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Influence of Synthetic fiber on Abrasion resistance on Concrete Pavements

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Abstract: Abrasion resistance of the pavement concrete is one of the parameters to measure its durability. It is a surface wear that causes progressive loss of material from surface. Pavement concrete surface are subjected to wear by scrapping or by the sliding action of vehicles. Vehicle movements result in wearing and abrasion on the surface layer of road structures due to the friction between the road surface and vehicle tire. When concrete is used in road construction as a bearing surface or overlays, then it is subjected to abrasive force which causes texture loss, surface deterioration and also affect in functional performance of the pavement which makes abrasion resistance of concrete is of a great significance. Many studies of fiber reinforced concrete presented contradictory effects of fiber on abrasion resistance. This study focuses on determining the effects of Synthetic fiber on the abrasion resistance of different grades concrete. Three grades of concrete (M30, M40 &M60) containing synthetic fiber at optimized dosages. Abrasion resistance is determined by two methods: horizontal slab method and sand blasting method. To develop correlation among rebound number, abrasion and compressive strength; rebound hammer test is also performed.

The results reveal that abrasion resistance of concrete increase by the addition of the fiber in pavement concrete. Appropriate relationship is developed among the parameter's compressive strength, rebound number, abrasion depth and mass loss.

***Index Terms* – Abrasion resistance, Synthetic Fiber, Rebound Number, Compressive Strength**

1. Introduction

Concrete has been used to build some of the longest-lasting highways, airports, roadways, and other pavements in the world. Across the U.S., there are concrete highways and roadsthat were designed to last 20 years, but have lasted 30, 40, or 50 years, or even longer. Many of these pavements are carrying significantly more traffic, including larger trucks carrying heavier loads, than formerly intended. Concrete pavements have many advantages overasphalt pavements. Abrasion resistance can be defined as the ability of a surface to resist being worn away by rubbing or friction (Scott and Safiuddin, 2015).Abrasion resistance is particularly dependent on good curing but also relies upon other factors including materials and surface finishing, aggregate hardness, mix proportions, aggregate/paste bond, and placing and compaction. It has been reported that concrete is weaker in abrasion which plays a vital role in service life of pavement. Wear phenomena occurs between the pavement and moving vehicles by rubbing or by the sliding action due to the friction between the wheels and the pavement surface, mainly influencing the skidding properties of the pavement and its resistance to traffic loads in a specific traffic situation. The weakness of concrete to abrasion causes a reduction in its thickness and friction of the pavement surface. The reduction in thickness of concrete slabs causes an increase in the tensile stress which leads to tensile cracking that shortens the service life of concrete. Moreover, reduction in the friction affects the safety of the traffic.

2.1 Synthetic fiber

Synthetic fibers are man-made fibers resulting from research and development in the petrochemical and textile industries. SNFRC utilizes fibers derived from organic polymers which are available in a variety of formulations. There are two different physical forms: Monofilament fiber and fiber produce from fibrillated tape. Currently two different type fiber used in application, namely low volume percentage (0.05% to 0.1% by volume) and high- volume percentage (0.4% to 0.8% by volume). Most synthetic fiber applications are at the 0.1% by volume level. At this level, the strength the concrete is considered unaffected and crack control characteristics are sought. Types that have been tried in cement concretematrices include: acrylic, Aramid, carbon, nylon, polyester, polyethylene, and polypropylene.

2.2 Fiber Reinforced Concrete

Fiber-reinforced concrete (FRC) is concrete containing fibrous materials which increases its structural integrity. It contains shot discrete fibers that are uniformly distributed and randomly oriented. Fibers include steel fibers, glass fibers, synthetic fibers and natural fibers- each of which lend varying properties to the concrete. In addition, the character of fiber- reinforced concrete changes with varying concretes fiber materials, geometries, distribution, orientation and densities (Bentur A, Mindess S, 2007). Fibers are usually used in concrete to control cracking due to plastic shrinkage and to drying shrinkage. They also reduce the permeability of concrete and thus reduce bleeding of water. Some types of fibers produce greater impact-abrasion and shatter resistance of concrete. Generally, fibers do not increase the flexural strength of concrete, and so cannot replace moment resisting or structural steel reinforcement.

