A review on hybrid fiber reinforced concrete pavements technology

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Abstract

The problems of soil-structure interaction involve different members or different materials behave together under applied loading. In the case of concrete pavement resting on soil under traffic loading, both concrete and soil will deform. Rigid Pavements are made of Portland Cement Concrete (PCC). It serves out two aims, to maintain a durable surface with comfortable driving for vehicles. The second purpose is to decrease the stresses on the layers of pavement beneath the surface such as subbase and subgrade. Concrete is considered a weak material in resisting tensile stresses. Therefore, when low tensile stresses are applied, rigid pavement begins to crack effortlessly. In concrete pavement, the usage of different kinds of fiber reinforcement could be an effective technique to improve these properties. Numerous kinds of fibers are utilized in the concrete pavement to behave as an alternative to ordinary reinforcement. They may differ in material like steel or plastic and could be in many shapes, and dimensions. The addition of fibers is during the mixing when the concrete is still fresh. The incorporation of different sorts of fibers could be a significant step in diminishing the cracks and achieving a higher performance of concrete. Two kinds of fibers or even more than two can be combined to achieve a mixture that produces profits for each type of fiber in this composite. In this paper, an intensive review was made to demonstrate the forms of distresses that could happen in concrete (rigid) pavement and the impact of incorporating different kinds of fibers into the concrete to enhance the concrete ability to eliminate or even delay the process of failure.

1. Introduction

The pavement may be defined as a relatively stable layer constructed above the natural soil for suitable distribution of wheel load and provides support to the wearing surface [1]. In history, the pavements have been divided into two types; flexible and rigid pavements depending on the way of transferring loads to the foundation soil. For flexible pavements, there is a gradual stiffness that increases from the foundation soil to the wearing way, which leads to high stress on the soil because the load is decadent over a relatively small area. On the contrary, in rigid pavements, the stresses on the soil are smaller because the stiffness of the road base is bigger than that of the soil. The main advantages of using Portland Cement
Concrete pavement has the durability and the ability to hold the required shape. The durability and serviceability of concrete pavement structures rely on the rate of pavement deterioration. The deterioration of pavement relies on features such as climatic effects, properties of a material, and vehicular loads characteristics. Cracks in concrete pavements can be seen as a tensile failure. Cracks are developed at different positions in the pavement, in cases where higher tensile stresses are developed in it which is greater than the concrete bending strength [2].

The PCC is a brittle material that possesses lesser tensile or bending strength and lower induced strain at failure. To solve such a problem, steel reinforcement or bars are incorporated in the concrete structures. Delaying and controlling tensile cracking is the main impact of fiber reinforced concrete. Reinforcing concrete with fiber significantly affects the costs of pavement construction due to decreased thickness requirements, reduced maintenance costs and effort, and therefore longer service life. The life cycle of asphalt pavement is comparable [3]. The main purpose of adding steel fiber to the concrete flooring is to modify the cracking mechanism. The cracking system is revised, and ultimately, there is an enhancement in its static and dynamic properties as well as performance at various applications of load [4]. During the previous researches, there have been advances to use discontinuous, randomly oriented, discrete fibers to overcome these weaknesses. This is recognized as concrete reinforced with fiber. The adding of fibers into the stiff concrete can enhance the control of growth and propagation of microcracks as the tensile strain in the concrete increases. The type and percentage of improvement are based on type, size, shape, amount, and strength of fiber [5].

2. Review of the Main Task
The main aim is to review the studies which focused on the influence of utilizing hybrid fiber in rigid pavement their response under different loading and addressing the main conclusions. Also, a comparison of the conventional concrete with the hybrid fiber reinforced concrete based on previous researches will be made.

3. Fiber Reinforced Concrete (FRC)
Fiber-reinforced concrete (FRC) is a composite material comprising cement mortar or concrete mixtures and frequently dispersed fibers are appropriate to improve the mechanical characteristics of pavement made from concrete. The amount of fibers that are supplemented to the concrete mixture is considered as a proportion of the overall compound volume is called Volume Fraction (\(V_f\)) of fibers. Based on several features such as Young’s modulus, density, tensile strength, and aspect ratio of fibers, the kinds of fibers combined in the concrete are selected [6]. In the beginning, fiber reinforced concrete was mainly adopted for pavements and manufacturing floorings nonetheless, the applications of fiber-reinforced concrete (FRC) are widespread nowadays such as bridges, hydraulic structures, tunnels, canal linings, pipes, safety vaults, explosion-resistant structures, cladding, and roller-compacted concrete.

