraq. The American specification ACI 437.2-13 was adopted in the assessment of the actual structural condition of the roof conditions under the monotonic load.

Testing of Reinforced concrete slab ceiling structures is covered in a large area of researches, studies, and modeling of the structural behavior subject so that the simulation and differences analysis between the theoretical analysis and site tests have been developed for many years. The loading test in most construction applications is a vital and decisive test applicable in different structures which used for evaluating the validity of different facilities because this test is considered as a destructive test and usually represented as the final solution and last decision for the problem of unknown and identification of actual reality of the reinforced concrete structures. The main problem of this test is the high cost and time consuming in addition to the highly safety risks for both workers and structures.

The loading test is often asylum in many cases, regardless of the creation of a new or up-to-date basis, and for many reasons, including inadequate technical tests (etc.) in the knowledge of the slab in the absence of real slab

*Corresponding author, Ph.D.
E-mail: oday.abdulrazaq@uobasrah.edu.iq
[a]Ph.D.
E-mail: jaffar.kadhim@uobasrah.edu.iq
[b]Ph.D.
E-mail: abdulamir.karim@uobasrah.edu.iq
[c]Ph.D.
E-mail: aqeel.chkeiwer@uobasrah.edu.iq

ISSN: 1225-4568 (Print), 1598-6217 (Online)

condition. For unreliable conditions or assessed conditions for unresolved situations such as unknown of the actual structure's status, postponed period of construction, or frameworks mistakes during concrete casting, changes in environmental circumferences like the moisture change or the level of groundwater variation, or failure situations close to the structure edges. In such cases, however, the problem is usually not related to the consultative materials valuation, but to the change of the nature of the slab properties from their initial properties that used in the final design of the structure.

For the above-mentioned reasons, the loading test is a final solution for the evaluation of the true reality for the ability to slab status. A good survey of this test was achieved by many refreshers such as Fellenius (2012) who collected 51 papers associated with loading tests so that many good ideas can be found from these studies. In the following paragraph, some applications used to check the foundations for sites and simulation applications will be given.

Paolo Casadei *et al.* (2004) reported the results of the load test method type diagnostic cyclic which compared with the presented monitoring procedure of one day procedure of standard ACI-318. The structures were built in 1970 for conducting proportional in situ experiments load testing and it is considered as a parking garage used in a research test bed before distortion at 2002. The structure consisted of a reinforced concrete frame with RC slabs (one way) in addition to the steel of two stories. Both the procedure of (ACI-318-02) and the proposed diagnostic load test had been used for two same RC slabs and later load test, the two RC slabs had been loaded until reaching limited failure in order to permissible seeing remarks on the margin of safety regards to failure.

Masetti *et al.* (2006) worked with the load test in order to evaluate a structure strength in which the load test procedure was based on ACI 318 Building Code which based on a 24-hour. The load was static load which uniformly distributed of a magnitude calculated from the design load. The procedure to determine patch loads had been provided in the paper based on the effects of the applied loads on the structure member lead to generating both shear or bending moment internal forces at critical locations that equal to those resulting from the used load which was uniformly distributed on the member. The field data analysis had been provided professionals guide with confirmation on the authority of field load test evaluation for the satisfactoriness for the actual status of RC structural members.

ElBatanouny *et al.* (2015) worked with two load test patterns which evaluated and compared in terms of the load test protocol, load value, load criteria, and allowable criteria. Two tests were carried out according to ACI 437 in order to determine the existing RC structure's status since the question of the integrity of a structure was a big problem, in addition, there was concerning if the structure satisfies the required safety conditions. The test was successful to achieve the purpose of employing it.

Buddhawanna *et al.* (2015) conducted a load test in the RC hospital structure in Thailand. This hospital was not working because of the existence of huge deflections of the deck slabs, where these large deflections were seen with the naked eye. Another problem was raised from the undrained rain-water monitor which was remaining on the roof slap that cause corrosion to the reinforced steel rebar. For such a situation, the owner felt much horror to use a hazardous structure for the hospital and the demand was for carrying out two test types; load test and non-destructive tests to decide the strength quality of the deck slabs. The results show that the comparison of the deflection of the slab by the permissible deflections of ACI 318 had fulfilled met the test requirements.

