# RE-USE OF POLYPROPYLENE FIBER MIXED RECYCLE AGGREGATES IN CONCRETE

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**Abstract**

This research analyses recycle of polypropylene fiber admixed concretes. Study aims to research reuse of fiber admixed recycled aggregates in concrete. In this research eight types of polypropylene fiber are used. Polypropylene fibers added to the mixture in three different ratios. The quantity of cement in the mixture is 300 kg/m$^{3.}$ Water-cement ratio is 0,52. For experiments, cylinder concrete molds with 150 mm diameter and 300 mm height were used. Samples were broken by jawbreaker at the end of 120 days. As a result of the break, recycled fiber aggregates were obtained with 0-4 mm, 7-15 mm and 16-22.4 mm sizes. Recycled aggregates' specific weight and unit weight were calculated. Values of specific weight and unit weight were decreased. By using fiber-reinforced recycled aggregates a new concrete mixture was made. To the new mixture, recycled aggregates with sizes of 7-15 mm and 16-22.4 mm were added. As fine aggregate, 0-4 mm natural sand is used. Ratio of cement in the new mixture is 350 kg/m$^3$ Ratio of water-cement is 0,56. Compression strength of the obtained concrete is analyzed for 28 days. Compression strengths of fiber admixture concrete and fiber admixture recycled aggregated concrete are compared. Compression strength is decreased by 22.59 % in some mixtures and increased by 11,14 % in some others. It is concluded that by changing water-cement ratio and quantity of chemical admixture, it is possible increase the compression strength. Therefore it is possible to use polypropylene fiber concretes in recycling.

***Keywords:*** Polypropylene fiber, recycled aggregate, specific-unit weight, compressive strength.

## 1. Introduction

Taking aggregates continuously from earth result in ecological imbalance [1-4]. Construction sector is the consumer of resource and producer of waste [5,6]. Construction wastes are more of used as filling material [7,8]. Concrete wastes comprise the half of construction wastes [9,10]. Usage of concrete wastes in structural concretes is significant in terms of environment [11]. After 1999 earthquake in Turkey, approximately about 2 million waste concrete revealed only in Adapazarı. It is stated that the value of waste concrete is 5,5 million dollars [12]. The studies on use of concrete wastes in fresh concrete as aggregate have increased [13,14]. The most negative effect of usage on structural concrete is the adherent mortar on aggregate [15]. Grading of recycle aggregate within concrete is a pretty substantial factor [16]. Water absorption value of recycled aggregates is high [1,6,16-19]. Recycled aggregate and rubber pieces are also used in green concrete production [20]. The cement is mineral added in a certain rate with the aim of improving the performance of the concrete produced by using recycled aggregate [21,22]. The way of re-use construction and destruction wastes without giving harm to environment is to turn those wastes into aggregate.

Recycled aggregates are mostly used in foundations of the buildings, coatings and soil stabilization [23]. The importance of use of super plasticizing in the concrete produced with recycled coarse

aggregate acquired from precast concrete wastes is expressed [24]. Use of fiber additives in concrete to improve the weak points of concrete has been increasing day by day. The effects of fibers on concrete vary as per the type, kind, form, and dimension of the fiber and as per the features of the other materials forming concrete [25]. Recycle of fiber admixed concretes have a significant place in terms of environmental pollution. This study aims at reuse of recycled aggregates acquired from polypropylene fiber admixed concretes having different types and features, in concretes.