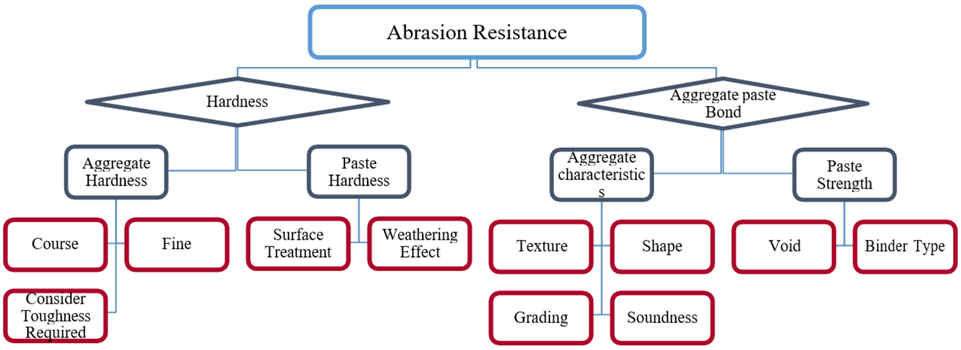

Fig 1.1: Factors influencing the abrasion resistance of concrete

2. Experimental Study

2.1 Materials

2.1.1 Cement- In this study a (43 grade) ordinary Portland cement and class F fly ash, Elkem Micro silica® 920 D dry silica fume powder certified to ASTM C 1240 were used. The chemical composition and Physical properties of cement fly ash and silica fume manufacturers provided from there are shown in table 2.1 and 2.2

Table 2.1 Properties of Cementitious material

Normal Consistency (%)	Initial Setting Time (Minutes)	Final Setting Time (Minutes)	Avg. Compressive Strength at 28 days (MPa)
29%	215	305	53 MPa

Table 2.2 Properties of Cementitious material

Characteristics	Measured/ tested value
Particles Retained on 45μ Sieve	38
Lime Reactivity, (N/mm2)	5.00
Specific Gravity	2.25
Loss of ingestion (%)	2

Coarse Aggregate – Crushed quartzite coarse aggregate of nominal M.S.A (maximum size aggregate) of 20mm downward was used as a coarse aggregate for concrete. Physical properties of aggregate such as gradation, specific gravity, density, water absorption was determined as per IS-2386:1963 & IS-383:1970. Combined Gradation obtained on sieve analysis of coarse aggregate is shown in Table

Table 2.3 Combined sieve analysis data of coarse aggregate

IS SIEVE SIZE	CUMULATIVE % WT. PASSING					IS-383 LIMIT
	20mm	10mm	20mm (45%)	10mm (55%)	Total	
40MM	100.00	100.00	45.00	55.00	100.00	100
20MM	91.90	100.00	41.35	55.00	96.35	90-100
10MM	14.81	85.04	6.67	46.77	53.44	25-55
4.75MM	7.80	17.60	3.51	9.68	13.19	0-10
2.36MM	3.54	3.59	1.59	1.98	3.57	-
1.18MM	2.86	1.66	1.29	0.91	2.20	-
600µ	2.57	0.00	1.16	0.00	1.16	-
300µ	2.30	0.00	1.03	0.00	1.03	-
150µ	1.73	0.00	0.78	0.00	0.78	-
75µ	1.14	0.00	0.51	0.00	0.51	-
Pan	-	-	-	-	-	-

Table 2.4 Results of maximum packing density

S.no.	Ratio of Aggregate 10mm:20mm		Density achieved gm/cc
1	40	60	**1.773**
2	45	55	**1.776**
3	50	50	**1.784**
4	55	45	**1.796**
5	60	40	**1.747**
6	65	35	**1.729**

Table2.5 Physical properties of nominal MSA aggregate

Properties	Measured Value
Specific Gravity of 20mm	2.78
Water Absorption (%) of 20mm	0.48
Crushing Value (%) of 20mm	20
Abrasion Value (%)of 20mm	20
Specific Gravity of 10mm	2.77
Water Absorption (%) of 10mm	0.66

Since the concrete pavement are subjected to dynamic load due to the vehicular movement, therefore some special properties of aggregate such as impact value, abrasion value and crushing value, in addition to its normal properties, evaluated generally for the common use of aggregate for making concrete, were also determined. The results and permissible limits for are presented in Table below.

2.1.1 Fine aggregate - Locally available land quarried sand was used as fine aggregate. The sand was double washed to reduced silt from it. Contains specific Gravity 2.68 & water absorption 1.12%. Gradation of aggregate was determined according to standard IS-2386:1963&IS-383:1970 and results of gradation, grading zone, fineness modulus and grain size distribution curve are presented in figure 2.1.

