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STRUCTURAL BEHAVIOR OF HOLLOW-CORE REINFORCED CONCRETE ONE WAY SLABS WITH PLASTIC PIPES

A Thesis Submitted to Council of College of Engineering, University of Diyala in Partial Fulfillment of the Requirements for the Degree of Master of Science in Civil Engineering

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بسم الله الرحمن الرحيم

"وَيَسْأَلُونَكَ عَنِ ٱلرُّوحِ قُلِ
ٱلرُّوحُ مِنْ أَمْرِ رَبِّي وَمَآ أُوتِيتُم
مِّنَ ٱلْعِلْمِ إِلاَّ قَلِيلاً "

صدق الله العظيم

مــن ســورة الاســراء ـ آيـــة ٨٥

CERTIFICATION

I certify that the thesis entitled **"Structural Behavior of Hollow-core Reinforced Concrete One Way Slabs with Plastic Pipes"** was prepared by **"Ahmed Abbas Mahdi"** under my supervision at the Department of Civil Engineering/College of Engineering/ University of Diyala in partial fulfillment of the Requirements for the Degree of **Master of Science in Civil Engineering.**

Signature:

Supervisor: Asst. Prof. Dr. Murtada Ameer Ismael

Date: / / 2020

In view of the available recommendation, I forward this thesis for debate by the examining committee.

Signature:

Name: Prof. Dr. Khattab S. Abdul-Razzaq
Chairman of the Department of Civil Engineering.

Date: / / 2020

COMMITTEE DECISION

We certify that we have read the thesis titled (**Structural Behavior of Hollow-core Reinforced Concrete One Way Slabs with Plastic Pipes**) and we have examined the student (Ahmed Abbas Mahdi) in its content and what is related with it, and in our opinion it is adequate as a thesis for the degree of Master of Science in Civil Engineering.

Examination Committee	**Signature**
Assist. Prof. Dr. Murtada Ameer Ismael (Supervisor)	....
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The thesis was ratified at the Council of College of Engineering/ University of Diyala

Signature:

Name: Prof. Dr. Anees Abdullah Khadom

Dean of College Engineering/ University of Diyala

Date: / /2020

Dedication

To whom he strives to bless me comfort and welfare, my dearest father, and to the spring that never stops giving, my mother, their love and encouragement made me able to get a great success.

To my darling wife who supported me in each step of my life, she is the candle of my way.

To all who teach, support and trust me, especially my wonderful supervisor "Dr. Murtada" who made me enjoy my work.

With my love and gratitude.

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Structural Behavior of Hollow-core Reinforced Concrete One Way Slabs with Plastic Pipes

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ABSTRACT

Reinforced concrete hollow-core slab is a new type of lightweight slabs which has longitudinal voids through the long direction of the slab. The hollow-core concrete slab has many advantages over the solid slab; however, the longitudinal voids provide the ability to reduce the concrete amount, resulting in reduction the dead loads which consequently leads to cost-saving, fast construction and getting long-span. Also, eliminate the concrete contributes in the sustainability process due to reducing the CO_2 emitted from the cement industry.

This thesis presents an experimental study to investigate the structural behavior of hollow-core reinforced concrete one-way slabs. The experimental program includes casting and testing twelve reinforced concrete one-way slab with dimensions 1700mm×435mm×125mm, to study the effect of longitudinal voids number (two, three and four), longitudinal voids diameter (50, 63,75mm) and type of concrete strength (normal and high strength) on the structural behavior of hollow core slabs.

The experimental results showed that elimination the concrete with percentages 16.25%, 24.37%, and 32.5% from the hollow-core slabs using two, three, and four longitudinal voids with diameter 75mm respectively, result in decreased the first crack load with percentages 6.06%, 11.36%, and 16.67% in normal strength slabs and with percentages 8.84%, 13.49%, and

17.21% in high strength slabs, and saving the ultimate strength with percentages 93.47%, 87.63%, and 82.92% in normal strength slabs and with percentages 89.29%, 85.07%, and 80.61% in high strength slabs. Also, elimination the concrete with percentage 10.83%, 17.20%, and 24.37% from the hollow-core slabs using three longitudinal voids with diameters 50mm, 63mm, and 75mm respectively, result in decreased the first crack load with percentages 2.27%, 5.30%, and 11.36% in normal strength slabs and with percentages 5.58%, 8.37%, and 13.49% in high strength slabs, and saving the ultimate strength with percentages 93.37%, 90.01%, and 87.63% in normal strength slabs and with percentages 90.06%, 87.84%, and 85.07% in high strength slabs.

