# Abstract use of fibers in brittle matrix

AbstractThis study deal with reviewing thepast researchers works and collecting information on toughness of different fibrousconcrete from various researches to determine how the different types of fibercan influence concrete toughness. The collecting information from researchesshows that the fiber has great effect on improving toughness of concrete and fractureresistance. Thisincreasing in toughness varies depending upon type of fiber, fiber content%, fiber geometry, aspect ratio and w/c ratio of concrete.  Toughness of fiber reinforced concreteincrease by increasing fiber content% for all fiber types.

Key words: Concrete, Fiber, Fiber reinforced concrete, Toughness 1-1 History of using fiberThe use of fibers in brittle matrix materialshas a long history going back at least 3500 years during building the 57 m high hill of Aqar Qufnear Baghdad in which straw was used with sun-baked bricks as reinforcement. Inmore recent times, asbestos fibers have been used to reinforce cement productsfor about 100 years, cellulose fibers for at least 50 years, and steel, polypropylene and glass fibers have been used for the same purpose for the past30 years 1. First studies transaction with use of steelfibers and glass fibers in concrete date back to the 1950, in the 1960 thefirst studies concerning fiber reinforced concrete using synthetic fibers. 1-2 Introducing Fiber reinforced concreteConcrete is weak in tension and has a brittlecharacter, concrete contains numerous microcracks due to low tensile strengthunder stress. Originally, it was assumed that tensile as well as flexuralstrengths of concrete can be considerably increased by introducing closelyspaced fibers that would prevent the dispersion of microcracks1. Fiber is a small piece of reinforcing material which increases structural

integrity. It contains short discrete fibers that are uniformly distributed and randomlyoriented. The main objectives of using fiber in concrete is modify theproperties of concrete (a) to improve the rheology or plastic crackingcharacteristics of the concrete in the fresh state or up to about 6 hours aftercasting, (b) to improve the tensile or flexural strength, (c) to improve theimpact strength and toughness ( as shown in figure 1-1), (d) to controlcracking and the mode of failure by means of post-cracking ductility, (e) toimprove durability2.

Figure 1-1 Relation between load and deflection 3 Fiber reinforced concrete is a composite material consist of fiberand cement matrix, its property depend upon the efficient transfer of stressbetween matrix and fiber, which is dependent upon (type of fiber, fibercontent%, fiber geometry, aspect ratio, orientation and distribution of fiber, size and shape of aggregate) 4. Important type of fiber used with concrete ispresented below: a-Steel fibers: Straight, crimped, twisted, hooked, ringed, and paddled ends. Diameter ranges from0. 25 to 0. 76mmb-Glass fibers : Straight. Diameterranges from 0.

005 to 0. 015mmc-Natural fibers: Wood, asbestos, cotton, bamboo, coir, hay and rock wool. They come in wide range of sizes. d- Synthetic fiber: Polypropylene fibers (plain, twisted, fibrillated, and with buttonedends), kevlar, nylon, and polyester. Figure 1-2 shows some typeof fiber. Figure 1-2 Typeof fiber1-3 Toughening mechanism· Thegreatest advantage in fiber reinforcement of concrete is the improvement inflexural toughness.

Toughness is defined by the total energy absorbed prior tocomplete separation of the specimen is given by the area under thestress-strain curve. Toughness or energy absorption of concrete is increasedconsiderably by the addition of fibers ( as shown in figure 1-3) .( For FRC, toughness is about 10 to 40 times that of plain concrete 5) . Toughness istotal area under the (stress – strain curve). It can also be defined asresistance to fracture of a material when stressed. Figure 1-3 Stress strain curve of differentconcretes

· Themagnitude of improvement in toughness is strongly influenced by fiberconcentration and resistance of fibers to pull-out, which is influenced byother factors such as shape or surface texture.

The energy absorbed Gcby the fiber pullout is given by 6. Where : Vf = fiber volume fraction Lf = length of fiber df = diameter, respectively, t= interface parameters Theaddition of fiber increases the toughness index of hooked and straight fibersup to 19. 9 and 16. 9, respectively 5. Table1-1 shows results of toughness index for different fibers volume.

Table 1-1 Effect of fiber content on the toughness index Fiber content % Toughness index Hooked fiber Straight fiber 0. 0 1 1 0. 5 11. 4 9.

2 1. 0 18 11. 1 1.

5 19. 9 13. 6 2 16. 7 16. 9 The toughness index is calculated as the area under the load deflectioncurve (Figure 1-4) up to the 1. 9 mm deflection divided by the area up to thefirst crack strength (proportional limit) Figure 1-4 Definition of toughnessindex according to ACI committee 544

· Aspect ratio of fiber has great effect on toughness, aspect ratio is ratio between length and diameter (L/d) of fiber.

Aspect ratio upto 75 increase in relative toughness, aspect ratio beyond 75 decrease inrelative toughness.(as summarized in Table1-2) 4. Table 1-2 effect ofaspect ratio of fiber in relative toughness Type of concrete Aspect ratio Relative toughness Plain concrete 0 1 With 25 2 Randomly 50 8 dispersed fiber 75 10. 5 100 8.