Numerous researchers studied the usage of FRC in building members such as slabs, beams, and columns [7]. The improvement of the concrete in the rigid pavement can be made by using the fibers. These fibers, which are used in concrete, will improve material properties such as flexural strength, ductility, toughness, fatigue strength, and impact resistance. In addition, there is a slight enhancement in compressive strength [5]. The amount of fiber that is added to the concrete mixture is expressed as a ratio of the total volume of the composite (concrete and fiber). This ratio is called the “volume fraction” (\(V_f\)) which typically ranges from 0.1 to 3%. The aspect ratio (\(l/d\)) is determined by dividing the length (l) by diameter (d) of fiber. In the case of non-circular, the cross-section of used fibers is selected to obtain the equivalent diameter in order to find the aspect ratio. When fibers have a modulus of elasticity greater than the matrix (concrete or mortar), it will help to bear the load by improving the material tensile strength [8]. In the case of using fibers in the concrete mixture, they bond the mix and delay the appearance of micro-cracks and proficiently tie these cracks
by producing stress allocation media that postpones their integration and the uneven growth [9]. Figure 1 shows the effect of fiber for bridging the crack. The process from the initiation of the crack to the collapse of the member is usually split into three zones; the first one of microcracks and the progress of macrocracks. The second zone is the bridging zone, and the third zone is the traction-free zone [10]. Based on the fiber ratio that crosses the crack and the bonding of fibers in the mixture, the post-crack load is greater than the cracking-load, which recognized to develop a strain hardening case with spread cracks. Nevertheless, at (1 %) of fiber content, the concrete illustrates strain-softening actions, that the damage restrains right after the first crack is started.

**Figure 1.** Comparison of the stress-crack opening relations for the nonfibrous concrete and fibrous concrete. [10]

### 4. Type of fiber
Fibers are manufactured from different types of materials in many forms and dimensions. The most common materials of fibers are: [11]

1. Steel Fiber
2. Glass Fiber
3. Natural Organic and Mineral Fibers
4. Polypropylene Fiber
5. Carbon Fiber
6. Nylon Fiber

#### 4.1. Steel Fiber
Steel fibers are mostly utilized in recent years to enhance the stiffness and tensile or flexural strength of concrete as illustrated in Figure 2 [12]. Steel fibers that are used to produce fibrous concrete are short lengths with an aspect ratio of about 20 to 100. The aspect ratio is the ratio between length to the diameter of the fiber. The fibers have various cross-sections, and these small size fibers are randomly dispersed in a fresh concrete blend that utilizing ordinary mixing procedures. Steel fibers have relatively high strength and elasticity modulus [13]. There are several types of steel fiber which vary in term of shapes and size as verified in Figure 2. These types of fibers might be straight or deformed in shape.
4.2. Glass Fiber
These are round and straight fibers with diameters of 0.005 to 0.015 mm, alkali resistant, less dense than steel, lightweight but strong. This fiber shows remarkable improvement in durability and acts as a crack arrester and improves its static and dynamic properties [15].

4.3. Synthetic Fibers
Synthetic fibers were employed mainly as a building material for the strengthening of cementitious ingredients in the twentieth-century. As stated in a report prepared by ACI 544 [10] on FRC, these fibers involve nylon, aramid, acrylic, carbon, polyethylene, polyester, and polypropylene. These fibers have tensile strength is high but a low modulus of elasticity. Their addition to concrete to get a better distribution of cracking and reduced crack size. Polypropylene fibers are available in several sizes and forms, and various properties such as hair-like or made of plastic as shown in Figure 3 [16].

5. Hybrid Fiber Reinforced Concrete (HFRC)
Hybridization is recognized as a blend of several kinds of fibers used to enhance or intensify the concrete mixture properties. The hybridization of various sorts of fibers could be vital in minimizing cracks and giving higher concrete performance. Two kinds of fibers or even more than two can be combined to achieve a mixture that produces profits for each type of fiber in this composite. The integration of short fibers plays an important role in the improvement of Concrete’s mechanical properties. It strengthens elastic modulus, regulates the initiation of cracks, and their propagation. That is, there would be an interaction. These interactions can be

![Figure 2. Types of steel fiber [14]](image)

![Figure 3. Photos of fibers: a) steel; b) fibrillated polypropylene; c) carbon](image)
split into three groups, based on the response mechanisms involved as shown in Figure 4 and given in Table 1 [17].

