Republic of Iraq

Ministry of Higher Education and Scientific Research

University of Kerbala

College of Engineering

Civil Engineering Department

Shear Behavior of Continuous Reinforced Concrete Deep Beams with Waste Plastic Fiber and Rehabilitated with CFRP Laminates

A Thesis

Submitted to the Civil Engineering Department /College of Engineering/ Kerbala University in Partial Fulfillment of the Requirements for the Master Degree of Science in Civil Engineering-Infrastructure Engineering

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2021 AD **1443 A**

بِسْمِ اللَّهِ الرَّحْمَٰنِ الرَّحِيمِ

"وَقُل رَّبِّ زِدْنِي عِلْمًا"

صدق الله العلي العظيم

القرآن الكريم-سورة طه -الآية 114

Dedication

To the Soul of My Martyr Brother….

To my parents who dedicated their lives to get to where I am and are still in their constant giving to me….

To my dear brothers and sisters….

To my husband and life partner who supported me throughout my studies and helped me in my research work….

To my children Ahmed, Mariam and Bashir… God's gift to me….

Acknowledgements

*I thank **ALLAH** Almighty and praise him for granting me health, appropriate circumstances and my family to finish my studies.*

Exceptional and special gratefulness for my such respectful supervisors, Assist. Prof. Dr. Laith Shakir Rasheed, and Assist. Prof. Dr. Wajde Shobar Saheb, for their guidance, support and follow up along the theoretical and experimental research period.

I would also like to introduce my thanks to the head and staff of the civil engineering department, the construction materials laboratory, and all those who stood with me to finish this work.

Finally, I would like to express my extreme love and appreciation to everyone who has supported this work.

Sawsan kareem kadhim

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Abstract

In terms of recycling and reuse business, the amount of plastic waste accumulated in the world nowadays are more than those consumed as it is a non-biodegradable material. This problem leads to the accumulation of large stocks of toxic plastic waste, which affect on public health and increase safety risks. Therefore, it has been proposed to use plastic waste in the construction of various structural members as a step to tackle accumulation problem. In this regard, this research aims on investigating the structural behavior in terms of shear of reinforced concrete continuous deep beams incorporating Polyethylene Terephthalate (PET). Indeed, and by following up the sustainability concept, various strengthening techniques were suggested to strengthen the pre-partially damaged reinforced concrete continuous deep beams by carbon fiber reinforced polymer (CFRP).

For this purpose, several tests were conducted using cubes and cylinders to investigate the influence of various volume fractions of Polyethylene (i.e. 0.5,1 and 1.5%) trephthalate (PET) fibers on the mechanical properties of concrete such as: workability, compressive strength and splitting tensile strength. Furthermore, the structural bahavior represented by shear resistance of RC continuous deep beams incorporating PET fibers were also investigated after been strengthened by CFRP at an angle (90° and 45°) as they initially designed with intended shear deficiencies. Twelve RC continuous deep beams have been designed to fail in shear with a length of (2000 mm), depth (300 mm), and width (150 mm). Four specimens with various PET fibers were tested to reach the shear failure and considered as references specimens. The remaining specimens were loaded up to (60%) of their designed load and then strengthened with CFRP sheets and tested later.

The results show the structural behavior of RC continuous deep beams with PET fiber exhibited better performance, finer failure cracks than those without fiber. Furthermore, the peak shear strength was recorded at sample with 1% fibers percentage as it recorded higher value by slight increase in comparison with that with no fiber. Furthermore, the experimental results illustrated that beams strengthened with CFRP sheets exhibited higher ultimate load capacity compared to the reference specimens. Likewise, the shear ductility increased by (33.42%) and (45.83%) with the increase in the fibers percentage until (1%) for beams strengthened by CFRP at 90° and 45°, respectively.

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Abbreviations

Symbol	Description
Ac	Cross-sectional area of the concrete (mm^2)
ACI	American Concrete Institute
Ag	Cross-sectional area of a section (mm^2)
As	Cross-sectional area of steel reinforcement (mm^2)
ASTM	American Society for Testing and Materials
BS	British Standard
CFRP	Carbon fiber reinforcement polymer
Ec	Concrete modulus of elasticity (GPa)
Es	Steel modulus of elasticity (GPa)
et al.	Others
f_{cu}	Concrete compressive strength (MPa)
FRP	Fiber reinforcement polymer
f_{st}	Splitting tensile strength of concrete(MPa)
f_{su}	Ultimate strength of steel reinforcement(MPa)
f_{sy}	Strength of steel reinforcement (MPa)
f_y	Yield strength of steel reinforcement (MPa)
GFRP	Glass fiber reinforcement polymer
IQS	Iraqi specification
L	Total length of column (mm)
L/d	clear span to depth ratio
mm	Millimetre
MPa	Mega Pascal (N/mm2)
NC	Normal concrete
No.	Number
Ø	Size of Bar diameter (mm)

P	Maximum applied load (kN)
PET	Polyethylene Terephthalate
P_u	Ultimate load (kN)
RC	Reinforced concrete
a/d	a shear span to an effective depth

Chapter one
Introduction

1.1 General

The ACI Code defines deep beams as those "which have a clear span to total depth less than four, or have a shear span to an effective depth less than two, and should be loaded on the top face and supported on the bottom face. Thus, the compression struts can develop between the loads and support points" (**ACI 318-2019-ch9. Sec.9.**). The increased necessity of high-rise concrete structures, resulting from the increase in the population density, the lack of spaces, the urban development and others, requires paying considerable attention to the structural bahavior of reinforced concrete deep beams. The application of reinforced concrete deep beams has appeared in high buildings, offshore structures, foundation walls, pile caps and transfer girders, as shown in Plate (1-1).

One crucial part of any concrete structure is the beams, as they transfer the loads to the foundation or columns. These beams, especially the deep ones could fail under flexural or shear, in which the latter occurs abruptly without sufficient warning. Indeed, the width of the shear cracks is larger than those caused by the flexural**(Ahmed, 2001).**

Plate 1-1 Examples of Deep Beams (a)Transfer girder in a bridge (b) according to A, Chicago (**Nie et al. 2017)**

1.2 Continuous Deep Beam

The reinforced concrete continuous deep beam is a widespread structural member, which can be witnessed in pile caps, transfer girders, areas over openings in load-bearing walls, and foundation walls (Figure (1-1) illustrates some typical examples) **(Singh et al. 2006)**. Continuous deep beams differ in bahavior from continuous shallow beams or simply supported deep beams as they can develop a particularly tied-arch or truss bahavior that does not exist in shallow continuous beams. The apparent result is that traditional reinforcement detailing principles based on simple deep beams or shallow continuous beams are not appropriate for continuous deep beams (**Kong, 2003)**. As in simple span deep beams, continuous deep beams can increase shear capacity by decreasing the shear span-to-depth ratio. In continuous deep beams, the inflection points are very close to the critical shear section and the location of the maximum shear and negative moment coincides. These two conditions make most strength equations of simple span deep beams not valid for continuous deep beams. Thus, the running empirical equations, founded from simple span beam tests, cannot be applied blindly on continuous ones. There are many variables and few existing tests to promote empirical equations on deep beams, especially on continuous ones (**Kong, 2003)**.

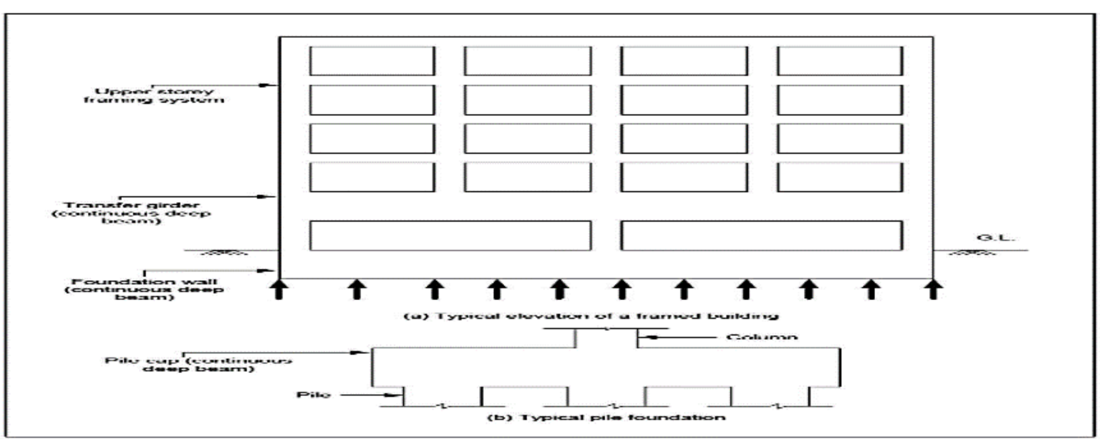


Fig. 1-1 Example of continuous deep beams **(Singh et al. 2006)**

1.3 Continuous Deep Beams Vs Simple Deep Beams

There are some characteristics in continuous deep beams that make equations gain from simple deep beams tests useless **(Kong, 2003)**:

- The point of contra flexure in continuous deep beams is usually close to the critical shear section, making empirical equations challenging to apply.
- In a continuous deep beam, the high shear and negative moment region coincide at interior support. In contrast, the low bending moment and high shear area coincide in a simple deep beam.
- The horizontal reinforcement has a negligible influence on the ultimate capacity of reinforced concrete continuous deep beams.

1.4 Shear Failure of Reinforced Concrete Continuous Deep Beams

Structural designers usually design buildings against bending and shear stresses. The horizontal reinforcement bars are used to resist the bending failure, while stirrups, which generally has a smaller diameter, are used to fight the shear failure **(Ahmed, 2001)**. In general, the shear failure occurs near the support and could be recognised from the crack angle, which approximately equals 45° with the axis of the beam. The shear failure is a very complex phenomenon due to the involvement of a large number of parameters **(Maroliya, 2012).** Several factors can affect the shear capacity of beams such as concrete compressive strength ($f_{c'}$), clear span to depth ratio (L/d), shear span to depth ratio (a/d), tension-steel ratio (ρ), fibers presence, concrete density, coarse aggregate size, concrete tensile strength, beam size, support conditions, tension reinforcement grade, number of tension reinforcement layers, and end anchorage of tension reinforcement **(Ghafar et al. 2010)**. Shear failure can happen without warning and typically includes the opening of major diagonal cracks like the sudden shear failures of large Air Force warehouse girders, as shown in Plate (1-2). Many other significant structures have collapsed because of brittle shear failures including, the Hanshin Expressway and the Sleipner offshore platform (**Collins et al. 2008)**.

Plate 1-2: Shear Failure of Air Force Warehouse Beams (**Collins et al. 2008)**

1.5 Fiber Reinforced Concrete

The low toughness and the presence of defects are the main reasons behind the poor tensile bahavior of concrete. As a result, there is a tendency to tackle such issues by adding a small fraction (usually 0.5-2% by volume) of short fibers while mixing the concrete ingredients since concrete is the most common construction material globally. In modern times, a considerable amount of studies has been made for developing new composite materials to be used for a wide range of application. These reinforcing materials could be fibers, metals, ceramics, resins, polymers, wood, and glass. Fibers have been used to reinforce brittle materials since ancient times. Some examples of using several types of fibers are as follows: horsehairs were used to reinforce plaster, straws were used to reinforce bricks, and fiber vegetable was used to mud walls **(Daniel et al. 2002)**. Numerous studies concluded that reinforcement by fibers could significantly improve the tensile characteristics of concrete by bridging the cracks in the matrix before being pulled out or torn. Figure (1-2) shows how plain and fiber reinforced concrete fail under tensile load in addition to the change in the failure mode from brittle to quasi-ductile due to fiber use (**Daniel et al., 2002)**.

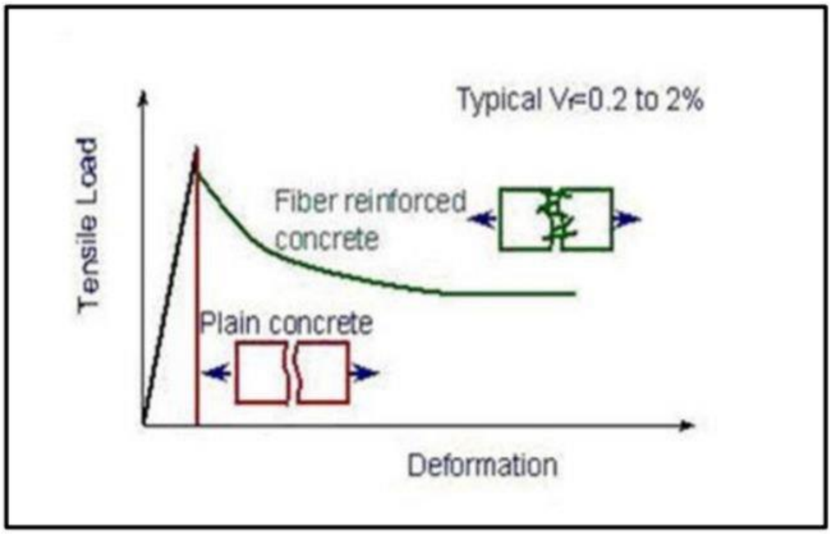


Fig. 1-2 Tensile load versus deformation of plain and fiber reinforced concrete **(Daniel et al. 2002)**

1.6 Waste Plastic

Concrete technology is considered as the most advancing fields. A great deal of inventions has expanded the horizon of the construction industry in the field of concrete technology. These new inventions facilitate the production of the requisite concrete with the required nature and property. In the last 20 years, several research studies concerning the use of several kinds of urban wastes resulting from the industries have been published, which are produced a significant number of products that incorporate scrap (residues) **(Murali, et al. 2012)**. The use of thermosetting plastics into construction materials can be considered the most feasible application because most present recycling methods are not economically advantageous. They are either burying or burning, emitting toxic and polluting gases **(Ouda et al. 2015).**

The use of waste plastic as short discontinuous fibers with the conventional concrete has attracted the attention of several researchers **(Manaseer and Dalal, 1997; Kim, et al. 2010 and Siddique, et al. 2008)** for number of reasons:

- To solve the overstock problem of waste plastic as it increases every year due to the high production and low recycling.
- To reduce the concrete production cost as plastic fibers are cheaper than other types of fibers.
- To improve the mechanical properties of concrete, such as the tensile and the impact strengths.
- To help in reducing the concrete cover as it is non-corrosive fiber.
- To reduce the total weight of the concrete member, which is significant in terms of the total cost due to the low density of plastic fibers (ranges from 1100 to 1380) kg/m^3**(Gestis, 2007)**.
- To absorb energy as plastic fibers have an excellent elongation value ranging (from 3 to 80 %) **(Manaseer and Dalal, 1997).**

Some types of plastic can be used many times without any health risks, but others can be used once, such as polyethylene terephthalate (PET) **(Geyer, et al. 2017) ;(Salem, et al. 2009)**. The single use of PET like soft drink bottles can contribute to the environmental problems through accumulating waste. Therefore, most of the previous studies examined the recycling ways of PET, especially in improving the properties of concrete **(Chowdhury, et al. 2018).**

1.6.1 Plastic Definition

The monomers are small units merged to form a big molecule of polymer, this process is called polymerisation, and the plastic is the trade name of polymer with additives to improve its performance and appearance. The chemical compositions of polymers are hydrogen, carbon, oxygen, nitrogen, and fluorine or chlorine (**Assessment Guidelines, 2009).**

1.6.2 Common Types of Plastic

It is difficult to describe the plastic briefly because it has the same component with many additions for different agents such as plasticizer or a blowing agent to make the plastic appear in multiple formats. There are (45) essential plastic families, but the most important species are **(Assessment Guidelines, 2009)**:

1. **High-Density Polyethylene (HDPE)**: is used in piping, automotive fuel tanks, bottles, toys...etc.
2. **Low Density Polyethylene (LDPE):** is used in plastic bags, cling film, flexible containers...etc.
3. **Polyethylene Terephthalate (PET):** is used in bottles, carpets and food packaging (**Jabarin, 1996)**.
4. **Polypropylene (PP):** is used in food containers, battery cases, bottle crates, automotive parts and fibers.
5. **Polystyrene (PS):** is used in dairy product containers, tape cassettes, cups and plates.
6. **Polyvinyl Chloride (PVC):** is used in window frames, flooring, bottles, packaging film, cable insulation, credit cards and medical products.

Polyethylene Terephthalate (PET) is a thermoplastic resin of the polyester family used to make beverages, food and other liquid containers. PET blends, unlike other plastics are engineering plastics with excellent processing characteristics and high strength and rigidity for a broad range of applications.

1.7 Fiber Reinforcing Polymer (FRP)

In the last decades, fiber-reinforced polymer (FRP) has been utilised in civil engineering structures to strengthen masonry and concrete structures (**Bank, 2006)**. This material is a composite type consisting of a polymer matrix reinforced with high strength fibers. It became a tremendous competing material with other traditional strengthening techniques. Compared with steel plates, FRP is superior in manufacturing, shipping and jobsite handling, faster construction time and more excellent environmental durability, which would require a shorter period of closure (**Allawi, 2006)**. Several polymer composites were used for strengthening, such as fibers aramid, basalt, carbon and glass. It has been stated that carbon fibers reinforcing polymers (CFRP) were considered as the highest strengthening material in comparison with other civil engineering materials (nearly 95%) **(Mohammed, 2007).** Figure (1-3) shows the stress-strain curve for the most used strengthening materials (**Carolin, 2003)**. The main benefits of CFRP are summarised as follows:

1. High tensile strength.
2. High lightweight to strength ratio.
3. High elastic modulus.
4. Easy and quick installation without the need for special equipment.
5. High resistance to moisture.
6. Available in different lengths.
7. Attachable to most irregular surfaces.

In the same regard, the main issues of CFRP can be reviewed as follows:

1. Brittle nature.

2. High-cost.
3. Necessity for epoxy in the installation.
4. High damage under fire risk.

CFRP has particular attention due to its high strength, low corrosion and fatigue resistance with reasonable cost, as shown in Plate (1-3). One advantage of using a fiber composite material is its negligible dead load due to its low weight. Also, it can be easily carried to the construction site in rolls, which makes the reinforcing technique much more straightforward. Furthermore, strengthening work is more convenient in a limited workspace and no specific work experience and heavy construction equipment are required at the site **(Nordin, 2003).** Furthermore, CFRP has a very high tensile strength with stiffness very close to steel **(Abdul-Razaq, 2010).**

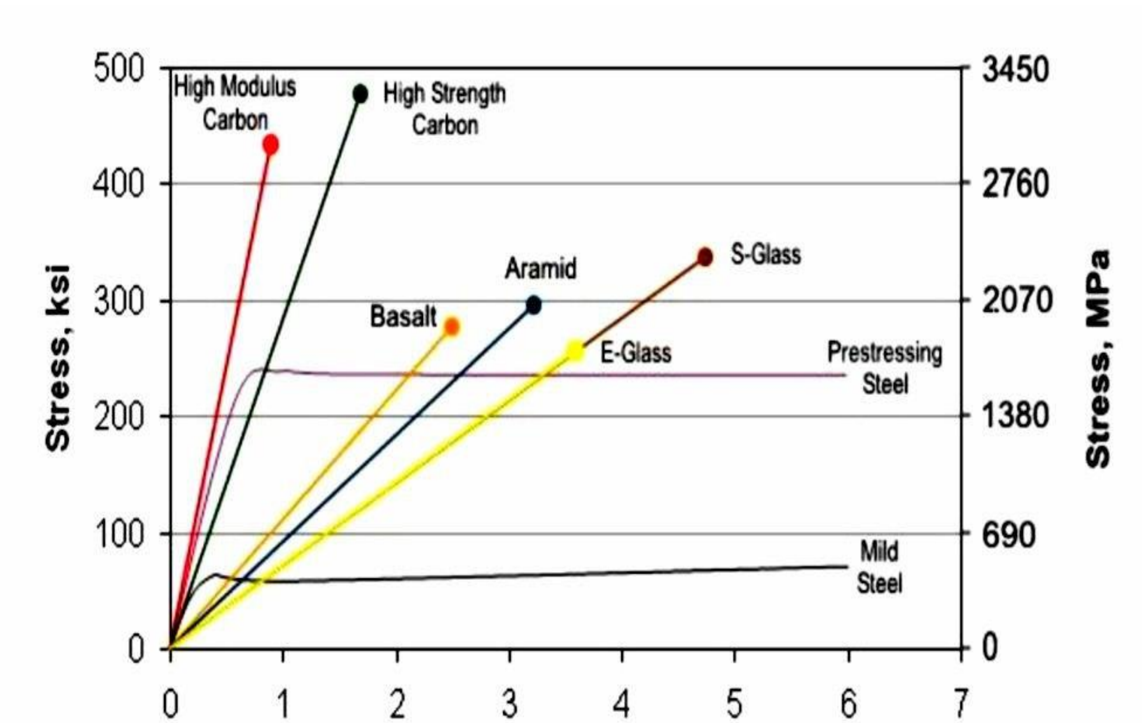


Fig.1-3 Stress-Strain Relationship of several strengthening materials (**Devi, 2015)**

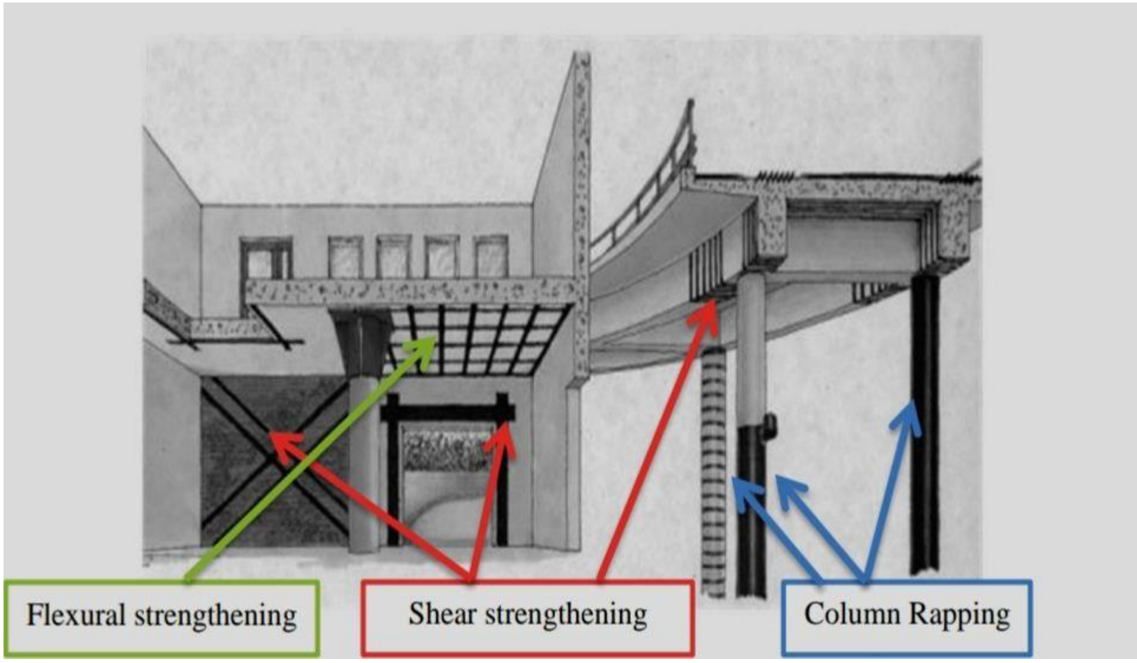


Plate 1-3 Strengthening Applications by CFRP(**Maki, 2010)**

1.8 Objectives of the Research

1. Investigate the effect of waste plastic PET fibers on the shear characteristics of reinforced concrete continuous deep beams experimentally;
2. Examine the effect of various strengthening schemes by CFRP on the shear characteristics of RC deep beams experimentally;
3. Reducing the environmental impact of plastic waste, recycling and using it to improve the properties of concrete to enhance the concept of sustainability.

1.9 Thesis Layout

This work is achieved in five chapters as follows:

Chapter One: covers the introduction, fiber reinforced concrete, waste plastic, and objective of the present study.

Chapter Two: presents the literature review on previous research that used waste plastic fiber in the production of concrete and those related to the shear strength of reinforced concrete continuous deep beams.

Chapter Three: deals with the materials considered throughout this study, mixing proportion, experimental investigation and testing procedure.

Chapter Four: presents the test results of the beam specimens, including the load carrying capacity, load-deformation curves, ductility and the failure modes for all beam specimens with their discussion.

Chapter Five: states the significant conclusions of the present research and some recommendations for future works in the same trend of this thesis.

Chapter Two

Literature Review

2.1 Introduction

Adeep beam has been a subject under considerable interest in the structural engineering practice. Generally, it can be defined as a beam that has a comparable depth to the span length **(ACI 318M-19)**. Reinforced concrete deep beams have been used in tall buildings, offshore structures, foundations, etc. This type of beams is mainly used as transfer girders, which supports loads from one or more columns, transferring laterally to other columns. Deep beam action can also occur in some walls and pile caps. For beams with the same shear and flexural reinforcements, shear failure is most likely to be occurred in deep beams rather than regular beams **(Hasan, 2017).**

In structural engineering, ductility is a significant factor for concrete structures as it contributes to damping the high external loads and seismic loads. Many scientists and researchers are trying to develop alternative construction materials that are environmentally friendly and contribute towards sustainable development. Plastic waste has been chosen due to the enormous daily production, which creates many environmental problems due to its disposing problem. In the last years, the interest of researchers in using waste plastic fibers in the production of concrete was evident, especially the Polyethylene Terephthalate (PET), which is used in manufacturing soft drink bottles.

Repairing deep beams with shear deficiencies is of great importance. In this regard, externally bonded reinforcement such as carbon fiber reinforced polymer (CFRP) provides an excellent solution in these situations. However, based on literature research, most CFRP shear strengthening research has been focused on regular beams rather than deep beams. This chapter will review the previous research, which includes using waste plastic fibers (PET) and strengthening reinforced concrete beams by using carbon fiber reinforced polymers (CFRP) sheets after describing types of failure of continuous deep beams and their bahavior under shear forces.

2.2 Structural Bahavior RC Continuous Deep Beams

The structural bahavior of deep beams is noticeably different from that of ordinary beams due to their main characteristics of considerable depth and the minor ratio of a/d. The compression strut in the deep beam is the element that is responsible for transferring the loads to the supports. It is formed between supports bearing plate and the loading bearing plate. Many vital parameters influence the structural bahavior of deep beam by affecting the compression strut directly. The most effective parameter is the a/d ratio, follows by web reinforcement arrangement and quantity, there influential factors such as concrete compressive strength and the upper and lower horizontal reinforcement, which affect directly on the total loading capacity of deep beams. In this section, the structural bahavior of reinforced concrete continuous deep beams will be discussed, with their failure mode and the influence of all the critical parameters stated above.