## 2. Test Programs

### 2.1. Materials and Specimens

In the experimental study, fiber admixed and fiber additive-free resource concretes are generated primarily. Eight kinds of polypropylene fiber are used in in fiber admixed concrete designs (Figure 1). Technical features of polypropylene fibers are given in Table 1. Each fiber kinds are added in Resource concrete design at three different rates. The rates of fiber are 600-1200 and 1800 g/m$^3$. Broken stones aggregates used in resource concrete production are shown with N, aggregates made of fiber additive-free resource concrete are shown with CN, the aggregates and concretes made of polypropylene fiber resource concrete are shown with A,B,C,D,E,F,G,H. For instance, A6 shows that admixed with A fiber, 600 g/m$^3$, B12 shows that B fiber, 1200 g/m$^3$, C18 shows that admixed with C fiber, 1800 g/m$^3$. Broken stone aggregates at 0-4mm, 7-15mm and 16-22,4mm sizes are used in resource concrete. Type of cement in all admixtures is CEM I 42.5 R. Water-cement rate in Resource concrete admixture is fixed. Hyper plasticizer additive is used to preserve the liquidity of fresh concrete. The more the rate of fiber in admixtures is increased, the more the rate of plasticizer is increased. Plasticizer additive rate is determined with trial mixes to provide fresh concrete's fall down and dropping below a certain value and not to unmix. 25 series resource concrete as fiber admixed and additive-free are used. Specimen size of Resource concrete is 150 mm diameter and 300 mm length. Resource concrete admixture rates are given in Table 2.

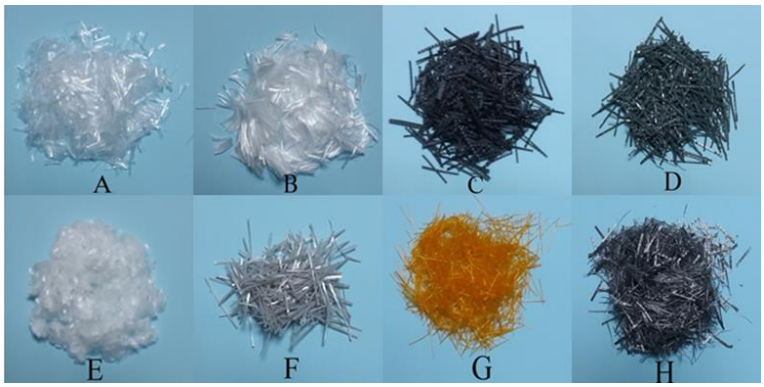



Fig. 1: Polypropylene fibers

### 2.2. Crushing resource concrete and features of recycle aggregate

Resource concretes are crushed in jaw breaker in the end of 120 days (Figure 2). Breaking is carried out according to the dimensions of aggregates used in Resource concrete production. Recycled aggregates at 0-4mm, 7-15mm and 16-22,4mm sizes are acquired as a result of crushing (Figure 3).



Fig 2. Jaw breaker

Table 1. Characteristics of Polypropylene Fibres

| Fiber | Tensile Strength (MPa) | Unit Weight ($g/cm^3$) | Fusing Point (˚C) | Elasticity Module (MPa) | Water Absorption (%) |
|---|---|---|---|---|---|
| **A** | 450-600 | 0.91 | 160-590 | 3500 | 0.01/0.02 |
| **B** | 400-500 | 0.91 | 160-590 | 3500 | 0.01/0.02 |
| **C** | 400-800 | 1.36 | 253 | 11300 | 0.04 |
| **D** | 400-800 | 1.36 | 253 | 11300 | 0.04 |
| **E** | 600-700 | 0.91 | 150-160 | 3500 | 0.01/0.02 |
| **F** | 620 | 0.90 | 160-590 | 9500 | - |
| **G** | 400-800 | 1.36 | 250 | 11237 | 0.4 |
| **H** | 600 | 0.90 | 230 | 3800 | 0.01/0.02 |
| | | | | | |
| **Fiber** | **Length (mm)** | **Width (mm)** | **Thickness (mm)** | **Fragility** | **Shape** |
| **A** | 12 | 0.48 | 0.30 | 25 | Circular |
| **B** | 19 | 0.48 | 0.30 | 37.5 | Circular |
| **C** | 30 | 1.20 | 0.30 | 100 | Ribbed |
| **D** | 30 | 1.20 | 0.45 | 25 | Clip Hook |
| **E** | 30 | 0.48 | 0.30 | 62.5 | Circular |
| **F** | 40 | 0.433 | 0.433 | 0.92 | Straight |
| **G** | 18 | 0.3 | 0.50 | 36 | Circular |
| **H** | 20 | 0.6/1.3 | 0.18/0.22 | 33/46 | Straight |

