وزارة التعليم العالي
والبحث العلمي
جامعة ديالى
كلية الهندسة

سلوك العتبات الخرسانية عالية الأداء تحت الاحمال الرتيبة والمتكررة

رسالة مقدمة إلى مجلس كلية الهندسة/جامعة ديالى
وهي جزء من متطلبات نيل درجة الماجستير في علوم الهندسة المدنية

من قبل

هدير أحمد خضير

(بكالوريوس هندسة مدنية ٢٠١٦)

بأشراف

أ . د . علي لفتة عباس

جمادى الاولى ١٤٤١هـ العراق كانون الثاني ٢٠٢٠م

Ministry of Higher Education
and Scientific Research
University of Diyala
College of Engineering

BEHAVIOR OF HIGH PERFORMANCE CONCRETE BEAMS UNDER MONOTONIC AND REPEATED LOADING

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

By

Hadeer Ahmed Khudair

(B.Sc. in Civil Engineering, 2016)

Supervised by

Prof. Dr. Ali Laftah Abbass

January, 2020 IRAQ Jumada al-awwal , 1441

CHAPTER ONE

INTRODUCTION

1.1 General

High Performance Concrete (HPC) is defined as a kind of concrete that gives the best performance and suitable result which cannot be carried out by normal concrete. HPC is vastly used in large scale projects due to its properties like high strength, high durability, and large flow ability. A high strength concrete may be high performance concrete but a high performance concrete may not be high strength concrete. High-performance concrete is concrete that has been designed to be more durable and, if substantial, stronger than traditional concrete. HPC components are composed of essentially the same materials as conventional concrete mixtures, but the ratios of materials are designed, or engineered, to supply the strength and traditional needed for the structural and environmental requirements of the project (Saini and Singh, 2018).

HPC is often made with the use of chemical and mineral admixtures such as superplasticizers, fly ash, ground granulated blast furnace slag, silica fume and steel fiber to produce a composite mainly characterized by its low porosity and fine pore structure. These, in turn, improve the resistance of concrete to the penetration of harmful substances such as chloride and sulphate, carbon dioxide, water and oxygen, and hence it provides high strength, stiffness, thermal resistance, ductility, and durability performance (Hassan and Cabrera, 1999) and (Hassan, et al., 2000).

HPC is a more brittle material compared with normal concrete. This problem can be solved by addition of short discrete fibers into the concrete mixture that rise HPC compressive strength and durability and makes it more homogeneous and isotropic, because the randomly oriented fibers arrest a micro cracking mechanism and limit crack propagation, thus improving strength and ductility (Al-Azzawi and Sarsam, 2010). The addition of steel fibers also increases tensile strength, flexural strength, impact strength and toughness. The improved in toughness by fibers is useful in preventing sudden and explosive failure under static loading and in the absorption of energy under dynamic loading (Ramadoss and Nagamani, 2008).

1.2 High Performance Fiber Reinforce Concrete (HPFRC)

High strength concrete combined with steel fibers is known as HPFRC shows a high compressive strength of more than (60 MPa), HPC is more brittle than normal concrete. This problem of brittleness can be carried out by the addition of steel fibers, this high compressive strength was obtained by mixing a well-defined type of cement, superplasticizer, steel fiber and coarse aggregate was replaced with sand (Kaïkea, et al., 2014). The properties of HPFRC that are high strength and low permeability that can lead it to have a good bond strength between normal concrete and HPFRC make it suitable to be a repair material (Tayeh, et al., 2012).

HPFRC as a repair material since its very low porosity leads to low permeability and high durability. This characteristic makes it suitable to repair and retrofit reinforced concrete structures (Tayeh, et al., 2013).Steel fibers are known to enhance the ductility of what is otherwise a brittle plain-concrete material. This is useful to avoid brittle modes of collapse such as shear failure. Furthermore, improvements to ductility and energy dissipation are particularly beneficial for structures under seismic loading (Tlemat, et al., 2006) and (Cho and Kim, 2003).