Lantsoght *et al.* (2017) conducted slab tests on bridges built after the Second World War. The rate types of the bridges were inadequate related to the Eurocodes standards hence appropriate methods had been introduced for the assessment of the RC slab bridges to help the transportation officials making knowledgeable decisions. Because of the lacking bridges data related to the structural capacity reduction which occurred due to the degradation of bridge material or if showing an inadequate expected capacity assessment therefore a bridge proof load test can be conducted as in situ test as a decision to ensure if the bridge that could carry a certain load level so that the dangerous locations which carefully selected to give the maximum effect of shear forces and bending moment. The analysis of test results gave a set of recommendations for the execution and systematic preparation.

Lam *et al.* (2018), investigated the flexural behavior of a full-scale composite floor slab made of steel and concrete. The composite floor slab of (10.6 m×4.0 m×0.13 m) was loaded repeatedly over four cycles under the effect of an equivalent uniform load of 20 kPa. The recorded deflection values under working load were acceptable and no serious damage was observed.

Saleem *et al.* (2019) worked with in-situ load testing of the flat slabs per the ACI-318 procedure of reinforced concrete buildings for allowing the evaluating of the sufficiency of existing structures through insufficient design data or unknown deterioration of interior material. The structure consisted of five stories which two of them located underground. The structure exposing to damage due to environmental mechanisms and it had been halted for eight years. Therefore, the load test had been selected on each floor for two slab panels. The test results showed that there were no severe defects found in the load test. Nevertheless, the slab related to the first floor displayed extreme deflection and cracking during the test. The permissible values of deflection had satisfied the required criteria for the tested slabs excluding those of the first floor.

Albareda *et al.* (2020) studied the behavior of a ceramic-reinforced slab (4.88 m×7 m×0.23 m), located in an old industrial building, under the effect of 6 load cycles of (7.5 kPa) as maximum uniform pressure. The load was applied using sacks filled with sand where each load cycle was applied for a duration of 1 day. Under the effect of the maximum cyclic load, it was found that the measured deflection values during the load test were very small.

Kigoye and Kyakula (2022) worked on the study of the concrete slab loads resulting from construction load on slabs before use. The slabs were stacked through construction with different construction materials. According to the survey conducted on 118 erratically selected sites in Kampala exposed that 87% of cases found that the supports were removed from the lower reinforced concrete slab then props were put on its top for support. Also, it had been revealed that 80.6% of the slabs had construction loads like sand, timber, bricks, blocks, and aggregates. It was discovered that the loads from freshly cast concrete were equal to 158% larger than working design live loads resulting in the maximum deflection due to a freshly cast slab and blocks were 1.15 mm and 11.815 mm, respectively, compared with the instant deflection was 0.103 mm from the design imposed load.

Li *et al.* (2022), prepared a study to strengthen a hollow slab bridge of (5 m×20 m) using polyurethane-cement composite (PUC). The static load test was used to check the reliability of the slab before and after the slab strengthening with PUC. It is revealed that the measured deflection and strain values after the strengthening process were 15% less compared to that before the strengthening process.

2. Problem description

The reinforced concrete frame structure (columns, beams, and slab) consists of three stories which was built in 2014 for one project at Shatt Al Arab District which is located in the north of the Basra Governorate, southern Iraq. After the construction reinforced concrete frame with slab, the project was postponed for reasons related to the events that the country went through at the time. The suspension continued until 2021, and during that pause period (approximately four years), it was observed that some cracks occurred in different parts of the buildings. It is recognized the main reason which caused these cracks is environmental effects such as humidity, rain, dust, differential temperature change, etc. Therefore, it is required to decide the type, importance, and development of these cracks during the loading test.