Ashraf (1996) reported the test results of eight reinforced concrete continuous deep beams. The main variables were the shear span-to-depth ratio, the amount of the central longitudinal reinforcement and the amount and type of web reinforcement. Test results showed that the vertical web reinforcement a higher effect on the shear capacity than the horizontal web reinforcement. All beams showed the same failure type, which was dominated by a significant crack propagated in the middle shear span between the load plates and intermediate support.

Keun et al. (2007) presented the test results of twenty-four two-span deep beams. The basic studied parameters were the shear span ratio to overall depth (a/h), concrete strength, and the arrangement and quantity of vertical reinforcement. Four reinforcement configurations had been done; (none, vertical only, horizontal only and orthogonal reinforcement) and two ratios of horizontal reinforcement (0.003 and 0.006) as minimum and maximum values of shear reinforcement, respectively. Test results showed that (a/h) had an apparent effect on the horizontal and vertical shear reinforcement. In more details, only the vertical shear reinforcement has reached its yield after the first diagonal crack. Nevertheless, the horizontal shear reinforcement reached its yield when a/h= 0.6. On the other hand, the horizontal shear reinforcement had more effect than the vertical one when a/h = 0.5. In contrary, when a/h =1, the vertical shear reinforcement exhibited higher impact than the horizontal shear reinforcement.

Yang et al. (2007) stated the test results for twelve two-span reinforced concrete deep beams. The essential studied variables were the shear span to overall depth ratio, concrete compressive strength, and the beam depth, which was varied from (400-720) mm. All specimens have the same longitudinal top and bottom primary reinforcement and no web reinforcement to estimate the shear capacity of such beams with changing the beam depth. All beams failed with a significant crack joining the points of central support and loading. Test results also showed that the influence of beam depth and concrete compressive strength on the shear strength was more pronounced on continuous deep beams than simple ones.

Zhang and Tan (2010) tested six continuous deep beams divided into two groups to indicate the effect of web reinforcement and differential settlement on their bahavior and strength. The first group of specimens was supported with spring and rigid supports and without web reinforcement. At the same time, the second group had the same supports but with web reinforcement. The test results covered the load-deflection curves, crack patterns, service loads, strains in steel and ultimate loads. Results showed that the middle support settlement impacted significantly on the service load, crack, and failure modes due to web reinforcement. Moreover, an acceptable match between the strut and tie modelling (STM) predictions and the test results has also been observed.

Keun and Ashraf (2011) tested twelve continuous deep beams with three types of concrete: sand-lightweight concrete (SLWC), all lightweight concrete (ALWC), and normal-weight concrete (NWC). The maximum aggregate sizes were 4, 8, 13, and 19 mm for all specimens. Results showed that there was an increase in the ultimate load of the deep beam as the maximum aggregate size increased due to the assistance of aggregate interlock to the ultimate capacity. The growth was higher for NWC than for the other types of concrete. The width of the diagonal crack increased with the decrease in the maximum aggregate size and it was broader in ALWC than in NWC.

Beshara et al. (2013) reported the test results of nine continuous deep beams. The basic studied parameters were horizontal web reinforcement, vertical web reinforcement, concrete compressive strength, and the ratio of shear span-to-depth (a/d). The tests results showed that stiffness reduction was prominent for a higher ratio of shear span-to-depth and lower concrete strength. The strain variation along the primary bottom and top bars were dependent on the shear span-to-depth ratio. Moreover, the horizontal shear reinforcement was more effective than vertical shear reinforcement for beams with a small percentage of shear span-to-depth. Finally, a comparison was made between the experimental and theoretical results obtained using ANSYS 10, and an acceptable match between them was found.

Salman (2015) presented numerical investigations of nine continuous deep beams, which were collected from literature and tested experimentally. Several parameters were covered from collected specimens as adequate depth, reinforcement ratio, concrete strength and the ratio of shear span-to-depth. All samples had a similar longitudinal bottom and top reinforcement, and for such beams, no web reinforcement to find the influence of changing the depth of beam on the shear capacity. A finite element model using (ANSYS 12) program is used. The results indicated the general bahavior of both linear and nonlinear ranges up to the failure of the finite element model show a good match with data and observations from experimental tests.

Khatab et al. (2016) tested eight continuous self-compacted concrete deep beams. The essential studied variables were the ratio of shear span to overall depth, the ratio of reinforcement and the reinforcement configuration. All specimens failed with major diagonal crack initiated between points of loading and central support. Results also indicated that the concrete strength and web reinforcement influenced the deep beams shear capacity significantly. In addition, the horizontal reinforcement found to have a marginal effect on the shear strength than the vertical reinforcement.

Jalil and Abdul-Razzaq (2017) reported a discussion of most parameters that were studied in previous research work on continuous deep beams such as shear span-to-depth ratio, several concrete strengths, and effect of location, size and number of openings, in addition to the impact of web reinforcement. Results exhibited that the load carrying capacity of continuous deep beams was higher than simple deep beams. Indeed, continuous deep beams that have reinforcement developed wider cracks than that without reinforcement. In addition, results stated that aggregate maximum size and concrete types have marginal effect on the formation of failure planes in deep beams. The crack width of standard concrete was lower than that of lightweight concrete. The vertical reinforcement and concrete strength have an important influence on load capacity for deep beams. The results of research also indicated that the load capacity decreases as the shear span to depth ratio increases as well as when openings are existing.

Ali and Noori (2018) investigated the bahavior and strength of self-compacting reinforced concrete continuous deep beams with and without web reinforcement. The included casting and testing five specimens, in which the vertical and horizontal shear reinforcement varied. All samples had the same length, depth and primary reinforcement. It was concluded that the addition of vertical shear reinforcement with minimum ratio (ρv=0.25%) increases both the cracking and ultimate loads by about 10%; when vertical shear reinforcement increased by nearly 80% (from 0.25% to 0.45%), a noticeable increase in the ultimate load capacity was observed (the enhancement reached to 18.6%). When providing horizontal web reinforcement of (ρh=0.343%) in addition to the vertical shear reinforcement (ρv=0.25%), the cracking and ultimate loads increased by about (17.5% and 25%) respectively. In comparison, the previous ratios of the cracking and ultimate loads increased to (20% and 33%), respectively when the vertical shear reinforcement increased to (ρv=0.45%).

2.3 Waste Plastic

The use of plastic has recently increased dramatically due to its many favourable properties, as it has become a necessary part of our modern lifestyle. Plastic has been used extensively in packaging, industrial applications, building and construction, preservation and distribution of food, security systems, communication materials, and other uses **(Gu and Ozbakkaloglu, 2016)**. This has significantly supported the generation of plastic-related waste. Waste plastic has represented one of the prime categories in municipal solid waste (MSW), especially in the industrialized countries, were accounted for 10-16% of the total MSW by weight and more by volume due to the low density of plastic (**Bajracharya et al., 2014).** Accumulation of non-degradable plastic in the ocean or land will be very threatening to the global environment. Also, the disposal of plastic through incineration leads to more pollution to the environment by releasing toxic gases. One of the best choices that decrease the volume of waste plastic and reduce environmental crises is the recycling process. Recycling various types of waste has drawn much attention due to the rising cost of waste dumping and decreasing space in landfills. It is worth mentioning that the recycling of waste materials is a sustainable action that keeps natural resources **(Babafemi et al., 2018)**. The amount of recycled plastic remains insufficient despite the importance of recycling, as shown in Figure (2.1), which indicates the cumulative quantity of generated and recycled plastic waste from 1950 to 2015 and the projected quantity up to 2050. Only about 16% of the plastic waste is recycled in 2015, while about 33% of the plastic is projected to be recycled in 2050. Even if this prediction comes true, the quantity of none-recycled waste will be still unacceptable where most of the plastic waste continues to be disposed to landfills and pollute the environment (**Geyer et al., 2017)**.

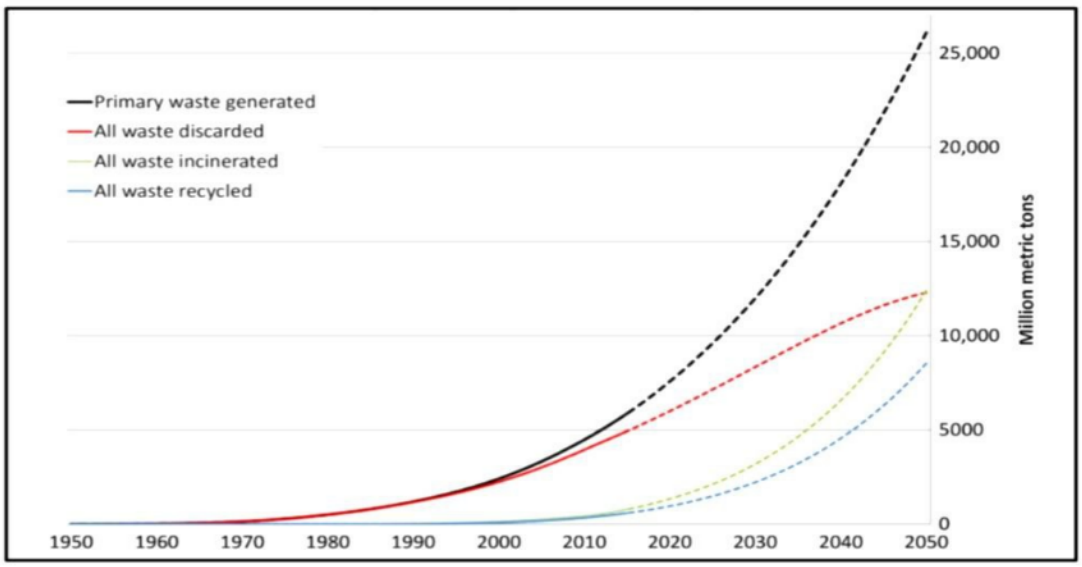


Fig. 2.1 Cumulative plastic waste generation and disposal **(Geyer et al., 2017)**

One potential solution is to reuse waste plastic materials in the construction industry. The versatile bahavior of plastic (durable, lightweight, flexible, easy to design and manufacture, cheap, moisture-resistant, and strong) enabled it to be used in existing composite materials like concrete. In most cases, plastics have been reused in concrete either as aggregate or fibers. Numerous studies reported the performance of concrete with waste and recycled plastic as coarse and/or fine aggregate **(Benosman et al., 2015); (Guendouz et al., 2016) (Aldahdooh et al., 2018) and (Al-Hadithi and Alani, 2018).** They concluded that although waste plastic material in concrete is preferred from an environmental point of view, its fresh, mechanical, and thermal properties are essentially altered from concrete with natural aggregates. Indeed, it has been stated that the incorporation of plastic aggregate can significantly enhance some properties of concrete due to its high toughness, low thermal conductivity, good abrasion bahavior, and high heat capacity.

2.3.1 Effect of PET Size and Content on Concrete Properties

Several studies have investigated the influence of recycling PET on concrete properties in which recycled fibers are blend with concrete ingredients allowing new characteristics of the materials. Therefore, studies have been extended to analyse the performance of concrete reinforced with PET fibers.

Kim et al. (2008) examined the influence of PET based fibers on the plastic shrinkage cracking in concrete. Three different geometries (straight, crimped, and embossed) and a five-volume fraction (0.1, 0.25, 0.5, 0.75, and 1%) were employed to study the shrinkage performance of plastic. The results yielded that using PET fibers at volume fraction up to 0.25% reduced significantly the plastic shrinkage, whereas increasing volume fraction beyond 0.25% had little influence on shrinkage reduction. The geometry of PET fibers also affected the plastic shrinkage, where the embossed type conferred the best resistance to cracking of plastic shrinkage.

Ypsilanti et al. (2009) and **Fraternali et al. (2011)** concluded that selecting PET into concrete as fibers can significantly be a competitive technique for improving thermal insulation. In addition, the degree of enhancement in thermal resistance varies with the ratio and geometry of added PET fibers.

Foti (2011) reported that the addition of waste bottles PET fibers prepared with two forms (short lamellar fibers and "O" shaped fibers) enhanced the post-cracking fracture bahavior and increased the ductility of concrete. The results also revealed that the use of “O” shape fibers in concrete improved significantly the toughness by higher percentage than the use of short lamellar fibers.

The possibility of utilising PET waste as a fiber in self-compacting concrete (SCC) was investigated by **Al-Hadithi and Hilal (2016).** Mixes with PET fibers at volume fractions ranging from 0 to 2% with an increment of 0.25% were cast. An experimental investigation on fresh and hardened properties, comprising slump flow diameter, t_{500}, L-box height ratio, V-funnel flow time, compressive strengths, tensile strength, and Ultrasonic Pulse Velocity (UPV) were performed. PET fiber inclusion in SCC showed adverse influence on concrete workability, whereas higher compressive and flexural strengths were observed in the SCC mix that contains 1.5% of PET waste fibers. Results also revealed that the highest UPV was 5.2 km/sec in the mix with 0.25% PET fibers while it was 3.6 km/sec in the control mix.

Borg et al. (2016) reported that increasing the volume fraction of PET fibers leads to a slight decrease in compressive strength and a significant increase in flexural strength. On the other side, deformed PET fibers gave better outcomes than straight ones. The same result was confirmed by **Faisal et al. (2016)** when incorporating ring-shaped PET- fibers with different widths (5 and 10 mm) in concrete. They observed that the concrete toughness index of I20 increased generally by 23.1% and 39.9%, respectively, in concrete with PET fiber.

In a study conducted by **Shahidan et al. (2018),** the optimum percentages of recycled PET bottle fibers in concrete were explored through tests of the slump, compressive strength, and splitting tensile strength. Concrete mixes were designed in which PET fibers were utilized at a volume fraction of 0.5%, 1%, 1.5% and 2.0%, confirming the decrease in both compressive strength and value obtained from the slump test. In contrast, the strength obtained from the splitting tensile test increases when the percentage of recycled PET fibers increases. Based on the results of this research, the optimum ratio of PET fibers to be incorporated into concrete was 1.0%.

2.4 Shear Strengthening of RC Deep Beams: Literature Review

The carbon fiber reinforced polymer (CFRP) sheet is used for strengthening various reinforced concrete members. It is usually bonded externally by a viable practicable method to increase the moment capacity and improve strength. The general concept of using CFRP is to reduce the deflections under service loads by increase the stiffness and durability of members. In other words, it is used for strengthening the beams or columns against flexural and shear loads **(Ola, 2005)**.

Al-Tai, (2010) studied the shear bahavior of strengthened reinforcement concrete deep beams by CFRP. Eight beams have been strengthened by using (CFRP) sheets. The main considered variables were the amount of CFRP, distribution, orientation and the end anchorage of CFRP. The results confirmed that the CFRP sheets are an applicable technique for strengthening deep beams, where the shear capacity increased by about (30 - 45) %. Also, it has been concluded that drilling the flange of RC beams to wrap the CFRP strips was the most influential and significant factor for strengthening RC beams. Indeed, decreasing the spacing between the CFRP strips or inclining them by 45° were less efficient than the drilling system. On the other hand, a numerical study has been conducted to investigate the performance of the CFRP technique for strengthening deep beams. The comparison of the results indicated that there was an agreement between the experimental and numerical where the average difference of the ultimate load and the central deflection were 4.7% and 4.3%, respectively, for the analysed and tested specimens.

Manos et al. (2012) tested a series of six reinforced concrete rectangular beams to study the effectiveness of external strengthening under shear forces by using a CFRP sheet. All beams were with a cross-section of (120) mm width and (360) mm depth. The sheet of carbon fibers was installed on the surface of beams by two methods: the first, by the anchored open-hoop (CFRP) strips and the second method was represented by bind the (CFRP) strips externally without anchoring by using the adhesives certified as depicted in Fig. (2-2). They found that the shear capacity by the first method increased much higher than the identical specimens without anchors.

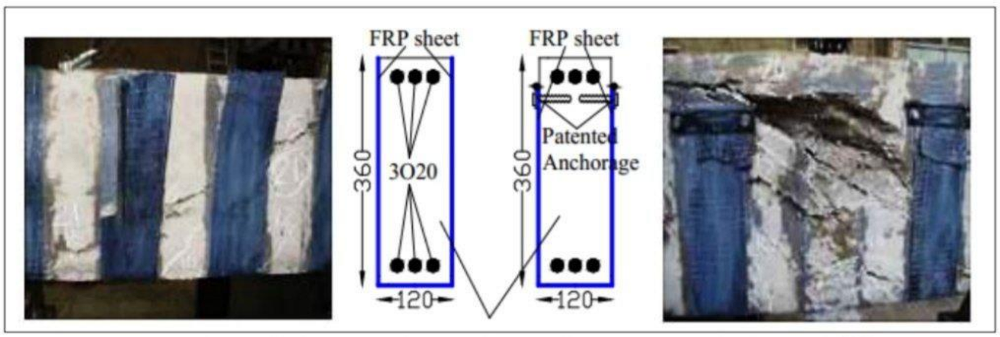


Fig. 2-2 Methods of installing CFRP (**Manos et al. 2012)**

Hawileh et al. (2015) studied the influence of the longitudinal reinforcement ratio of rectangular beams on the concrete shear capacity when strengthening it by externally bonded CFRP sheets. They tested thirteen beams with dimensions (120) mm width, (240) mm depth and (1840) mm length without shear reinforcement and divided them into three groups with different longitudinal steel reinforcement ratios. They found the increase of concrete shear capacity ranges between (10–70%) for all strengthened specimens compared with control specimens. Also, the beam with a low longitudinal reinforcement ratio showed the highest percentage of increasing the concrete shear strength when strengthened with longitudinal (CFRP) sheets.

Wei (2015) presented an investigation to study the bahavior of deep beams reinforced concrete containing openings by utilising a finite element numerical analysis. In this investigation, modelling of three–dimensional deep beams was adopted. 13 samples of deep beams beside one sample as a reference beam were prepared. The research aimed to identify the practical method of CFRP strengthening, which is different in the orientation of CFRP alignment (horizontal (0^o) or vertical (90^o)), U-wrap or surface of strengthening, and cut strips or the whole piece. From the results, the circular and the square opening reduced the beam capacity by about 51.3% and 62.0%, respectively. In addition, the effective CFRP strengthening method restored increased the beam capacity of the samples with circular and square openings by 85.0% and 63.0%, respectively. The samples containing the opening was unsuccessful because of the shear cracks due to the sharp opening's edges. From the different CFRP strengthening methods, the U-wrap, vertical alignment, and whole piece CFRP strengthening techniques were effective. In addition, experimental and numerical results were compared and the comparison presented strong agreement of the patterns of crack and bahaviors of the load deflection.

Sarsam et al. (2017) examined nine reinforced lightweight concrete. The tested beams were rectangular solid deep beams of 1400 mm total length, 150 mm the width and 400 mm overall depth. All the nine beams were made from (lightweight porcelain aggregate) RC deep - beams. Un strengthened beams were three, and the others were strengthened by CFRP externally bonded sheets with different orientations (vertical and horizontal) tested with different (a/d) ratios (0.8,1,1.2).

The results of these investigations were as follows:

- The deflection reduced by about 50%, and the ultimate capacity enhanced by 45% when the deep beams strengthened with CFRP sheets.
- (a/d) the ratio did not affect the de-bonding failure of CFRP because this type of failure was observed in all specimens.
- Using CFRP sheets improved the shear resistance of strengthened deep beams because it decreased the growth of diagonal cracks.

Al-Ghanim et al. (2017) conducted twenty tests in two groups, one for studying the shear bahavior and the other for investigating the flexural bahavior of deep beams upgraded by CFRP with externally bonded. The beams dimensions were 0.19 m in width, 0.40 m overall height and a total length of 1.90 m. Different modes of CFRP composites (laminates and sheets) were used in this research. The results showed that the efficiency of the CFRP technique on strengthening shear and flexural capacity of deep beams depends on the type of CFRP (sheet or laminate) ranges, and the CFRP affected the following:

- CFRP enhanced the shear resistance. A continuous wrap of two CFRP sheets upgraded the strength by about 86%, while the inclined laminate increased the strength by just 36 %.

- Regarding the flexural strengthening, the increase in capacity was about 51% for two-layer CFRP sheets strengthening compared with 26% for inclined laminate.

Jassem (2018) tested 12 reactive powder concrete (RPC) deep beams, which were externally bonded by CFRP sheets. The deep beams dimensions were (1400 × 150 × 400) mm. One was a solid beam selected as a reference beam, and the others contained two symmetrically square openings (150×150 mm), one in each critical shear path. Two Ø16 mm deformed bars were used flexural reinforcement while the shear reinforcement was neglected to study the CFRP effect. The variables studied were the orientation of CFRP sheets and fixing the sheets by epoxy rising only or by mechanical anchorage (bolts) besides the epoxy. The study concluded the following:

- The existence of an opening in the critical shear path decreases the capacity of the deep beam by approximately 30% of that in the solid beam.
- The ultimate strength capacity of upgrading RPC deep beams increased by (11-94%) due to the externally bonding CFRP sheets.
- The deflection of strengthened deep beams was less than the deflection in the unstrengthened beams. At the same loads, the decrease of deflection was about 7.5 to 24 %.
- The inclined CFRP strips (45º strips) layout significantly impacted ultimate strength than 90º CFRP strips. The increase was (24% and 11%), respectively.
- Using horizontal (0º CFRP strips) to the system of vertical (90º CFRP strips) improved the shear capacity by 36% while using the inclined CFRP strips (45º strips) enhanced the shear strength by 51%.

- Improving the vertical and horizontal layout of CFRP by adding short inclined sheets (45° and 135° CFRP sheets), to the corners of the opening increased the ultimate strength by 27%.
- Mechanical anchoring using bolts in fixing enhanced the ultimate capacity by (9 to 15) % in comparison with the same CFRP layout fixed by epoxy.

2.5 Summary and Concluding Remarks

Depending on the literature review presented previously, the following conclusions can be drawn:

1. The basic key parameters that influenced the total shear capacity of RC continuous deep beams was the shear span to the effective depth ratio followed by web reinforcement configuration, compressive strength, and configuration of longitudinal reinforcement. Stirrups reinforcement affected the load strength of beep beams more than longitudinal reinforcement for beams with a significant ratio of the shear span- to-depth. The ratio of shear span to depth (a/d) was an essential factor that affects the bahavior of the deep beams reinforced concrete.

2. Inclined reinforcement affects more than horizontal reinforcement on the load capacity of deep beams.

3. Beams depth has more effect on continuous deep beams strength than simple deep beams.

4. Strengthening deep beams with and without openings by externally CFRP sheets can significantly increase the ultimate strength and improve deep beams' stiffness.

5. It can be noticed that from the previous review that there was an increase in conducting deals with adding waste plastic to concrete mixes because of its positive effects on concrete properties and the environmental pollution.

6. It is clear that waste plastic fibers play a good role in enhancing the properties and flexural strength of reinforced concrete beams. However, the investigation of the effect of these fibers on the shear strength of beams is still unknown. Therefore, there is a need to study the impact of polyethelne terephthalate (PET) fibers on the shear bahavior of beams.

7. There is an evident that using CFRP sheets to strengthen structural members (especially the concrete structures) was an effective method despite their brittleness nature.

8. The orientation and the distribution of the CFRP sheets affected the rehabilitation of deteriorated members significantly; therefore, the strengthening specimen by inclined CFRP strips gave better results compared with the other different models of CFRP strengthening. This can be attributed to the perpendicular of the CFRP orientation and the inclined crack.

9. The literature about RC continuous deep beams with fiber is still limited and should be fulfilled. The current study aims in the second part to accomplishing this gap regarding the properties of RC continuous deep beams with fiber. The used type of fibers is the plastic fiber (PET) to keep up with the current society need in becoming sustainable and protecting the environment.

Chapter Three

Experimental Work

3.1 Introduction

The primary aim of this work is to study the influence of waste plastic fibers on the ultimate capacity and cracking loads, deflection response, and the crack width. In addition, the effect of strengthening by CFRP in improving the shear capacity of the deep beams incorporated plastic fibers is also investigated. Description of the tested specimens, material properties, strengthening configuration system, and testing procedure are detailed in this chapter.

3-2 Specimen Details

Twelve reinforced concrete continuous deep beams with and without waste plastic fibers were prepared: total span length of 2000 mm, the overall depth of 300 mm, and width of 150 mm, with shear span-to-overall depth ratio (a/h) equal to 1.5 and effective length to overall depth ratio (ln /h) equal 3.0, to ensure that the beams will behave as deep beams.

All beams were tested under two-point top loading. Two top and two bottom bars of Ø 12 mm were provided longitudinal reinforcement, and a diameter of 10 mm @ 100 mm were used for linking longitudinal reinforcement. All the continuous deep beams, have the same flexural and shear reinforcement, were designed to reach shear failure. The prepared concrete compressive strength was (f_c'= 30 MPa).

Four specimens were without strengthening as control beams. One of the control specimens was without the plastic fiber, while the others were with one of the following percentages of plastic fibers (0.5, 1, and 1.5%). Figure (3-1) shows the details geometrical dimensions and reinforcement details of the continuous deep beams.

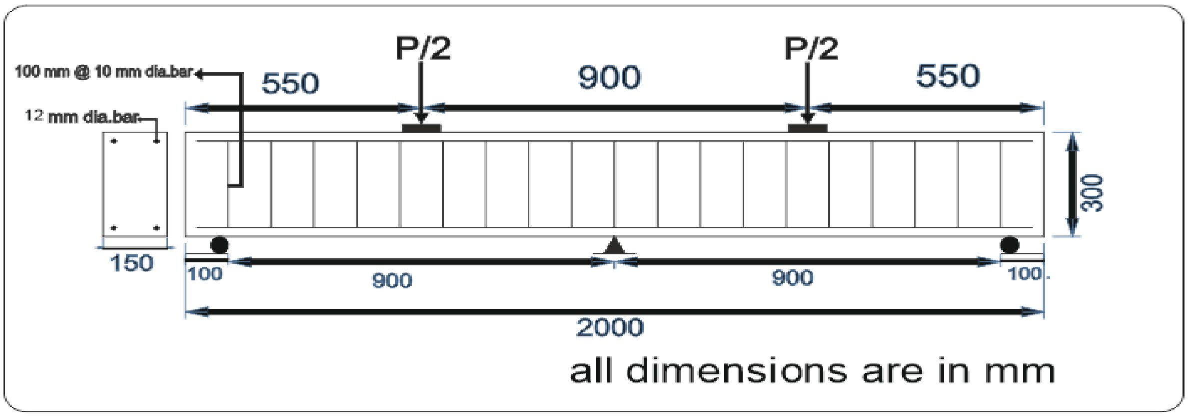


Fig. 3-1 Geometrical dimensions and reinforcement details of the continuous deep beams

3.3 Strengthening Configuration by CFRP

Various strengthening schemes were suggested according to many considerations such as cracks pattern, modes of failure, and actual applying ability in practice and economic concerns. Four specimens were kept without strengthening as controls. The first strengthening beam (BF%,90°) is strengthened by wrapping the CFRP sheets vertically (90°) around the specimen. This system aims to cut the diagonal and flexural cracks and improve the shear and flexural strengths.