In the field of sustainability, using the hollow-core slabs can reduce the raw materials weight up to 30% with cost-saving up to 23% in normal strength slabs and 28% in high strength slabs. Also, using the hollow-core slabs can reduce the CO_2 emission and the embedded energy by about 33%.

Table of Contents

CHAPTER THREE: EXPERIMENTAL WORK

CHAPTER FOUR: EXPERIMENTAL RESULTS AND DISCUSSION

CHAPTER FIVE: CONCLUSIONS AND RECOMMENDATIONS

List of Figures

List of Plates

List of Tables

List of Symbols

Ø	Reduction factor
Δy	Deflection at yield load
Δu	Deflection at ultimate load
$\mathcal{E}y$	Strain at yield load
$\mathcal{E}u$	Strain at ultimate load
a/d	shear span to effective depth
D	Diameter of longitudinal voids
d	Effective depth
E	Elastic modulus of elasticity
fc'	cylinder Compressive strength
fct	Splitting Tensile Strength
fcu	Cube Compressive strength
fr	Flexural Strength
h	Total thickness of slab
L	Span length
Pcr	Crack load
Pu	Ultimate load
Py	Yield load

LIST OF ABBREVIATION

ACI	American Concrete Institute
ASTM	American Society for Testing and Materials
BS	British Standard
CO_2	Di oxide Carbon
DCC	Dry Cast Concrete
FRP	Fiber Reinforced Polymer
GFRP	Glass Fiber Reinforce Polymer
H	High Strength
HCS	Hollow-core Slab
HSSC	High Strength Self-compacted Concrete
I	Moment of Inertia
LSP	Limestone Powder
LVDT	Linear Variable Deflection Transducer
N	Normal Strength
N.A	Neutral Axis
NSM	Near Surface Mounted
NSSC	Normal Strength Self-compacted Concrete
RC	Reinforced Concrete
SCC	Self-compacted Concrete

CHAPTER ONE
INTRODUCTION

1.1 General

Reinforced concrete slab is the member that used as floors and roofs in the building and used in the decks of bridges. The floor system can take many forms such as solid slab, precast slabs, and ribbed slabs. The slabs may be supported on a concrete beams, steel beams, and walls or directly on the columns **(Mosley, et al., 2012).**

The slab is the most important structural member in the building which is the largest member consuming concrete. When increasing the span of the building, the thickness of the slab must be increased to decrease the deflection and that leads to an increase in the size of the column and foundation, therefore, the building will consume more materials and this will increase the cost of the building and the time of construction **(Chung, et al., 2011)**.

Varies attempts have been carried out on reinforced concrete slabs to reduce its self-weight with a minimum reduction in the flexural capacity of the slabs, the reduction in the self-weight of the slab will reduce the deflection and will make slabs with larger span length without using intermediate supports. Waffle, bubbled and hollow-core slabs were used to reduce the slab self-weight and to provide slabs with a long span **(Marais, 2009).**

1.2 Hollow-core Slabs (HCS)

The Hollow-core slab is a concrete slab with continuous voids that extend through the long direction of the slab as shown in Plate (1-1), these voids provided for reducing the weight and cost of the slabs and for passing the mechanical or electrical facilities. The hollow core slab has a very long span reach up to 18 m without supports. The HCS provides high structural efficiency with low material consumption **(Stephen, 2013).**

The hollow-core slab were developed at about 1950s as precast units with depth ranging from 150mm to 300mm and width ranging from 600mm to 1200mm, it has half the self-weight of the solid slab with the same dimensions **(Elliott, 2002).**

Plate (1-1) Hollow core slab (Way, et al., 2007)

1.2.1 Advantages of Hollow-core Slabs

The main advantages of the hollow-core slabs can be summarized as follows **(Buettner and Becker, 1998):**

- Reducing the self-weight of the slabs and that leads to reduce the dimensions of the structural members and foundations. Reducing the slabs self-weight come from the reduction in concrete volume due to using the recycled plastic pipe to create the longitudinal voids in hollow-core slabs and this technique meets the sustainability requirements.