1. The efficiency of hybrids relies on the reaction of fiber components, in which one fiber is stronger and stiffer, while another fiber is more ductile and provides high strain resilience.
2. Hybrids depend on the sizes of fiber, in which one fiber is tiny giving micro-crack control at the early stages of the loading while another one is bigger, to propose a bridging process transversely macro crack.
3. Hybrids rely on the role of fiber, that one fiber delivers strength or roughness in the hardened concrete, while another one gives new mixture characteristics suitable for processing.

![Figure 4. Fiber crack bridging action during loading; (a) SFRC, (b) PPFRC, and (c) Hybrid FRC [18]](image)

### Table 1. Physical/mechanical characteristics of fibers. [19]

| Fiber type                  | Density (g/cm³) | Modulus of elasticity (GPa) | Tensile strength (MPa) | Elongation at break (%) |
|-----------------------------|-----------------|-----------------------------|------------------------|------------------------|
| Polypropylene (PP)          | 0.91            | 1.5-4.2                     | 240-500                | 50-80                  |
| Nylon (PA)                  | 1.14            | 2.5-5.17                    | 750-1000               | 15-30                  |
| Polyacrylonitrile (PAN)     | 1.18            | 2-3                         | 240-1000               | 20-45                  |
| Polyvinyl-alcohol (PVA)     | 1.29-1.3        | 20-42.8                     | 1100-1600              | 6-7                    |
| Steel (ST)                  | 7.84            | 200                         | 500-2000               | 0.5-3.5                |
| Polyethylene (PE)           | 0.92-0.96       | 5-100                       | 80-600                 | 4-100                  |
| Cellulose                   | 1.2             | 10                          | 300-500                | -                      |
| Jute (Ju)                   | 1.34-1.46       | 13-26.5                     | 400-800                | 1.8                    |
| Sisal (Ss)                  | 1.33            | 9-22                        | 600-700                | 2-3                    |

6. Ultra-High-Performance Fiber Concrete (UHPFC)

UHPFC is one of the advances in this century in the field of concrete technology in which this composite material is provided with significant development in strength, ductility, durability, and workability when compared with non-fibrous reinforced concrete. According to Uchida (2006) [20]. According to Uchida (2006), UHPFC can be defined as: “The UHPFC is a type of cementitious composites reinforced by fiber with characteristic values above 150 N/mm² in compressive strength, 5 N/mm² in tensile strength, and 4 N/mm² in first cracking strength. The matrix of this composite is as follows: it should be composed of aggregates, whose
maximum particle sizes are less than 2.5 mm, cement, and pozzolans and the water-cement ratio is less than 0.24. It contains reinforcing fibers of more than 2% by volume, whose tensile strength exceeds 2000 N/mm², ranging 10 to 20 mm in length and 0.1 to 0.25 mm in diameter”

The improved UHPFC characteristics are based on:
- The reduction theory as a consequence, the volume of free water in a concrete matrix contributes to fewer and fewer air voids
- They improved the homogeneity of the concrete matrix by eliminating all the coarse aggregate and replace it with well-graded fine sand and add highly active pozzolanic material such as silica fume.
- The introduction of very high strength ductile steel fibers in the formulation [21].

7. Literature Survey

The impact of various kinds of fibers on the mechanical characteristics of concrete has been studied by several researchers. Some of the studies are shown below.

In 2006, Bentur and Mindess [22] concluded that hybrid steel fibers with a combination of short and long fiber enhanced the toughness and ductility of the concrete. This improvement was because short fibers in the mixture tie the micro-cracks and this resulted in enhancing the flexural or tensile strength of the composite. Meanwhile, the long fibers minimized the propagating of macro cracks and meaningfully improve the toughness and ductility of the pavement. This is as shown in the following Figure 5.

![Figure 5. The advantages of hybrid steel fibers in managing cracks [22]](image)

In 2008, Eswari S. et al [23] studied the ductility performance of HFRC. The parameters of the research involved modulus of rupture service, ultimate loading, service, and eventual deformation, energy ductility, and crack size. The samples were 27 prisms, of 100 ×100×500 mm, were tested to investigate these parameters. The samples were modified with a steel and polyolefin fiber ratio in the range between 0.0% to 2.0%. A comparison was made between the performance of hybrid fibrous concrete and non-fibrous concrete samples.