The second strengthening beam (BF%,45°) was strengthening by wrapping the CFRP sheets in an inclined direction (45°). This system aims to cut diagonal cracks, improve deflection response, and increase the shear strength.

The primary goal of the different strengthening configurations is to find out the influence of the two configurations on ultimate load, crack pattern, deflection and mode of failure. The different configurations of beams containing plastic fibers are detailed in Figs. (3-2) to (3-3).

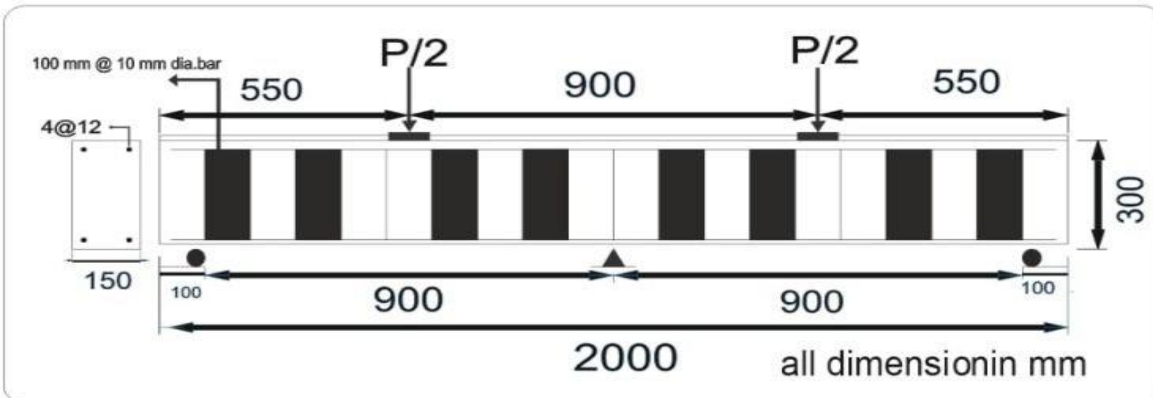


Fig. 3-2 Vertical CFRP Strengthening

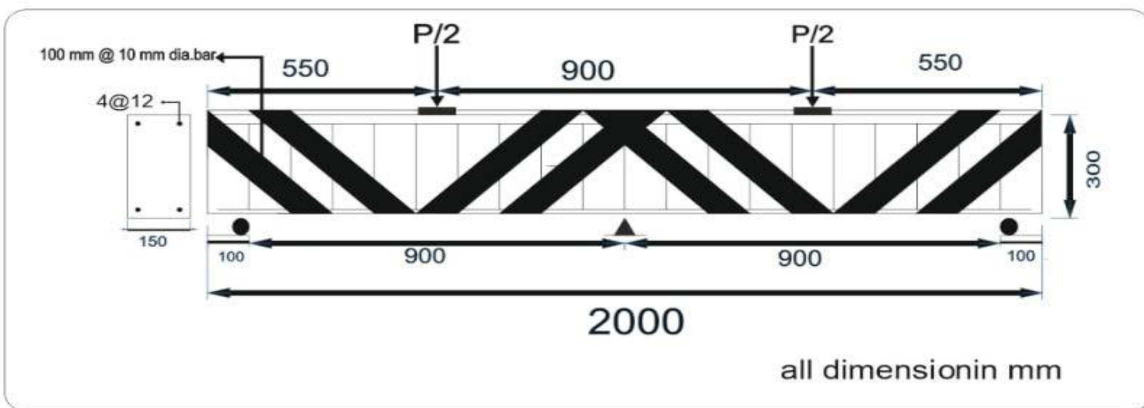


Fig. 3-3 Inclined CFRP Strengthening

All specimens were strengthened with one layer of bilinear CFRP strips completely wrapping-scheme with a width of 100 mm and a thickness of 0.167 mm. Table (3-1) provides all details of the tested specimens with the percentage of plastic fibers, loaded rates% from the ultimate load and strengthening configurations.

Table 3-1 Details of the tested specimens

Specimen Designation	Description
BR0%	Fiber (0%)- Control
BR0.5%	Fiber (0.5%)- Control
BR1%	Fiber (1%)- Control
BR1.5%	Fiber (1.5%)- Control
BF0%,90°	Fiber (0%)- Loading rate 60% from the ultimate load- Strengthened by Vertical CFRP sheets Warpping (90°)
BF0.5%,90°	Fibers(0.5%)- Loading rate 60% from the ultimate load- Strengthened by Vertical CFRP sheets Warpping (90°)
BF1%,90°	Fibers(1%)- Loading rate 60% from the ultimate load- Strengthened by Vertical CFRP sheets Warpping (90°)
BF1.5%,90°	Fibers(1.5%)- Loading rate 60% from the ultimate load- Strengthened by Vertical CFRP sheets Warpping (90°)
BF0%,45°	Fiber (0%)- Loading rate 60% from the ultimate load- Strengthened by inclined CFRP sheets Warpping (45°)
BF0.5%,45°	Fibers(0.5%)- Loading rate 60% from the ultimate load- Strengthened by inclined CFRP sheets Warpping (45°)
BF1%,45°	Fibers(1%)- Loading rate 60% from the ultimate load- Strengthened by inclined CFRP sheets Warpping (45°)
BF1.5%,45°	Fibers(1.5%)- Loading rate 60% from the ultimate load- Strengthened by inclined CFRP sheets Warpping (45°)

3.4 Material Properties of the Tested Specimens

Standard tests according to the Iraqi specification were conducted to examine the material properties.

3.4.1 Cement

Sulfate resistant Portland cement, manufactured by AL-JESR / Lafarge Cement Factory, has been used in producing all mixes. The compliance of the cement was carried out according to the **Iraqi Standard Specification No.5/2019**. The physical and chemical properties of cement used are presented in Tables (3-2) and(3-3), respectively.

Table 3-2.: Physical requirements of cement

<table>
<tr><th colspan="2">Physical property</th><th>Test result</th><th>Iraqi Specification (No. 5/2019)</th></tr>
<tr><td rowspan="2">Compressive strength, N/mm^2</td><td>3-day</td><td>21</td><td>≥ 15</td></tr>
<tr><td>7-day</td><td>25</td><td>≥23</td></tr>
<tr><td rowspan="2">Setting time (min)</td><td>Initial</td><td>110</td><td>≥ 45</td></tr>
<tr><td>Final</td><td>240</td><td>≤ 600</td></tr>
</table>

Table 3-3: Chemical composition and main compounds of cement*

Oxide	% by weight	Limits of IQS No.5/2019
SiO_2	20.7	-
CaO	61	-
Al2O_3	4.1	-
Fe_2O_3	5.5	-
Lime Saturation Factor	0.89	0.66-1.02
MgO	3.1	≤ 5%
SO_3	2.3	≤ 2.5% if C3A≤ 5% ≤2.8% if C3A≤ 5%
Loss on Ignition	3.5	≤ 4%
Insoluble Residue	0.4	≤ 1.5
(C_3S)	49.04	-
(C_2S)	22.35	-
(C_3A)	1.56	≤ 3.5
(C_4AF)	16.74	-
Al_2O_3 / Fe_2O_3	0.75	-
Free lime	0.78	-

**These tests were implemented at Kufa University, College of Engineering, Civil Department Laboratories*

3.4.2 Fine Aggregate

Al-Ukhaidher natural sand has been used in the production of the concrete mixes of this study. The grading and physical properties are consistent with the **Iraqi standard specification No. 45/ 1984**, as given in Table (3-4).

Table (3-4) Sieve analysis of fine aggregate*

Sieve Size (mm)	Passing%	IQS 45/1984 Zone (2)
10	100	100
4.75	95	90-100
2.36	88	75-100
1.18	62	55-90
0.60	45	35-55
0.3	19	8-30
0.15	3	0-10
Physical properties		
SO_3 (%)	0.3	≤0.5
Passing 75 µm sieve (%)	1.5	≤5
Specific gravity	2.7	---
Absorption	0.8	---

**This test was made at Al-Qassim Laboratory for structural investigations*

3.4.3 Coarse Aggregate (Gravel)

Crushed gravel with a maximum size of (5-20 mm) has been used as coarse aggregate. The gradation, specific gravity, density and sulphate content are given Table (3-5), which were conform to the **Iraqi specification No. 45/1984**.

Table 3-5: Grading and physical properties of coarse aggregate*

Sieve size (mm)	Passing, %	IQS Limits No. 45/1984
37.5	100	100
20	99	95-100
14	/	/
10	30	30-60
5	0	0-10
SO_3 (%)	0.072	≤0.1
Specific gravity	2.7	---

* *These tests were carried out in the Al-Qassim Laboratory for structural investigations*

3.4.4 Water

Tap water was used for washing the fine and coarse aggregate as well as in casting and curing the cubes, cylinders and reinforced concrete beam specimens.

3.4.5 Steel Reinforcing Bars

All beams have been reinforced with a (12) mm bar as a longitudinal reinforcement and (10) mm bar as transverse reinforcement (stirrups) according to(**ASTM A615-01b)**, and their properties are tabulated in Table (3-6).

Table 3-6 Properties of steel bars

Bar diameter (mm)	Actual diameter(mm)	Elongation %	Yield strength (MPa)	Ultimate strength (MPa)
12	11.7	14.7	590	687
10	9.8	14.2	583	672

3.4.6 Carbon Fiber Reinforced Polymer (CFRP)

The Sika Wrap Hex – 301 C type and Sikadur – 330 epoxy-based impregnating resin have been used to strengthen the reinforced concrete deep beams externally according to **(ACI 440.8B,440 2R-17)**. The properties of carbon fiber laminate and epoxy used are shown in Table (3-7) and Table (3-8). Plate (3-1) shown these materials.

Table 3-7 Properties of Carbon Fiber

Type	Weight (g/m^2)	Thickness (mm)	Modulus of Elasticity (GPa)*	Tensile Strength (GPa)*	Break Elongation (%)
High strength carbon fibers	304 ± 10	0.167	230	4.9	1.7

* The technical data sheet provided from the manufacture were adopted.

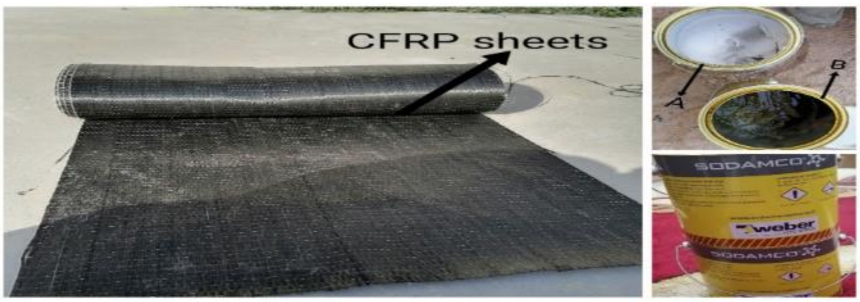


Plate 3. 1 CFRP sheets & epoxy

Table 3-8 Properties of the used Epoxy Resin

Appearance	Mixing Ratio	Density (g/cm^3)	Tensile Strength (MPa)	Modulus of Elasticity (MPa)	Break Elongation %
Com A: White Com B: Dark Gray	A: B 4 :1	1.7	30	4500	0.9

3.4.7 Waste Plastic Fibers (PET-Fibers)

Shredded soft drink bottles obtained the ribbed (PET) fibers into rectangular pieces with nearly a length of (50) mm, an average width of (5) mm, and thickness of (0.33) mm using a paper shredder, as shown in Plate (3-2) and Table (3-9) **(Gourmelon, 2015)**. The percentages of PET fibers used were (0.5, 1, and 1.5) by volume.

(a) (b) (c)

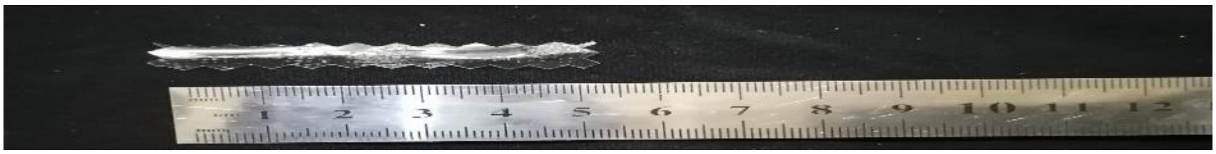


Plate 3.2 a) Paper shredder. b) Plastic bottles c) Ribbed waste plastic fibers

Table 3-9 Physical properties of the waste plastic fiber

Dimensions (mm)	Aspect Ratio (%)	Density (Kg/m^3)	Water Absorption (%)	Colour
50×5×0.33	34.5	1100	0	Crystalline White

3.5 Concrete Mix Properties

In this regard, the **ACI 211** has been adopted to design a concrete mix with 30 MPa as a target 28-days compressive strength. Trial mixes have been carried out to find an appropriate combination that meets the requirement of workability and compressive strength. The amounts of ingredients for the standard concrete mix are shown in Table (3-10).

Table 3-10 Proportions of concrete mix ingredients

Ingredients	Mix proportions (kg for 1 m^3)
Cement	415
Sand	701
Gravel	1009
w/c	0.47
f'_c at 28 days	30 MPa

3.6 Fresh Concrete Tests

3.6.1 Slump Test

According to **ASTM C143**, the slump test has been considered to determine the workability of all fresh concrete mixes. as shown in Plate (3-3).

Plate 3-3: Slump flow for fresh concrete test

3.7 Hardened Concrete Tests

3.7.1 Compressive Strength

Three cubes with dimensions (150×150×150) mm were cast according to **BS 1881-116 (1983)** to measure the compressive strength of various prepared mixes with various PET fiber volume fractions at the ages of (7) and (28) days by using a compression testing machine, as shown in Plate (3-4). The compressive strength (f'_c) of the concrete cylinder was obtained by converting the test results of cubes (f_{cu}) according to **EN 206-1** as the following formula:

$$f'_c = 0.8\, f_{cu} \quad \text{...... (3-1)}$$

Plate 3-4: Cube compressive strength test

3.7.2 Splitting Tensile Strength

Three a standard cylinder (100×200 mm) was tested using the same machine used for testing compressive strength test to determine the splitting tensile strength of concrete at ages (7) and (28) days for all mixes with various PET fiber percentages according to **ASTM (C496-17)**, as shown in Plate (3-5). The formula used to calculate the value of the splitting tensile strength is:

$$f_t = 2P/\pi d L \qquad (3\text{-}2)$$

where:

f_t: Splitting tensile strength (MPa).

P: Maximum applied load (N).

d: Cylinder diameter (100 mm).

L: Cylinder length (200 mm).

Plate 3-5 Splitting tensile strength test

3.8 Molds Details

In the present work, twelve plywood formwork were prepared and formed as rectangular-section deep beams with 300 mm height, 150 mm width and 2000 mm length. Plate (3-6) shows the plywood moulds and reinforcement of deep beams.

Plate 3-6 Plywood formwork and reinforcement of specimens

3.9 Concrete Casting and Curing

The designed concrete mix was used to cast the twelve continuous deep beam specimens, six cylinders for splitting tensile strength test and six cubes for compressive strength tests for all mixes with various PET fiber percentages (0%,0.5%,1%,1.5%). Below is a description of the procedure of the casting and curing of concrete according to **ASTM C31/08 b,C192/02**.

1. All moulds (cylinders and cubes) and samples formworks were cleaned and oiled.

2. The central mixer was used to mix the ingredients as designed.

3. Vibrator table was used as a compaction process and the mix was finished and levelled using surface finishing levelling tools.

4. The formworks and moulds were removed after 24 hours, and burlap sacks were used to cover the specimens to keep the moisture for 28 days.

Plate (3-7) below shows the casting and curing processes for the samples.

Plate 3-7 Casting and Curing Process

3.10 Application of CFRP System on RC Continuous Deep Beam

The procedure used in applying the CFRP sheets is detailed below. These steps matched the specification of the CFRP manufacturer datasheet and recommendations of **ACI committee 440.**

3.10.1 Concrete Surface Preparation

The bond between the surface of concrete and the CFRP considers as the most crucial part for any application technique of concrete strengthening as it can ensure the effective transition of the load from the structural member to the CFRP After loading the eight samples at 60% of the ultimate load, then we follow the following steps: First, the painting and dye were removed from the beam surface with a grinder machine, as shown in Plate (3-8), to get a clean concrete surface and free from the contaminants like the latency of cement or dirt. Then, it was cleaned using air blasted and water jet to remove the powdered concrete produced by the grinding process and all possible loose materials.

Plate 3-8 Removing the painting from the beam surface

3.10.2 Fixing Procedure of CFRP Sheets by Epoxy

• The CFRP sheet is measured and cut to have a 100 mm width.

• The epoxy paste is prepared by mixing type A with type B according to technical data of manufacturer until the paste colour becomes light grey.

• A layer of the mixing epoxy is applied on the concrete surface by nearly (1-1.5 mm) thickness.

• Another layer of the epoxy paste is applied on the CFRP sheet.

• The CFRP strip is pasted on the beam surface on the region that is already coated with epoxy.

• Iron blade is used to push out bubbles, which my confine under the CFRP sheet.

Plate (3-9) shows the steps of fixing the CFRP on the RC deep beam.

Plate 3- 9 Steps of CFRP Fixing

3.11 Test Measurement and Instrumentation

The instruments used in the test were as follows:

3.11.1 Deflection Measurement

The mid-span deflections were measured with a dial gauge that has a sensitivity of 0.01 mm/div. According to **ASTM 1609/10**, as shown in Plate (3-10).

Plate 3- 10 Dial Gauge Device

3.11.2 Crack Width measurement

The width of cracks is measured with a particular device named crack meter that has a magnification factor of 30 times, as shown in Plate (3-11).

Plate 3-11 Crack meter device

3.11.3 Test Procedure

All specimens were tested as continuous deep beams using a two-point loading with shear span to overall depth ratio (a/h) equal to (1.5). All samples were tested using a calibrated electrohydraulic testing machine (PHILIPPHOLZMANN) with a maximum range capacity of 2000 kN in the structural laboratory of Kufa University, as shown in Plate(3-12) below. The loading on the beams was carried out under a monotonical increment of load and up to failure. The beam was loaded at the upper face with a vertical load. Then, the first reading of the mechanical dial gauge was recorded. The load was applied at a constant rate on the specimens and it gradually increased up to the failure. For each stage of increment of load, the reading of the mechanical deflection (vertical displacement) was recorded in the mid-span of the beam. In addition, for each step of load, the patterns of crack were checked, as well as the load of the first crack and failure of the beam was recorded.

Plate 3- 12 Universal Machine

Chapter Four

Experimental Results and Discussion

4.1 Introduction

The results and discussions of the experimental work that is illustrated in chapter three will be presented in this chapter. The results summarize the mechanical properties of the ordinary concrete that incorporated waste plastic fibers (PET) such as workability as well as the compressive and splitting tensile strengths. The results of the experimental work of the twelve continuous deep beams are given, discussed and reported here. The results are given in terms of the ultimate load, cracking loads, deflection response, ductility index, stiffness criteria and crack width for four specimens with different plastic waste contents (0, 0. 5, 1.0 and 1. 5) % in addition with the strengthened specimens.

4.2 Fresh and Hardened Properties of Normal Concrete With Waste Plastic Fibers

4.2.1 Slump Test

According to **ASTM C143**, the slump test has been considered to determine the workability of all fresh concrete mixes. The results showed that PET fibers had an adverse effect on the slump test results. The workability become lower as the added contents of PET fibers increased for the same value of w/c, as shown in Fig. (4.1)

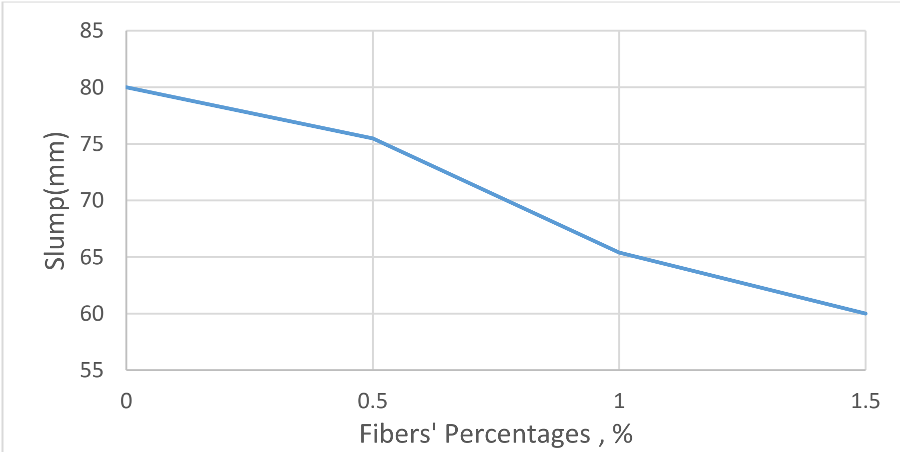


Fig. 4.1 Effect of (PET) fibers on workability

The reason behind such behavior that could be the concrete components have a high specific surface area, which requires high amount of water to keep the same value of slump. Indeed, the form and length of fibers can restrain the movement of the concrete’ constituents, which could be considered as another reason for such reduction in its workability.

4.2.2 Compressive Strength "f_{cu}"

Cubes with a side length of (150) mm were used to measure the compressive strength of various prepared mixes with various PET fiber volume fraction at the ages of (7) and (28) days and the average results are given in Table (4.1), and shown in Fig. (4.2).

Table 4.1 Concrete's compressive strength for all fiber percentages

Fiber % by vol.	7 days			28 days		
	f_{cu} (MPa)	$f_{c'}$ (MPa) *	percentage change%	f_{cu} (MPa)	$f_{c'}$ (MPa) *	percentage change%
0	28.35	22.68	--	37.51	30.01	--
0.5	28.75	23.00	+1.41	38.12	30.5	+1.633
1	26.94	21.55	-4.98	35.14	28.11	-6.331
1.5	26.25	21	-7.40	34.44	27.55	-8.12

* $f_{c'} = 0.8 f_{cu}$

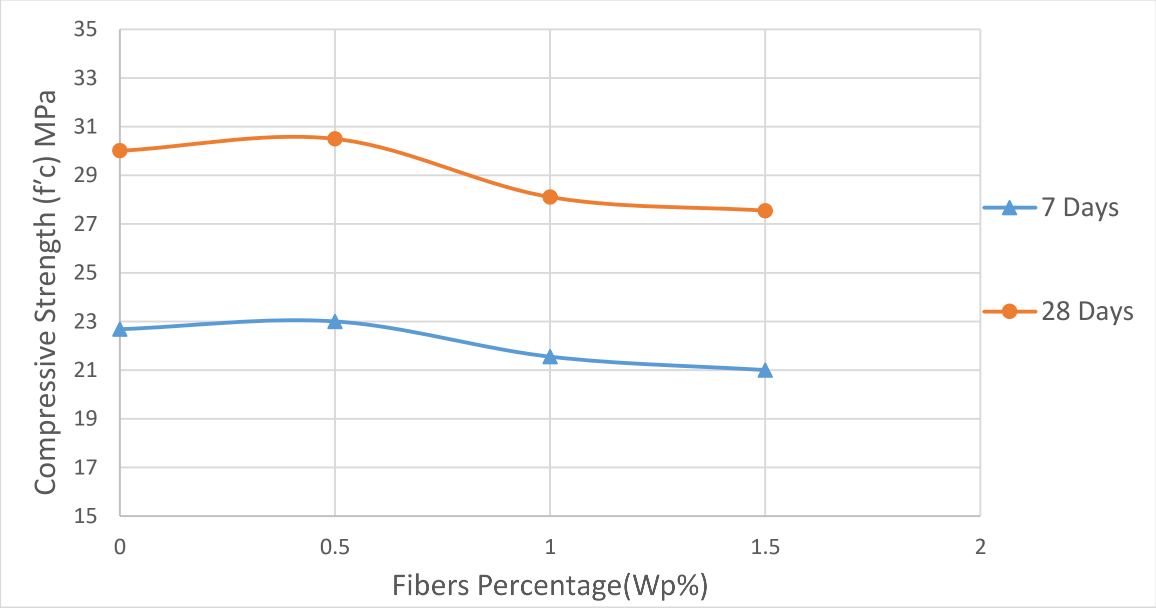


Fig. 4.2 Relationship between the compressive strength and fibers percentages

The higher value of the compressive strength at the age of (7) days was (23.0 MPa) for the specimen with (0.5%) while it was (30.5 MPa) at the age of (28) days. It can be noticed that increasing the volume of the waste plastic fibers causes a decrease in the compressive strength.

At the age of (28) days, no clear effect was recorded of fibers on the compressive strength only at percentage (0.5%) and showed decreasing the strength with increase the fibers percentage (1 % and 1.5%). Plate (4.1) displays the cracks of the cubes after the compressive strength test at (28) days that shows the role of fibers in the cohesion of concrete after failure.