Table 2. Ratios and amounts of materials used within the source concretes.

| **Ingredients** | | **CNL** | **Mixtures with Fibre, $g/m^3$** | | |
|---|---|---|---|---|---|
| | | | **600** | **1200** | **1800** |
| Sand (0-4 mm) | ($kg/m^3$) | 1127 | 1127 | 1127 | 1127 |
| Crushed Stone (7-15 mm) | ($kg/m^3$) | 451 | 451 | 451 | 451 |
| Crushed Stone (16-22,4 mm) | ($kg/m^3$) | 301 | 301 | 301 | 301 |
| Water | ($kg/m^3$) | 156 | 156 | 156 | 156 |
| Cement | ($kg/m^3$) | 300 | 300 | 300 | 300 |
| Polypropylene Fiber | $g/m^3$ | - | 600 | 1200 | 1800 |
| Admixture | % | 0,6 | 0,8 | 0,9 | 1,1 |
| **Water-cement ratio** | **W/C** | **0.52** | **0,52** | **0,52** | **0,52** |
| **Unit weight** | **($kg/m^3$)** | **2335** | **2335** | **2335** | **2335** |

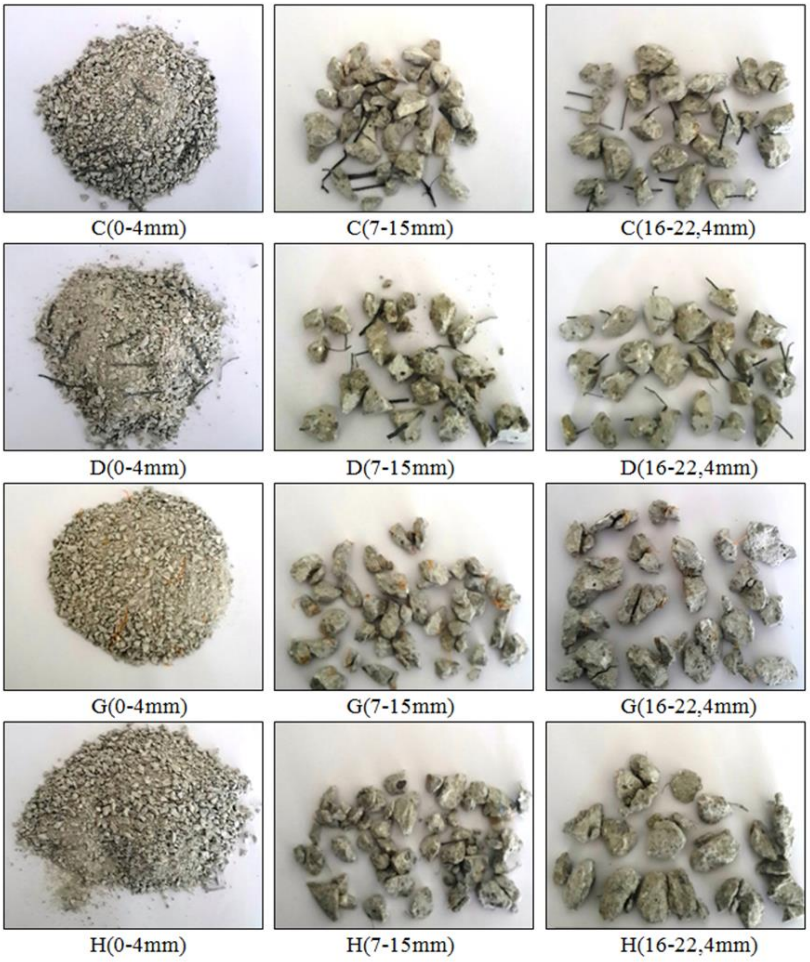



Fig 3. Recycling aggregates

## 3. Aggregate Tests and Findings

### 3.1. Specific weight

Specific weight tests of recycled aggregates obtained as a result of breaking of Resource concrete are conducted according to EN 1097-6 standards (Figure 