In 2011, Thanon and Ramli [24] discussed the use of steel fiber (0, 1.0, 1.25, 1.5, 1.75, and 2%) as a percent of volume in concrete. Therefore, the effect of using the hybrid steel and palm fibers as 2 percent of volume on the compressive, flexural strength, stiffness, and density for all mixtures was inspected. The outcomes displayed that the compressive strength was amplified by 13% when adding 1.0 % of steel fibers. Although, using a percentage of palm fiber more than 0.75% as a hybrid fiber mix reduced the concrete strength in compression because the stiffness of palm fibers is being lowered which results in a drop in the compressive strength. Regarding the strength in tension of fiber-reinforced concrete mixtures, it was noticed that it improved with the increase of volume percent of the fiber and the optimal proportion of steel fiber is 1.5 % that delivers higher properties. The usage of 0.25 % of palm fibers provided a higher raise in flexural strength as hybrid fiber mixtures. And the
increase in toughness indicates high strength concrete when the usage of the hybrid fiber of 1.5% steel and 0.5% palm fibers.

In 2012, Patodi SC et al. [25] investigated the influence of using different volume fractions of polyester fibers and curly steel fibers to get HFRC and assess compression, tension, and flexure strength. Specimens were prepared of M20 grade concrete with and without fly ash and by changing the proportion of fibers from 0% to 1% of the volume of concrete. The mechanical characteristics of the mixture with a volume fraction of hybridization that comprises 0.7% of steel and 0.3% of Recron fiber were found to be the best.

In 2012, Empelmann and Oettel [26] examined the impact of using steel fibers with the volume fraction of (1.5 and 2.5 %) in the torsional UHPFRC box girder behavior. They were experimentally tested and it has been observed that the inclusion of steel fibers has contributed to a better performance cracking, such as smaller crack widths and multitudes cracks, higher ultimate and cracking torque, and improved torsional stiffness. Interestingly, this is the angle of the diagonal cracks were found to be approximately 45 for all test series, regardless of the quality of the steel fiber.

Usually, fibers are used as resistance to concrete. In 2013, Rana [27] carried out tests on steel fibrous concrete to explore the impact of steel fiber on the concrete flexural strength and compared it with M25 grade concrete. From thorough laboratory work, it was observed that the rise in steel fiber amount in the mix led to a significant rise in flexural strength. Even at 1% of steel fiber amount provides flexural strength of 6.46 N/mm² that compared with a flexural strength of 5.36 N/mm² at 0% of fiber. Consequently, flexural strength was increased by about 1.1%.

In 2013, Sekar and Ramamoorthy [28] presented a study of improving the concrete tensile properties to a limited level by using a single type of fiber as a reinforcement. Although the hybrid fibers with two or more types in the same mix may produce better benefits, they investigated the impact of hybrid fibers on the ductility of RC beams and made a comparison between solo fiber, hybrid fiber reinforced concrete, and controlled reinforced concrete. Different aspect ratios of hooked end steel fiber; Polyester recron fiber and coir fiber at a percentage of 1 % of fiber content were used. The parametric study included compressive, flexural strength, stiffness, ductility, and ultimate load-carrying capacity. To achieve this, 7 beams and 42 cubes were cast. The experimental outcomes revealed that the addition of fibers decreased strength in compression, although the ductility was larger in concrete reinforced by steel and Hybrid fibers as compared with controlled concrete.

In 2013, Vasudev and Vishnuram [29] made a study on the mechanical properties of steel fibrous concrete. Experimental investigations were showed to evaluate the behavior of both tensile and compressive strengths of concrete mixes with different percentages of fibers. The concrete mixtures were M20 and M30 with variable ratios of fibers starting from 0% to 1% with an increment of 0.25%. Based on the investigation of test outcomes, the concrete modified with steel fibers performed better than the concrete of conventional steel fibers.

In 2013, Mehul and Patel [4] investigated the impact of using different ratios of polypropylene fibers on the high strength concrete properties. The grade of M40 concrete mixture with the amounts of 0.5%, 1%, and 1.5% of polypropylene fibers. Experimental work was carried out by cast concrete specimens and tested at different age levels to find its impact on the tensile or flexural and compressive strength. Also, the fiber impact on plastic shrinkage cracking is considered. The result showed that the flexural, tensile, and shear strength were notably increased.

