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University of Diyala
College of Engineering

Structural Performance of Fibrous Reinforced Concrete One-way Bubbled Slabs

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

By

Ahmed Sardar Hakeem

(B.Sc. in Civil Engineering, 2016)

Supervised by

Prof. Ph.D. Ahmed A. Mansor

2022 A.D **IRAQ** **1444 A.H**

CERTIFICATION

I certify that the thesis entitled " **Structural performance of fibrous reinforced concrete one-way bubbled slabs**" was prepared by " **Ahmed Sardar Hakeem** " under my supervision at the Department of Civil Engineering-College of Engineering- Diyala University in partial fulfillment of the Requirements for the Degree of **Master of Science in Civil Engineering**.

Signature:

Supervisor: Prof. Dr. Ahmed A. Mansor

Date: / /2022

COMMITTEE DECISION

We certify that we have read the thesis entitled " **Structural Performance of Fibrous Reinforced Concrete One-way Bubbled Slabs** " and we have examined the student **(Ahmed Sardar Hakeem)** 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.

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3- Lecturer. Dr. Huda M. Mubarak (Member) ....

4-Asst. Prof. Dr. Mohammed A.Elwi (Member) ....

Prof. Dr. Wissam D. Salman (Head of Department) ....

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Signature..

Name: Prof. Dr. Anees A. Khadom

Dean of College of Engineering / University of Diyala

Date: / / 2022

بسم الله الرحمن الرحيم

﴿ وَيَسْألَونَكَ عنَ اَلرُّوحَ قُلِ
الرُّوحُ مِنْ أَمْرِ رَبِي وَمَا
أُوتِيتُم مِّنَ الْعِلْمِ إلا قَلِيلاً ﴾

صدق الله العظيم

سورة الاَّسراء – آية 85

Dedication

To My Family

With Love and

Respect

Acknowledgments

All praise is to Allah, who enabled me to accomplish this valuable work.

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I would also like to thank the construction laboratory staff for their support in completing this work.

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Abstract

A reinforced concrete slab with plastic voids (Bubbled-Deck system) is a form of a slab with a two-dimensional configuration of voids designed to reduce the slab's self-weight while keeping about the same load-bearing capability as solid slabs. Plastic voided slabs may decrease the quantity of concrete by 35%, which is crucial in terms of cost savings and structural performance improvement. This study experimentally examines the strength and behavior of bubbled reinforced concrete one-way slabs. The experimental program evaluates eleven one-way slabs with (1760×420×125mm) diminution; one solid slab (without balls and fibers), and one bubble slab (with spherical balls but without fibers), which is used as a reference.; the other nine slabs are fibrous bubbling slabs (with a spherical ball and fibers), and these nine slabs are divided into three groups based on fiber types (steel fiber bubble slabs, polypropylene fiber bubble slabs, and chopped carbon bubble slabs). The experimental study includes the following parameters: the types of fibers and the percentage of each type, the experimental findings showed that basic bubbled slabs containing spherical ball had 90% of the ultimate load of solid slab and for steel fiber bubble slabs the increase in ultimate load capacity was (14.5 to 25.2 %) compared to solid slab and (26.8 to 39.8 %) compared to basic bubble slab , for polypropylene fiber bubble slabs the increase ultimate load capacity was (12.8 to 20.64 %) compared to solid slab and (25 to 33.6%) compared to basic bubble slab , for chopped carbon fiber bubble slabs the ultimate load result showed a

variation (13.15 to -6 %) compared to solid slab and (25.3 to 4 %) compared to bubble slab in addition, the first crack load result showed a reduction for basic bubble slab compared with sold slab by (15.4%); for steel fiber bubble slabs first crack load increase by (38.46 to 84.6 %) compared to solid slab and (63.3 to 118.1 %) compared to basic bubble slab , for polypropylene fiber bubble slabs first crack load increase by (13 to 30.7 %) compared to solid slab and (33.6 to 54.4%) compared to basic bubble slab , for chopped carbon bubble slabs first crack result showed a variation (13.15 to -6 %) compared to solid slab and (34.5 to 7.3 %) compared to basic bubble slab in addition the type of failure had been changed form shear failure in bubble slab to flexural failure for all fibrous bubble slabs.