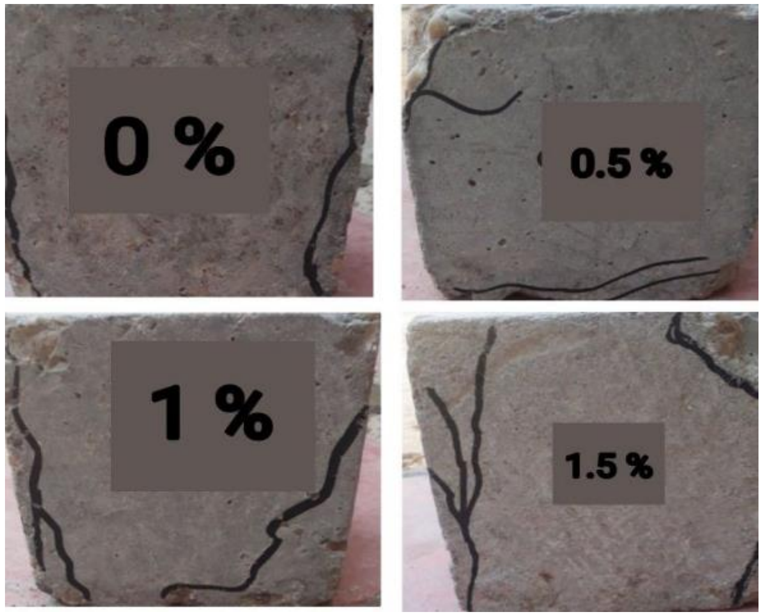


Plate (4.1) The cubes after the compressive strength test at (28) days

The slight increase in the compressive strength at (7) days can be explained in two ways: the (PET) fibers as strengthening bridges, binding the parts of the cement paste at the early stages of the curing period when it is still weak and fragile due to incomplete hydration interactions. The other reason is that the presence of fibers in the mix increases the amount of absorbed energy before failure, which has a minor impact on loading potential at early ages. On the other hand, one explanation of the reduction in the compressive strength at the age of (28) days with fiber contents of (1% and 1.5 %) is that the (PET) fibers reflected no homogeneous matrix defects in the cement paste that became apparent, in addition to, the (PET) fibers reduced the workability of concrete and made it more porous.

4.2.3 Splitting Tensile Strength (f_t)

As shown in Figure (4.3) and Table (4.2), At (7) and (28) days, the splitting tensile strength of a three standard cylinder (100×200 mm) for each age and for each PET% were tested, according to **ASTM (C496-86)**.

Table 4.2 Splitting tensile strength for all fiber percentages

Fiber vol. %	f_t (MPa) 7 days	f_t (MPa) 28 days	percentage change%
0	1.31	1.39	--
0.5	1.45	1.52	+9.3
1.0	1.50	1.59	+14.4
1.5	1.41	1.55	+11.5

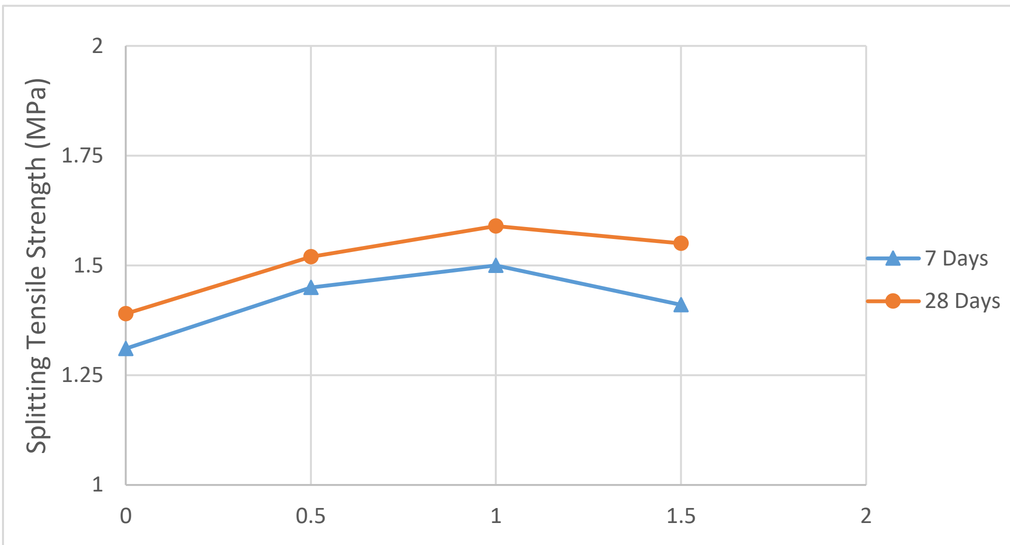


Fig. 4.3 Relationship between fiber percentages and splitting tensile strength

The results showed that the splitting tensile strength increased as the percentage of (PET) fibers increased until the percentage of (PET) fibers reached (1.0 %), in contrast to the control specimen which split into two sections after the happening of failure as shown in the Plate (4.2) as the parts of the (1.0%) PET specimen has a strong cohesion after failure. It was also discovered that the control specimen splits abruptly with a loud sound, while the cylinders with fiber percentages (1 % and 1.5 %) made soundless, which could refer that the using of (PET) fibers can make concrete more ductile. This bahavior was already expected with the presence of fibers due to the interdependence of cement paste, which causes internal stresses to be reduced and the ultimate applied load to be increased. Furthermore, in the splitting strength for the specimen with 1.0% PET fiber was a high decrease, which may be because the fiber after such value forms bulks and segregation inside the mix after such value.

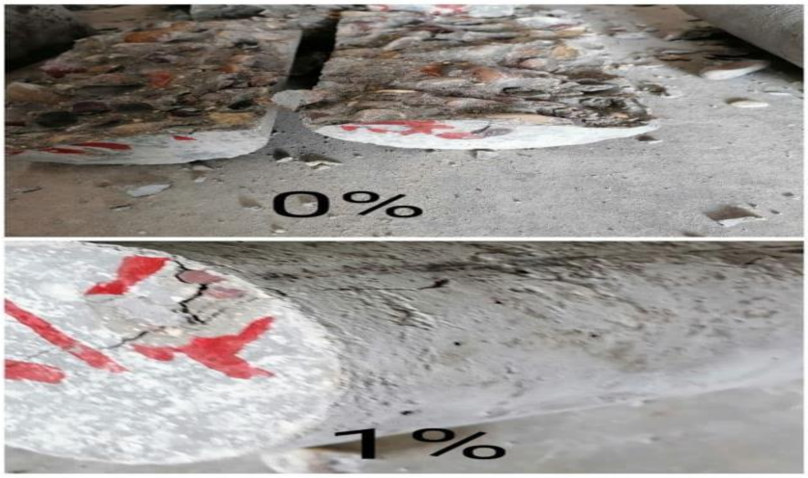


Plate (4.2) Specimens after the splitting tensile test

4.3 General Behavior of Tested RC Continuous Deep Beam Specimens

All specimens were tested as continuous deep beams using a two-point loading with shear span to overall depth ratio (a/h) equal to (1.5). The beams were tested using a calibrated electrohydraulic testing machine (PHILIPPHOLZMANN) with a maximum range capacity of 2000 kN in structure laboratory of Kufa University. The structural properties were examined in terms of the ultimate load, cracking loads, deflection response and width of cracks. The results were based on the study variables such as the waste plastic contents and the orientation of the CFRP in the vertical and inclined direction. The details of tests results are given in Table (4.3).

Table 4.3 Experimental test results of beam specimens

Group	Deep beam symbol	Fiber (%)	CFRP orientation	Failure Loads (kN)	60% of Failure Loads of Control	First Crack load (kN) (1st stage)	First Crack load (kN) (2nd stage)	Maximum Deflection(mm)	Max. cracks Width (mm)	Ductility Index(DI)	Stiffness ,K (kN/mm)	Failure Mode
Group(A)	BR0%	0	--	350	-	70	-	4.0	1.2	1.9	097.2	Shear failure
	BR0.5%	0.5	--	355	-	90	-	3.9	0.9	2.08	102.4	Shear failure
	BR1%	1	--	360	-	100	-	4.25	0.7	2.4	108.0	Shear failure
	BR1.5%	1.5	--	320	-	80	-	3.75	1.0	1.88	098.0	Shear failure
Group(B)	BF0%,90	0	90	430	210	70	75	6.25	1.6	2.76	100.6	Flexural failure
	BF0.5%,90	0.5	90	445	213	90	95	6.25	1.1	2.91	109.1	Flexural failure
	BF1%,90	1	90	450	216	100	108	6.5	1.0	3.2	116.4	Flexural failure
	BF1.5%.90	1.5	90	440	192	80	85	6.25	1.9	2.8	103.1	Flexural failure
Group(C)	BF0%,45	0	45	450	210	70	78	5.25	1.1	2.8	121.4	Flexural failure
	BF0.5%,45	0.5	45	460	213	90	100	6	1.0	3.03	132.7	Flexural failure
	BF1%,45	1	45	470	216	100	110	5.5	0.95	3.5	153.3	Flexural failure
	BF1.5%,45	1.5	45	450	192	80	90	6.04	2.00	2.91	125.0	Flexural failure

Table (4.3) includes all the results of the tested specimens for the two stages of the test before and after the strengthening process. The four control beams were tested without strengthening. One of the control specimens was solid (BR0%), while the other control which named as (BR0.5%, BR1% and BR1.5%) were with three percentages of plastic fibers (0.5, 1, and 1.5%). In the first stage of loading, the beam specimens were loaded to a service load percentage of (60) % of the ultimate load, as illustrated at Plates (A1) to (A4) at Appendix A. The second stage of test was after the completion of the strengthening with CFRP strips as eight specimens were strengthened and tested. These specimens (beams) have plastic fibers percentages of (0,0.5, 1, and 1.5%) and strengthened by using CFRP strips at an angle of 90° and 45°. And their discussions are based on the plastic fibers percentages used, as illustrated at Table (4.3), which includes the ultimate load after strengthening, maximum deflection, width of crack and the failure mode of the tested beams after strengthening.

4.3.1 Group A (Control Specimens)

Specimen (BR0%) failed by major crack between the loading and supporting areas. The first visible crack was narrow flexural crack between the two loading areas in the mid at about 70 kN at top. After the 70 kN load, the inclined shear cracks initiated and propagated gradually from the supports toward the loading points. These cracks become wider as the applying load increases. Then, the failure happened at a load level of 350 kN by diagonal shear crack failure, which split the beam into two pieces, as shown in Plate (4.3).

Plate 4.3 Cracks pattern for (BR0%) beam

The load-deflection curve at the mid-span for BR0% beam and the width of the inclined crack are shown in Figure (4.4), and Figure (4.5), respectively.

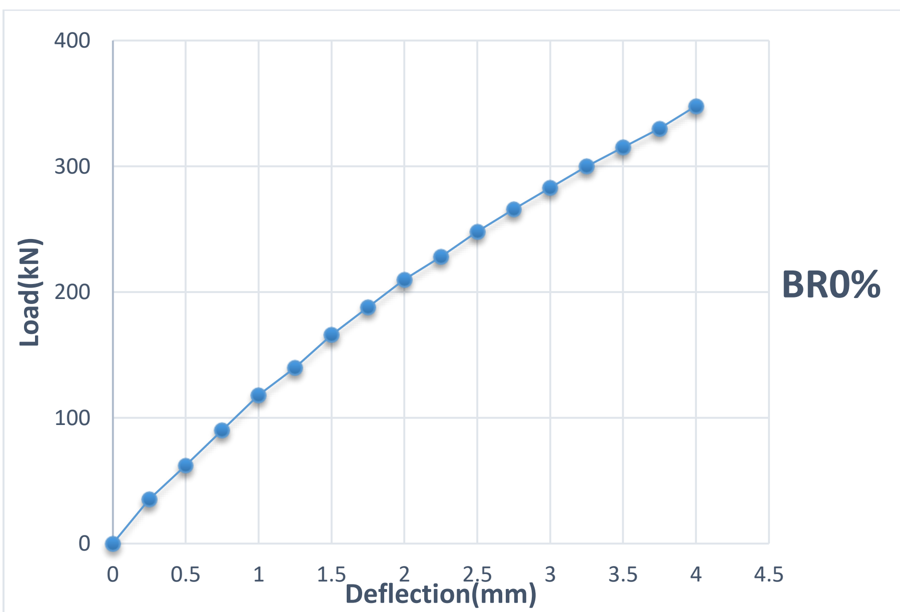


Fig. (4.4) Load-mid-span deflection curve for the control beam (BR0%)

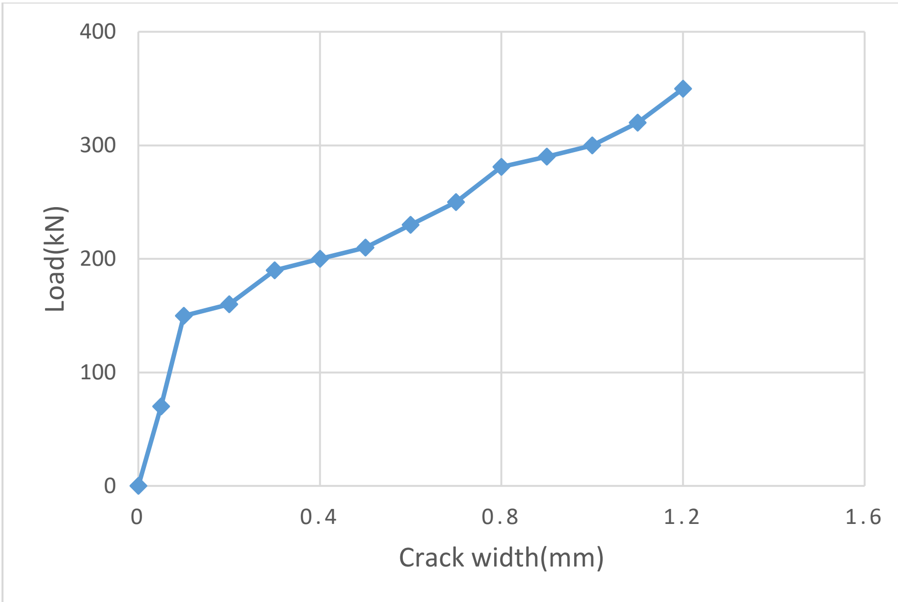


Fig. (4.5) Crack width versus load for control beam (BR0%)

Specimen (BR0.5%) was tested to investigate the effect of plastic fiber of (0.5%) by volume of the concrete mix on the its shear characteristics. The first visible crack between the two loading areas in mid span was at about 90 kN and a small flexural crack was appeared. After the loading of 90 KN, the shear crack propagates and widens as the load increases. The beam failed at approximately of 355 kN of bending load causing diagonal shear cracks, as shown in Plate (4.4).

Plate 4.4 Cracks pattern for (BR0.5%) beam

It can be seen that the inclusion of plastic fiber increases the shear capacity by (1.43%) concerning the BR0% beam. Also, an increase in the first crack load was observed by about (28.57%) compared to BR0% as the (PET) fibers content increases by (0.5%). Figures (4.6) and (4.7) below show the load-deflection and crack width curves, respectively.

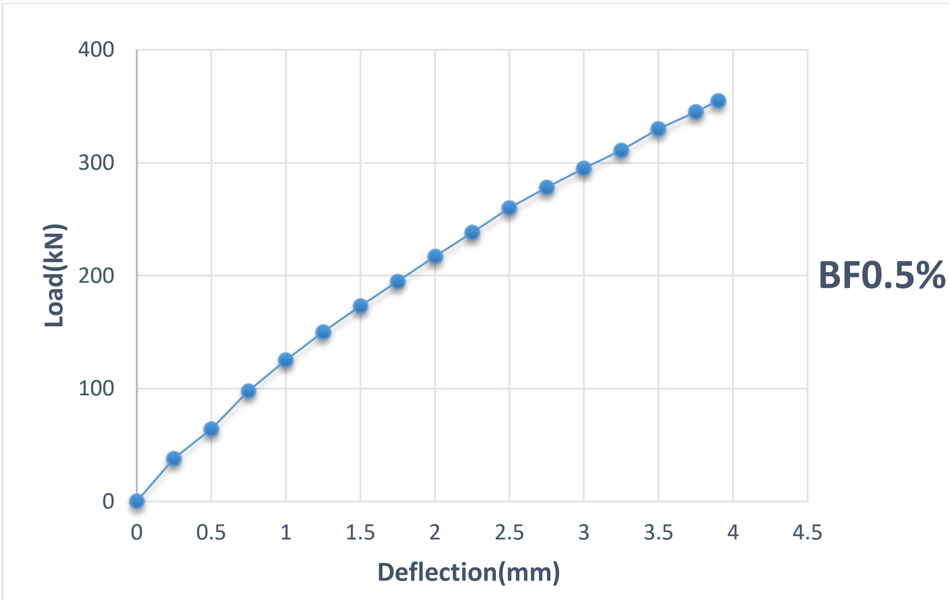


Fig. (4.6) Load-mid-span deflection curve for BR0.5%

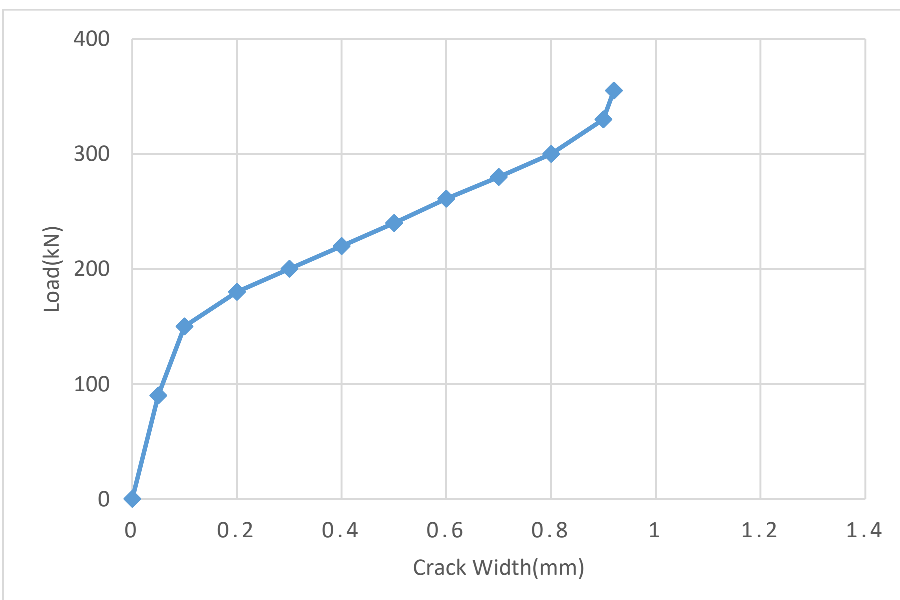


Fig.(4.7) Crack width versus applied load for BR0.5%

Specimen (BR1%) was used to study the effect of plastic fiber of (1%) by the concrete mix volume on the structural capacity of two span deep beam. The first visible crack between the two loading areas in mid span was at about 100 kN, as small flexural crack was appeared. After the loading of 100 kN, the shear cracks start to propagate and widen with increasing the load. After the beam reached approximately at 360 kN, the beam failed due to the diagonal shear cracks, as shown in Plate (4.5).

Plate 4.5 Cracks pattern for BR1%

It can be concluded that the presence of plastic fiber by (1%) of the concrete mix volume led to an increase in shear capacity by about (2.86 %) compared to BR0%. Also, increasing in the first crack load by about (42.8%) compared to BR0% was observed for deep beams with the increase in the (PET) fibers content by (1%). The load-deflection relationship at mid-span of beam (BR1%) is shown in Fig. (4.8) and cracks pattern are shown in Fig. (4.9).

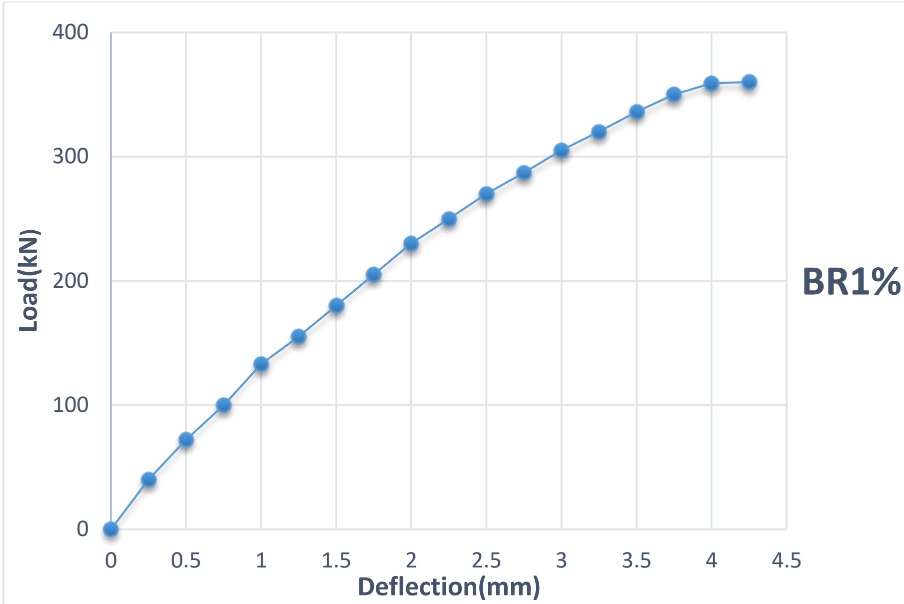


Fig. (4.8) Load-mid-span deflection curve for BR1%

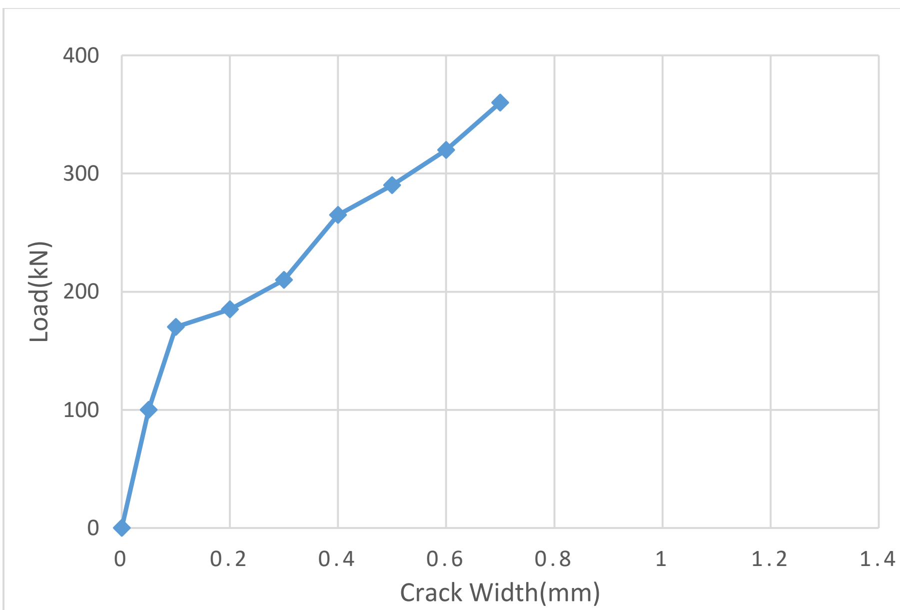


Fig.(4.9) Crack width versus applied load for BR1%

Specimen (BR1.5%) was used to investigate the influence of plastic fiber by (1.5%) of the concrete mix volume on the structural capacity of the two span deep beam. At a load of (80) kN, the first flexural cracks between the two loading areas in the mid span were observed. Follow that, the shear cracks were widened and propagated rapidly towards the loading and supporting points. Some flexural cracks were noticed at load level of (260) kN. Then, at load level of (320) kN, the specimen failed by developing a diagonal cracks passing through a peel of concrete separating at the top, as shown in Plate (4.6).

It can be concluded that the inclusion of plastic fiber by (1.5%) of the concrete mix volume reduced the shear capacity by about (8.6%) comparing with BR0%. Furthermore, an increase in the first crack load was observed for deep beams with PET fiber content of (1.5%) by about (14.28%) compared to BR0%.

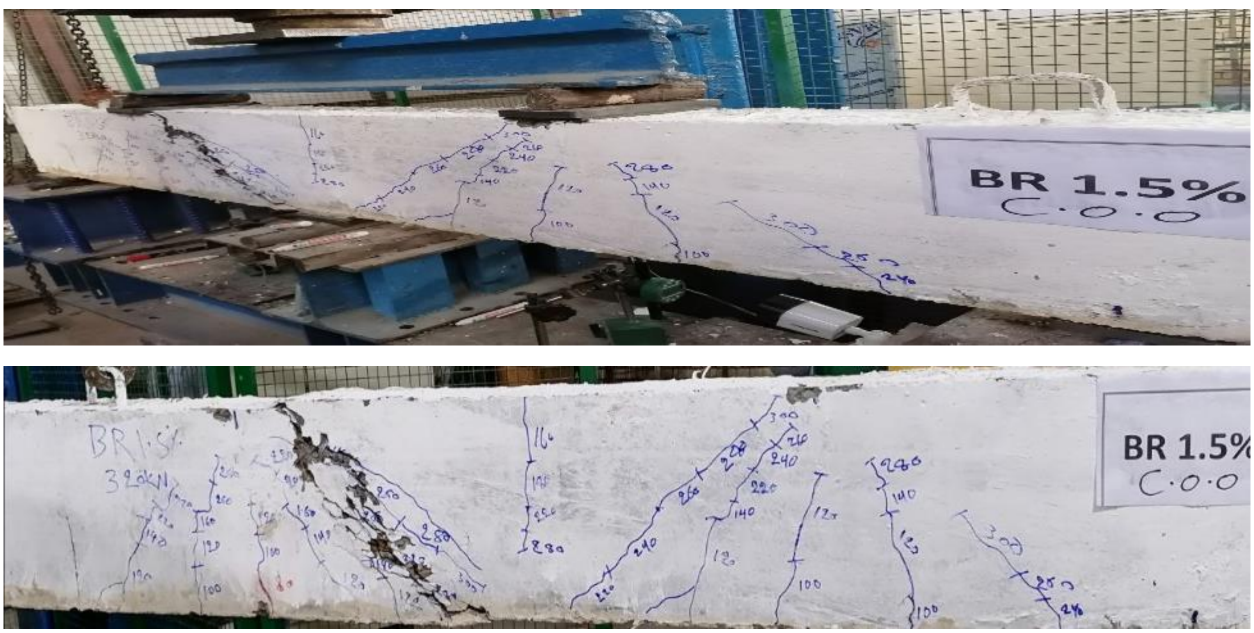


Plate 4.6 Cracks pattern for BR1.5%

Figure (4.10) shows the load-deflection of mid-span curve of specimen (BR1.5%) and Figure (4.11) shows the width of the inclined crack.

