Strength comparison of highly reinforced concrete sheets containing fine fibers

Kaveh Ostad Ali Askari*

Esamaeil Masoomi

Ali Yousefi

* Corresponding author : Kaveh Ostad-Ali-Askari , Email: Kaveh_oaa2001@yahoo.com

Abstract:

Using new structure materials with the capability of increasing stability and reinforcing constructions is very important as one of the best ways for repairing the parts of the reinforced concrete buildings. In order to repair the reinforced concrete buildings harmed by earthquake, or, for performing shake reinforcement of the current reinforced concrete buildings, it is possible to use different ways. There are two ways of using steel and FRP sheets for repairing or strengthening the parts of reinforced concrete.

Each of these two ways has its own advantages and disadvantages. As disadvantages of both ,one can point to the lack of adaptation of these materials with concrete and also disorder in their characteristics and their behavior .It is endeavored here to remove defects of the mentioned ways and to present new ways derived from the researches. Essentially a highly reinforced concrete with glass fibers, aramid or carbonic, has more suitable behavioral adaption, and regarding their bending and shearing strength, it can increase strength of the reinforced concrete alike the exterior steel jacket and FRP ways. It is endeavored here to have an inclusive comparison between the concretes containing the above fibers, in terms of pressed and tensile strength to produce highly reinforced concrete sheets which at the end SFP fibers have better pressed and tensile strength when they are compared to other cases.

Key words: reinforcing – concrete sheet – SFP fibers – steel fibers – glass fibers – aramid fibers

Introduction:

Although it has been a few changes in concrete structure from the beginning, the wide range of its usage indicates the shadowing of its advantages over the other matters. (inexpensiveness , availability ,and having strength).

In order to make equal conditions and to decline the frangibility of the concrete as much as possible, in recent decades, long and thin filaments that are dispersed equally has been used.

In order to strengthen cement matrixes, various fibers as steel, glass, nylon, poly propylene, asbestos, carbon, Kevlar ,and Bilbo have been used. Due to this fact that the function of these fibers in cement matrixes depends on the physical and mechanical characteristics of the used fibers, it is endeavored here to distinguish the positive characteristics of the used fibers in the concrete. These important features are: shape, fiber size, appearance proportion, and stretch and property factor, matrix joint capability, properties among the levels, surface texture, poison factor, tensile factor, flexibility and fiber arrangement in matrix.

In recent years the discussion of repair and stability of current structures has become fashionable among civil engineers. Primary reasons for enhancing stability of the constructions are:

1- To increase stability to enhance strength under the remained loads.

2- To prevent cracking and failure that would cause an unsuitable part.

3- To retrieve load bearing capacity in order to prevent load dominance, earth quake, and other factors that would cause erosion or friction.

Using fibers in order to improve concrete characteristics, has become very common in concrete constructions and ferroconcrete. The major reasons of this widely usage are numerous technical and mechanical advantages in the material of the concrete. The positive effects of the fiber function in the concrete are the following:

1- To increase bending strength
2- To increase shearing strength
3- To increase tensile strength
4- To increase strength against dynamic loads
5- To increase the amount of energy absorption
6- To increase section strength
7- To decrease the amount of contraction, creep and surface erosion

- History of the fibers

In the past, fibers was being used to strengthen brittle and fragile mortars among which the straw because of its availability and inexpensiveness was very popular ,and has been used to strengthen and reinforce straw bricks. Straw mortar is also used in coats to prevent cracking which happens after drying. Nowadays it is still very common in rural areas of Iran.

The usage of straw and goat or horse hair tail has had an old record in Iranian masons, especially in domes, which shows the awareness of those experts who have used it.

Using steel fibers has begun since the middle of this century. But there is no exact date for this common usage. But different people with the help of various methods, as using borings and parts of wire, have recorded the inauguration of this way for themselves.

The widespread usage of the concretes with fibers started in 1960. It has been used for building roads, floor of industrial salons, and the wall of furnaces. The most important fibers that have been used widely are glass fibers began to be used in England and Soviet and simultaneously in U.S.A. This technique is done with spraying the glass fibers and the dense cement paste from two channels at the same time.

- Reinforced concrete with steel fibers

In recent years, numerous researches have been done in order to improve the positive features of the cement with steel fibers and other kinds of fibers. At this time the cement reinforced with SFP fibers is known as one of the newest construction materials in terms of its strength, tensile strength and crushing strength.