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A List of Symbols

Symbol	***Definition***
D	Ball diameter (mm)
d	Effective depth (mm)
E	Elastic modulus of elasticity
ε_{cr}	Strain at crack load (mm)
ε_{u}	Strain at ultimate load (mm)
ε_{y}	Strain at yield load (mm)
f'_c	Cylinder Compressive strength (Mpa)
f_{ct}	Splitting Tensile Strength (Mpa)
f_r	Flexural Strength (Mpa)
H	The total thickness of the slab (mm)
L	Span length (mm)
P_{cr}	Crack load (kN)
P_u	Ultimate load (kN)
P_Y	Yield load (kN)
Vu	Vertical shear force (kN)
Δ_u	Deflection at ultimate load (mm)
Δ_y	Deflection at yield load (mm)

List of Abbreviations

Abbreviation	***Definition***
AASHTO	American Association of State Highway Officials
ACI	American Concrete Institutes
ASTM	American Society for Testing and Material
BS	British standards
CO_2	Carbon Dioxide
C.F.B.S	Carbon fiber bubble slab
C.F.C	Carbon fiber concrete
F.R.C	Fiber reinforcement concrete
N.C	Normal concrete
P.F.B.S	Polypropylene fiber bubble slab
P.F.C	Polypropylene fiber concrete
R.C	Reinforced Concrete
S.F.B.S	Steel fiber bubble slab
S.F.C	Steel fiber concrete

CHAPTER ONE

INTRODUCTION

1.1 General (Bubble Slab)

The slab is one of the most significant structural parts of a building, and it consumes the most concrete **(Chung, 2011)**. The initial design constraint for a reinforced concrete slab is the column span. Large spans between columns frequently need thick slabs and support beams. Using significant volumes of concrete increases the structure's dead weight. Heavy constructions are less resistant to seismic forces than light buildings due to the considerable dead load and rising inertia forces. Adding support beams increases floor-to-floor heights, which increases finish material prices **(Midkiff, 2013)**. For decades, many efforts have been undertaken to manufacture biaxial hollow slabs to save weight. Many attempts were employed, such as waffle slabs/grids. Only waffle slabs have some market value, but their resistance to shear, local punching, and fire is limited **(Joseph, 2016).**

"Bubble-Deck System," invented by (Jorgen Breuing) in the nineties, was used to decrease the slab's weight. This system uses spherical balls made of recycled industrial plastic to create air voids while providing strength through the arch action, as shown in Plate (1-1).

Plate (1-1) Bubbled RC Slab System (www.BubbleDeck.com)

Reducing the dead load makes the long-term response more economical for the building while offsetting increases the slab deflection **(Lai, 2010)**. The Bubble-Deck system offers many advantages in building design and construction **(Fuchs,2009).**

1. By reducing the slab's self-weight by around 30% to 50%, the bubble slab decreases the amount of concrete used in columns, walls, and foundations by approximately 20%, so the total reduction was in the whole building not only the slab.

2. A bubbling slab requires less concrete than a solid concrete structure; one kilogram of plastic replaces more than 100 kilograms of concrete. As a result, CO_2 emissions into the atmosphere throughout the production process are reduced. Additionally, it complies with environmental standards by using recycled plastic balls.