The routine nondestructive tests such as the rebound hammer, the half-cell potential, the ultrasonic pulse velocity and even the concrete core test are not sufficiently considered here to decide the performance and behavior of the building after stopping for four years. Therefore, to check the changes in slab properties during these four years past and to determine the creep and shrinkage effects it is decided to conduct a load test for the slab by selecting the major portion of the entire ceiling in the loading test as permitted by ACI 437.2-13 code instead of testing the overall ceiling area, hence a larger part of the reinforced concrete building where the problem of precipitation occurred, based on the visual cracks formation to know the real behavior of the slab and to compare the resulting precipitation with the permissible values for the project according to ACI 437 before starting to using the building.

3. Statement method

3.1 Test load

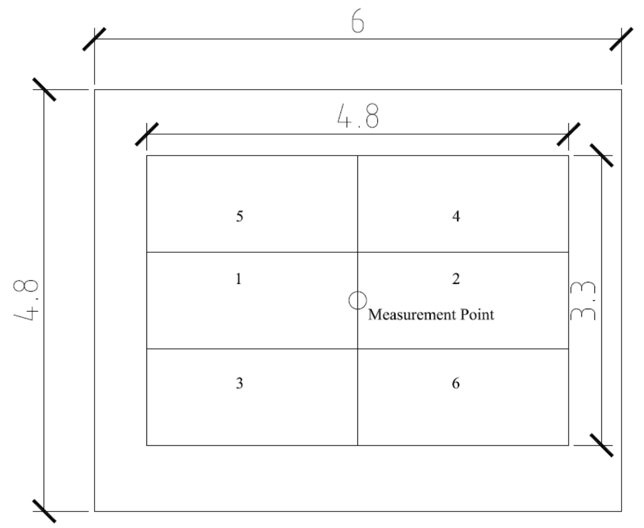

Fig. 1 RC block sequence placement for roof test monotonic load test

The loading test required concrete blocks with dimensions of (2.4×1.1×0.75 m) which are readily available so that each block weight equals 5.0 tons used to satisfy the recommended magnitude and distribution of loading (the layout of the loading area with respect to slab locations was shown in Fig. 1. The blocks are to be placed on one layer (increments) in order to simulate the existing slab loads resulting the total load equals to 285.12 kN in which the blocks are numbered according to their placement sequence.

To obtain the slab deflection, a steel column of circular section (3.0 m length, outer diameter 12 cm and wall thickness 6 mm) in which at both ends a steel plate is welded. The top plate is fixed to the bottom face of the slab by four steel bolts while at the bottom end of the steel column, two dial gauges are glued to measure the free movement of the steel column. The location of the measurement point was chosen because it corresponds to the gravity center of both the applied testing load and the center of clear spans of the ceiling.

3.2 Monotonic load test per ACI 437.2-13

The ACI Code 437.2-13 adopt the monotonic load test method with some differences in the load magnitude and acceptance criteria combated with the monotonic load test per ACI 318. The ACI 437.2-13 is stated that “If only part of the structure in question is to be evaluated and these members are statically indeterminate, TLM shall be determined using Eq. (1) as”

$$TLM = 1.3(Dw + Ds) \tag{1a}$$

$$TLM = 1.0Dw + 1.1Ds + 1.6L + 0.5(Lr\ or\ S\ or\ R) \tag{1b}$$

$$TLM = 1.0Dw + 1.1Ds + 1.6(Lr\ or\ S\ or\ R) + 1.0\ L \tag{1c}$$

where:

TLM=Test Load Magnitude

D=total dead load= $Dw + Ds$, or related internal moments or forces

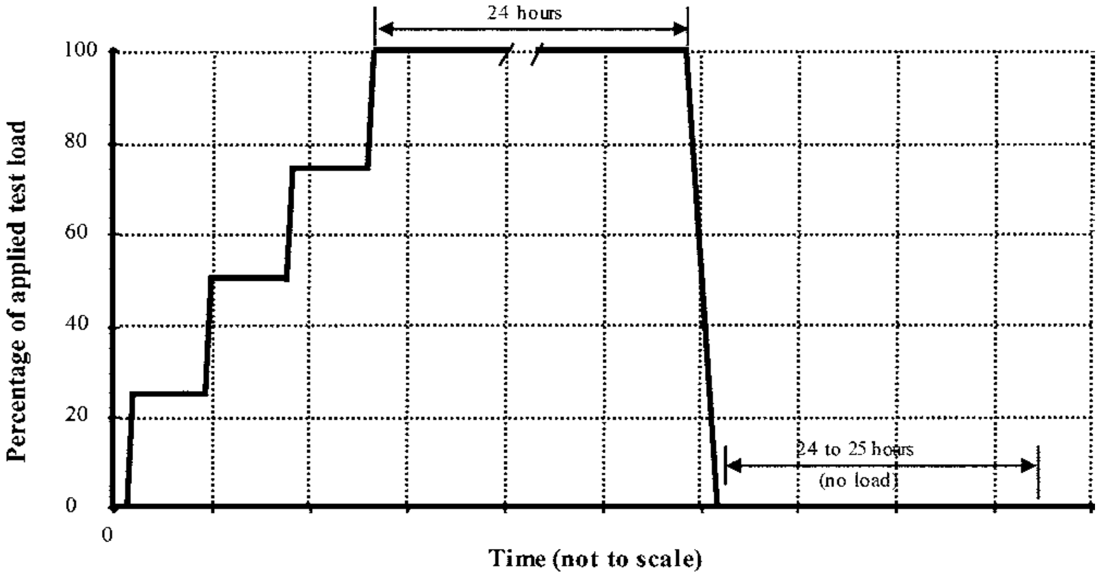

Fig. 2 Loading protocol for the monotonic load test procedure

Ds =superimposed dead load, or related internal moments or forces

Dw =load due to the self-weight of the concrete structural System

L=live load due to use and occupancy of the building not including environmental load and superimposed dead load, or related internal moments or forces

Lr=roof live load produced during maintenance by workers, equipment, and materials or during the life of the structure by moveable objects such as planters and people, or related internal moments or forces

R=rain load, or related internal moments and finishing materials

S=snow load, or related internal moments or forces

For the building of interest, the values of TLM per square meter of roof area are estimated as follows:

Dw =Slab thickness×Concrete density=0.15×24=3.60 kN/m^2

Ds=Weight of finishing materials+weight of False ceiling+weight of additional equipment related to water, electric systems and other additional imposed dead load

Finishing materials=Bituminous waterproof+sand+ Precast concrete flags

Weight of Bituminous waterproof=0.01×11=0.11 kN/m^2

Weight of sand=0.06×16=0.96 kN/m^2

Weight Precast concrete flags=0.042×24=1.01 kN/m^2

Weight of False ceiling=0.25 kN/m^2

Weight of additional equipment=0.25 kN/m^2

Additional imposed dead load=0.50 kN/m^2, Therefore:

Ds=0.11+0.96+1.01+0.25+0.25+0.50=3.08 kN/m^2

Live load for building roof is taken usually=1.50 kN/m^2

Roof live load produced during maintenance is not defined accurately and its value is approximately assumed equal to 0.50 kN/m^2.

No snow load in Basra city also rain load is small compared with the maintenance load. So that the TLM is found from Eq. (1) as follows:

TLM=1.3(Dw+Ds) =1.3(3.60+3.08)=8.69 kN/m^2, or;

TLM=1.0Dw+1.1Ds+1.6L+0.5(Lr or S or R)

TLM=1.0×3.60+1.1×3.08+1.6×1.50+0.5×0.50=9.64 kN/m^2, or;

TLM=1.0Dw+1.1Ds+1.6(Lr or S or R) +1.0L

TLM=1.0×3.60+1.1×3.08+1.6×0.5+1.0×1.5=9.29 kN/m^2

Finally, the proof and total test load is collated as given below;

Proof Load=(D+L)×Roof area=(3.60+3.08+1.5+0.5)× 28.8=250.0 kN, and:

Total TLM=TLM×Roof area=9.64×28.80=277.63 kN

3.3 Loading protocol

There are several ways to apply the test loads, including using of sand bags or cement bags in addition to the use of water barrels or bricks or concrete blocks. The choice of any method depends on what is available in the project site as well as economic considerations. According to the conditions prepared at the project site, the concrete block will be selected to apply the loads. The load test method which adopted by ACI Code 437.2-13 is displayed as in Fig. 2 which required at least four equal load increments. Also, the ACI 437.2-13 allows using either the uniform distributed load on the entire roof area or using a portion (patch) of the same area in which in this pattern the applied load can be considered as concentrated load or strip load. In the current test, the patch area is used by taking 6 concrete blocks of dimension 2.4 m×1.1 m×0.75 m (loading area is 15.84 m^2) which produce a total load magnitude equal to:

TLM=6×2.4×1.1×0.75×24=6×4.752=285.12 kN>Required TLM (277.63 kN)

In addition, the applied load will take 6 load increments which satisfy the 437.2-13 requirements (minimum 4 increments).

Finally, the load arrangement will satisfy section R5.2 of ACI 437.2-13 which is distributed at the center zone of the roof area as illustrated in Fig. 1 which gives the details about concrete block placement location and the two dial gauges location (at the center point of roof area). As mentioned in Fig. 3, the patch (zone) area of the loading test

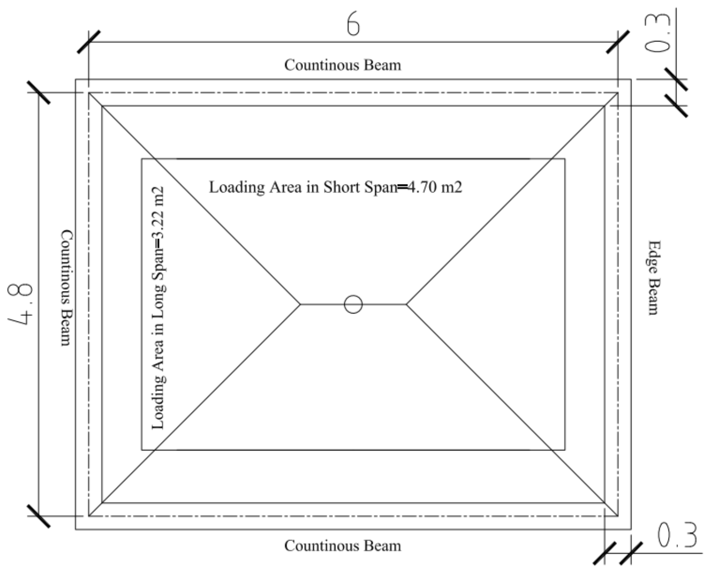

Fig. 3 Block load distribution for half portion in long and short direction of slab orientation

Fig. 4 Pictures show the main aspects of loading test

is (6×2.4×1.1=15.84 m^2) meaning that the patch area ratio is (15.84/28.80=0.55) which is located at and near the center line of roof area so that this arrangement will give a higher structural response (deflection and internal stresses) leading to the results of loading test using concrete block is more safe than the uniformly distributed load on the entire area of the roof when using the same value of LTM.

To demonstrate the main important aspects of the loading test such as the equipment used in lifting the concrete block, the dial gauges used to measure the deflection, and the distribution of concrete blocks in the final stage of the loading test, Fig. 4 displays the related pictures for this purpose.

3.4 The acceptance criteria

The acceptance criteria could be summarized as flows;

A- The portions or sections of the structure tested using the cyclic loading protocol or monotonic loading protocol shall show no evidence of failure.

B- If at any time during the load test a member develops cracks indicating imminent shear failure, it shall be considered as having failed the load test. Retesting of the failed member is not permitted.

C-The member or structure shall be considered to have passed the load test if the residual deflection,

Δ_r, satisfies Eq. (2a) and the maximum deflection,

Δ_l, measured during the test satisfies Eq. (2b)

$$\Delta_r \leq \Delta_l/4 \tag{2a}$$

$$\Delta_l \leq 180 \tag{2b}$$

where;

L_t=span of the member under load test and taken as the smaller of: (a) distance between centers of supports; and (b) clear distance between supports plus thickness *h* of member; for a cantilever, it shall be taken as twice the distance from the face of support to cantilever end, in. In the present test, the span of member (L_t) equals 4.8 m (188.0 in) which results in the following limits of acceptance criteria:

Δ_l≤188.00/180=1.044 in≤26.53 mm

4. Results and discussion

The summary of the loading test data recorded is given in Figs. 5 to 7 that show the time-load, time-deflation, and

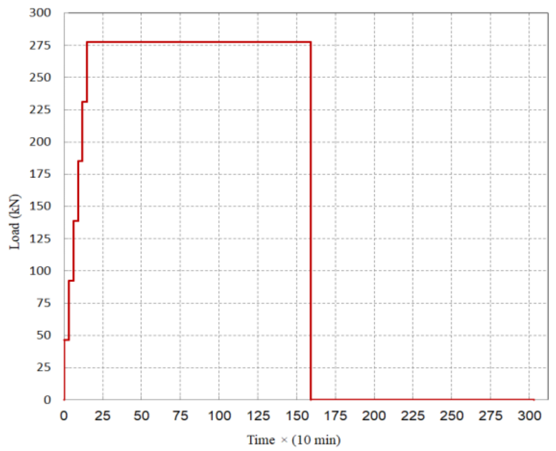

Fig. 5 Relationship between the time and the applied load for the tested roof

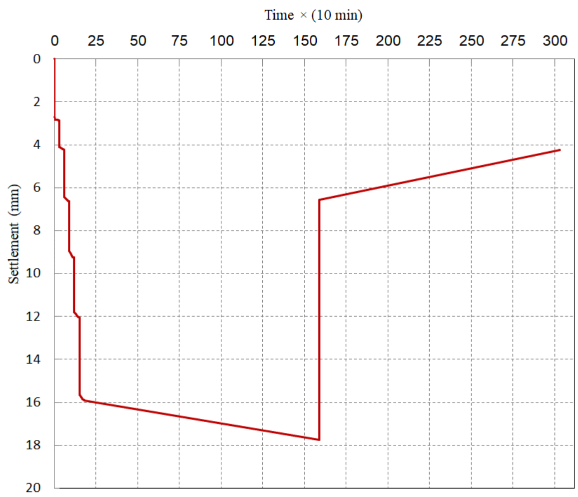

Fig. 6 Relationship between the time and the settlement for the tested roof

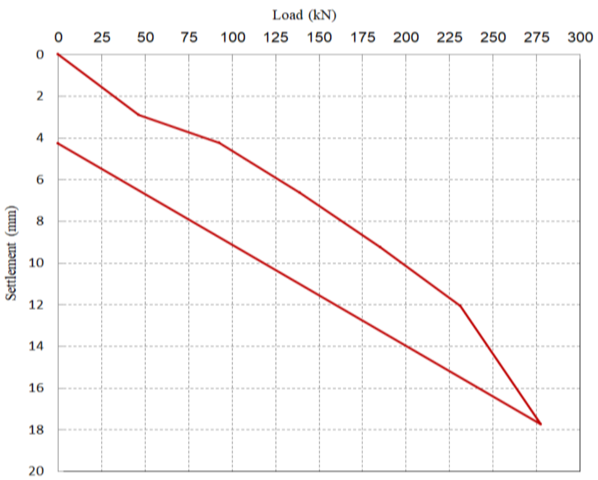

Fig. 7 Relationship between the applied load and the settlement for the tested roof

load-deflection curves respectively. Also, Table 1 gives the loading test results associated with the maximum and residual deflection compared with the allowable limits in addition to their assessment of the loading test.

Table 1 The loading test results summary

List	Computed deflection (mm)	Limited deflection (mm)	Ratio
Maximum deflection	17.74	26.53	0.67
Residual deflection	4.25	4.44	0.96

Table 2 Slab stiffness for each load increment

Load stage	Total load (kN)	Max. deflection (mm)	Slab stiffness (kN/mm)
Loading 1	46.27	2.88	16.066
Loading 2	92.54	4.24	21.826
Loading 3	138.82	6.64	20.906
Loading 4	185.09	9.24	20.031
Loading 5	231.36	12.05	19.200
Loading 6	277.36	17.74	15.635

It appeared during the loading test that no evidence of failure had been noticed such as a progressive increase in deflection under any load stage, new cracks formation, and falling of concrete cover pieces. It is observed at the end of the loading test, that the existing cracks remain unchanged meaning that no structural behavior defects exist. Also, Table 1 shows the tested roof slab passed the loading test so the roof slab can be used to satisfy the design load.