4-5-6). While specific weight of fine aggregate used in production of Resource concrete is 2.66, specific weight of fiber additive-free recycled aggregate is 2.44. Specific weight values of fiber admixed recycle fine aggregates change between 2.21 and 2.50. In general, it can be said that the more the rate of fiber in the admixture increase, the more specific weight value of recycle fine aggregates decrease (Figure l 4). Specific weight of coarse aggregate used in the production of Resource concrete is 2.94, while specific weight of fiber additive-free recycle coarse is decreased to 2.50. Specific weight of fiber admixed recycle coarse aggregates vary between 2.43 and 2.53. Increasing the fiber rate in the admixtures does not influence the specific weight value of coarse aggregate. It is only decreased compared to specific weight value of normal aggregate used in resource concrete (Figure 5-6).

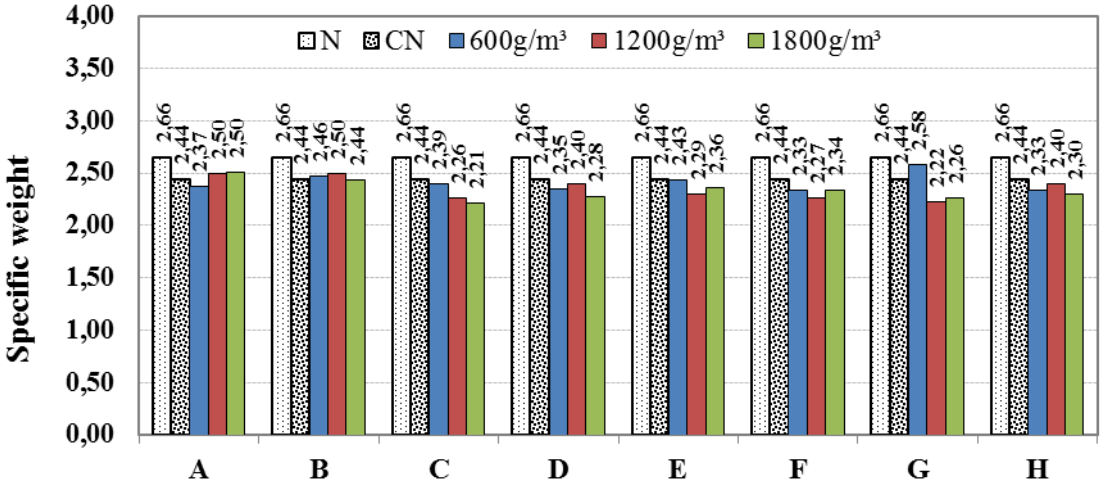



Fig 4. Specific weight (0-4mm)

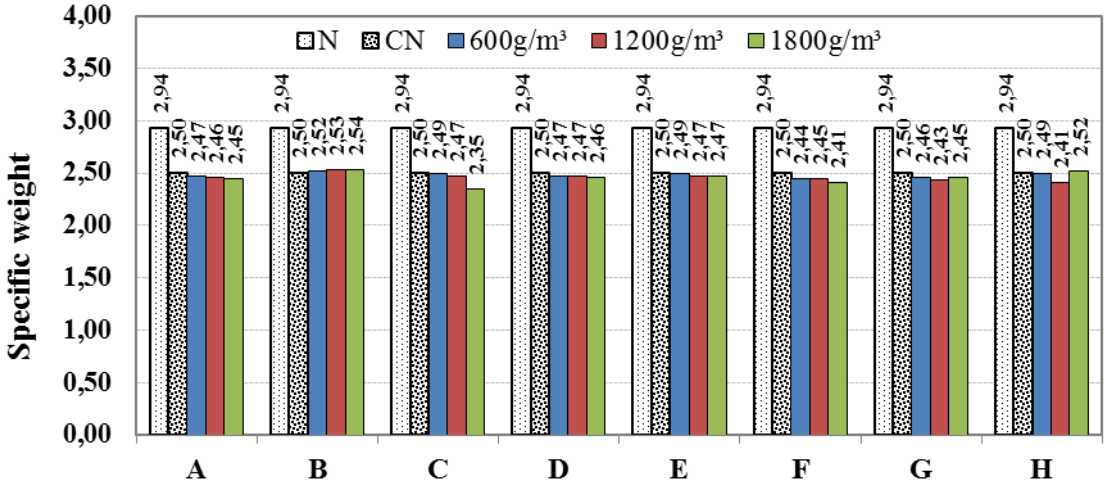



Fig 5. Specific weight (7-15mm)