In 2013, Vihbuti and Aravind [30] studied the hardened properties of concrete pavements after adding single and hybrid fibers in mixtures. The proportion of 1% and 0.036 % of steel and polypropylene fibers respectively. The fibers were implemented separately in the concrete mixture firstly as mono fibers and then in combination to formulate a hybrid fiber-reinforced concrete. A variety of tests for samples were conducted to assess the hardened properties such as compressive, flexural, and split tensile strength. The outcomes displayed that hybrid fibers develop strength in compression slightly larger in comparison with mono fibers. While the flexural and split tensile strength were improved meaningfully as a result of
hybridization. The enhancement in mechanical characteristics of HFRC leads to the decrease in warping stresses, short and long-term cracking, and reduction in the pavement thickness.

In 2013, Thirumurugan and Sivakumar [31] used polypropylene fibers in concrete and studied the workability and mechanical properties. They concluded that the polypropylene fibers decrease the workability of concrete (segregation problems) but it can be overcome by the adding of “high range water reducing Admixtures”. Compressive, split tensile, and flexural strength was increased with the addition of polypropylene fibers.

A study presented by Sinha in (2014) [32] on the pavement made of Portland cement concrete delivers a strong lifespan and has an obvious performance when heavy traffic loading is applied. The main objectives of the Sinha study were:

• Investigate the impact of variability in steel fiber percentage on fiber-reinforced concrete-like features of the pavement's workability, compressive, and flexural strength.

• to calculate the optimal amount of steel fiber added to the mixture for economic construction of pavement compare to normal concrete pavement

The test outcomes revealed that the utilizing of fibers in the concrete mix affects the properties of fresh concrete such as slump value and toughened characteristics such as flexural and compressive strength. The slump value was declined with the rise in the used steel fiber ratio in concrete mixtures. Increase in the compressive strength for mix comprising the addition of 1% steel fibers and then a gradual reduction in the compressive strength for the 2% steel fibers mix. The fibrous concrete is more than normal mixed concrete. Compared to traditional concrete, SFRC is a significant indication of composite material as the pavement thickness is reduced without affecting load-carrying capability and cost-effective technology.

In 2016, Anand and Pammar [33] studied the inclusion of hybrid fibers in conventional concrete. The hybrid fiber used consisted of two various types of fiber such as glass and polypropylene fibers. These fiber proportions of 0%, 0.25%, 0.5%, 0.75%, 1% and 1.25% as a percent of total weight of cement were used. The parameters that were tested are compressive and split tensile strength.

To improve the behavior of concrete, there is a need for both mineral and chemical additives. Hence, in 2016, Kumar et al. [34] used different additives like coconut fiber and fly ash. Because the present way in concrete technology is to raise the durability and strength of concrete to achieve the requirements of modern construction. In that work, an attempt was made to examine the behavior of glass fibrous concrete. Glass fiber has high tensile strength and fire-resistant. The tests have been done for the glass fiber concrete with a percentage of glass fiber 0.5%, 1%, 2%, and 3% of cement by addition to the mixture. The incorporation of these fibers into the concrete will greatly improve the concrete's compressive strength and tensile strength. Under various loading conditions, this fiber reduces the cracks.

In 2016, Mohammed, Bakar and Bunnori [35] revealed the efficacy of using ultra-high-performance fiber reinforced concrete (UHPC) for the strengthening of reinforced concrete (RC) beams under torsion is investigated. The main advantages of the used UHPFC jackets are:

• its high compressive and tensile strength

• its excellent rheological properties have facilitated concrete casting for work-enhancing purposes, and this is of interest to many researchers and practicing engineers.

The research contained experimental results of all specimens of various configuration types and UHPFC thickness. Ten beams were strengthened on two, three, and four sides with only longitudinal reinforcement (i.e. without transverse reinforcement). A single beam is used as a control beam with the same reinforcement ratio but without UHPFC. Furthermore, following the testing work to compare and justify the effect of a repair technique, finite element analysis was performed. The results showed the efficiency of the proposed torque technique for various beam strengthening configurations, crack patterns, and behavioral curves. Strengthened four-sided RC beams have improved torsional behavior and greater capacity with a thin layer of UHPFC compared with the three and two strengthened beams. Generally, for RC beams without stirrups, the UHPFC can be used as an effective external
reinforcement. It was noted that the behavior of the beams strengthens with UHPFC jackets are better than the control beams. The use of UHPFC led to delaying the growth of crack formation. The finite element analysis is a good agreement with the experimental data.