In custom work, the results of the loading test appeared that the test has fulfilled the requirements in specification ACI 437, but for accurate knowledge of the nature of the structural behavior of the RC slab during the test with its other edges components (such as supporting beams end condition) the results to be need another deep sight inside the obtained test results by introduce additional two parameters that must be made for this type of test; the first parameter is the stiffness factor of the RC slab roof, which is equal to the total load applied to the roof divided by the largest deflection at each stage of loading as well as shown in Table 2. The other parameter is the degree of fixity coefficient (DOF).

From (Fig. 7), it is so clear that the ceiling exhibits three different cases; the first where the ceiling shows a lower stiffness than all other two stages and the reason for this can be traced back to the fact that there are some defects that occurred over time (about 4 years) and among these defects a percentage of wear from creep, as well as the impact of environmental conditions on the condition of the structural roof.

The second case of loading shows a similar structural behavior, and here it can be considered the linear behavior of the RC slab roof after exceeding the old defects in the roof, and this linear stage gives us an important indication that the roof is in the normal service loads condition will behave in a linear manner as a result of the expected loads.

The last stage of the loading has a decrease in the stiffness parameter which is an important indicator of the occurrence of the nonlinear cracking condition, i.e. the completion of the linear behavior stage and the beginning of the nonlinear stage due to the occurrence of micro-cracks in the concrete roof slab in which this fact can be deduced and comprehend from the residual deflection which represents the permanent defection (plasticity effect in RC slab) occurred after removal of the test load.

One of the important and indirect results of the loading test is to know the status of the slab fixity ends condition in the short direction because it represents the critical case in the load partition, considering that both ends are continuous and casting with beams because the project was left for non-short period of time. To achieve this goal, the proposed method is presented here to determine the support condition, which depends on the degree of fixity coefficient (DOF) that is introduced here as the second parameter used in the assessment of the end slab condition. It works by comparing the test results in the middle of the short direction with the results for the free and fixed slab states to determine the degree of restriction at the ends and on the following transformation based on the unit width of the short span knowing that the slab thickness is 200 mm and concrete compressive cylinder strength is 28 MPa and from Fig. 3 which leads to;

Loading portion in short direction based on area partitions; (LP)=4.70/(4.70+3.22)=0.59

Stiffness parameter for free end condition; $K_{free} = (384EI/5L_S^3) \times LP$

Stiffness parameter for fixed end condition; $K_{fixed} = (384EI/L_S^3) \times LP$

$$E = 4750\sqrt{f_c{}'} = 4750\sqrt{28} = 25135 \text{ N/mm}^2$$

$$I = t^3/12 = 200^3/12 = 66666 \text{ mm}^4$$

$$K_{free} = 384 \times 25135 \times \frac{66666}{5 \times 4800^3} \times 0.59 = 6.870 \text{ kN/mm}$$

$$K_{fixed} = \left(384 \times 25135 \times \frac{66666}{4800^3}\right) \times 0.59 = 34.330 \text{ kN/mm}$$

$$DOF = \frac{K_{slab} - K_{free}}{K_{fixed} - K_{free}} = \frac{15.635 - 6.870}{34.330 - 6.870} = 0.32 \text{ , and}$$

$$Kr = \frac{K_{slab}}{K_{fixed}} = \frac{15.635}{34.330} = 0.46$$

Where Kr is the ratio of rigidity of the actual slab state compared with fixed condition.

The degree of fixity coefficient (DOF) of short support indicates an important fact that the slab nature lies between the free and the fixed states and approximately half the fixed rigidity, which means the slab behavior is maintained as intermediate nature and exhibits the continuous state as the slab-beam constructed and the stopped period do not affect the or causing serious damage at the support zones.