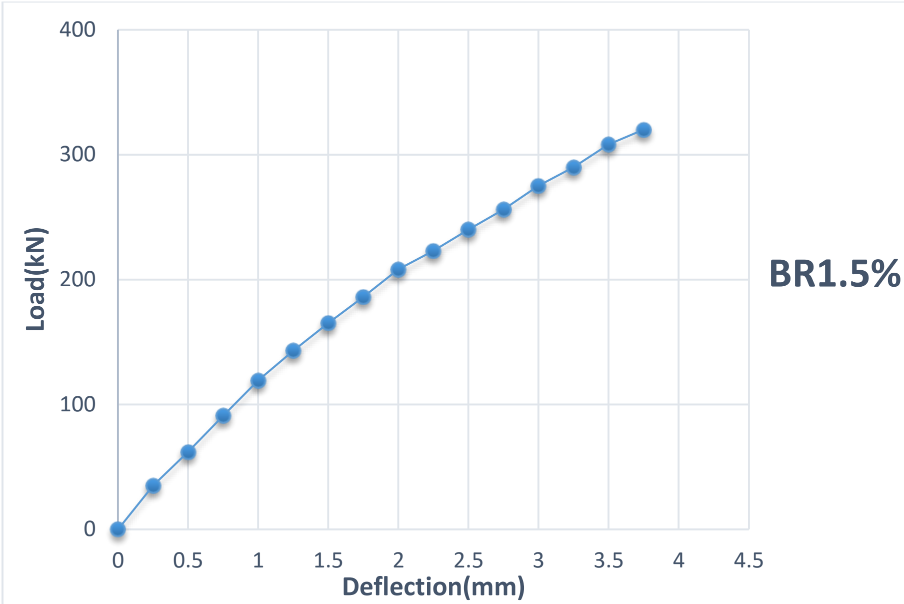


Fig. (4.10) Load-mid-span deflection curve for BR1.5%

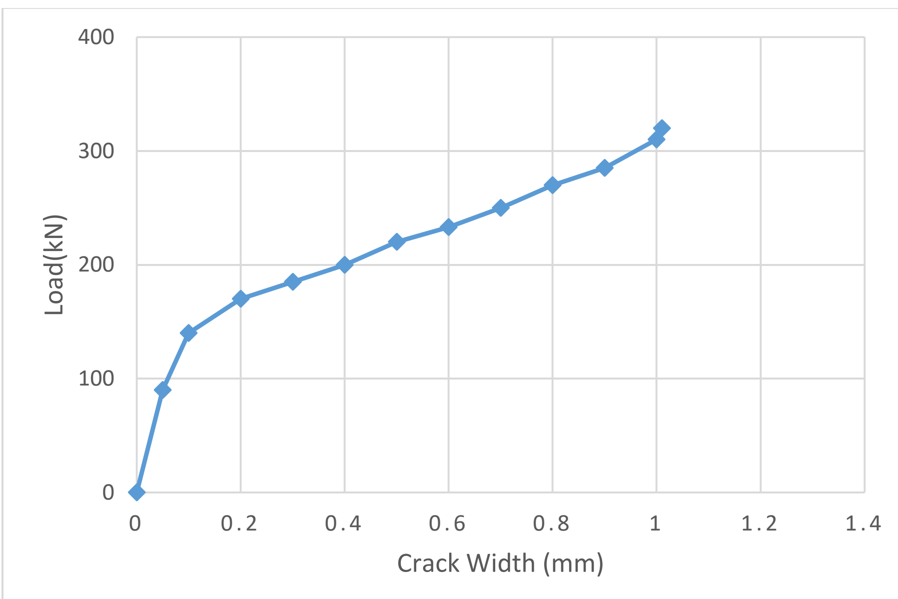
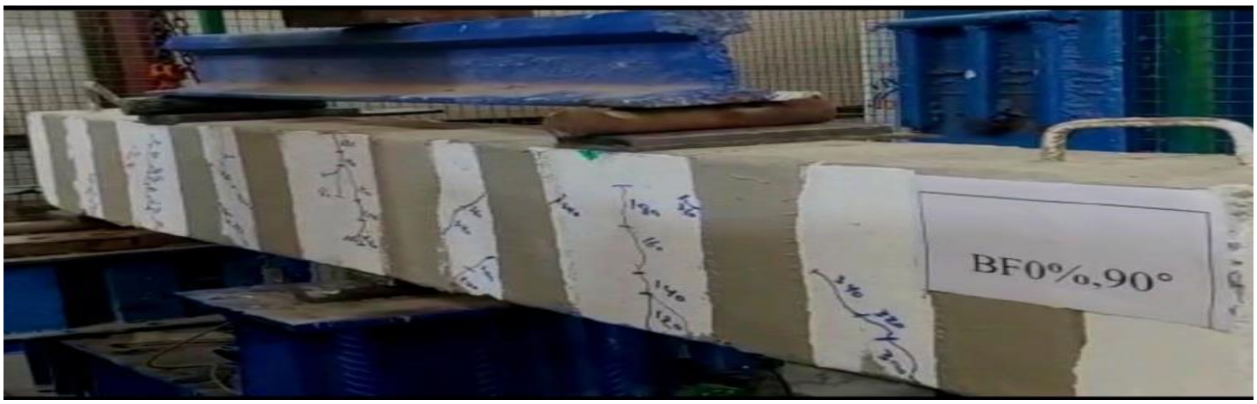


Fig. (4.11) Crack width versus applied load for BR1.5%

4.3.2 Group B (Rehabilitation by a vertical CFRP sheets with an angle 90°)

The results of the experimental work of the rehabilitated beam specimens (BF,90) will be discussed in Group B, as illustrated in Table (4.3).

For the Specimen (BF0%,90°), the first stage of loading is about (60%) of the loading of reference beam specimen (BR0%), which is equivalent to 210 KN, as illustrated at plate (A1). In next stage, the beam specimen was repaired with (90°) CFRP orientation and tested until failure, after the rehabilitation, the load via the first apparent crack was 75kN, the ultimate load was 430 kN, and the failure was flexural. Plate (4.7) and Figure (4.12) illustrate the crack distribution and the load deflection curve of (BF0%,90°) beam specimen.



Plate(4.7): Cracks pattern after failure for (BF0%,90°) beam

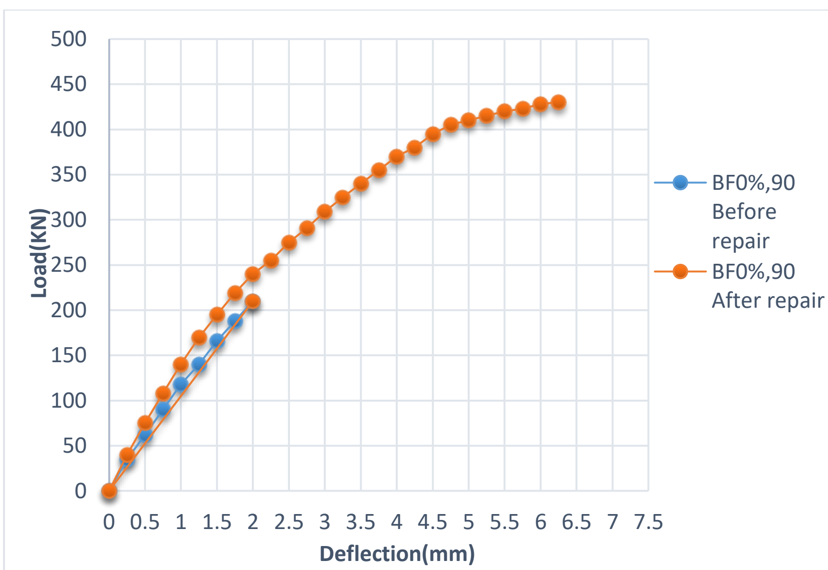


Fig. 4.12: Load-deflection curve for BF0%,90 beam

For the specimen (BF0.5%,90°), the first stage of loading is about (60%) of the loading of reference beam specimen (BR0.5%), which is equivalent to 213 KN, as illustrated at plate (A2). In next stage, the beam specimen was repaired with (90°) CFRP orientation and tested until failure, after the rehabilitation, the load via the first apparent crack was 95 kN, the ultimate load was 445 kN, and the failure was flexural. Plate (4.8) and Figure (4.13) illustrate the crack distribution and the load deflection curve of (BF0.5%,90°) beam specimen.

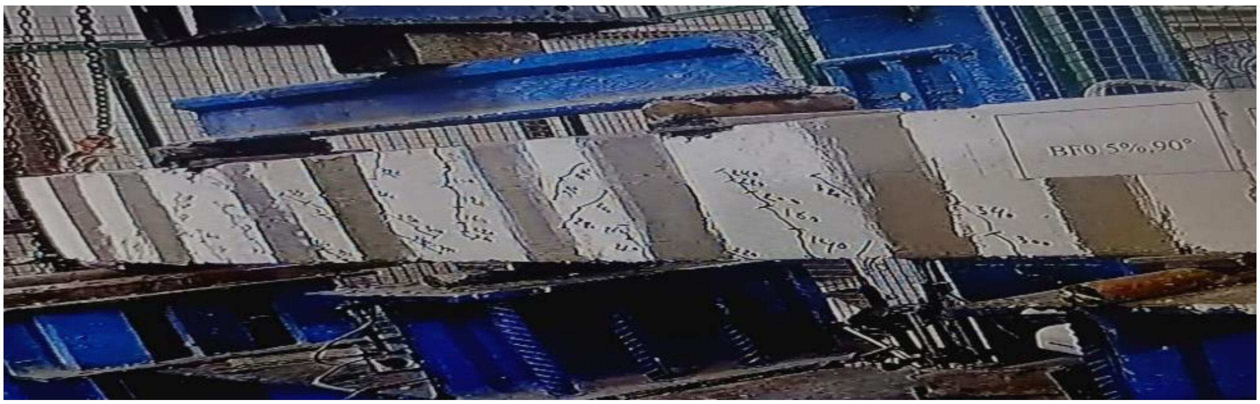


Plate 4.8 Cracks pattern after failure for (BF0.5%,90°) beam

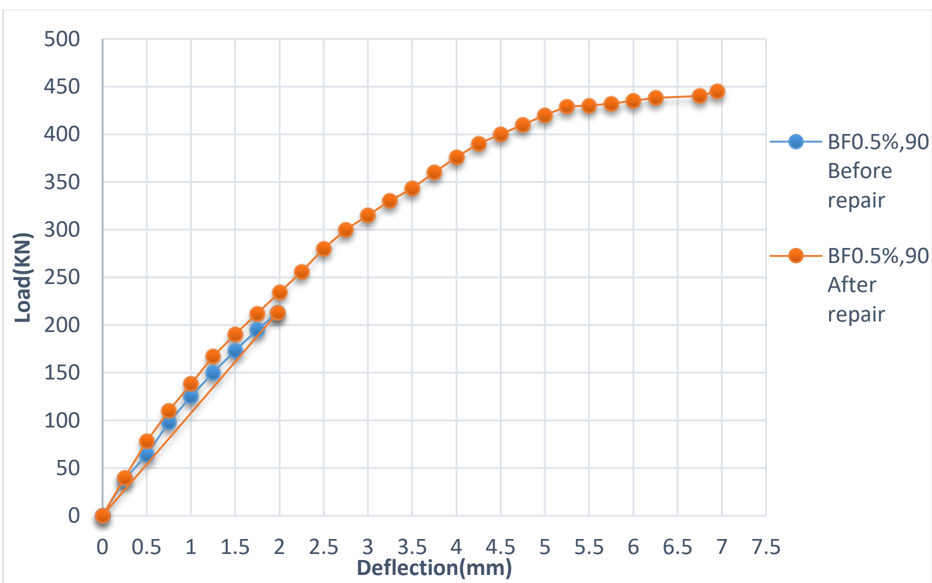


Fig. 4.13: Load-deflection curve for BF0.5%,90 beam

For the specimen (BF1%,90°), the first stage of loading is about (60%) of the loading of reference beam specimen (BR1%), which is equivalent to 216 KN, as illustrated at plate (A3). In next stage, the beam specimen was repaired with (90°) CFRP orientation and tested until failure, after the rehabilitation, the load via the first apparent crack was 108 kN, the ultimate load was 450 kN, and the failure was flexural. Plate (4.9) and Figure (4.14) illustrate the crack distribution and the load deflection curve of (BF1%,90°) beam specimen.

Plate 4.9 Cracks pattern after failure for (BF1%,90°) beam

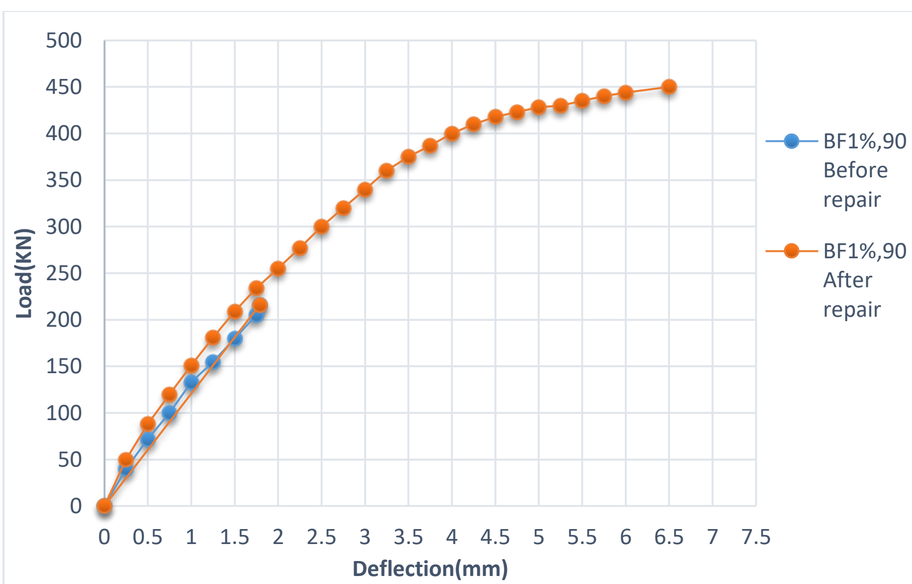


Fig. 4.14: Load-deflection curve for BF1%,90 beam

For the specimen (BF1.5%,90°), the first stage of loading is about (60%) of the loading of reference beam specimen (BR1.5%), which is equivalent to 192 KN, as illustrated at plate (A4). In next stage, the beam specimen was repaired with (90°) CFRP orientation and tested until failure, after the rehabilitation, the load via the first apparent crack was 85 kN, the ultimate load was 430 kN, and the failure was flexural. Plate (4-10) and Figure (4-15) illustrate the crack distribution and the load deflection curve of (BF1.5%,90°) beam specimen.

Plate 4.10 Cracks pattern after failure for (BF1.5%,90°) beam

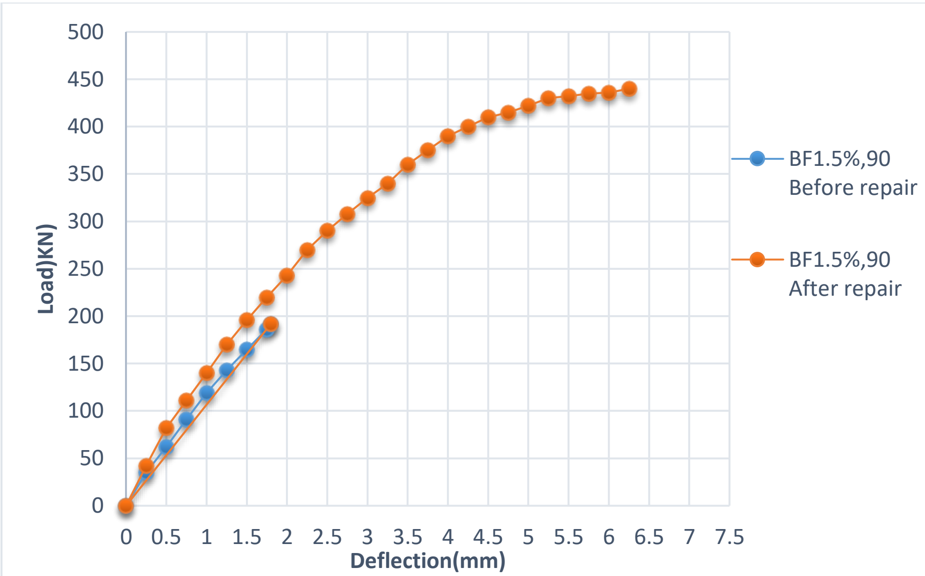


Fig. 4.15: Load-deflection curve for BF1.5%,90 beam

4.3.3 Group C (Rehabilitation by an inclined CFRP sheets with an angle 45°)

This group deals with the results of the experimental work of the rehabilitated beam specimens (BF,45), as illustrated in Table (4.3).

Specimen (BF0%,45°) was also initially loaded to (60%) of the reference beam specimen (BR0%) that equivalent to 210 KN, as illustrated at plate (A1). Then the beam was repaired with (45°) CFRP orientation and tested until failure, the load via the first crack is at 78 kN, the failure load is 450 kN, and the failure is flexural. Plate (4.11) and Figure (4.16) illustrate the crack distribution and the load deflection curve of (BF0%,45°) beam specimen.

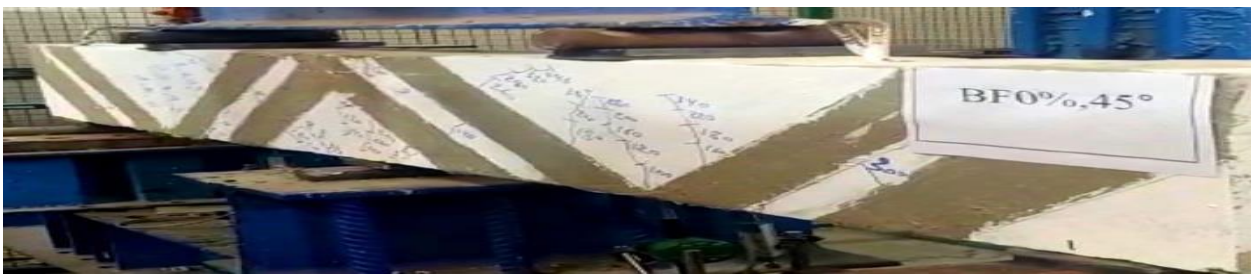


Plate 4.11 Cracks pattern after failure for (BF0%,45°) beam

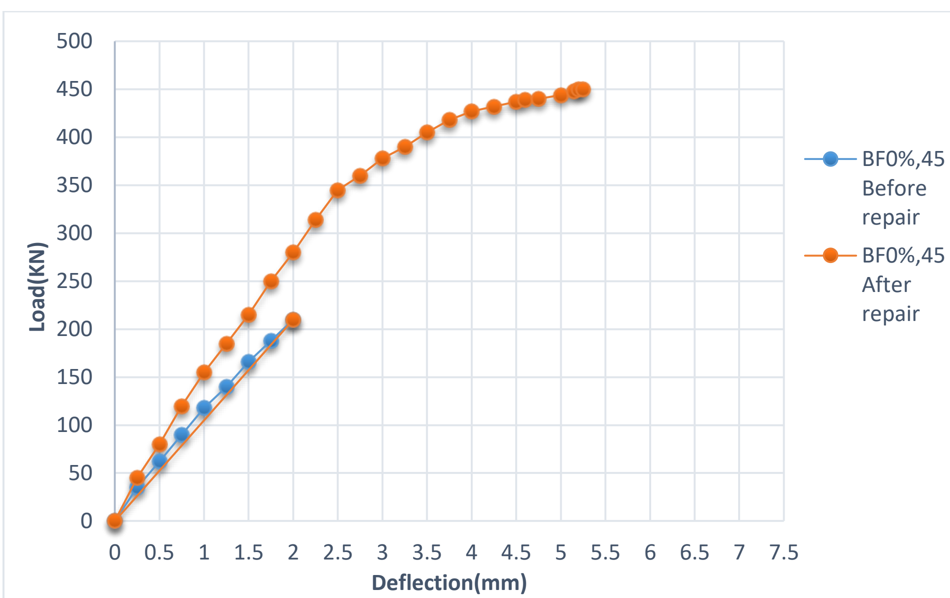


Fig. 4.16: Load-deflection curve for BF0%,45° beam

Specimen (BF0.5%,45°) was also initially loaded to (60%) of the reference beam specimen (BR0.5%) that equivalent to 213 KN, as illustrated at plate (A2). Then the beam was repaired with (45°) CFRP orientation and tested until failure, the load via the first crack is at 100 kN, the failure load is 460 kN, and the failure is flexural. Plate (4-12) and Figure (4-17) illustrate the crack distribution and the load deflection curve of (BF0.5%,45°) beam specimen.

Plate 4.12 Cracks pattern after failure for (BF0.5%,45°) beam

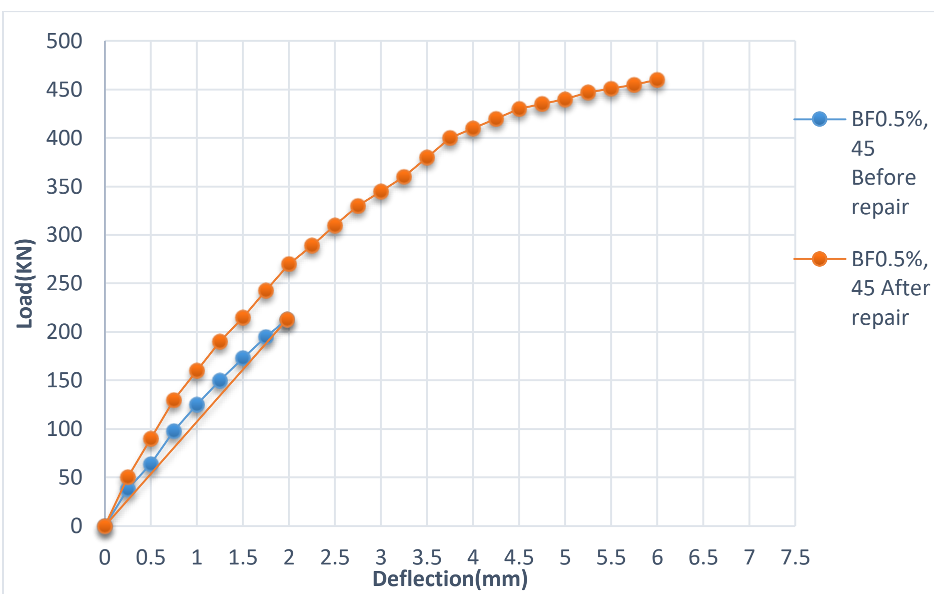


Fig. 4.17: Load-deflection curve for BF0.5%,45° beam

Specimen (BF1%,45°) was also initially loaded to (60%) of the reference beam specimen (BR1%) that equivalent to 216 KN, as illustrated at plate (A3). Then the beam was repaired with (45°) CFRP orientation and tested until failure, the load via the first crack is at 110 kN, the failure load is 470 kN, and the failure is flexural. Plate (4-13) and Figure (4-18) illustrate the crack distribution and the load deflection curve of (BF1%,45°) beam specimen.

Plate 4.13 Cracks pattern after failure for (BF1%,45°) beam

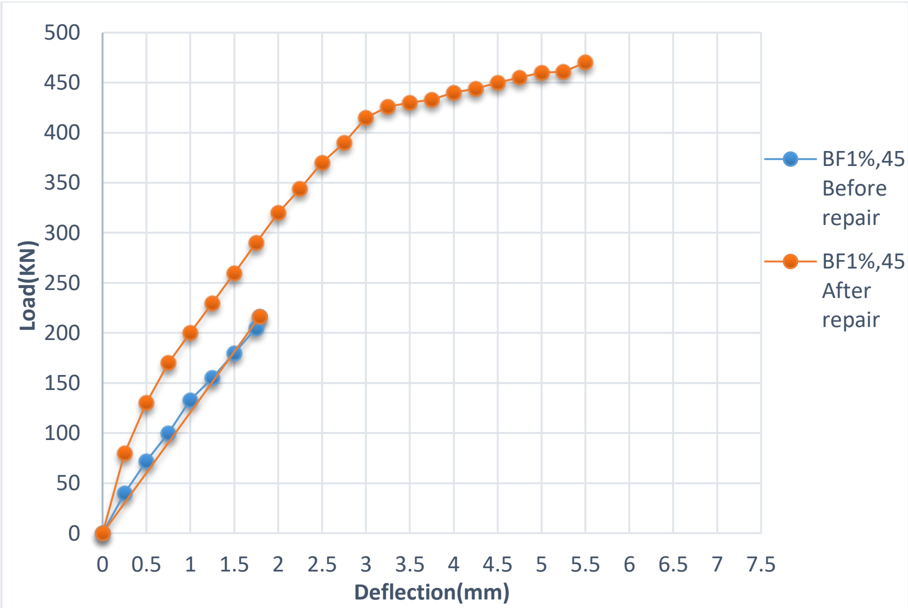


Fig. 4.18: Load-deflection curve for BF1%,45° beam

Specimen (BF1.5%,45°) was also initially loaded to (60%) of the reference beam specimen (BR1.5%) that equivalent to 192 KN, as illustrated at plate (A4). Then the beam was repaired with (45°) CFRP orientation and tested until failure, The load via the first crack is at 90 kN, the failure load is 450 kN, and the failure is flexural. Plate (4-14) and Figure (4-19) illustrate the crack distribution and the load deflection curve of (BF1.5%,45°) beam specimen.