Reinforcing of concrete with steel fibers has some advantages such as the randomly oriented fibers arrest a micro cracking mechanism and limit crack propagation, thus improving strength and ductility, an increase of durability and age of concrete, increase of ductility, toughness, tensile, flexural and shear strength of concrete, and some disadvantages such as corrosion of fibers, decrease of workability of concrete, irregularity of distribution and accumulation around the local area. The fibers differ in size and shape such as straight, hooked and corrugated (Wang, 2006).

The addition of steel fibers also increases impact strength and toughness. The improved toughness in compression imparted by fibers is useful in preventing sudden and explosive failure under static loading and in the absorption of energy under dynamic loading (Ramadoss, et al., 2009).

1.3 Application of High Performance Concrete

- High-performance concrete opens the door to more slender structural elements and more audacious designs than is possible with ordinary-strength concrete. High-performance concrete using in structural members such as columns, mainly subject to compression, would allow reduction cross section of the member's (Skokie, 1984), (Skokie, 1987) and (Cadoret and Richard, 2018).
- High-performance concrete used in variably yields savings for high rise buildings and significantly increases rental space.
- High-performance concrete has been used by Norway in constructing enormous drilling platforms for oil and natural-gas exploration in the North Sea (Norvtge, 1984).
- High-performance concrete is also used in Norway in pavement (road) construction for its superior resistance to abrasion from studded types (Helland, 1990).

- High-performance concrete most suitable for architectural applications, especially since it can be polished as easily as granite and marble (Pierre, 1994).

1.4 Repeated load

Large applications in structural engineering, like pile caps, foundations, bridge girders, and offshore structures, as well as transfer girders in tall buildings were subject to repeated load. The total number of load cycles may be as low as a few cycles to as high as several million cycles during the service life of beams (Teng, et al., 2000) as shown in Table (1-1). The repeated load may be just compression (cyclic axial compressive loading) (AlSulayfani, et al., 2010) and (Lam, 1979) or compression tension (reversed loading) (Jurcevic, et al., 1990) as shown in Figure (1-1) and Figure (1-2).

Table (1.1): Classes of fatigue load (Hsu, 1981)

Low-cycle fatigue			High-cycle fatigue				Super-high-cycle fatigue		
1	10^1	10^2	10^3	10^4	10^5	10^6	10^7	10^8	10^9
Structures subjected to earthquakes			Airport pavements and bridges		Highway and railway bridges, highway pavements		Mass rapid transit structure		Sea structures

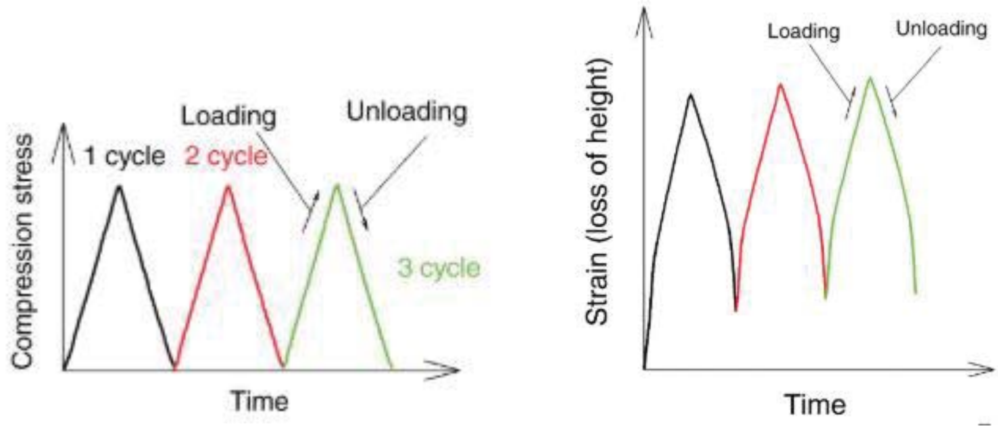

Figure (1.1): Load history for compression repeated load (Zhang, et al., 2019)