From the previous discussion, it appeared during the loading test that no evidence of failure had been noticed such as a progressive increase of deflection under any load stage, new cracks formation, and falling of concrete cover pieces. Also, the maximum deflection and the residual deflection of the loading test lie under to the allowable limits. Also, it appeared that the reinforced concrete roof slab passed the loading test and the roof slab can be used in safe condition as mentioned in the required design load.

5. Conclusıons

From the obtained test results (the test was carried out according to ACI 437.2-13 code), it is evident that:

- The assessment of the loading of the concrete ceiling has been successfully completed and its required criteria have been exceeded according to Specification 437 A. The damages that exist due to leaving work on the project for a period of four years are minimal and do not lead to any real risks.
- The structural analysis and the field results showed that the structural behavior of the roof is of a linear type.
- The structural behavior of the roof varies from a linear state to a non-linear state in the case of final loading.
- The creep effect of the concrete was small and lesser than the allowable limits so its effect can be neglected.
- Using a new proposed method, the slab status and the structural behavior of the supported beams at short direction remain unaffected by the stopped time of the project.

References

ACI 318 (2014), Building Code Requirements for Structural Concrete, American Concrete Institute.

ACI 437.2 (2013), Code Requirements for Load Testing of Existing Concrete Structures, American Concrete Institute.

ACI 562 (2013), Code Requirements for Evaluation, Repair, and Rehabilitation of Concrete Buildings, American Concrete Institute.

Albareda-Valls, A., Rivera-Rogel, A., Costales-Calvo, I. and García-Carrera, D. (2020), "Real cyclic load-bearing test of a ceramic-reinforced slab", *Appl. Sci.*, **10**(5), 1763. https://doi.org/10.3390/app10051763.

Buddhawanna, S., Witchayangkoona, B. and Panmekiat, S. (2014), "Structural strength evaluation by NDE and load test of RC slab structure, case study: RC deck slab of primary hospital building", Faculty of Medicine, Thammasat University, Thailand.

Casadei, P., Parretti, R., Nanni, A. and Heinze, T. (2005), "In situ load testing of parking garage reinforced concrete slabs: Comparison between 24 h and cyclic load testing", *Pract. Period. Struct. Des. Constr.*, **10**(1), 40-48.

ElBatanouny, M., Ziehl, P., Larosche, C. and Nanni, A. (2015), "Load testing techniques for the strength evaluation of existing reinforced concrete structures", *Forensic Engineering*, 30-39.

Hussein, M.H., Massarsch, K.R., Likins, G.E. and Holtz, R.D. (2012), "Full-scale testing and foundation design: Honoring Bengt H. Fellenius", *American Society of Civil Engineers*, March. https://doi.org/10.1061/9780784412084.

Kigoye, E. and Kyakula, M. (2022), "Load deflection relationship of a solid slab under the action of construction loads", *Adv. Civil Eng.*, **2022**, Article ID 3125920. https://doi.org/10.1155/2022/3125920.

Lam, D., Dai, X. and Sheehan, T. (2019), "Testing of a full-scale composite floor plate", *Eng.*, **5**(2), 223-233. https://doi.org/10.1016/j.eng.2018.11.021.

Lantsoght, E., van der Veen, C., de Boer, A. and Hordijk, D.A. (2017), "Proof load testing of reinforced concrete slab bridges in the Netherlands", *Struct. Concrete*, **18**(4), 597-606. https://doi.org/10.1002/suco.201600171.

Li, C., Sun, Q. and Liu, Y. (2021), "Study on static load test of simply supported hollow slab bridge flexural strengthened with polyurethane–cement composite", *Int. J. Struct. Integr.*, **13**(1), 112-132. https://doi.org/10.1108/IJSI-08-2020-0073.

Masetti, F., Galati, N., Nehil, T. and Nanni, A. (2006), "In-situ load test: a case Study", *Fédération Internationale du Béton*

Proceedings of the 2nd International Congress, Naples, Italy.
Saleem, M.A., Abbas, S. and Nehdi, M.L. (2019), "Assessment of reinforced concrete slabs using in-situ load testing: A case study", *J. Build. Eng.*, **25**, 100844. https://doi.org/10.1016/j.jobe.2019.100844.

CC