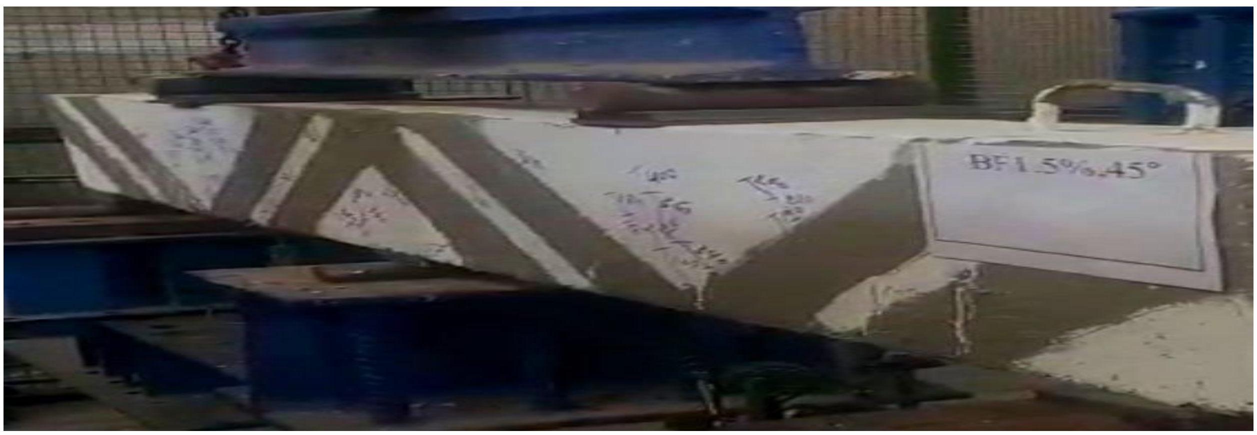


Plate 4.14 Cracks pattern after failure for (BF1.5%,45°) beam

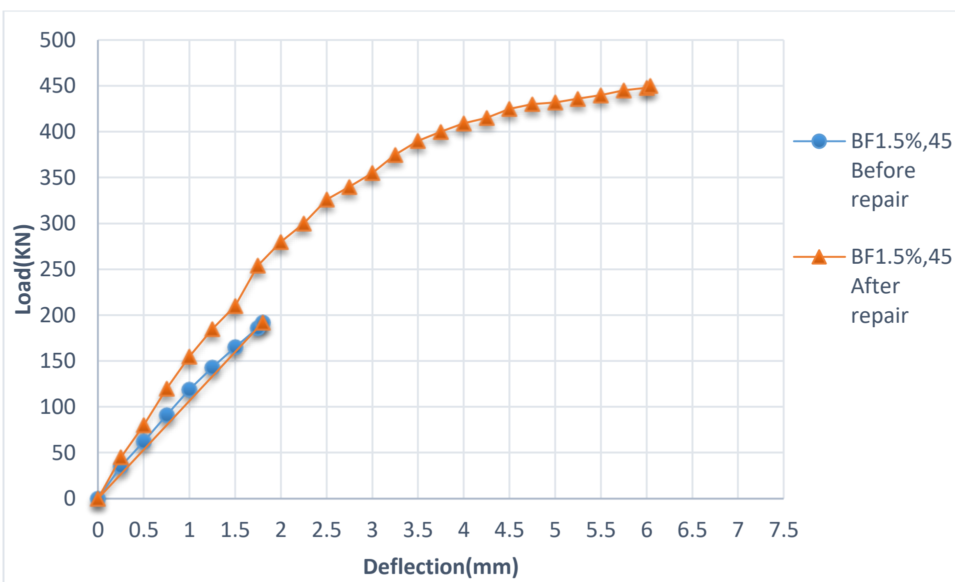


Fig. 4.19: Load-deflection curve for BF1.5%,45° beam

4.4 Ductility Index

The broad concept of ductility in the structural engineering is represented by the ability of the member to be deformed with the continuous application of a load after the maximum load stage **(Grimaldi, A. and Rinaldi, Z. 2004; Galli, G. et al., 2004; Xie, Y.et al., 1994)**. The ductility is an important property of the structural element. This property works to redistribute the stresses and gives enough warning before the failure occurs. When the ductility index is high. Thus, the risk of sudden shear failure can be reduced using many techniques such as the using of fibers in the concrete mixture these methods that utilized to increase the ductility and make the member less brittle. In the current study, the ductility factors are assessed according to the vertical displacement at maximum load divided by vertical displacement at the service load (**Russell, J.S. 2003),** as shown in Table (4.4).

Table(4.4) Ductility index for the tested deep beams

Group	Deep Beam symbol	Service deflection (mm)	Ultimate deflection (mm)	Ductility index
A	BR0%	2.1	4.0	1.9
	BR0.5%	1.875	3.9	2.08
	BR1%	1.77	4.25	2.4
	BR1.5%	1.99	3.75	1.88
B	BF0%,90	2.26	6.25	2.76
	BF0.5%,90	2.38	6.95	2.91
	BF1%,90	2.03	6.5	3.2
	BF1.5%.90	2.23	6.25	2.8
C	BF0%,45	1.855	5.25	2.83
	BF0.5%,45	1.98	6	3.03
	BF1%,45	1.57	5.5	3.5
	BF1.5%,45	2.07	6.04	2.91

* Assumed service load = Ultimate load /1.66 **Mansur, M.A., (2006)**

From the results in Table (4.4). The improvement of the ductility of the beams can be clearly observed with increasing the waste plastic fibers except for the ratio(1.5%) in group (A). The increase in the ductility due to the reinforced concrete member that can bear large deflections before failure (**Huda, J.et al., 2016).** This means that the (PET) fibers reduce the problem of the sudden shear failure. The larger effect on the ductility was recorded for deep beams that were reinforced against the shear stresses with fibers percentage (1.0%) for each groups, but the best improvement with CFRP was at a 45° angle and at 1% fibers.

4.5 Stiffness Criteria

As displayed in the R.C. continuous supported deep beam**,** the stiffness criteria of any member can be determined as the slope of the secant, which is drawn in the load deflection curve. The stiffness of the deep beams at load (75% of the ultimate load) **Muthuswamy,K. and G. Thirugnanam, (2014),** is calculated using the formula ($k=F/\Delta$), the load and the mid-span deflection curves show the deflection happened at 75% of the ultimate load).

The stiffness criteria of the deep beams are given in Table (4.5).

Table (4.5) Stiffness criteria of the tested deep beams.

Group	Deep Beam symbol	0.75 Pu. (kN), F	Deflection at 0.75 Pu. (mm), Δ	Stiffness,K (kN/mm)
A	BR0%	262.5	2.7	97.22
	BR0.5%	266.25	2.6	102.4
	BR1%	270	2.5	108
	BR1.5%	240	2.45	98
B	BF0%,90	322	3.2	100.625
	BF0.5%,90	333.75	3.06	109.07
	BF1%,90	337.5	2.9	116.38
	BF1.5%.90	330	3.2	103.125
C	BF0%,45	337.5	2.78	121.4
	BF0.5%,45	345	2.6	132.7
	BF1%,45	352.5	2.3	153.26
	BF1.5%,45	337.5	2.7	125

Table (4.5) shows all the stiffness of the tested deep beams with plastic fibers percentage of (0.5%,1.0%,1.5%) ,the stiffness of all beams has been increased compared to the reference specimen. The more significant effect of PET on the stiffness is recorded for deep beams with 1.0% fibers for each group. However, the best improvement with the CFRP was at a 45° angle and 1.0% fibers. Figure (4.18) shows that at the early stages of loading, the deflection decreases as the volume fraction of fibers increases. This behavior may be attributed to the enhanced stiffness of the deep beams and improving the mechanical properties of concrete such as (modulus of elasticity, tensile strength and compressive strength) when the amount of plastic fibers is increased.

4.6 Crack Width

Generally, similar cracks have been noticed in the control specimens. Flexural cracks initially occurred, followed by shear cracks that became bigger and deeper and concentrated at the shear zone, as illustrated in plates (4.3) to (4.6), while the deep beam specimen has been repaired with (90^o) and (45) CFRP orientation. The resulted flexural cracks are exhibited in plates (4.7) to (4.14). Table (4.6) explains the maximum crack width which was decreased with the increase of fibers percentages. of the presence of waste plastic fibers causes delaying the appearance of the cracks and controlled on their widths. This behavior refers to increasing the interconnection and attraction points between the separate parts of concrete after failure.

Table (4.6) Width of larger crack of tested deep beams

Fiber (%)	Load KN	Width of the larger crack (mm)		
		Shear cracks	Flexural cracks	
		Group (A)	Group (B)	Group (C)
0	320	1.0	0.91	0.85
0.5	320	0.89	0.78	0.70
1	320	0.66	0.57	0.45
1.5	320	1.01	0.90	0.83

4.7 Effect of Waste Plastic Fibers on the Shear Structural Behavior of Deep Beams

The main objective of this experiment is studying the effect of the (PET) fibers on the shear strength of the reinforced concrete Continuous Deep beams. The results are stated in Table (4.3) and Figures (4.4) to (4.19) which reveal that the improvement in the shear strength of the beams with the presence of waste plastic fibers in concrete and the brittle shear failure became more ductile for all fibers percentages.

The ultimate load is recorded during the test at a moment of appearing of the first crack load; also the value of deflection that is recorded for each (10kN) increase in the applied load until the failure of the beam. Table (4.3) presents the details of the first crack load and ultimate load of beams. The results have confirmed, In spite of the increase of the first crack load for beams (Group A) is slight with the increase of fibers percentages. However, this explains that the plastic fibers made the concrete paste more interconnected and contributed by a high resistant to tensile stresses before occur the first crack. Likewise, the cracks are distributed on a larger area rather than one crack only, which can be noticed even in the bending region (between two concentrated loads). It is worth mentioning that the reasons behind increasing the first crack load for beams of (Group A, Group B and Group C) with the presence of waste plastic fibers might be attributed to the fact that the efficiency of the carbon fiber reinforced plastics in stopping the reproduction of cracks and controlling their growth within the beam. Furthermore, they can absorb energy and delay the first appearance of the crack, which makes specimens bear large loads and deflection before failure (Figs. (4.4) to (4.14). Considering the continuous deep beams of Group A (i.e. (BR0.5%, BR1%, BR1.5%) and their ultimate loads illustrated in Fig. (4.20), the results demonstrated that there is an additional increase in the ultimate load by (1.43%,2.86%, -8.5), respectively compared to (BR0%). On the other hand, the results of continuous deep beams of Group B (i.e., BF0.5%,90, BF1%,90, BF1.5%,90), asserted that there is an additional increase in ultimate load by (3.5%,4.65%,2.3%) respectively compared (BF0%,90). Indeed, the results of beams in Group C (i.e. BF0.5%,45, BF1%,45, BF1.5%,45) showed that there was an additional increase in ultimate load by (2.22%,4.44%,0%) respectively compared (BF0%,45) .The optimum load was recorded at fibers percentage (1%) for the Groups (A), (B) and (C), but the highest increase in ultimate load was for the beam which reinforced by (CFRP) sheets (BF1%,45) and reached to (30.55%). Increasing the ultimate load capacity of beams refers to the role of waste plastic fibers in improving the tensile properties of concrete and restricting the spread of cracks inside the concrete structure. Still, the reduction of ultimate load at fibers percentage (1.5%) of the group(A) possibly as a result of loss the workability of concrete and became more porous and lower density, in other words, due to the loss of the mixture homogeneity balling the fibers **Shireen, HH(2021).**

The relationships between the load and deflection of all beams are displayed in Figures (4.6) to (4.19), where the curves show that the value of deflection at the same load level decreases with the presence of waste plastic fibers that worked to bridge the cracks. Also, the deflection of specimens with the CFRP stirrups at 90 and 45 is higher than the control specimens, It is worth to mention that the reduction in the beams deflection at the first crack with the presence of the waste plastic fibers is good due to the resistance of the plastic fibers to tensile stresses. The fibers start working at a moment of the growth in the crack, whereas in the case of using steel fibers be better. and that leads to increase the load of the first crack and significantly decreasing in the deflection of beams (**Najim, K.B., 2012).** Generally, all types of fibers are able to bridge the cracks and redistribute the stresses in the beam body to carry more load with a smaller deflection at the same load level.

Before discussing the remaining results of testing the beams, there is a benefit from describing the behavior of the continuous deep beams during the shear failure. In the tensile regions, cracks appear and form when the tensile stresses exceed the tensile strength, these cracks divided into two categories; shear and flexural cracks, the first occurs in response to the acting of the principal or inclined tensile stresses in the region of combining the shear and moment which is evident in (Group A). As for the flexural cracks, acrack appears between the two loading areas in mid due to the flexural tensile stresses which was evident in (Group B,GroupC). After testing all reinforced concrete beams and shear cracks became visible along the surface of an enclosed area between the support and concentrated load, the Microscope was used to measure the width of larger diagonal cracks to know the fibers contribution in maintaining the cohesion of the concrete after failure. The Table (4.3) gives the width of the larger diagonal crack of beams which decreases with the increase of fibers percentages of all groups. This behavior refers to increasing the interconnection and attraction points between the separate parts of concrete after failure.

The results that are illustrated in Figure (4.24) provide a clear enhancing in the ductility of the beams that can be observed with increasing the waste plastic fibers. This means that the (PET) fibers reduced sudden shear failure, for three types of the (without and with CFRP stirrups), are presented in Group A (BR0.5% ,BR1%) beam specimens are more ductile than Group A (BR0%) beam specimens with percentage of (9.47%,26%) respectively.

On the other hand, the percentages of Group B (BF1%,90, BF0.5%,90,BF1.5%,90) beam specimens revealed to be more ductile than Group B (BF0%,90) beam specimens with percentages of (16%,5.43%,1.45%) respectively.

And the Group C (BF1%,45, BF0.5%,45 ,BF1.5%,45) beam specimens have proved to be more ductile than Group C (BF0%,45)beam specimens with percentages of (23.6%,7%,2.83%) respectively. Yet, the larger effect of (PET) fibers on the ductility is recorded for the beam which reinforced by (CFRP) sheets (BF1%,45) and reached (23.7%) with fibers percentage (1%). Table (4.3) and Figure (4.25) show that the stiffness of Group (A) for the plastic fibers (0.5%,1%,1.5%) deep beam specimens increased about (3.5%,%,11.1%,0.8%) respectively compared to the reference specimen (BR0%),While the stiffness of repaired with (45) CFRP orientation highest values with percentage of (9.31%,26.24%,2.96%) respectively. Unlike, the plastic fibers (0.5%,1%,1.5%) which have increased with using angle (90) CFRP orientation of (8.4%,15.7%,2.5%) respectively. The optimal results require to add (0.5%,1%) of plastic fibers because the deep beams of (0.5%,1%) plastic fibers mix (BF 1%,45) show the maximum value of stiffness .

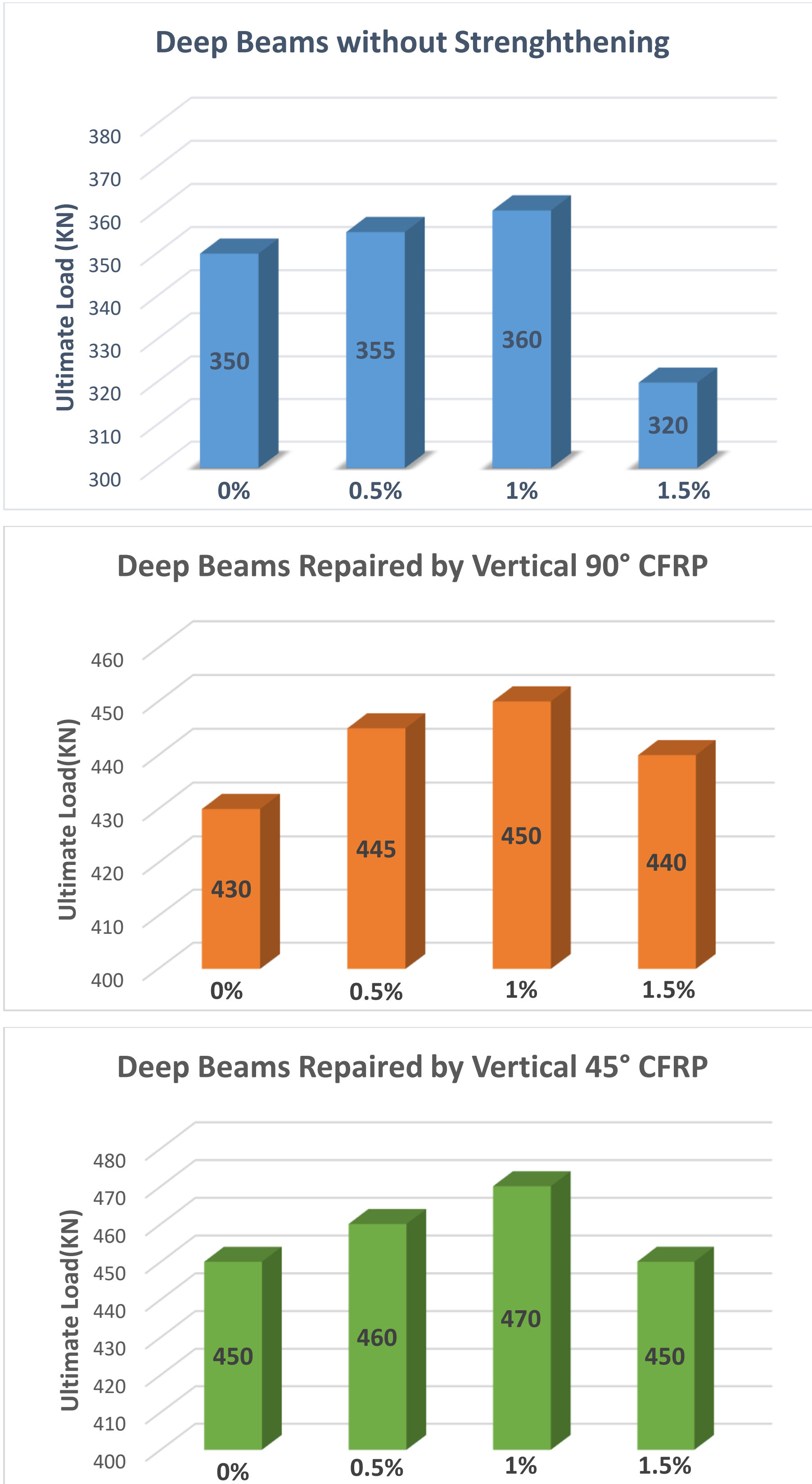


Fig. (4.20) The ultimate load of the beams

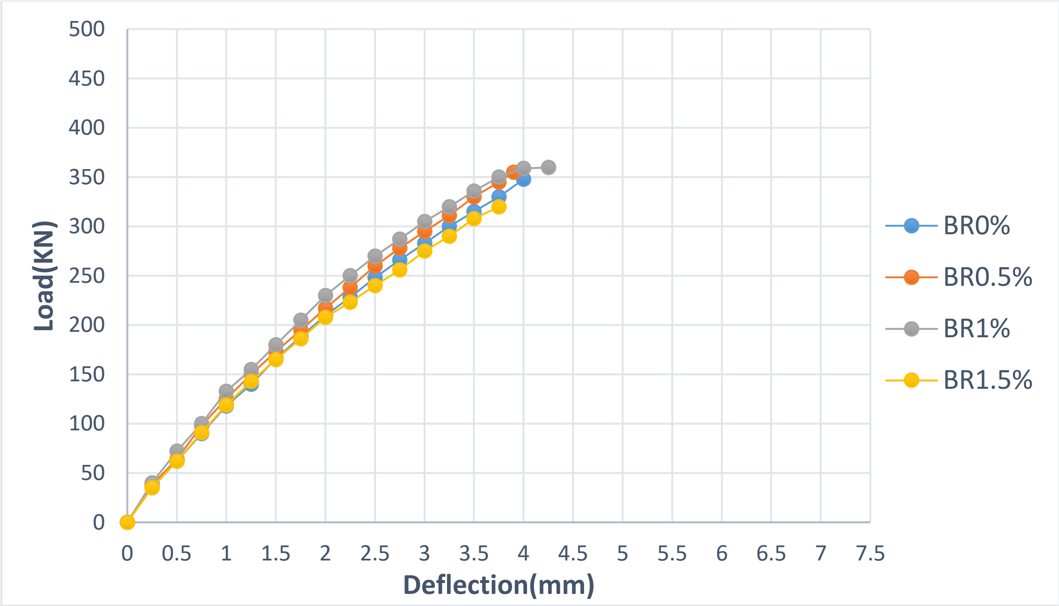


Fig. 4.21 The relationship between the load and deflection of the reference and beams with fibers percentages of (0.5%,1%,1.5%) for Group (A)

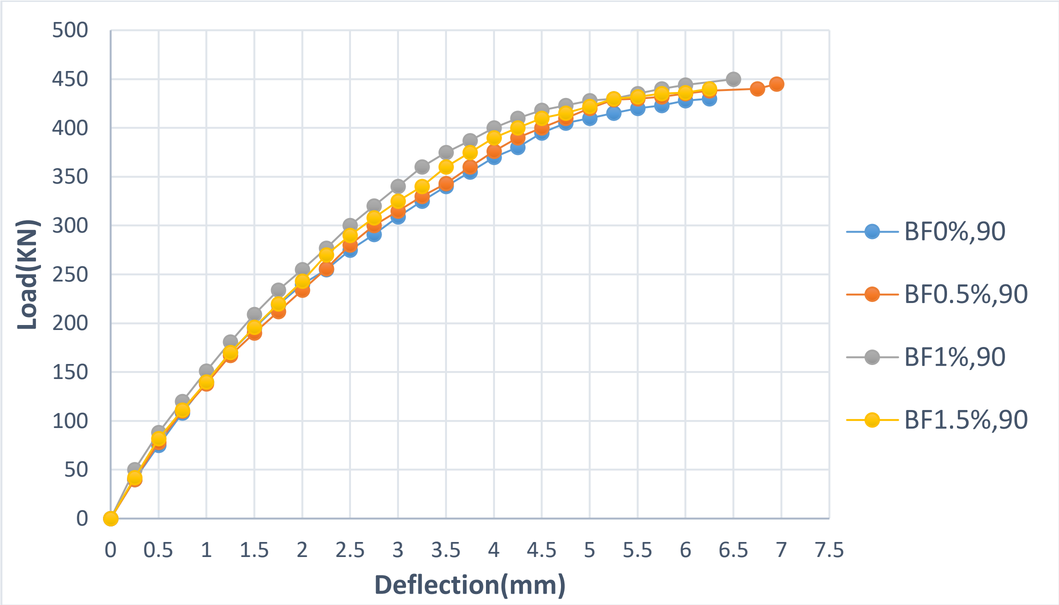


Fig. 4.22 The relationship between the load and deflection of the reference and beams with fibers percentages of (0.5%,1%,1.5%) for Group (B)

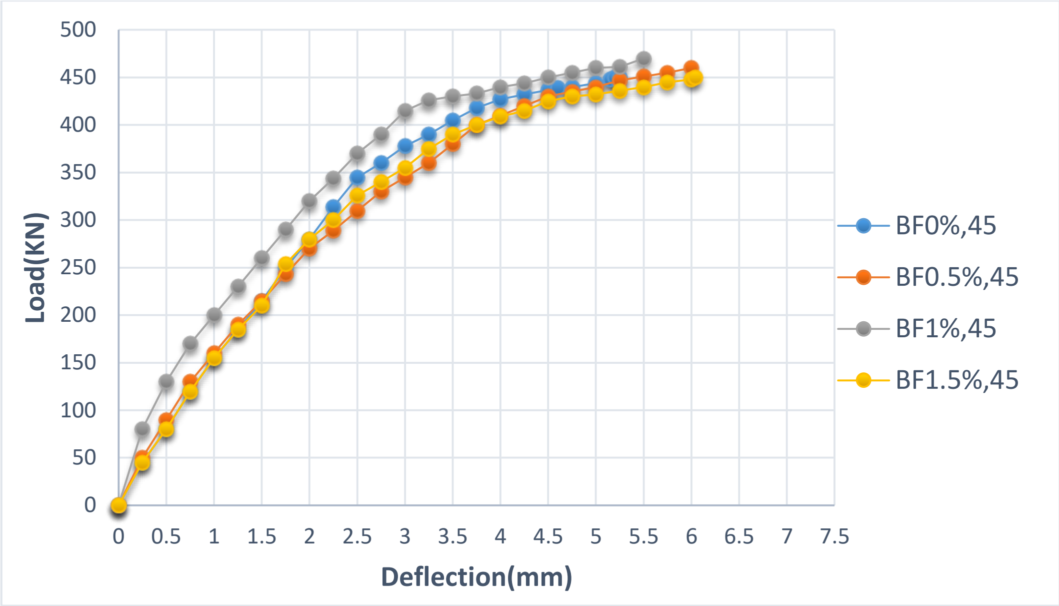


Fig. 4.23 The relationship between the load and deflection of the reference and beams with fibers percentages of (0.5%,1%,1.5%) for Group (C)

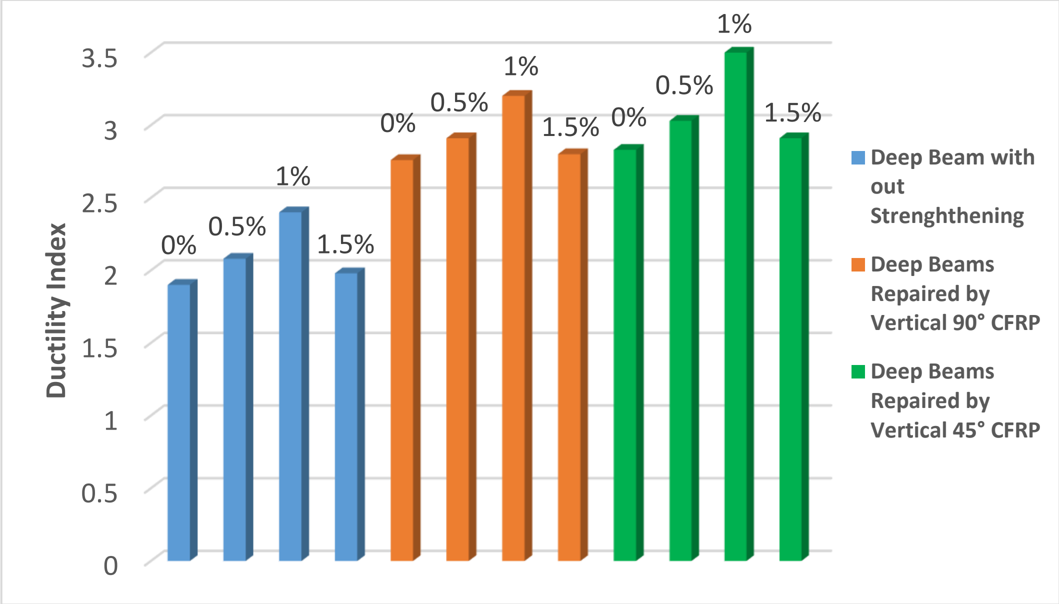


Fig. 4.24 The ductility Index effected by the Plastic Fibers Various Percentage For the whole of the Deep Beam

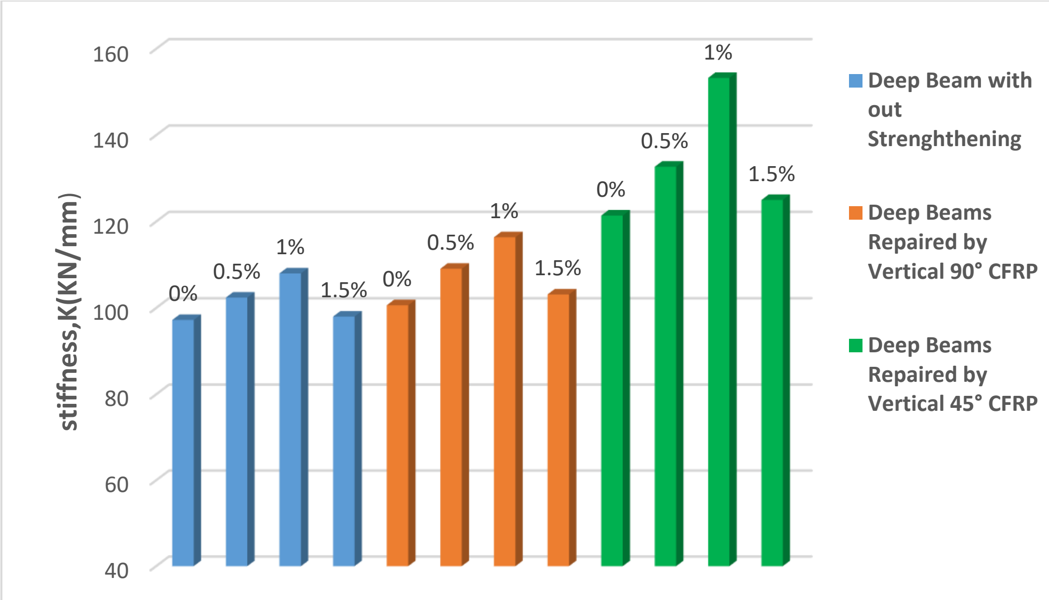


Fig. 4-25 Stiffness ,K effected by the Plastic Fibers Various Percentage For the all Deep Beams

4.8 Effect of CFRP orientations on the Shear Behavior of Deep Beams

Table (4.3) assures that the testing of the continuous deep specimens strengthened with 45º CFRP strips has provided higher cracking and ultimate loads than the test of the continuous deep beams strengthened with 90º CFRP strips. The increases in the cracking loads were (7.14 %, 6.25 %, 10 % and 0.0) at plastic fibers percentages of (0%,0.5%,1%,1.5%), respectively. On the other hand, the increase in the ultimate loads were (4.65 %, 3.37 %, 4.45 % and 2.27 %) at plastic fibers percentage (0%,0.5%,1%,1.5%), respectively. Moreover, the ultimate load for beams with angle (90 º) and angle (45 º) shows higher values with the rates (25.35 %, 25%, 37.5 %) and (29.57 %, 30.56 %, 40.62 %) for plastic fibers percentages (0.5,1,1.5), respectively compared with the reference beams, as shown in Fig. (4.26). This is because the repairing inclined reinforcement in continuous deep beam had effectively arrested the growth of diagonal cracks, which prevents the usual diagonal – cracking failure from occurring. Figures (4.27) to (4.30) display the load-deflection curves of the beams in Group(B) and beams of Group(C) compared to the control beams (Group A) when the percentage of plastic fiber is constant. The ductility of the beams with angles (45º) and (90º) improves ductility compared to control beams. In comparison, the ductility has for the beams with angle (45 º) has yielded the highest values with the rates of (2.5%,4.12%,9.3%, and 3.9%) for plastic fibers (0%,0.5%,1%,1.5%), respectively compared with the beams repaired with angle (90 º), that are illustrated in Figure (4.31). This enhancement in the structural capacity refers to the existence of inclined CFRP sheets working as externally shear resistance, which increased load and cut cracks propagation. The results mentioned above indicate that the stiffness for the deep beams that are repaired by inclined 45° CFRP are higher than the deep beams that are repaired by Vertical 90° CFRP with the percentage of (20.64% ,21.66% ,31.68%, 21,21%) at plastic fibers percentages (0%,0.5%,1%,1.5%) respectively. Figure (4.32) reveal that the stiffness of the deep beams in Group(B) and deep beams Group(C) are higher in percentage compared to control deep beams (Group A) when the percentage of plastic fiber is constant.