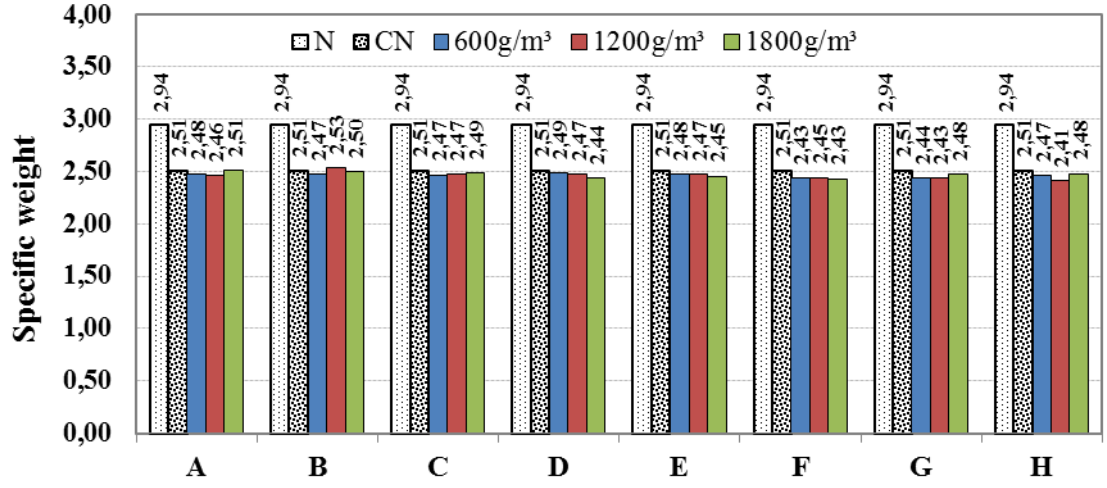



Fig 6. Specific weight (16-22,4mm)

### 3.2. Loose unit weight

Loose unit weight tests are carried out according to EN 1097-3 standard (Figure 7-8-9). While loose unit weight of fine aggregate used in Resource concrete is 1.65, unit weight value of fine aggregates obtained from fiber additive-free concrete is 1.57. Unit weights of fine aggregates acquired from fiber admixed concretes change between 1.52 and 1.57. Loose unit weights of recycled coarse aggregates vary between 1.37 and 1.49. There is not much change in unit weight of recycled coarse aggregates. The more the size of particles of aggregates increase, loose unit weight values decrease. This case can be explained with fibers' holding aggregates together serving as bridge. The gaps between aggregates, being connected to one another through fibers cause decrease in the value of unit weight (Figure 8-9).