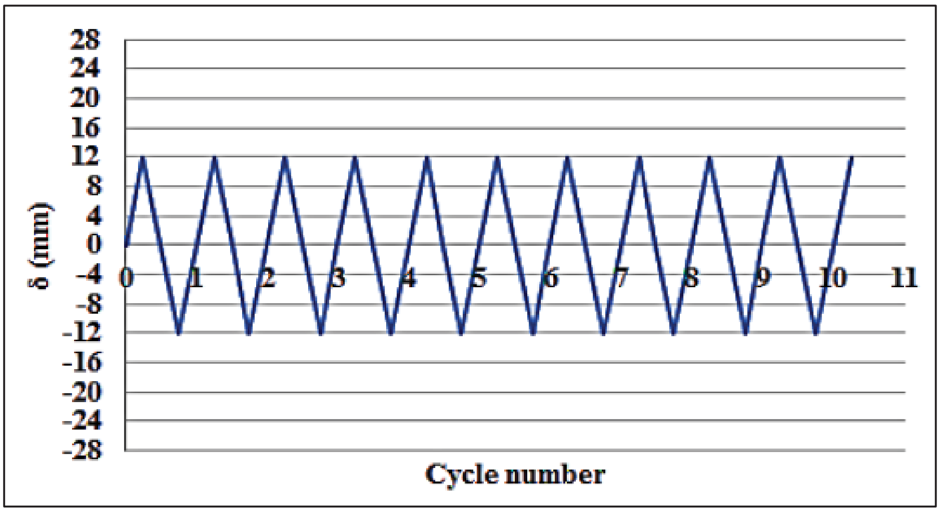

Figure (1.2): Load history for cyclic load (Ibrahim and Abdulkhalik, 2017)

1.5 Steel Plate

In this research, due to fast development of manufacturing by Computer Numerical Control (CNC) machine and some difficulties in stirrups stand with high cost and time entailed, some efforts have been made to discover new techniques are adopted for shear reinforcement depend on using the elongated steel plate as shear reinforcement instead of normal stirrups (Ibrahim, et al., 2016).

1.6 Design Considerations for Steel Fiber Reinforced Concrete According to ACI 544-99

Equation for nominal moment M_n of a singly reinforced steel fibrous

concrete beam is as shown in Figure (1-3).

$$Mn = As\ fy\ (d-\frac{a}{2}) + \sigma t\ b\ (h - e)\ (\frac{h}{2} + \frac{e}{2} - \frac{a}{2})$$

$$e = [\epsilon_s\ (fibers) + 0.003]\ \frac{c}{0.003}$$

where

or $\sigma_t = 0.00772\ L_f / d_f\ \rho f\ F_{be}$ (SI units, MPa)

σ_t : tensile stress in fibrous concrete

L_f : fiber length

d_f : fiber diameter

ρf : percent by volume of steel fibers

F_{be} : bond efficiency of the fiber which varies from 1.0 to 1.2 depending upon fiber characteristics

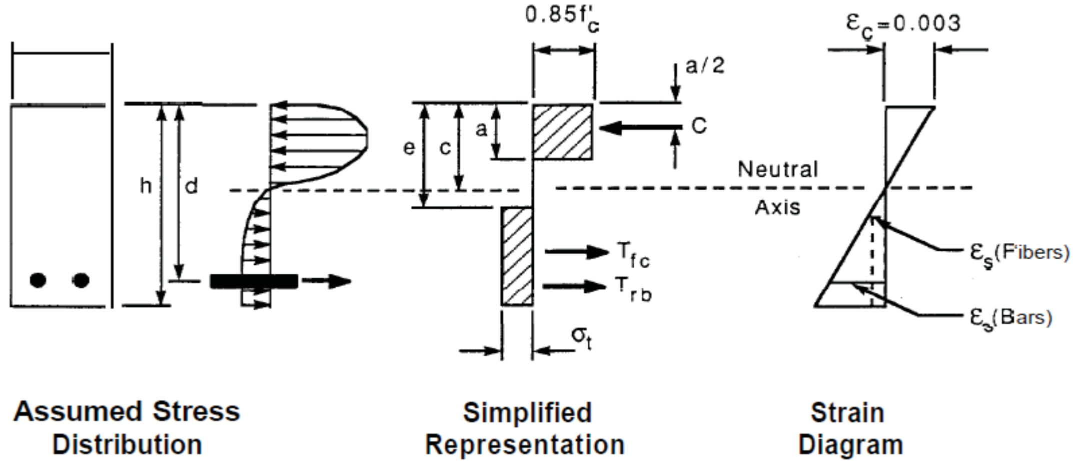

Figure (1.3): Design assumptions for analysis of singly reinforced concrete beams containing steel fibers