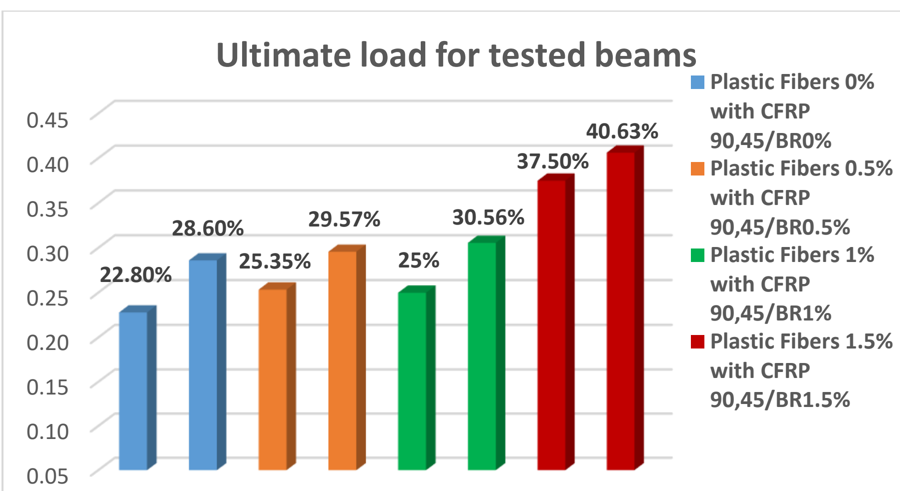


Fig. 4.26 The ultimate load of the beam specimens relative to the CFRP orientation effect

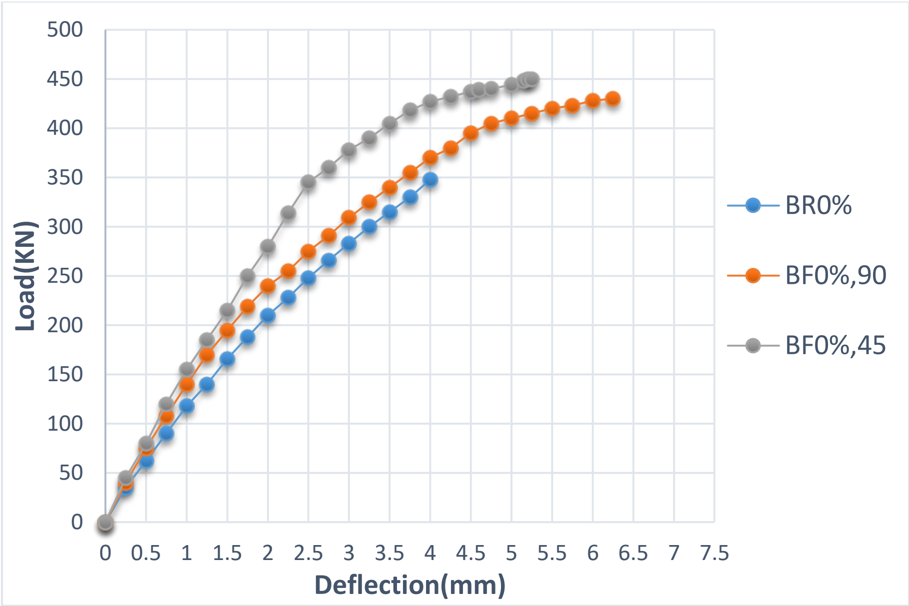


Fig. 4.27 The relationship between the load and deflection for the Plastic Fibers (0%) specimens

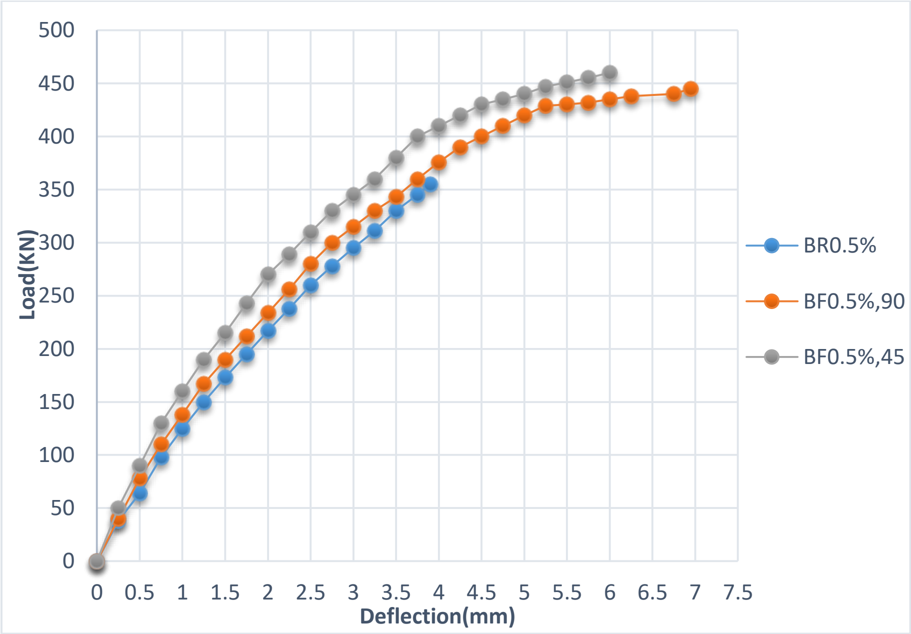


Fig. 4.28 The relationship between the load and deflection for the Plastic Fibers (0.5%) specimens

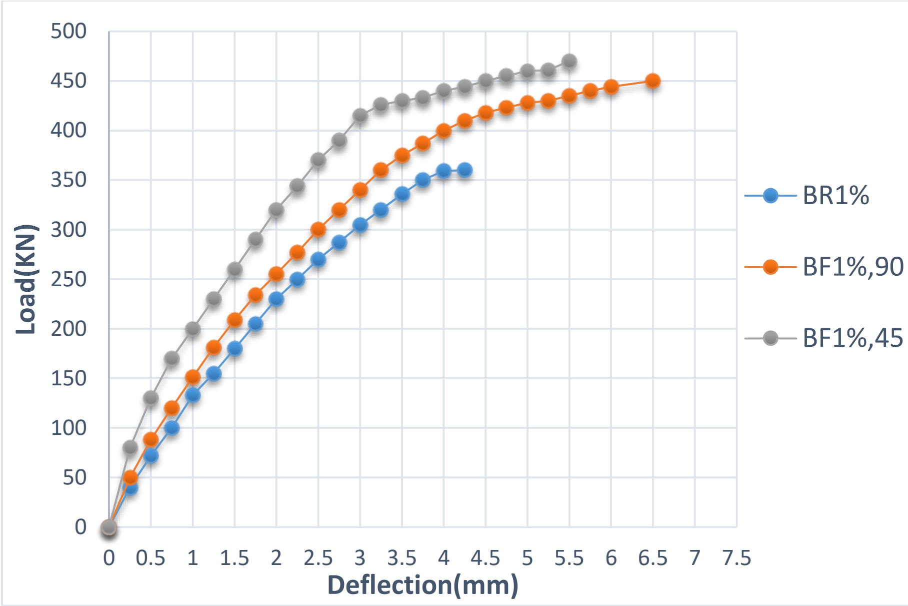


Fig. 4.29 The relationship between the load and deflection for the Plastic Fibers (1%) specimens

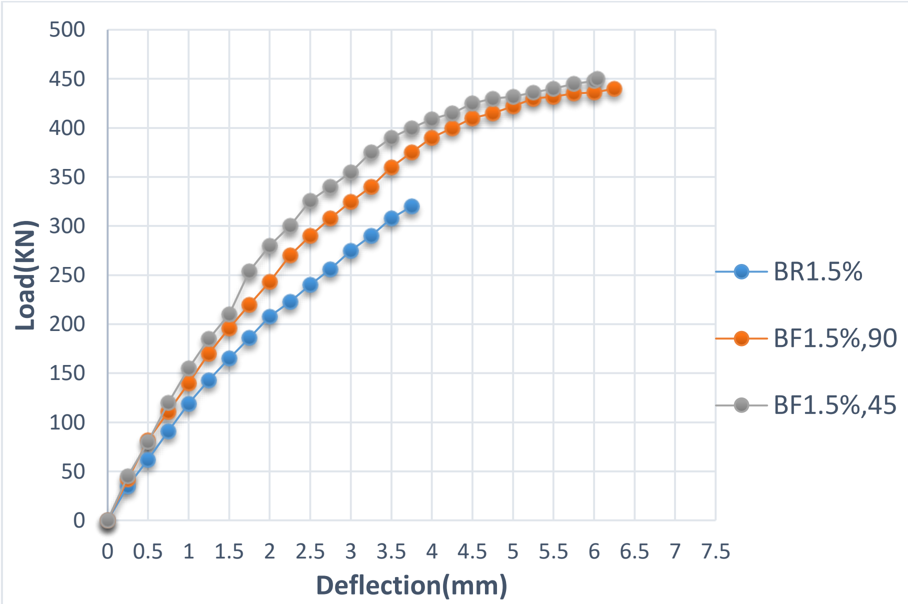


Fig. 4.30 The relationship between the load and deflection for the Plastic Fibers (1.5%) specimens

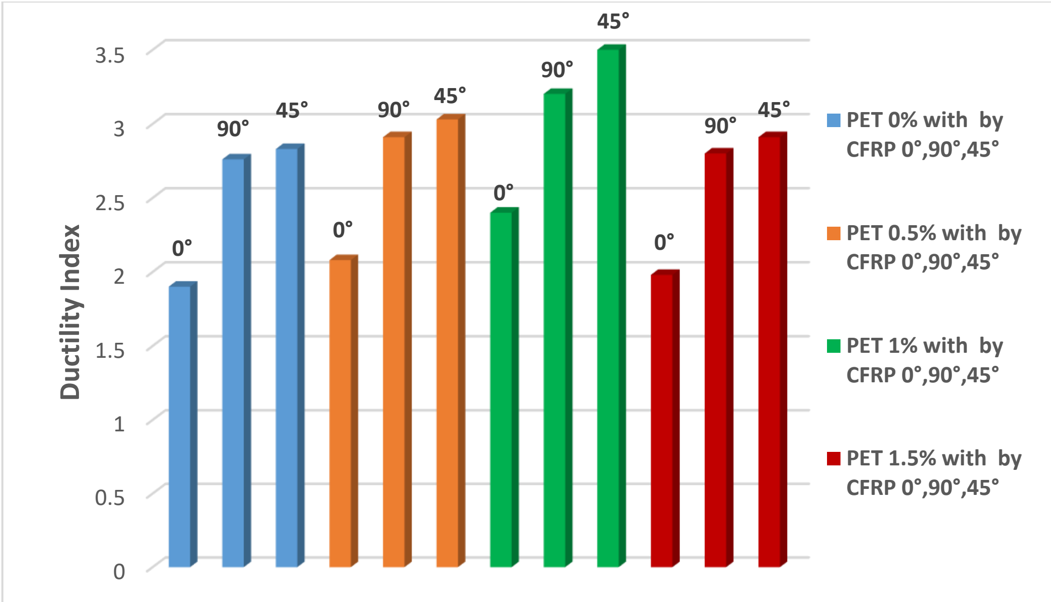


Fig. 4.31: Ductility Index of the Deep beam specimens relative to CFRP orientation effect

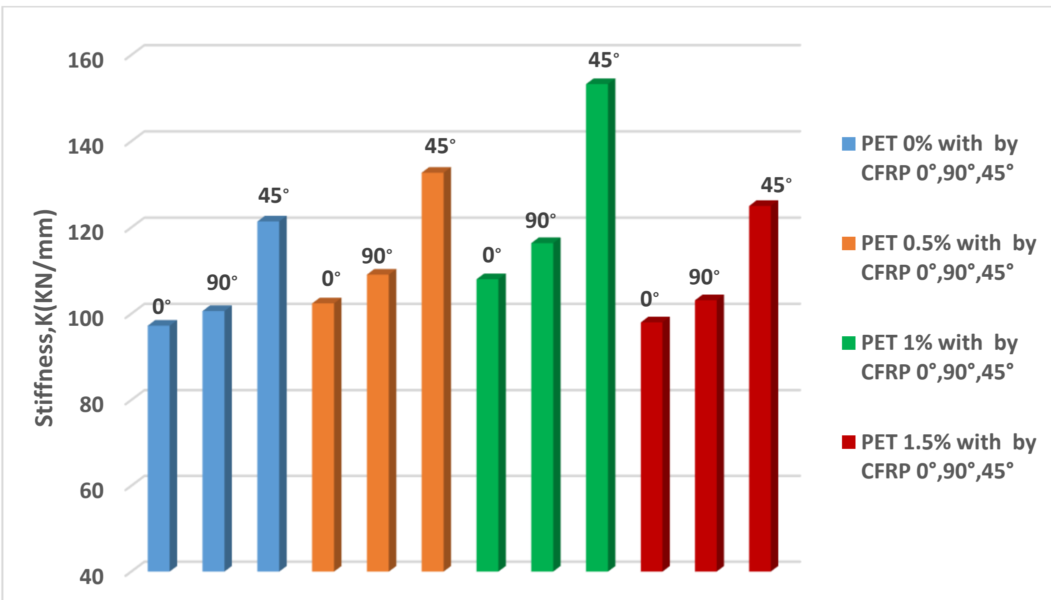


Fig. 4-32: Stiffness, K of the Deep beam specimens relative to CFRP orientation effect

4.9 Summary

The results show all the control specimens reached its ultimate load due to induce shear crack. The shear failure is occurred because the specimens are designed to fail in shear, but the results display improvement in the shear strength of the beams with the presence of waste plastic fibers in concrete. Consequently, the brittle shear failure became more ductile for all fibers percentages. This indicates the success of the presence of plastic fibers that have led to an increase in the shear resistance. In this regard, the overall results show that the eight deep beam specimens have reached its ultimate load due to intermediate flexure crack induced bending failure, and indicates the success of the repairing process by using the CFRP strips which can increase the shear capacity significantly, with efficiency that varies depending on the tested variables. Of all types of different proportions of plastic fibers, which used in the concrete deep beam specimens, the plastic fibers percentages (0.5%,1%,1.5%) deep beam specimens showed the best repaired performance, especially plastic fibers percentage (1%) deep beam specimens. The reason for the high performance of deep beams with plastic fibers percentages of (0.5% and 1%) might be attributed to the fact of increasing the interconnection and attraction points between the separate parts of concrete after failure, which is contributed to the ability to bridge the cracks and redistribute the stresses in the beam body to carry more load with a minor deflection at the same load level. As for the type of the specimens has displayed an increase in the results when tested under plastic fibers percentages (0.5%, 1%).

The results were converging for using the two angles (90^o, 45^o) for repairing the deep beam specimens, have both of them shown good repairing results. However, the larger effect on the shear bahavior is recorded for the beams that are reinforced against the shear stresses by CFRP at angle (45) with fibers percentage (1.0%). This technique can be attributed to the fact that the efficiency of the CFRP materials in arresting the propagation and which working as externally shear resistance and controlling the growth of cracks within the beam, also its ability in energy absorption and delay the appearance of the first crack, hence the beam could withstand great loads and deflection before failure. The results which mentioned above assure the good distribution of CFRP strips are the main sources for enhancing the strength of the beam specimen agents the shear deficiency, where the failure after the repair was flexure.

Chapter Five

Conclusions and Recommendations

5.1 Introduction

The present study investigates the effect of the (PET) fibers on the mechanical properties of standard concrete and examines the shear behavior of reinforced concrete deep beams. In addition, the impact of using CFRP sheets for repaired beams on their bahavior by using the sheets around the beams with wrapping angles of 90 º and 45 º with (PET) fibers to achieve sustainability in the existing structures. This chapter contains some conclusions that are worth mentioning and suggestions and recommendations for future work.

5.2 Material Properties Conclusions

Conclusions for the experimental work results can be summarized as follows:

1. The mixing of plastic fibers concrete can be achieved by utilizing the same regular techniques used for typical ordinary concrete.
2. The increasing of the volumetric ratio of waste plastic fibers has led to decreasing the workability of concrete mixes and value of this decrease is almost (25%) at fibers content (1.5%).
3. The experimental results reveal that the effect of waste plastic fibers on the compressive strength of concrete has slightly decreased the percentages in all fibers with an almost (1.411 %) at (7) days and (1.633 %) at (28) days with 0.5%. However, no increasing is observed in

compressive strength for higher values of the PET% due to fiber collections during process of mixing.

4. The PET effect on splitting tensile strength more than the compressive strength. Increased the splitting tensile strength with increasing of fibers content until the percentage of (1%) that recorded a significant increase in tensile strength by (14.4%) at 28 days. Besides, the width of the axial crack for the tested cylinders became very small after failure with incorporating the waste plastic fibers.

5.3 Structural Behavior of Deep Beam Specimens

Conclusions can be drawn based on the experimental results that were described in previous chapters as the following:

1. Waste plastic fibers can be used to produce sustainable continuous deep beams, where the deep beams with plastic fibers failed in a gradual and ductile manner while as for the non-fiber models, they failed suddenly and in a brittle way.
2. The presence of the plastic fibers percentages of (0.5%,1%) causes increase in the ultimate load by (1.43%,2.86%) comparing with the control deep beam PET (0%), while by increasing the percentage of plastic fibers in more than (1%) leads to decrease in ultimate load compared to the control deep beam.
3. The failure cracks in normal concrete with non-fiber models are very clear and wide, while such cracks are much finer in deep beams with PET. This is due to the fact that fibers increase the internal bonding of concrete. An increasing in the first crack load has been observed with the increase in the (PET) fibers content up to (1%), which that

has reached (42.86%), and the experimental tests have showed that the width of first crack has decreased with increasing the fibers content at the same load, which reflect the improved performance of RC deep beams with fiber (PET).

4. With the presence of the waste plastic fibers in concrete, the shear ductility of the beams has increased except the fibers percentage of (1.5%), the highest increasing in shear ductility is recorded at fibers percentage (1%) and reaches (26.31%). The increments in the stiffness amount to 11.1 %, which results in decrease in the deflection of these beams. and confirmed the positive impact of PET (1%) on the stiffness of is more than control deep beam PET (0%).

5. After repairing with the CFRP strips, all the deep beam specimen's have demonstrated a good rehabilitation results. The CFRP improves the shear strength, which produces flexural failure.

6. The reinforced concrete continuous deep beams with the plastic fibers percentages of (0.5%,1%,1.5%) that are strengthened with 45º CFRP strips exhibited higher cracking load and ultimate load as compared with 90º CFRP strips.

7. In relation to combining the CFRP strips with the presence of the plastic fibers in the concrete mixture of the continuous deep beam followed by the 90º CFRP strips, the results confirm that there is an additional increase in the ultimate load by (22.8 %,25,35%,25%,37,5) respectively compared to the control beams(Group A).

8. In terms of combining the CFRP strips with the presence of plastic fibers in the concrete mixture of the continuous deep beam followed

by 45º CFRP strips, the results prove that there is an additional increase in the ultimate load by (28.6%,29.6%,30.56%,40.6%) respectively compared to the control beams(Group A).

9. For ductility and stiffness, the plastic fibers (1%) deep beam specimens that is repaired with the (45) CFRP orientation shows the high results in the ductility and stiffness with (3.5) and (153.26) respectively. The plastic fibers (1.0%) deep beam specimens that are repaired with the (90) CFRP orientation shows high ductility and high stiffness with (3.202) and (116.38) respectively. As for those that are repaired with (90,45) CFRP orientation, the ductility and stiffness was high when compared to control deep beams (Group A).

5.4 Recommendations for Further Research

In order to develop an understanding of the shear behavior of reinforced concrete beams, the following topics are recommended for future works:

1. Studying the behavior of other structural plastic fibers members such as deep beams with opening, columns, slabs, and beam-column joints.
2. Investigating the effect of waste plastic fibers on the shear strength of reinforced concrete deep beams with different aspect ratio.
3. Investigating the effect of (CFRP) stirrups on the shear strength of reinforced beams under distributed loads (4, 6 and 8-point loading).
4. It is recommended to work on more related experimental tests on plastic concrete service properties such as fire resistance, and sound and thermal insulation, in future works.
5. Repairing continuous deep beams with the PET by using another strengthening material or technique such as steel plates or GFRP.

References

A. Babafemi, B. Šavija, S. Paul, and V. Anggraini, *“Engineering Properties of Concrete with Waste Recycled Plastic: A Review,”* Sustainability, vol. 10, no. 11, p. 3875, 2018.

A. F. Ali, A. N. Noori" *Effect of Web Reinforcement on Self Compacting Reinforced Concrete Continuous Deep Beams “*Journal of Engineering and Sustainable Development Vol. 22, No. 4, ISSN 2520- 0917, July 2018.

A. Ghafar, A. Javed, H. ur Rehman, K. Ahmed, and M. Ilyas, *“Development of Shear Capacity Equations for Rectangular Reinforced Concrete Beams,”* Pakistan J. Eng. Appl. Sci., vol. 6, pp. 1–8, 2010.

A. I. Al-Hadithi and M. F. Alani, *“Importance of adding waste plastics to high performance concrete,”* in Proceedings of the Institution of Civil Engineers-Waste and Resource Management, vol. 171, no. 2, pp. 36–51, 2018.

A. I. Al-Hadithi and N. N. Hilal, *“The possibility of enhancing some properties of self compacting concrete by adding waste plastic fibers,”* J. Build. Eng., vol. 8, pp. 20–28, 2016.

A. S. Benosman et al., *“Effect of addition of PET on the mechanical performance of PET-Mortar Composite materials,”* J. Mater. Environ. Sci., vol. 6, no. 2, pp. 559–571, 2015.

Abdul-Razaq, A., H., *" Behavior of Concrete Beams Reinforced In Shear with CFRP"*, Ph. D. Thesis, University of Baghdad / College of Engineering , Civil Engineering Department, 2010.

Abdul-Razzaq, K. S., and Jalil, A. M.,*"Behavior of Reinforced Concrete Continuous Deep Beams-Literature Review."* In the Second Conference of Post Graduate Researches. College of Engineering, AlNahrain Univ., Baghdad, Iraq-4th, 2016.

Al-Ghanem, H., Al-Asi, A., Abdel-Jaber, M., & Alqam, M. *Shear and Flexural Behavior of Reinforced Concrete Deep Beams Strengthened with CFRP Composites*. Modern Applied Science, 11(10), 110, 2017.

Allawi, A. A.*"Nonlinear Analysis of Reinforced concrete Beams Strengthened by CFRP in Torsion.",* Ph. D. thesis, Dept. of Civil Engineering, College of Engineering, Univ. of Baghdad, Baghdad, Iraq, 2006.

Al-Manaseer, A. and Dalal, T., *"Concrete containing plastic aggregates"*, Concrete International, 19(8): pp. (47-52), 1997.

Al-Tai, S., L.,*" Nonlinear Bahavior of Reinforced Concrete T-Beams Strengthened with CFRP Subjected to Shear "*, M.Sc. Thesis, College of Engineering ,University of Babylon, Iraq, 2010.

American Concrete Institute *"Building Code Requirements for Reinforced Concrete"*, Detroit, ACI-381-08, 2014.

American Society of Testing and Materials (ASTM), "*Standard Specifications for Concrete Aggregates*", ASTM C-33, West Conshohocken, PA., 2002.