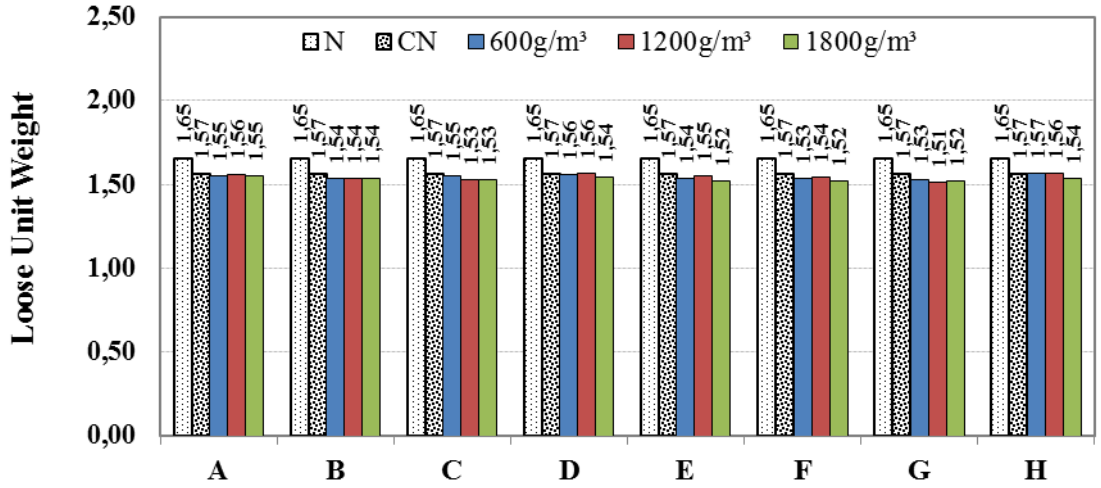



Fig 7. Loose unit weight (0-4mm)

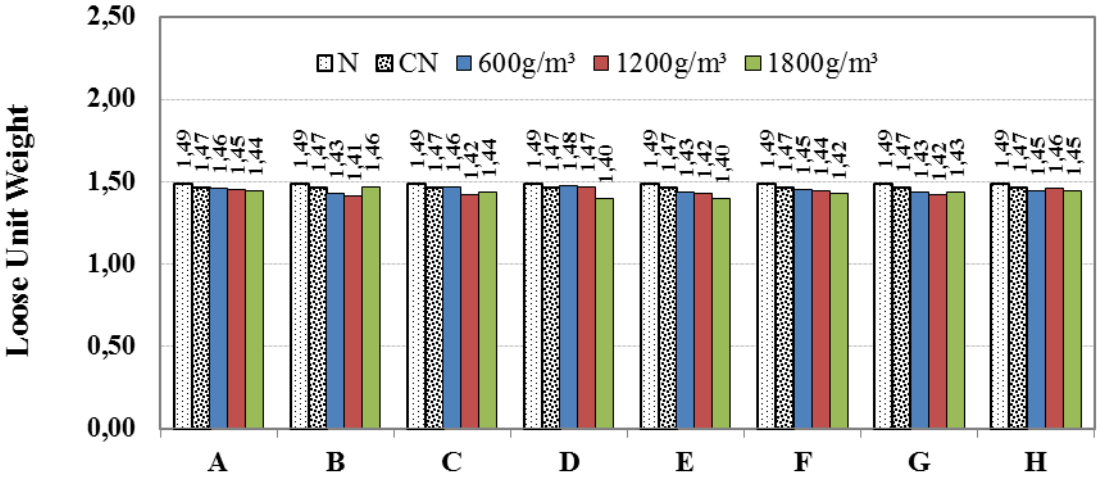



Fig 8. Loose unit weight (7-15mm)

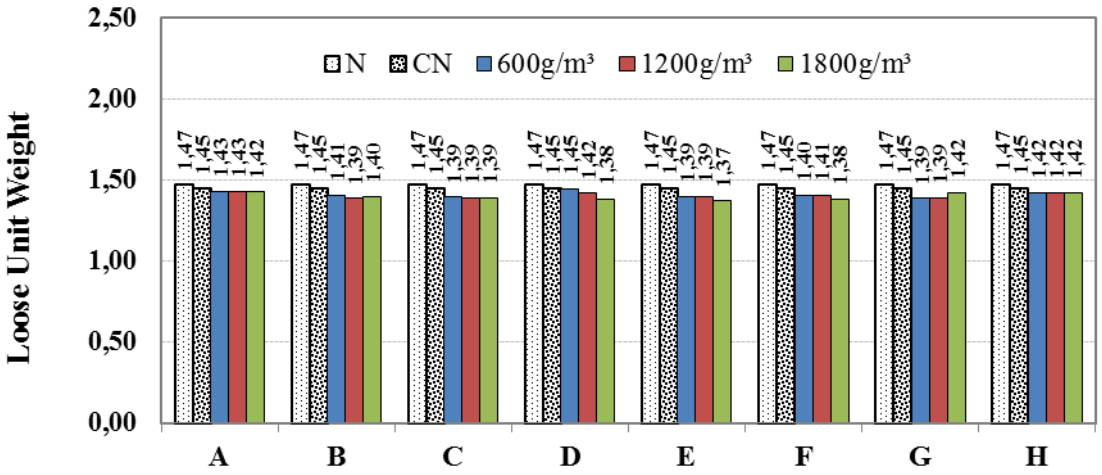



Fig 9. Loose unit weight (16-22.4mm)