3. Reducing energy consumption in production, transportation, and carry out.

4. Reducing the total building construction cost by about 8 to10%.

5. Decreasing the time of construction.

6. Green technology.

7. Providing sound and thermal insulators.

1.2 Application of Bubble-Deck Slab

Bubble slabs have many applications, such as (**www.BubbleDeck.com):**

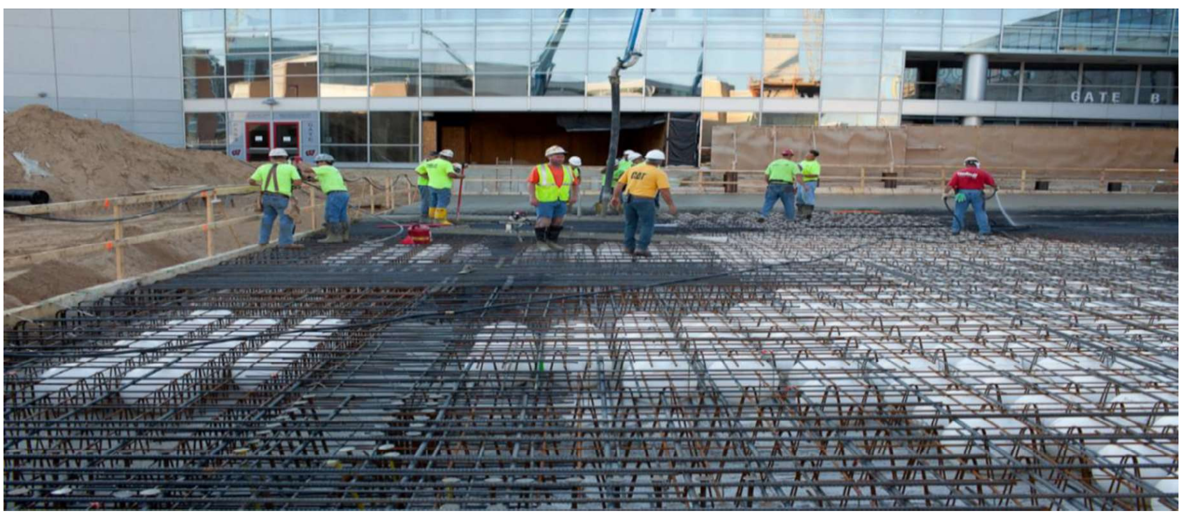
- Car parker building
- Office building
- High rise building
- Factory and warehouse building

- Public building

  In Germany, Holland, Denmark, and United States, the bubbling slab technology has been applied in several structures. Several of these systems are shown below:

- **La Bahn Hockey Arena La Bahn**

La Bahn Hockey Arena La Bahn is the University of Wisconsin's hockey team arena in the United States. Following consultation with a Bubble-Deck manufacturer, the designer's team recommends adopting a Bubble-Deck system for the walkway. Filigree panels are installed within two days of the location's delivery. It consists of the plastic ball, the primary reinforcement, and the concrete bottom layer. The top layer of concrete is done after one week. By incorporating a bubble deck into the walkway, plate (1-2) illustrates the arena's construction. **(Midkiff, 2013)**.



Plates (1-2) Construction of La Bahn Hockey Arena (www.BubbleDeck.com)

- **Millennium Tower**

Millennium Tower is one of the first high-rise structures in Holland to use Bubble-Deck, with 35 floors (25000m^2) and 140m high. The Tower was finished in 2000., as shown in Plate (1-3).