Ashraf F. A. *"Experimental bahavior of reinforced concrete continuous deep beams."* WIT Transactions on the Built Environment, PP.267– 277, 1996.

Assessment Guidelines, *"Converting Waste Plastics into a Resource"*, Compiled by United Nations Environment Programme (UNEP), Division of Technology, Industry and Economics International Environmental Technology Centre Osaka/Shiga, 2009.

ASTM C43-143, *"Standard Test Method for Slump of HydraulicCement Concrete*", ASTM International,2003.

ASTM C43-143: *"Standard Test Method for Slump of Hydraulic-Cement Concrete*", ASTM International, 2003.

ASTM C496/C496M-11 'ASTM C496-11 *Standard Test Method for Splitting Tensile Strength of Cylindrical Concrete Specimens*', Annual Book of ASTM Standards Volume 04.02, 2011.

B. Yesilata, Y. Isıker, and P. Turgut, *"Thermal insulation enhancement in concretes by adding waste PET and rubber pieces,"* Constr. Build. Mater., vol. 23, no. 5, pp. 1878– 1882, 2009.

B.Singh, S.K. Kaushik, K.F. Naveen and S. Sharma. *"Design of A Continuous Deep Beam Using the Strut and Tie Method"*, Asian Journal of Civil Engineering (Building and Housing) Vol. 7, No. 5, 461- 477pp, 2006.

Bank, L.C.*" Composites for construction: Structural design with FRP materials"*. John Wiley & Sons,2006.

BS 1881-116:‘*Testing concrete- compressive strength of concrete cubes’*, British Standard Institution, 1983.

Carolin, A.*"Carbon Fiber Reinforced polymers for Strengthening of Structural Elements."* , Ph. D. Thesis. University of Luleå tekniska, Sweden, 2003.

D. Foti, *“Preliminary analysis of concrete reinforced with waste bottles PET fibers,”* Constr. Build. Mater., vol. 25, no. 4, pp. 1906–1915, 2011.

Daniel, J.I., Gopalaratnam, V.S., Galinat, M.A., Ahmad, S.H., Hoff, G.C., Schupack, M., Arockiasamy, M., Jindal, R.L., Shah, S.P. and Balaguru, P.N., *"Report on Fiber Reinforced Concrete"*. ACI 544.1R-96, pp. (2-5), 2002.

Devi, N. G. *"Fiber Reinforced Polymer Reinforcing Bars in Concrete Structures."* International Journal of Innovative Research in Science Vol. 4 Issue 6, 2015.

EN 206-1, “*Concrete-Part 1: Specification, performance, production and conformity,*” Europen Standards Institution, London. 2000.

F. Fraternali, V. Ciancia, R. Chechile, G. Rizzano, L. Feo, and L. Incarnato, *“Experimental study of the thermo-mechanical properties of recycled PET fiber reinforced concrete,”* Compos. Struct., vol. 93, no. 9, pp. 2368–2374, 2011.

F. K. KONG. *“Continuous deep beams”,* in Reinforced Concrete Deep Beams , New York, 2003.

F.B.A. Beshara, I.G. Shaaban and T.S. Mustafa*" Behavior and Analysis of Reinforced Concrete Continuous Deep Beams"* The 12th Arab Structural Engineering Conference, pp. 1-13, 2013.

Grimaldi, A. and Rinaldi, Z., "*Influence of the steel properties on the ductility of RC structures*", in Novel Approaches in Civil Engineering, Springer, pp. (297-309), 2004.

Hawileh, R.A., Nawaz, W., Abdalla, J.A. and Saqan, E.I., "*Effect of flexural CFRP sheets on shear resistance of reinforced concrete beams*", Composite Structures, 122: pp. (468-476), 2015.

Huda, Md Nazmul J., Mohd Z. B.I., and ABM Saiful, "*Flexural Performance of Reinforced Oil Palm Shell and Palm Oil Clinker Concrete (PSCC) Beam*," Construction and Building Materials, vol. 127, pp. 18-25, 2016.

Iraqi Specification No.45, "*Natural Sources for Gravel that is used in concrete and construction*", Baghdad,1984.

Iraqi Specification No.5, "*Portland Cement*”, Baghdad,1984

J.-H. J. Kim, C.-G. Park, S.-W. Lee, S.-W. Lee, and J.-P. Won, *“Effects of the geometry of recycled PET fiber reinforcement on shrinkage cracking of cement-based composites,”* Compos. Part B Eng., vol. 39, no. 3, pp. 442–450, 2008.

Jabarin, A.S., *“Polyethylene terephthalate chemistry and preparation",* The Polymeric Materials Encyclopedia, CRC Press Inc., 1996.

Jassem, Hyder . Abd . Allatif . (2018). *Structural Behavior of Reactive Powder Deep Beams with Opening Strengthened by CFRP* M. Sc. Thesis, College of Engineering ,University of Kufa, Iraq, 2018.

K.-H. Yang, H.-S. Chung and A. F. Ashour *"Influence of section depth on the structural behavior of reinforced concrete continuous deep beams"* Magazine of Concrete Research, 59, No. 8, 575–586, October 2007.

Keun H. Y., Heon-Soo Chung and Ashraf. F. A.*"Influence of shear reinforcement on reinforced concrete continuous deep beams."* ACI Structural Journal, Vol. 104, PP.420–429, 7 Jan. 2007.

Keun-H. Y. and Ashraf F. A.*" Aggregate interlock in lightweight concrete continuous deep beams."* Engineering Structures, PP.136–145, 2011.

Kim, S.B., Yi, N.H., Kim, H.Y., Kim, J.H. and Song, Y.C., *"Material and structural performance evaluation of recycled PET fiber reinforced concrete"*, Cement and concrete composites, 32(3): pp. (232- 240), 2010.

L. Gu and T. Ozbakkaloglu, *"Use of recycled plastics in concrete: A critical review,"* Waste Manag., vol. 51, pp. 19–42, 2016.

M. A. A. Aldahdooh, A. Jamrah, A. Alnuaimi, M. I. Martini, M. S. R. Ahmed, and A. S. R. Ahmed, *"Influence of various plastics-waste aggregates on properties of normal concrete,"* J. Build. Eng., vol. 17, pp. 13–22, 2018.

M. Guendouz, F. Debieb, O. Boukendakdji, E. H. Kadri, M. Bentchikou, and H. Soualhi, *"Use of plastic waste in sand concrete,"* J. Mater. Environ. Sci, vol. 7, no. 2, pp. 382– 389, 2016.

M. P. Collins, E. C. Bentz, E. G. Sherwood, and L. Xie, *“An Adequate Theory for the Shear Strength of Reinforced Concrete Structures,”* Mag. Concr. Res., vol. 60, no. 9, pp. 635–650, 2008.

M.A.T. Khatab. Ashraf F. A., T. Sheehan and D. Lam. *"Experimental investigation on continuous reinforced SCC deep beams and Comparisons with Code provisions and models."* Engineering Structures, 2016.

Maki.R.F.*"Experimental And Theoretical Investigation Of The Structural Behavior Of R. C. Slabs Strengthened By (Cfrp) "*. Ph. D Thesis, University of Basrah , pp.182,2010.

Manos, G.C., Katakalos, K., Koidis, G. and Papakonstantinou, C.G., "*Shear strengthening of R/C beams with FRP strips and novel anchoring"*, Journal of Civil Engineering Research, 2(6): pp. (73- 83) 2012.

Mansur, M.A., *Design of reinforced concrete beams with web openings*. in Proceedings of the 6th Asia-Pacific structural engineering and construction conference (ASPEC 2006): p. pp. 5–6, 2006.

Muthuswamy, K. and G. Thirugnanam, *Structural bahavior of hybrid fiber reinforced concrete exterior Beam-Column joint subjected to cyclic loading*. International journal of civil structural engineering, 4(3): p. 262, 2014.

Mustafa, A. A.," *Shear Behavior of Waste Plastic Fibers Concrete Beams Enhanced with CFRP Stirrups*" Ph Thesis, Univ. of Anbar, 2018.

N. Zhang and K. H. Tan. *"Effects of support settlement on continuous deep beams and STM modeling."* Engineering Structures, PP.361– 372, 2010.

Najim, K.B., "*Determination and enhancement of mechanical and thermo-physical bahavior of crumb rubber-modified structural concrete*", University of Nottingham, 2012.

Nie, Jian-Guo, et al. *"Experimental and numerical investigations of composite frames with innovative composite transfer beams."* Journal of Structural Engineering 143.7 ,2017.

Ola, E., *"CFRP strengthening of concrete slabs, with and without openings: experiment, analysis, design and field application"*, 2005.

Ouda, O.K., Raza, S.A., Al-Waked, R., Al-Asad, J.F. and Nizami, A.S., *"Waste-to-energy potential in the Western Province of Saudi Arabia"*, Journal of King Saud University-Engineering Sciences, 29(3): pp (212-220), 2015.

Prestera J. R., Boyle M., Crocker D. A., Chairman S. B., E. A. Abdun-Nur, Barton S. G., et al., "*Standard Practice for Selecting Proportions for Structural Light weight Concrete (ACI 211.2-98)*," 1998.

R. Geyer, J. R. Jambeck, and K. L. Law, *"Production, use, and fate of all plastics ever 130 made.,"* Sci. Adv., vol. 3, no. 7, p. e1700782, 2017.

R. M. Bajracharya, A. C. Manalo, W. Karunasena, and K. Lau, *"An overview of mechanical properties and durability of glass-fiber reinforced recycled mixed plastic waste composites,"* Mater. Des., vol. 62, pp. 98–112, 2014.

R. P. Borg, O. Baldacchino, and L. Ferrara, *"Early age performance and mechanical characteristics of recycled PET fiber reinforced concrete,"* Constr. Build. Mater., vol. 108, pp. 29–47, 2016.

Rinaldi, Z., Grimaldi, A., and Galli, G., "*Ductility of RC Beams Reinforced with FRC*", 13th World Conference on Earthquake Engineering, Vancouver, B.C., Canada, August 1-6, pp. (2761), 2004.

Russell, J.S., Perspectives in Civil Engineering: *Commemorating the 150th Anniversary of the American Society of Civil Engineers*, p. 375, 2003.

Shireen, HH," *Rehabilitation of Lightweight RC Beams with Shear Deficiencies by CFRP*" Ph Thesis, Univ. of Kerbala, 2021.

S. K. Faisal, J. M. Irwan, N. Othman, and M. H. W. Ibrahim, *"Flexural toughness of ring-shaped waste bottle fiber concrete,"* in MATEC Web of Conferences, vol. 47, p. 1002, 2016.

S. Shahidan, *"Concrete incorporated with optimum percentages of recycled polyethylene terephthalate (PET) bottle fiber,"* Int. J. Integr. Eng., vol. 10, no. 1, 2018.

Siddique, R., Khatib, J. and Kaur, I., *"Use of recycled plastic in concrete: a review"*, Waste management, 28(10): pp. (1835- 1852), 2008.

The Gestis Substance Database of the Institute for Occupational Safety and Health,accessed on 7 November 2007 , (http://gestis.itrust.de/nxt/gateway.dll/gestis_en/000000.xml?f=templates&fn=default.htm&vid=gestiseng:sdbeng).

WEI, S., C., "*Numerical Analysis on the Bahavior of CFRP Shear-strengthened RC Deep Beams with Large Square and Circular Opening*" , Report submitted to University Malaysia Pahang, Faculty of Civil Engineering and Earth Resources, 2015.

Wissam D. Salman*" Nonlinear Behavior of Reinforced Concrete Continuous Deep Beam “*International Journal of Engineering Research & Technology (IJERT) ISSN: 2278-0181 Vol. 4 Issue 04, April-2015.

Xie, Y., Ahmad, S.H., Yu, T., Hino, S. and Chung, W., "*Shear ductility of reinforced concrete beams of normal and high-strength concrete*",Structural Journal, 91(2): pp. (140-149), 1994

APPENDIX (A)

DESIGN OF CONTINUOUS DEEP BEAMS

According to the design equations of ACI Code 318-99 (and adopted by ACI-Code 318-08), the design calculations are induced, as follows:

1-Design for flexural

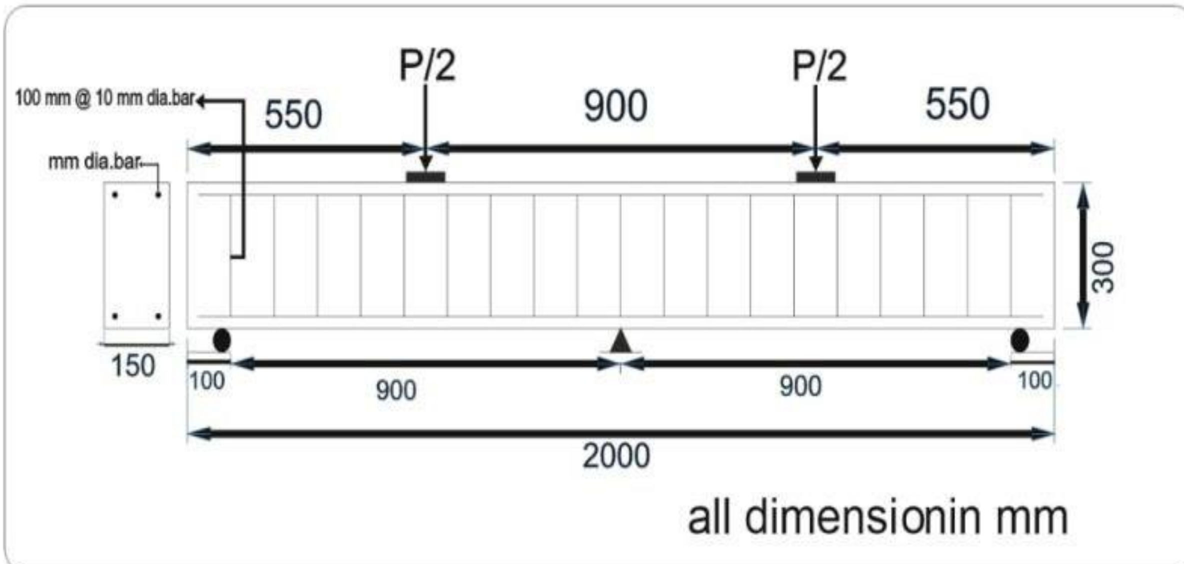
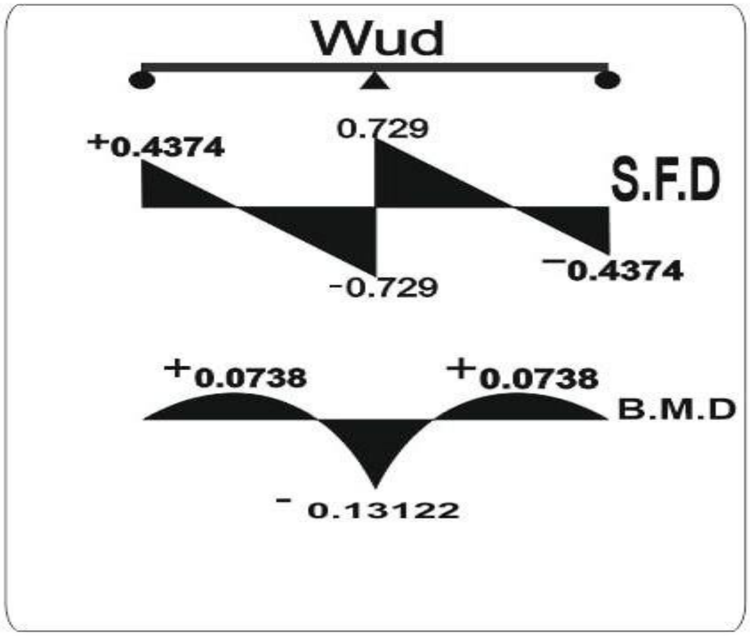


Figure A.1 Details of the dimensions of the continuous deep beams with reinforcing steel

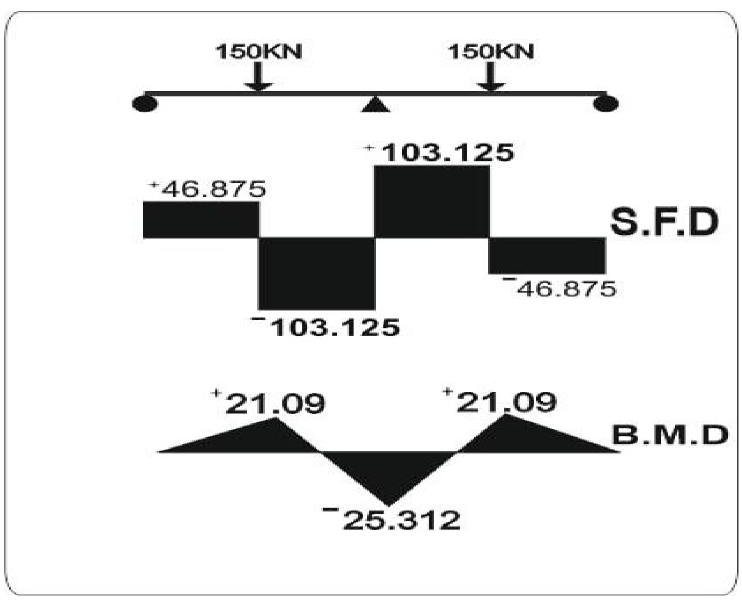
#For self-weight:

Wd= 0.15*0.3*24 =1.08 KN/m , Wud = 1.2 *1.08=1.296 KN/m.



#For point load :

Pu=150KN .



Mu+ = (M1+M2)+ =21.1638 KN.m @(0.45 m)

Mu- = (M1+M2)- =25.444 KN.m @(0.9 m) .

for $f'c$= 30MPa , Fy=460 MPa

At a/h= 450/300=1.5

jd=0.2(L + 1.5h)=0.2(950 + 1.5×300) = 280 mm

$As^{+}_{=}$ Mu+/ Ø. Fy. jd=142.344KN.m

As min=($\sqrt{f'c}$/4 Fy)b.d=90.165mm^2

As min=(1.4/ Fy)b.d=92.18mm^2 ≥ As min=($\sqrt{f'c}$/4 Fy)b.d….OK

use ϕ 12 mm. No. of bars = 1.5≈ 2

Use 2 ϕ 12 mm. As=226.19 for top longitudinal

As^{-} = Mu^{-}/ Ø. Fy. jd=171.13mm^2 ≥ As min….0k

use ϕ 12 mm. No. of bars = 2

Use 2 ϕ 12 mm. As=226.19 for bottom longitudinal

2-design for shear

Vn=0.729+103.125=103.854 KN

Vn_{max}=0.83*$\sqrt{f'}$ *b*d=176.6KN

Vn_{max} ≥ $Vn_{app.}$ ….ok

(3.5 – 2.5 Mu/ Vu. d)=1.136≤2.5 ….ok

Vu d/ Mu =1.05≤1.0 use Vu d /Mu =1.0

$V_c = (3.5 - 2.5\, M_u / V_u .d)(0.16\sqrt{f'c} + 17\, \rho_w .V_u d / M_u)\, b_w d \leq 0.5 \sqrt{f'c}\, b_w.d$

Vc=43.04KN ≤ 106.4……OK

Vn > Vc need for shear reinf.

Vs=Vn-Vc=60.814KN

Use Φ10 mm stirp ..Sv=d/5=52mm ≤ 300 …....OK

$A_v = A_{v_h} = 2 * A_s$ stirrp= 157.08mm^2

$V_s = [A_v / S_v [(1 + l_n / d)/12] + A_{v_h} / S_h [(11 - l_n / d)/12]]\, f_y\, d$

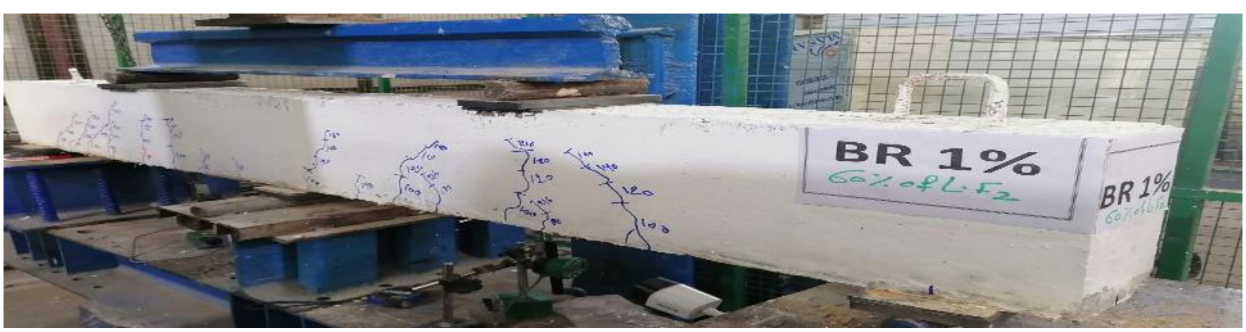
S_h=135mm

Use Φ10 mm @ 100 mm. for minimum number of stirrups to cause a shear failure

Appendix A

PlateA1: Beam No. BR0% at the first stage of testing (60% ratio of loading)

PlateA2: Beam No. BR0.5% at the first stage of testing (60% ratio of loading)



PlateA3: Beam No. BR1% at the first stage of testing (60% ratio of loading)

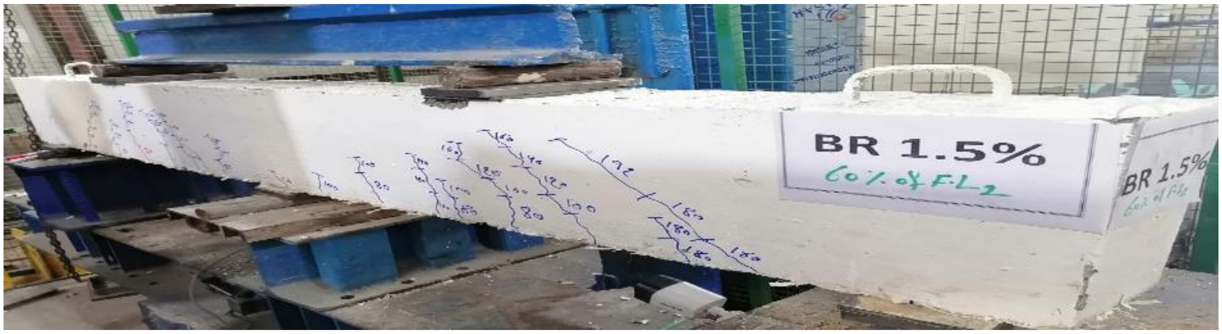


Plate A4: Beam No. BR1.5% at the first stage of testing (60% ratio of loading)

الخلاصة

فيما يتعلق بأعمال إعادة التدوير وإعادة الاستخدام ، فإن كمية النفايات البلاستيكية المتراكمة في العالم في الوقت الحاضر أكبر من تلك المستهلكة لأنها مادة غير قابلة للتحلل. تؤدي هذه المشكلة إلى تراكم كميات كبيرة من النفايات البلاستيكية السامة ، مما يؤثر على الصحة العامة ويزيد من مخاطر السلامة. لذلك ، تم اقتراح استخدام المخلفات البلاستيكية في بناء العديد من الأعضاء الهيكلية كخطوة لمعالجة مشكلة التراكم. في هذا الصدد ، يهدف هذا البحث إلى التحقق من السلوك الإنشائي فيما يتعلق بقص العتبات العميقة المستمرة للخرسانة المسلحة التي تحتوي على مادة البولي إيثيلين تيريفثاليت (PET). في الواقع ، ومن خلال متابعة مفهوم الاستدامة ، تم اقتراح تقنيات تقوية مختلفة لتقوية الكمرات العميقة المستمرة للخرسانة المسلحة المتضررة جزئيًا بواسطة البوليمر المقوى بألياف الكاربون (CFRP).

لهذا الغرض ، تم إجراء العديد من الاختبارات باستخدام المكعبات والأسطوانات للتحقق من تأثير الالياف البلاستيكية ذات الأحجام المختلفة من ألياف البولي إيثيلين (0.5 % ، 1% و 1.5%) على الخواص الميكانيكية للخرسانة مثل: قابلية التشغيل ، وقوة الانضغاط. وقوة شد الانقسام. علاوة على ذلك ، تم أيضًا فحص السلوك الهيكلي المتمثل في مقاومة القص للحزم العميقة المستمرة RC التي تتضمن ألياف PET بعد تقويتها بواسطة CFRP بزاوية (90 درجة و 45 درجة) لأنها صممت في البداية مع قصور القص المقصود. تم تصميم اثني عشر عارضة عميقة من نوع RC بحيث تفشل في القص بطول (2000 مم) ، وعمق (300 مم) ، وعرض (150 مم). تم اختبار أربع عينات بألياف PET مختلفة تصل إلى فشل القص وتم اعتبارها عينات مرجعية. تم تحميل العينات المتبقية حتى (60٪) من حملها المصمم ثم تقويتها بألواح CFRP واختبارها لاحقًا.

أظهرت النتائج أن السلوك الهيكلي للحزم العميقة المستمرة RC مع ألياف PET أظهرت أداءً أفضل وشقوق فشل أدق من تلك التي لا تحتوي على ألياف. علاوة على ذلك ، سجلت أعلى مقاومة قص عند العينة بنسبة ألياف 1٪ حيث سجلت أعلى قيمة بنسبة زيادة طفيفة مقارنة مع عدم وجود ألياف. علاوة على ذلك ، أوضحت النتائج التجريبية أن الحزم المقواة بألواح CFRP أظهرت قدرة تحميل قصوى أعلى مقارنة بالعينات المرجعية. وبالمثل زادت ليونة القص بنسبة (33.42٪) و (45.83٪) مع زيادة نسبة الألياف حتى (1٪) للحزم المقواة بالبلاستيك المقوى بألياف الكربون عند 90 درجة و 45 درجة على التوالي.

جمهورية العراق

وزارة التعليم العالي و البحث العلمي

جامعة كربلاء /كلية الهندسة

قسم الهندسة المدنية

سلوك القص للعتبات الخرسانية المسلحة العميقة المستمرة الحاوية على الياف مخلفات البلاستيك والمعاد تأهيلها بواسطة شرائح الياف الكاربون البولميرية

رسالة مقدمة الى

قسم الهندسة المدنية في كلية الهندسة /جامعة كربلاء

كجزء من متطلبات نيل شهادة الماجستير في علوم الهندسة المدنية (البنى التحتية)

من قبل

سوسن كريم كاظم

(بكالوريوس في الهندسة المدنية–2007)

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1443هـ **2021م**