## 4. Reuse of recycled aggregates in concrete

First of all trial mixes are done for re-use of recycled aggregates acquired from resource concrete in concrete. In the trial mixes done, it is observed that usage of all of fine aggregates (0-4mm) obtained from recycle in concrete as fine aggregate negatively affects the characteristics of fresh concrete. Especially, it causes segregation of fresh concrete. The reason for that is the amount of fine materials within fine aggregates obtained from recycle is inadequate. Therefore, 0-2 mm natural sand, at the amount of half of total fine aggregate, is used. 7-15 mm and 16-22.4 mm recycled aggregates are added to new admixture as coarse aggregate. The amount of aggregate in 1 $m^3$ concrete is 1794 $kg/m^3$. 68,5% of total aggregate in concrete is comprised of recycled aggregate. As three different rates (600-1200 and 1800 $g/m^3$) of each fiber are used in resource concrete designs, three different recycled aggregate are obtained from each kind of fiber. Aggregates acquired from each fiber kinds are mixed and used in the new admixture. For example, 600-1200 obtained from A-fiber admixture and 1800 $g/m^3$ fiber admixed recycled aggregates are mixed in itself. Admixture rates of concrete with recycle aggregate are given in Table 3. Recycle concrete with fiber additive-free aggregate is shown with RC, and recycle concrete with polypropylene fiber admixed aggregate is shown with PRC. A,B,C,D,E,F,G and H show fiber admixed resource concretes.

Table 3. Admixture rates of concrete with recycle aggregate

| **Ingredients** | | **RC** | **PRC, $g/m^3$** |
|---|---|---|---|
| Sand (0-2 mm) | ($kg/m^3$) | 565 | 565 |
| Recycling aggregates (0-4 mm) | ($kg/m^3$) | 565 | 565 |
| Recycling aggregates (7-15 mm) | ($kg/m^3$) | 410 | 410 |
| Recycling aggregates (16-22,4 mm) | ($kg/m^3$) | 254 | 254 |
| Water | ($kg/m^3$) | 196 | 196 |
| Cement | ($kg/m^3$) | 350 | 350 |
| Polypropylene Fiber | $g/m^3$ | - | 600+1200+1800 |
| Admixture | % | 0,5 | 0,5 |
| **Water-cement ratio** | **W/C** | **0.56** | **0,56** |
| **Unit weight** | **($kg/m^3$)** | **2340** | **2340** |

## 5. Compressive strength and findings

The concrete obtained by reuse of recycled aggregates acquired from fiber admixed and fiber additive-free concretes in concrete is analyzed in terms of 28 days compressive strength. Compressive strength of resource concretes and of fiber admixed and fiber additive-free recycle aggregated concretes are compared. Cylinder specimens of 15x30cm are used for compressive strength. Compressive strength of fiber additive-free resource concrete is 41.58 MPa. Trial studies are carried out for RC concrete's ensuring compressive strength of resource concrete. When the amount of cement is increased as 50 kg in the studies, resource concrete compressive strength is provided. Compressive strength of RC concrete is 41,65 MPa. While the amount of cement in resource concrete is 300 kg/m$^3$, the amount of cement in recycle concretes is 350 kg/m$^3$. Compressive strength of concrete with recycle aggregate obtained from fiber admixed concretes changes between 32 MPa and 46 MPa. Compressive strength of concrete with D,E and H fiber additive recycle aggregate has increased compared to compressive strength of fiber additive-free concrete. And it has decreased in other admixtures. The highest compressive strength has increased about 11% in D fiber admixture (46.29 MPa) compared to fiber additive-free concrete. The lowest compressive strength are B and G fiber admixtures. Compressive strength has decreased in B and G fiber admixtures about 22% compared to fiber additive-free admixtures (Fig 10). Compressive strength of recycle aggregate concrete acquired from C and E fiber admixtures is close to the values of compressive strength of resource concrete.