5 2-Objectives of this studyThe mainpurpose of this study is to investigate theinfluence of different types of fiber that mixed with concrete on toughnessproperty of concrete. Available factors affecting the toughness of fiberreinforced concrete studied by the past researchers are discussed. 3-Toughnessof different types of fibrous concrete3-1 Toughness of Steel Fiber reinforced concreteSteel fibers are short, discrete lengths of steel with an aspectratio (ratio of length to diameter) from about 20 to 100. Some steel fibershave hooked ends to improve resistance to pullout from a cement-based matrix. Steel fiber has great effect on increasing toughness of concrete under stress, this increasing varies due to some factors that has effect on toughness ofsteel fiber reinforced concrete (SFRC) including w/c ratio of concrete, steelfiber content %, aspect ratio of steel fiber, shape of steel fiber. Increasingtoughness of SFRC at different condition is presented in the section a) Effect of steel fiber content % on toughnessFigure (3-1), (3-2) and (3-3) shows that further steelfiber content lead to increasing fracture resistance via increasing toughness. Figure 3-1 variationof toughness index with fiber content % 7 Figure3-2 Load-deflection curves for fiber concrete 7 Figure 3-3 . Effects of Steel Fibers Content onCompressive Stress- Strain Curve of FRC 8 b) Effectof water cement ratio on toughness ofSFRC w/cratio in SFRC greatly affect the

amount of energy required toextend a crack, increasing w/c ratio of SFRC cause reducing toughness (as shownin the figure 3-4).

Figure 3-4 Load- deflection curve 9 c) Effect of varioustypes of steel fiber on toughness of SFRC . Figure 3- 5 and table 3-2 shows that the end-deformed fibersF1 and F4 appear to be significantly more effective than fibers F2 and F3 ontoughness (energy absorbed). Table 3-1 Detail of various type of steel fiber in figure (3-5) Figure 3-5Load deflection curve of various type of normal strengthfiber Concrete 10.

Table 3-2 Energy absorbed at 2mmdeflection of F1, F2, F3 and F410 Type of fiber Energy absorbed at 2mm deflection(N-mm) Plain concrete 0. 44 F1 Hooked end(circular) 37. 80 F2 Crimped (circular) 24. 08 F3 Crimped (crescent) 18. 69 F4 Twin code(circular) 32. 79 3-2 Toughness of Glass Fiberreinforced concreteGlass fiber-reinforced concreteconsists of high-strength, alkali-resistant glass fiber embedded in a concrete matrix11. In this form, both fibers and matrix keep their physical and chemicalproperties, while by this mixing concrete can give properties that cannot beachieved with either of the components alone. Glass fiber is available in continuousor chopped length, fiber length up to 35 mm lengths used in spray applicationsand fiber length up to 25 mm lengths used in premix applications.

Concrete with reinforced by glass fibermore tough and better resistance to cracking than plain concrete, by increasingglass fiber content % further fracture energy (toughness ) can obtain13. Figure(3-6) and ( 3-7 )shows that concrete with furthertoughness(resistance to fracture) can obtain by adding

glass fiber, also byincreasing volume of fiber content fracture energy (resistance to fracture) increase. Figure 3-6 Load and crack mouth openingdeflection (CMOD) curve 12.

Figure 3-7 Fracture energy(J/m²) and fiber volume % 12. R= concrete mixture (cement, fly ash, water, coarse aggregate, crushed sandand river sand) without glass fiberGF= concrete mixture(cement, fly ash, water, coarse aggregate, crushed sand, river sand and glass fiber 1% by volume) 3-3 Toughness ofNatural Fiber reinforced concreteNatural organicand mineral fiber has some type like wood, asbestos, cotton, bamboo, coir, hayand rock wool. Natural fibers offer manybenefits for reinforcement (a) Low cost and abundant (b) Renewable (c)Non-hazardous(d) Can improve some characteristics of concrete, inside them toughness of concrete 13. Figure 3-8 shows that adding natural fiber to concrete improvetoughness (area under the curve) of concrete, also the figure tell us that longfibers are more effective than short fibers in increasing toughness. Figure 3-8 Typicalstress-strain curves for natural fiber concrete 14. 3-4 Toughness ofsynthetic Fiber reinforced concrete.

Polypropylene fiber is a synthetic hydrocarbon polymer, Fibers in general and polypropylene fibers particular have gainedpopularity in recent years for use in concrete, mainly to improve shrinkagecracking resistance and toughness of plain concrete. Polypropylene fibers arenot expected to increase the strength of concrete, but to enhance its ductilityand toughness, and impact resistance 15. Figure 3-9 shows that the existenceof polypropylene fiber enhances toughness of concrete. This improvementincrease by increasing fiber content %. The figure also shows

that thetoughness of light weight concrete reinforced with polypropylene fiber isbetter than normal weight reinforced concrete. Figure 3-9 Typical load (crack mouth openingdeflection) curve of different volume of Polypropylenefiber AL-PE(all-light weight Polypropylene fiber reinforced concrete), N-PE (normal weight Polypropylenefiber reinforced concrete) 16 4-Conclusion Fromthe data presented in this study the following conclusion can be drown.

1) All types of Fiber improve the toughness (fractureresistance of concrete)

2) Aspect ratio of fiber (L/D) and fiber content%for all type of fiber reinforced concrete has great effect on toughness ofconcrete. 3) In steel fiber reinforced concrete increasingw/c ratio lead to reducing toughness. 4) Geometrical shape of steel fiber in concretehas influence on toughness. Hookedend (circular) fiber is more effective one among all steel fiber that giveshigh toughness to concrete.