The major materials of the fiber reinforced concrete are like the normal concrete and the characteristics of the hardened concrete will be a function of casting the concrete and compacting of the cement paste.

The fiber concrete is a mixture including a concrete framework which consists of cement, water and some fine fibers that are dispersed randomly and in different directions. The presence of SFP fibers improves characteristics of the concrete. In this analysis mesh reinforcement, gauze or thin and long reinforcement (armature) can not be considered as sporadic and outspread fibers in the concrete.

- Advantages of the fiber reinforced concrete

Normal concrete is brittle and frangible, while fiber reinforced concrete has priority over the normal concrete because of its higher strength and its capacity to prevent frangibility. The advantages of normal concrete in comparison with the normal concrete can be summarized as:

1- Good impact strength
2- Good ductility
3- High load bearing capability after being cracked
4- Tensile, bending and cutting strength
5- High resistance

Picture 1- case study

◆ SFP fibers

An appropriate parameter that defines a strand of fiber is the appearance proportion of the length of fiber to the equal diagonal of the fiber. The amount of appearance proportions is 30-150 and 0.25 to 0.6 cm in length. SFP fiber has maximum proportion of 115. SFP fibers with circular cross section are produced also with 0.15 to 0.5 , and 0.25 to 0.9 in width .

Generally the quality of the fiber concrete depends on the fallowing major factors:

1- Proportions of the concrete mixture
2- Geometrical characteristics of SFP fiber
3- The proportion of length to the fiber diagonal
4- Mechanical restrain of fibers and removing roughness of the fiber surface
5- Physical characteristics and the sort of steel fiber

◆ Aramid fibers were introduced in 1970. They are the organic convoluted composition of carbon, hydrogen, oxygen and nitrogen. Low density and high tensile strength in these fibers cause the formation of a strong and tough structure, with half solidity less than of carbon fiber. Aramid fibers were firstly made to replace steel in radial tire and then used for other functions. Bullet proof waist coat is one of the most successful functions of the aramid fiber.

Aramid exists in two structures: right – chain known as Kevlar, and curve – chain known as Nomex.

- Chemical structure of Kevlar:

Aramid fibers exist in different shapes and the same as glass fibers and carbon can be used in the formation of composites.

Aramid fibers have been focused by experts because of their thermo stability, lightness and their great solidity.

Kevlar fibers have been made of long molecular chains of ----------

Strong molecular orientation of chains makes a unique mixture of features that some of them are:

1- High tensile strength and light weight
2- Low elongation in case of being broken
3- Strong solidity
4- Maximum modulus
5- Dimension stability??
6- Maximum rupture strength
7- Minimum thermal contraction
8- Minimum creep
9- Good wear resistance and frictional resistance

After synthesis, aramid polymer is melted in sulfuric acid solution and then becomes fiber.

Fiber diagonal is about some micrometers, and the ultimate morphology is attained with heating in temperature of 150 oC to 550 oC.

Kevlar has different solidity depending on the degree of its molecular order:

Kevlar 29 is used as wire tire and Kevlar 49 as cables under the water.

Kevlar are considered as special magnifiers in space industries.

In recent years, Kevlar 149, a harder kind of kevlar, has been introduced. Kevlar is known because of its function in space industries, their thermal protection and also because of its solidity and ability to absorb energy.

Dissimilar structure of polymer in longitudinal direction would intensify tensile strength of the fibers.

The direct loading is taken by strong chemical bonds of polymer chains. The jaded polymers chains are kept by Vander – walls interaction and hydrogen bonds, that are weaker than chemical bonds, and are separated easier. Therefore, fibers have weaker mechanical characteristics in width. Tensile modulus and Kevlar strength power is approximately comparable with glass fiber. But its density is entirely half less than the glass fiber. So in primary estimation, Kevlar fiber can be a good alternative for glass fiber that is considered to have a lower weight.

◆ Glass fiber

Glass fiber is the most famous amplifier in composite industry, and there are different kinds of it in the market. Some of them are E, S, C, ECR, and AR. Chemical compositions of these fibers are different, and each of them is sufficient for a special application.