- Longer span without intermediate supports.
- The hollow-core can be used for passing the mechanical and electrical facilities.
- Reducing the time of construction.
- Reducing the total cost of the building.
- Providing an efficient floor and roof system.
- Providing good thermal and sound insulator.
- Green technology.

1.2.2 Applications of Hollow-core Slabs

The Hollow-core slabs have many applications, one of these applications was a multi-storey building in Birmingham city in the United Kingdom as shown in Plate (1-2). This building was a residential building with a 1500m^2 slab floor and 6.1m span between beams, the slab thickness of this building was 200mm **(Way, et al., 2007).**

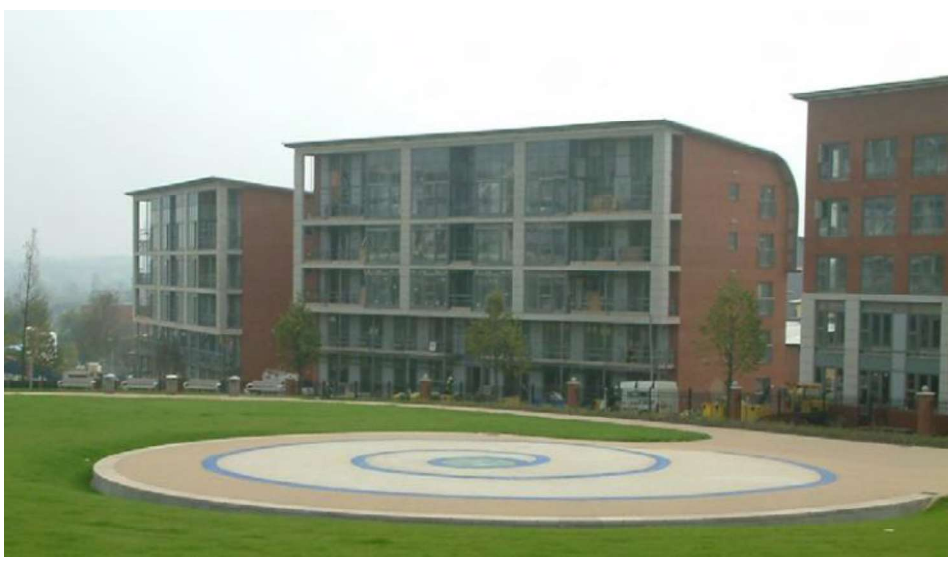

Plate (1-2) Multi-storey building in United Kingdom (Way, et al., 2007)

Another application of the hollow-core slabs was the headquarters monetary agency building in Riyadh city in Saudi Arabia as shown in Plate (1-3) **(Yee and Eng, 2011).**

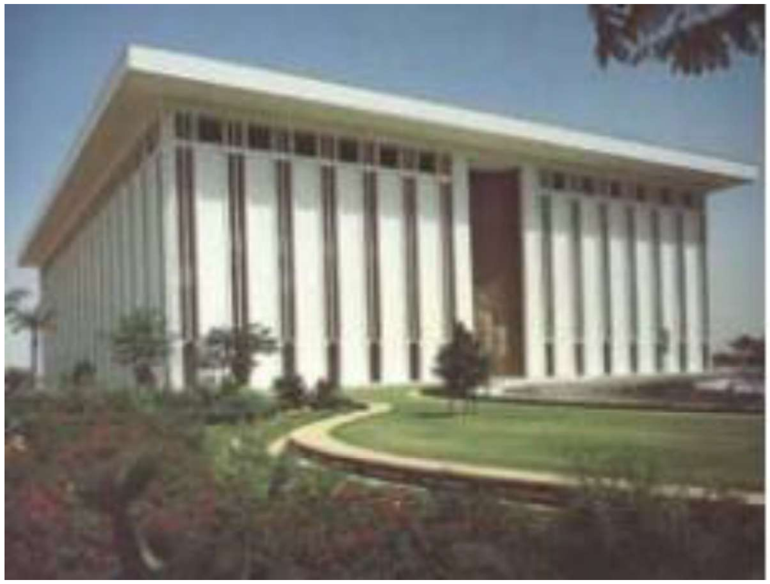

Plate (1-3) Headquarters monetary agency building in Saudi Arabia (Yee and Eng, 2011)

One from the applications of the hollow-core slabs in Iraq was Al-Mumenat School in Diyala governorate in Al-Kalis city which is under construction school and has a 7m span between walls as shown in Plate (1-4).