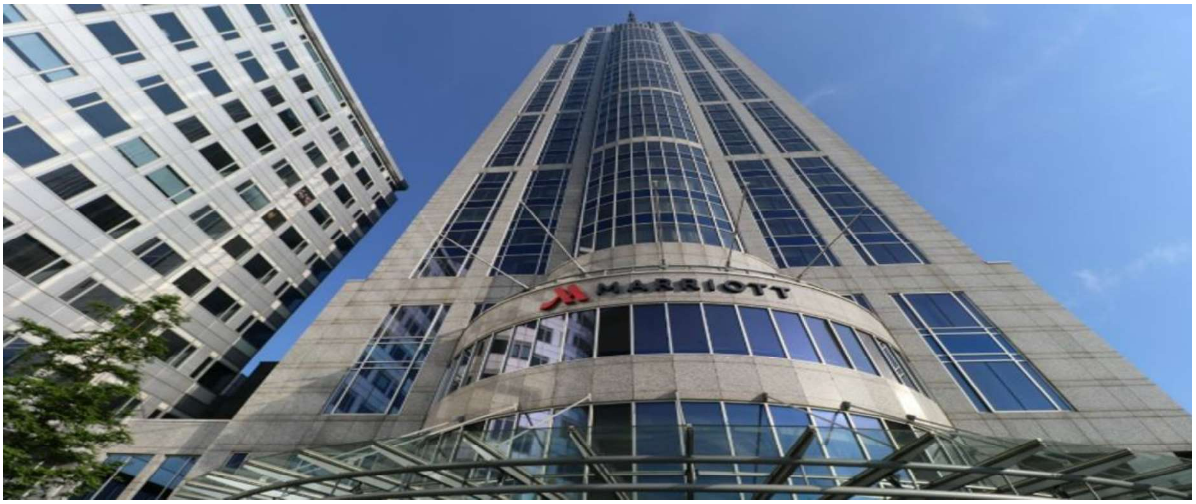


Plate (1-3) Millennium Tower (www.BubbleDeck.com)

1.3 One-way Slab

The one-way slab is a slab that is supported by parallel walls or beams as shown in plate (1-4), and the short span to long span ratio is equal or greater than two and it bends in only one direction (spanning direction).

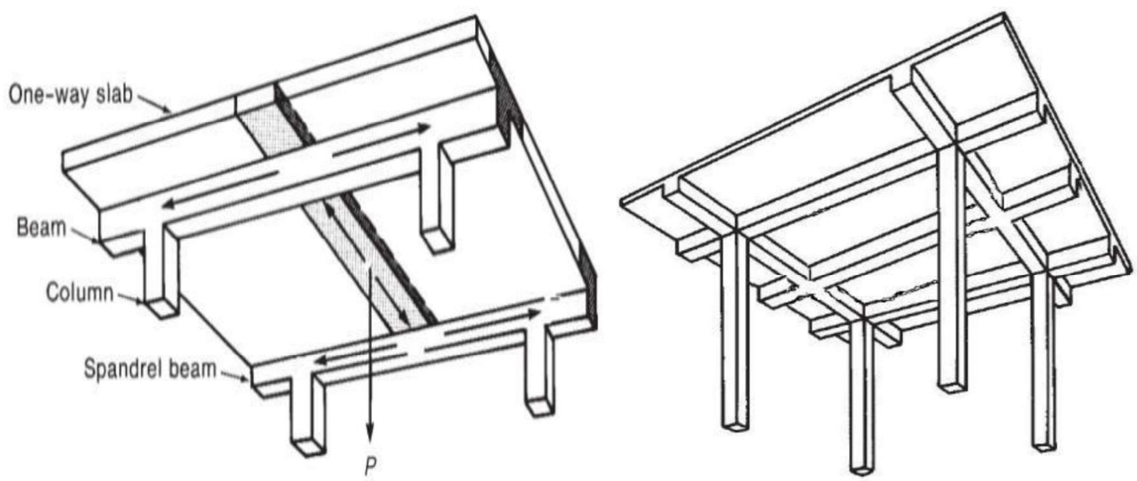


plate (1-4) One-way Slab

1.4 Strengthening by Fibers

In civil engineering, strengthening is one of the most desirable tasks in Reinforced Concrete (RC) structures. One of the methods used to strengthen concrete is using fibrous material in the concrete mix; the mechanical behavior of fiber-reinforced concrete (FRC) depends mainly on the interactions between the fibers and the brittle concrete matrix: physical and chemical adhesion; friction; and mechanical anchorage induced by complex fiber geometry or by deformations or other treatments on the fiber surface.