Almost 90% of fibers used in engineering composites are glass fibers. Glass fiber has an appropriate stability and strength, and keeps its mechanical characteristics in high temperatures. It has appropriate corrosion and moisture strength and is fairly inexpensive.

The process at fiber glass production can be summarized as the fallowing:

1- Preparation of the raw material: more than half of the raw material is silica sand that forms the major element of each glass fiber. Other elements consist of small amount of other chemical compositions.

2- Batch house: the materials are blended with each other here, and prepared for the furnace. Literally this blended mixture is called Batch.

3- Furnace: furnace temperature is high enough to melt sand and other elements, and to make them as melted glass. The interior part of the furnace is made of some specific bricks that are replaced in specific periods.

4- Bushing part: the melted glass is flown on numerous thermal resistance platinum trays. There are thousands of holes in these trays, which are called bushing.

5- Fiber formation: the flow of melted glass is drawn out of the bushings and would be thinned up to a special diagonal.

Then, they are chilled in water or exposed to the air to from the fiber.

Starching: hair – like fiber is covered with a chemical composition. Starching has two major reasons:

1- Protection of fibers from eroding with each other in the process of working and production.

2- Ensuring viscosity of fibers to resin

Each strand includes some tows and each two indicates the number of fibers that are woven from a bush, for instance it is possible to have 200 fibers. Some strands are called roving. The roving is swung to be used easier. For joint fiber composites, choosing the kind of fiber depends on formation process and the rate of fiber orientation.

The number of filaments of a roving is shown by tex. For example (100mlg – 1 tex) can 600,1200,2400 tex chop the roving and be used to produce chopped strand mat. In this way a binder is used to keep the fibers firmly. Coating the fiber with resin, the mentioned binder controls the wetting out, so the accidental orientation of the fiber would be maintained. Choosing a binder depends on the material application and sustainability of a composite section can be caused by the sort of binder

- material used in the project

By making laboratory samples and the repetition of them with different materials and the design of different mixtures ,we would reach an economic design of mixtures in a way that the sample shows a good tensile and pressed strength and its shapeable capability.

It should be noted that economy is one of the objectives of the project and this kind of stuff is used because of being highly available and its inexpensiveness.

Different samples (for example tensile sample and 5.5.5 cm pressed sample)are made of different design commixtures ,supper thinner with the base of ether poly carboxylate ,and cement type one which are tested by tensile and pressed tests. The other materials that are used in this research are: quartz sand, microcylis ,and metakaolen.

In table 1, the commixture design of concrete without fiber is presented.

Table 1, materials and the amount of their usages in the sample concrete

Cement (kg)	Quartz sand(kg)	Microcylis	Metacaloein(kg)	Water(lit)	Super lubricant(lit)
۱۰۰۰	۸۹۰	۱۱۰	۱۱۰	۲۵۰	۸.۵

In order to make these samples, firstly, 50% water, super lubricant, sand, and gravel are blended together for three minutes. Next, there is a break for 2 minutes, after that for two minutes the remaining water and super lubricant would be added to the concrete. The sample would be taken out of the cast after one day, and will be kept in 45_ centigrade_ water for three days. After that, the samples were put in the temperature of 28 degrees of laboratory for 25 days. Finally, at the end of this period they were broken by a special machine.

- The results of pressed samples

With this assumption that the fiber reinforced samples have maximums strength and the machine is capable of breaking them, pressed samples in 5.5.5 cm scale are selected. Here the results of tests of the pressed samples are presented in detail in the tables, and the related diagram in each section is drawn.

Sample without fiber is only made for a comparison of pressed strength between the fiber reinforced sample and the sample without fiber.

Picture two shows the produced samples. As it appears in the picture, the samples are broken conically, which is an ideal breaking of concretes.

Picture 2-broken samples without fiber addition.

Table 2- pressed strength of samples without fiber

Sample size(cm)	sample	Weight(g)	Pressed strength(Mpa)	sample	Weight(g)	Pressed strength(Mpa)
۵× ۵×۵	۱	۳۰۸	۱۰۱	۳	۳۰۴	۹۸
۵×۵×۵	۲	۳۰۵	۱۰۴	۴	۳۰۷	۱۰۳

After making the samples without fibers, the next stage is for making samples containing steel, glass , aramid , and SFP fibers. The mortar of these concretes are produced as it was explained. Moreover; the mentioned fibers are added separately to the mortars of different samples.

fiber is thrown on a sieve and moved slowly on the mortar to be added equally to the mortar. Tables 3, 4 , and5 present the results of fiber reinforced samples.