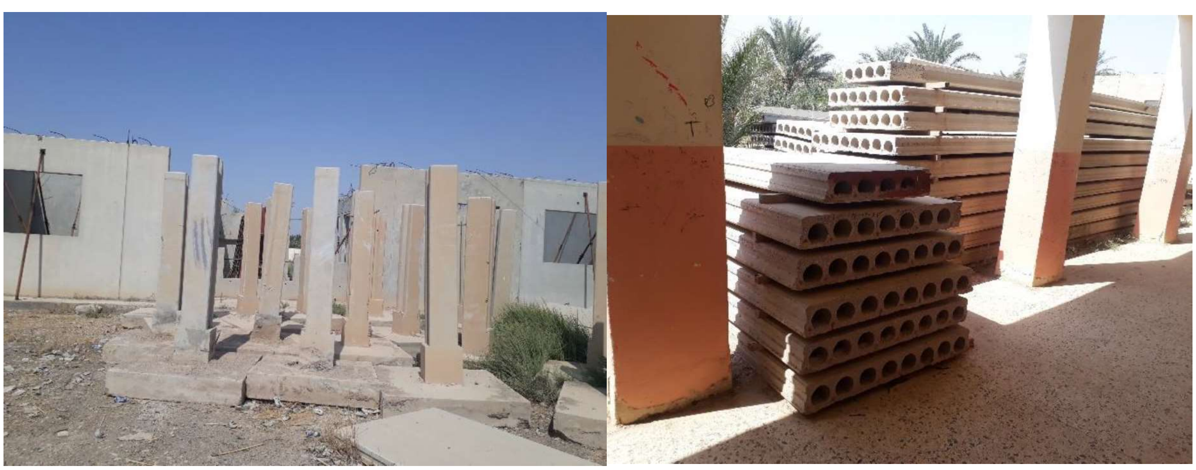

Plate (1-4) Al-Mumenat School in Diyalaa governorate

1.3 Objective of the Study

The objectives of this research are to investigate the structural behavior of the hollow-core reinforced concrete one-way slab with different number and size of longitudinal voids for both normal strength self-compacted concrete (NSSC) and high strength self-compacted concrete (HSSC) and compare this result with the structural behavior of the solid slab. Also, studying the sustainability of the hollow-core slabs due to placing the recycled plastic pipes in the middle of the slab cross-section where the flexural stress is minimum to eliminate some amount of concrete. This process leads to reduce the self-weight of the slabs and then it leads to reducing the embedded energy and the CO_2 emission from the cement industry and this process is considered environmental-friendly action which contributes to the sustainability process.

1.4 Methodology and Limitations

The experimental program of this research starting by casting and testing two solid slabs and ten hollow-core slabs. The study ending with discussion the result in terms of cracking load, ultimate load, crack pattern, mode of failure, load-deflection relationship, concrete compressive strain, and steel tensile strain. The experimental work has the following variables:

- Number of longitudinal voids in the hollow-core slabs (two, three, and four).
- Size of longitudinal voids in the hollow-core slab (50mm, 63mm, and 75mm).
- Type of concrete strength (normal strength and high strength)

1. 5 Layout of the Thesis

This thesis divide to five chapters as they are presented below:

- **Chapter one:** contains a general introduction about the hollow-core slab with its advantages and applications. It also contains the objective of this study.
- **Chapter two:** contains a review on the methods of reducing the self-weight of the slabs which includes a review on the hollow-core slabs, the sustainability developments, and the previous studies.
- **Chapter three:** presents the experimental program, properties of the construction materials, concrete mixes, slabs details and tests of the slabs.
- **Chapter four:** contains analyses and discussions of the experimental result of the tested slabs in this study.
- **Chapter five:** contains conclusions drawn from this research and offers recommendations for future studies.