1.5 Applications of Fiber

- Highway Bridges
- Hydraulic Dam
- Railway Engineering Pilrest
- Port and Marine Engineering
- Tunnel and Mine Works
- Pipework
- Other construction works

This technology has been applied in several structures. Some of these systems are shown below in plates (1-4) and (1-5):

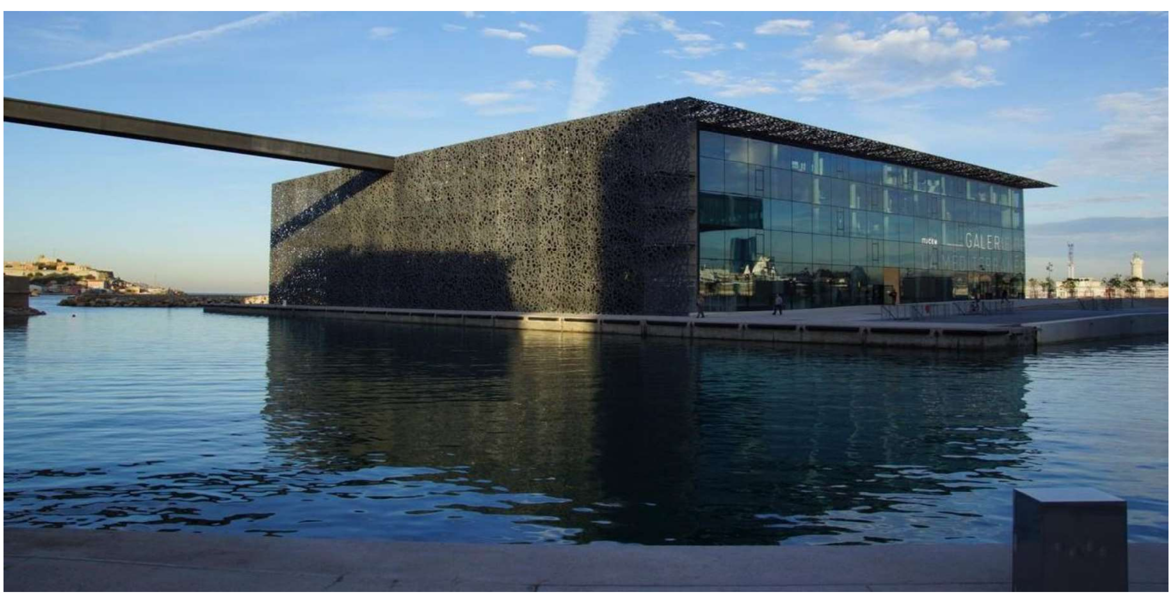


plate (1-5) Museum of Civilisations From Europe and the Mediterranean (www.structurae.net)

plates (1-6) L'Oceanogràfic – L'Oceanogràfic - Access Building (www.structurae.net)

1.6 Research Justification

Numerous types of research have been conducted on the Bubble-Deck system, but most of them have concentrated on bubbled slabs' behavior. At the same time, less research seeks to compensate for the messing efficacy of bubble slab compared to solid slab; this research aims to cover the messing efficacy caused by a plastic ball by using fiber materials.

1.7 Aim of the Research

This research investigates the fibrous one-way bubbled slab structural behavior with plastic sphere bubbles. The main aims of this study are:

1-To investigate the strength and behavior of using plastic sphere bubbles in a one-way slab

2-To Evaluate the strength and behavior of the fibrous material with different types and different percentages of fiber in bubble slab.

1.8 Layout of the Thesis

This study is presented in five chapters, as shown below:

- Chapter one briefly introduces the bubble slab with plastic sphere bubbles, the study's application, scope, and amis.
- Chapter two displays the introduction, background, and design of bubble slabs and the types of fibers used. In addition, this chapter presents some previous research with experimental studies that were carried out for both bubble slabs and fiber slabs.
- Chapter three explains the properties of the materials used in this study experimental work, casting, and test procedures of control specimens.
- Chapter four results and discusses the slab's experimental result.
- Chapter five presents the conclusions obtained from the study and recommendations for further work.