1.7 Research Objective

The aims of this study is to discuss and study the effect of using longitudinal shear steel plates contain vertical or inclined rectangular holes instead of stirrups for the reference and the effect of the direction of opening. Also Study the behavior of a simply supported beam after replacing the stirrups by the steel plate, which is a techniques to enhance shear resistance with use of HPC high performance beam by change method and type of shear reinforcement under static and repeated load and comparison the behavior between specimens.

1.8 Research Justification

Due to the fast development of manufacturing by the CNC machine due to difficulties in stirrups stand with a high cost and time. The need has driven researchers to explore better structural in fabrication, installation and speed of construction and other behavior of structures.

1.9 Research Methodology

The experimental test of this study was casting ten reinforced concrete beams by preparation of mix HPC, mold, geometrical of steel plate and dimensions, the results were analyzed and discussed.

1.10 Thesis Layout

The thesis consisted of five chapters:

- **Chapter One** includes an introduction to HPCS, it's application, definitional of repeated load, the research objective, justification, and methodology.
- **Chapter Two** includes the available literature and an overview of research work, which are related to the present study.
- **Chapter Three** specifies the used construction materials properties as well as the details of the experimental work.
- **Chapter Four** demonstrates the results of specimens, and discussion of these results.
- **Chapter Five** views the conclusions drawn from this study, in addition to recommendations and future research work.

Behavior of High Performance Concrete Beams under Monotonic and Repeated Loading

Asala Asaad Dawood

Supervisor:
Prof. Khattab Saleem Abdul-Razzaq (Ph.D.)

ABSTRACT

In the past few years anew techniques of using steel plate instead of normal stirrups in normal reinforce concrete beam was appeared using steel plate to resist the shear stresses in reinforced concrete beams. The main aim of this research is to study the effect of using longitudinal shear steel plates as a shear reinforcement of high performance concrete beams instead of using traditional reinforcement bars (stirrups), and study the effect of their spacing, inclination (45°), and type of loading. Experimental program consisted of casting and testing ten specimens under two points load. Beams had identical cross-section of (300mm) width and, (150mm) depth and clear span of (1400mm) divided into four groups. The difference between the groups was the type of shear reinforcement and type of loading (monotonic load and repeated load). Every group contained three specimens. The first specimens of each group were the conventional reference and the rest were reinforced with longitudinal shear steel plates with a combination of variables including the spacing between holes in steel plate and direction of holes in steel plates. Steel plates of (3mm) thickness is use, furthermore, the spacing of holes in steel plates are different from (65 to 125 mm), also, the direction of holes in steel plate is different one time vertical and the other was inclined with (45°). The effect of replacing stirrups with longitudinal shear steel plate, the response of load-deflection, cracking load, deflection at first crack, cracks characteristics (spreading, width, number and type of cracks), strain in steel bars, strain in the surface of concrete and, failure conditions were studied. The result showed that using longitudinal shear steel plates increased ultimate carrying capacity by an average of (3.69%) under monotonic and (4.64%) under repeated load for beams using longitudinal shear

steel plates contain vertical or inclined rectangular holes with (125mm) spacing, and also increased by about an average of (8.96%) under monotonic and (7.24%) under repeated load for beams using longitudinal shear steel plates contain vertical or inclined rectangular holes with (65mm) spacing. Ductility was also increased by using longitudinal shear steel plates contain vertical or inclined rectangular holes with (65mm) spacing was greater than the reference beam reinforced with stirrups by an average of (47.55%) under monotonic and (34.07%) under repeated load, but it is lower than the reference beam reinforced with longitudinal shear steel plates contain vertical rectangular holes with (65mm) spacing by an average of (35.35%) under monotonic and (31.5%) under repeated load.