Table 3- the results of pressed samples with SFP fibers

Sample size(cm)	sample	Weight(g)	Pressed strength(Mpa)	sample	Weight(g)	Pressed strength(Mpa)
۵×۵×۵	۱	۳۷۰	۲۵۰	۳	۳۶۵	۲۴۲/۲
۵×۵×۵	۲	۳۶۹	۲۵۳۶/	۴	۳۶۸	۲۴۸/۶

Table 4- the results of pressed samples with aramid fibers

Sample size(cm)	sample	Weight(g)	Pressed strength(mpa)	sample	Weight(g)	Pressed strength(mpa)
۵×۵×۵	۱	۳۴۸	۱۱۷.۶	۳	۳۵۰	۱۲۵
۵×۵×۵	۲	۳۴۷	۱۲۳.۴	۴	۳۵۱	۱۲۴.۳

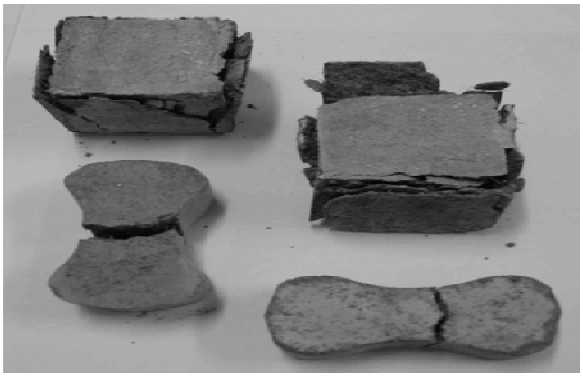
Table 5- the result of pressed sample with glass fibers

Sample size(cm)	sample	Weight(g)	Pressed strength(Mpa)	sample	Weight(g)	Pressed strength(Mpa)
۵×۵×۵	۱	۳۴۲	۱۵۴	۳	۳۴۴	۱۵۸/۷
۵×۵×۵	۲	۳۴۶	۱۵۹/۶	۴	۳۴۶	۱۴۲/۶

In picture 4,5,6, and 7 the samples containing these three fibers(SFP, glass, and aramid) are shown. Being broken, the samples, because of having fibers, are crushed.

Pictures 3 and 4- the broken samples with SFP fibers

Picture 5- the broken samples with glass fibers



Picture 7- the broken samples without fiber

Picture 6- the broken samples without aramid fiber

Table 7- the results of tensile samples containing SFP fiber

Size sample	sample	Weight()	tensile strength(kg)	sample	Weight(g)	tensile strength(kg)
BOW TIE SAMPLE	۱	۱۲۰	۱۷۳	۳	۱۲۱	۱۵۴
BOW TIE SAMPLE	۲	۱۱۲	۱۳۸	۴	۱۱۹	۱۸۲

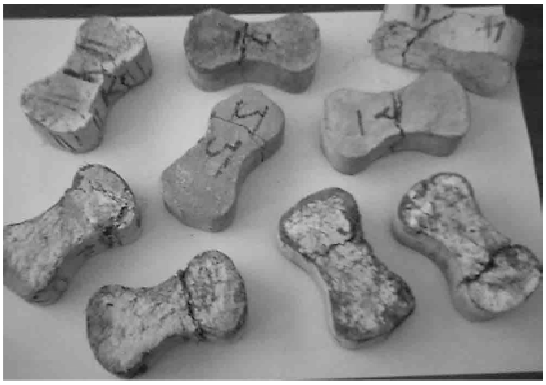
Finally, after making 5.5.5 cm pressed samples, it is found out that microcilious, fiber, super lubricant and Metacaloein can be effective in increasing the strength of the samples. Below the load bearing increase diagram of them can be seen.

The diagram of a load bearing curve of different samples with different fibers

- Tensile or bow tie samples

In order to save time and cost, it is endeavored to make tensile sample for the commixture designs that have already had acceptable records in their pressed samples. However, it has been worked on some other design blends for tensile samples.

As it is revealed from the pressed section samples, fiber kind microcilious ,and metakaolen are very influential in strength of the samples. Regarding this fact, the result tests on tensile samples are shown in tables 6,7,8 and 9.