In 2017, Al-Osta et.al [36] investigated the flexural behavior of RC beams retrofitted with UHPFRC. Two different approaches for the strengthening of RC beams by using UHPFRC with various configurations were evaluated in this research. The two techniques are as follows:

- The normal concrete surface was made rough by sandblasting and in situ casting of UHPFRC around beams with different configurations
- The precast UHPFRC plates with traditional RC beams have been connected with an epoxy initially.

The results of the two strengthening methods were found to be of no substantial difference. The technique for the preparation of sandstroke interfaces was however more encouraging. The rigidity and cracking load of strengthened beams were increased, the cracking expansion was delayed and cracks in the middle third part of the beam were concentrated, reflecting an increase in shear strength of the beam.

In 2017, Navilesh et al. [37] made a comparison between mixes with and without fiber based on the newly made and hardened characteristics of concrete. Five mixtures were made, one nonfibrous control mixture and four hybrid fibrous concrete (HFRC) mixes including steel fiber and various percentages of coconut (coir) fiber. The volume of steel fiber was 1% and the volume of coconut fiber was (1%, 3%, 5%, and 7%). A slump test is used to study the fresh properties of the HFRC and a compressive, flexural, and split tensile test is used to study the hardened properties. The test outcomes have been shown that the HFRC specimen gave higher strength than the nonfibrous control specimen.

The construction pavements have high strength, better durability, and have a moderate economy for a long time. In 2018, Jamwal and Singh [38] aimed to design the slab thickness of Pavement Quality Concrete (PQC) using achieved flexural strength of the concrete mixture. Glass fiber has been added to the concrete at various percentages like 0.05%, 0.1%, 0.2%, and 0.4%, and the results were compared with the normal concrete mix. As the fiber content increases, the split tensile and flexural strength will increase. The study showed that the high split tensile and flexural strength values of the concrete lead to enhance the load-carrying capability and produce greater predictable life. The addition of glass fiber to concrete lead to reduce the slab thickness and the least thickness of the pavement slab was found for the addition of 0.4% glass fiber to concrete as shown in figure 6. The study helped in decreasing the cost of the project, by saving the cost of the material without decreasing the strength of concrete. As for the pavement slab, the thickness was also reduced for M4-GF (0.4%) mix by 110 mm in comparison with the control mixture result.