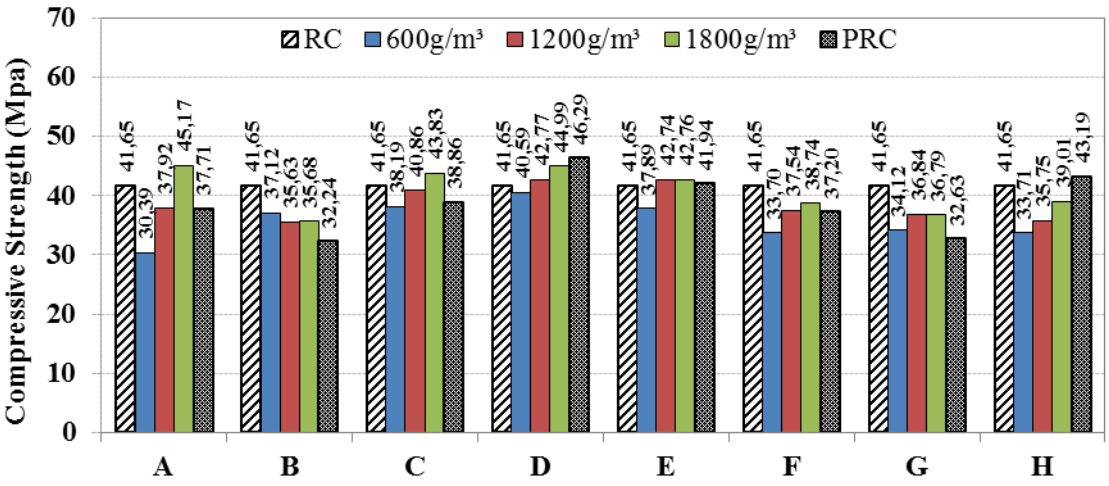



Fig 10. Cylinder compressive strength (28 days)

## 6. CONCLUSIONS

It is observed that some fibers are broken and some are easily eluded from the mortar during crushing. Especially, hooked fibers and ribbed fibers decrease the disintegration during crushing by serving as bridge between aggregates and mortar. When the lump size of aggregates gets bigger, loose unit weight values decrease. This case can be explained with fibers' holding aggregates together serving as bridge. The gaps between aggregates, being connected to one another through fibers cause decrease in the value of unit weight. Loose unit weights of recycled coarse aggregates are close to one another in all admixtures. Unit weight of fiber additive-free fine aggregate has decreased about 5% of unit weight of normal fine aggregate. Unit weight of fiber admixed fine aggregates has decreased at about 8% of unit weight of normal fine aggregate.

Specific weight values of fiber admixed and fiber additive-free recycled aggregates are under specific weight value of normal aggregate. Specific weight value of recycled fine aggregate is 8% lower than specific weight value of normal fine aggregate. Specific weight value of fiber admixed recycled fine aggregate has decreased as 17% of specific weight value of normal fine aggregate. Specific weight values in all of A12, A18, G6 and B fibers measured higher than specific weight value of fiber additive-free aggregates. It is known that polypropylene fiber additives in concrete reduce the compressive strength of concrete in general sense. The reason for that is fibers cause undesired gaps within concrete. The amount of fine material in fine aggregate during the breaking of resource concretes is not adequate. It is required that natural sand (0-2mm) at the rate of 31,5% and amount of cement shall be increased at 50 kg as aggregate to provide compressive strength of resource concrete. In D-fiber admixture, compressive strength has increased at 11% by resource concrete. In E and H fiber admixtures, the compressive strength has increased too few compared to resource concrete. The compressive strength in other fiber admixtures has decreased compared to resource concrete. The lowest compressive strength is in B and G fiber admixtures and compressive strength decreased at 22% compared to resource concrete.

It is concluded that the compressive strength in the beginning can be exceeded by changing the rate of water-cement in the admixtures, admixture rates and the amount of chemical additives. As separation of fibers from concrete completely will require energy, use of polypropylene fiber concretes in recycle can be provided. Our experimental studies on these issues continue.

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