Picture 8- the broken sample containing fibers

Table 6- the result of tensile samples without fiber

Size sample	sample	Weight	tensile strength(kg)	sample	Weight(g)	tensile strength(kg)
BOW TIE SAMPLE	۱	۱۳۵	۱۴۳۷	۳	۱۳۷	۱۳۲۸
BOW TIE SAMPLE	۲	۱۴۳	۱۵۲۵	۴	۱۳۳	۱۴۱۹

Table 8- the result of tensile samples containing glass fiber

Size sample	sample	Weight	tensile strength(kg)	sample	Weight(g)	tensile strength(kg)
BOW TIE SAMPLE	۱	۱۲۸	۷۷۶	۳	۱۳۲	۸۲۲
BOW TIE SAMPLE	۲	۱۲۹	۷۴۰	۴	۱۳۱	۷۹۳

Table 9- the result of tensile sample containing armid fiber

Size sample	sample	Weight	tensile strength(kg)	sample	Weight(g)	tensile strength(kg)
BOW TIE SAMPLE	۱	۱۳۵	۱۱۱۲	۳	۱۳۳	۱۲۳۱
TIE BOW SAMPLE	۲	۱۳۹	۹۹۸	۴	۱۳۶	۱۱۷۶

As it appears in picture 6, the samples without fibers because of their low volume and tensile strength are broken from the middle. But in image 7, the samples with fibers are broken from the part of jack's jaw.

- Conclusion:

1- Reinforced concrete can be made by easy ways and accessible materials.

2- According to the results, using fibers and pozzolan increase physical parameters (pressed and tensile strength) of the concrete.

3- With increase of pressed strength, bending and tensile strength will increase.

4- Regarding the comparison between the used fibers this result can be attained that using steel fibers is better in terms of strength and also more economic.

5- Because of hardship of performing FRP sheets, in all over the world HPFRCC sheets reinforced with SFP fibers are used, that are more economical. Below, the increase load bearing diagram of them can be seen.

❖ Diagram, bearing curves of different samples with different fibers.

Sources:

[1] Strength comparison of fiber reinforced concrete sheets with high strength

[2]AKBAR HAJIPOUR,PROF.MAHMOD REZA MAHERY ,MEHRAD ARAM, PRODUCING HIGH STRENGTH CONCRETE PLATES REINFORCED TO STEEL FIBERS TO PROTECT REINFORCED CONCRETE CONSTRUCTION.

[3] BURAK FELEKOG˘LU *, SELC¸UK TU RKEL, YIG˘IT ALTUNTAS,EFFECTS OF STEEL FIBER REINFORCEMENT ON SURFACE WEAR RESISTANCE OF SELF-COMPACTING REPAIR MORTARS, DEPARTMENT OF CIVIL ENGINEERING, DOKUZ EYLU¨ L UNIVERSITY, 35160 IZMIR, TURKEY2007.

[4] OSMAN U¨NALA, FUAT DEMIRB, TAYFUN UYGUNOG˘LUA,FUZZY LOGIC APPROACH TO PREDICT STRESS–STRAIN CURVES OF FIBER-REINFORCED CONCRETES IN COMPRESSION ,BUILDING AND ENVIRONMENT ,OCTOBER 2006

[6] CONCRETE TECHNOLOGY ,A.M. NEVILLE & J.J. BROOKS

[7] PULLOUT BEHAVIOUR OF FIBERS IN STEEL FIBER REINFORCED CONCRETE , BERND WEILER, CHRISTIAN GROSSE 2008

[8]DUCTILE DOUBLE-LAP JOINTS FROM BRITTLE GFRP LAMINATES AND DUCTILE ADHESIVES, PART II: NUMERICAL INVESTIGATION AND JOINT STRENGTH PREDICTION, JULIA DE CASTRO, THOMAS KELLER, COMPOSITES: PART B 39 (2008) 282–291

[9] THE STATIC BEHAVIOR OF A MODULAR FOAM-FILLED AFRP BRIDGE DECK WITH A STRONG WEB-FLANGE JOINT , GOANGSEUP ZI, BYEONG MIN KIM, YOON KOOG HWANG, YOUNG HO LEE C , COMPOSITE STRUCTURES 85 (2008) 155–163