![Figure 6. Saving in slab thickness](image-url)
Table 2. Literature Survey

| Authors name                      | year | study                                                                 | Result                                                                                                                                                                                                 |
|-----------------------------------|------|----------------------------------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Bentur and Mindess                | 2006 | Effect of hybrid steel fibers (short and long fiber) on the          | The results showed an improved toughness and ductility of the pavement because short fibers tie the micro-cracks this resulted in enhancing the flexural strength and the long fibers minimized the propagating of macro cracks. |
|                                   |      | toughness and ductility of the concrete                              |                                                                                                                  |
| Eswari S. et al                   | 2008 | studied the ductility performance of HFRC                             | The fibers enhanced the ductility of HFRC compared with non-fibrous RC                                                                                                                                     |
| Thanon and Ramli                  | 2011 | discussed the use of steel fiber with a different percent of          | The mechanical properties of concrete improved with the increase of volume percent of the fiber and the optimal proportion of steel fiber is 1.5 %. The increase in toughness indicates high strength concrete when the usage of the hybrid fiber of 1.5% steel and 0.5% palm fibers |
|                                   |      | volume in concrete as a hybrid steel and palm fibers on the          |                                                                                                                  |
|                                   |      | mechanical properties of mixture                                      |                                                                                                                  |
| Rana                              | 2013 | explore the effect of steel fiber on the concrete flexural strength   | The rise in steel fiber amount in the mix led to a significant rise in flexural strength. Consequently, flexural strength was increased by about 1.1% compared with M25 grade concrete. |
|                                   |      | and compared it with M25 grade concrete                               |                                                                                                                  |
| Mehul and Patel                   | 2013 | the impact of using different ratios of polypropylene fibers on the   | The result showed that the flexural, tensile, and shear strength were notably increased. The fiber impact on plastic shrinkage cracking is considered |
|                                   |      | high strength concrete properties                                     |                                                                                                                  |
| Sinha                             | 2014 | to calculate the optimal amount of steel fiber added to the mixture   | Compared to traditional concrete, SFRC is a significant indication of composite material as the pavement thickness is reduced without affecting load-carrying capability and cost-effective technology |
|                                   |      | economic construction of pavement compare to normal concrete         |                                                                                                                  |
| Mohammed, Bakar and Bunnori      | 2016 | the flexural behavior of RC beams retrofitted with UHPFRC.            | It is noted that the behavior of the beams strengthens with UHPFC jackets are better than the control beams. The use of UHPFC led to delaying the growth of crack formation. |
|                                   |      |                                                                     |                                                                                                                  |
| Al-Osta et al                     | 2017 | Effect of different percentage of glass fiber to design the slab      | The rigidity and cracking load of strengthened beams were increased, the cracking expansion was delayed and cracks in the middle third part of the beam were concentrated, reflecting an increase in shear strength of the beam |
|                                   |      | thickness of (PQC) using achieved flexural strength of the concrete   |                                                                                                                  |
|                                   |      | mixture                                                              |                                                                                                                  |
| Jamwal and Singh                  | 2018 | Effect of different percentage of glass fiber to design the slab      | The study showed that the high split tensile and flexural strength values of the concrete lead to enhance the load-carrying capability and produce greater predictable life. The addition of glass fiber to concrete lead to reduce the slab thickness |
|                                   |      | thickness of (PQC) using achieved flexural strength of the concrete   |                                                                                                                  |
|                                   |      | mixture                                                              |                                                                                                                  |
A decline was found in the compressive strength when fibers were added to the mix [In 2009 Atics and Karahan,[39], 1997, Eren and Celik [40], 2008, Bencardino et al.[41],2013 Khitab et al.[42]]. In 1997, Eren and Celik [40] suggested that the inclusion of 2% of the volume percentage of 60 mm long and 0.8 mm diameter steel fiber into a high-strength concrete (compressive strength is 56 MPa) at the age of 28 days lowered the concrete's compressive strength by up to 41%. Similarly, In 2013, Hossain et al. [43] showed that there was no effect on the compressive strength of the addition of polyvinyl alcohol (PVA) fiber to the concrete mix. Regularly, the explanation for the decrease in compressive strength is that the fibers spreading, with a high fiber percentage in the concrete, are very difficult and thus contribute to a decrease in workability and incomplete consolidation.

8. Conclusion
The concrete rigid pavement is unsatisfactory in resisting the tensile stress. Therefore, cracks occur simply under the effect of low tensile stresses. The use of various kinds of fibers in reinforced concrete pavements is essential to improve performance-related properties. Fibers are used individually or simultaneously (hybrid) in concrete pavements and are obtainable in a variety of shapes, lengths, sizes, and depths. The main conclusions observed based on previously studied are:

1- It is obvious from past findings that fiber hybridization improves the properties of concrete better than mono fibers.
2- Compared to normal concrete, the incorporation of fibers into the concrete led to an increase in the cost of the structure, but this cost increase is not an actual problem because the use of fibers in a mixture improves the properties of both fresh and hardened concrete.
3- Polymeric fibers such as polyester or polypropylene have proven cost-effective and corrosion-resistant but they gave lower mechanical behavior than steel fibers in concrete.
4- It can be concluded that using hybridization in reinforced concrete pavement allows to reduce the thickness up to 30% by the improvement of compressive and tensile strengths.
5- The process of adding fibers to the concrete mixture has led to an increase in the air voids and air content of the trapped air, causing a decrease in workability, and therefore causing difficulties in compacting mixtures. This defect can be improved by adding superplasticizers.
6- An increase in the mechanical properties of concrete such as compressive strength, split tensile strength and flexural strength was caused by the addition of fibers to the concrete mixes. The compressive strength of normal strength fibrous concrete is comparatively scarcely affected by the presence of fibers compared to the tensile strength.
7- Used of UHPFRC in the repairing and strengthening of RC members led to increases the ultimate load and stiffness, as well as reducing the crack width of the structural member.

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