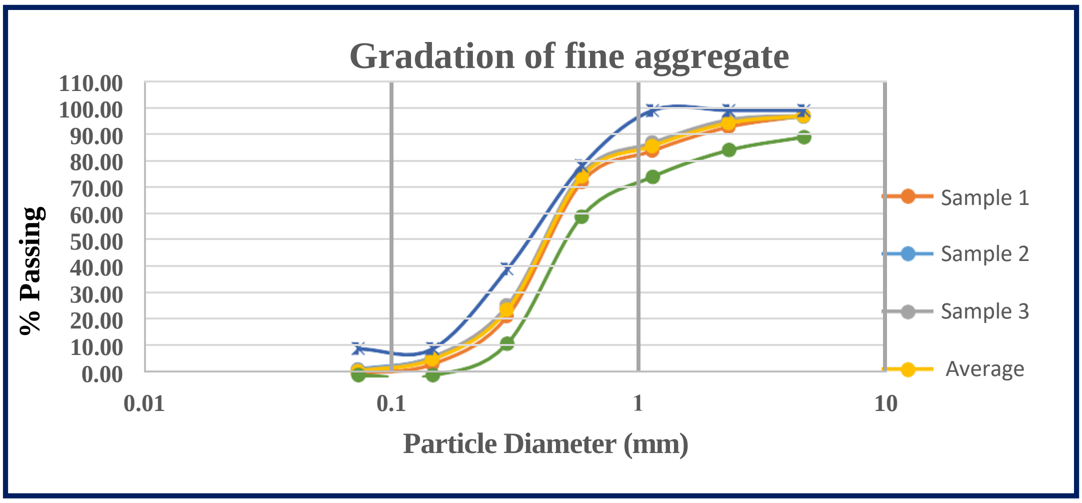

Fig. 2.1 Gradation of Sand

2.1.2 Fibers - In this study synthetic fiber were used. Synthetic fiber used polypropylene 18mm fibrillated fiber as shown in Fig.2.2 to Fig. 3.8 Further details of fibers are given in Table 2.6.

Table 2.6 Detail of fibers used in study and their physical properties

Sr. No.	Description of fibers	Length (mm)	Diameter (mm)	Aspect ratio	tensile strength, MPa	Modulus of elasticity, GPa	Sp. Gravity
1.	300e^{3}polypropylene fiber	18	0.035	514	450	3.5	0.91

Fig. 2.2 Synthetic Fiber

2.1.4 Super plasticizer - It is known that addition of fibers reduces the workability of concrete, therefore to have desired slump of concrete, a SUPERPLASTICIZER GLENIUM SKY 8777(PCE based) was used as Super plasticizer, typical properties of GLENIUM SKY 8777 as reported by the manufacture are given in Table

Table 2.7 Typical Properties of GLENIUM SKY 8777 SUPERPLASTICIZER

1.	Aspect	Light brown liquid
2.	Relative density	1.10±0.01 at 25°C
3.	pH	≥6
4.	Chloride ion content	< 0.2%
5.	Specific gravity	1.1

***2.2* Mix Proportion -** A total of three mixtures are water cement ratios 0.4, 0.45 & 0.35 were proportioned for the study

- ***Mix Detail***- Concrete mix was designed for M30, M40 & M60. The mix proportions of concrete were arrived according to standard IS-10262-2010 and presented in Table 2.8. The grade was selected keeping in mind the concrete generally used in construction of concrete pavement for highways and other important roads.

Table 2.8 Final mix proportion of Different grade of concrete

grade	Mix proportion	W/C	SP
M30	1:1.76:3.52	0.45	0.35%
M40	1:1.48:2.98	0.45	0.50%
M60	1:1.98:2.20	0.35	1%

- ***Mixing procedure***- All the ingredients except Super plasticizer were mixed in dry state for few seconds in a tilted drum type concrete mixer then $3/4$ of total required water was added and mixed for further couple of minutes. The Superplasticizer was mixed in the remaining $1/4$ water and added to the mix in the final stage of mixing. The mixer was mixed for another 9 to 10 minutes before evaluating its fresh properties.

2.2 DETERMINATIONS OF FRESH PROPERTIES OF CONCRETE

2.2.1 Compacting factor - Workability of concrete in terms of Compacting factor was determined using Compacting factor apparatus as shown in Fig.2.3, as per IS-1199:1959. It was observed that on addition of fiber, the workability of concrete reduces drastically.

Fig. 2.3 Compacting Factor Apparatus

2.2.2 **Fresh density of concrete -** Density of concrete is the measure of strength as it is well known that, higher is the density lower is the pores in structure and higher is the strength. Average fresh density of concrete was determined using three 150mm cubes. Fresh density was determined by just dividing the weight of concrete filled in cubes from volume of cube in fresh state that is immediately after the compaction of concrete.

2.3 Hardened Properties of Concrete

2.3.1 Compressive strength **-**Cube specimen with dimension 150mm x 150mm x 150mm were casted from concrete mix with and without fibers for the determination of compressive strength at 28 days according to the Indian standard codes IS-516-2000 & IS-1199-1959. The cubes were demolded after 24hours of casting and moist curing in steel mould. There after the molded specimens were marked for identifications and kept submerged in curing tanks at room temperature for 28days. Compressive strength of cube was determined as per standard method of testing as shown in Fig.2.4.

Fig. 2.4 Compressive Strength testing in progress

2.3.2 Flexural strength - The design of concrete pavement also known as rigid pavements is based on the flexural tensile strength of concrete. The flexural strength of concrete is determined by the use of beam specimen under 4 point loading standard test procedure. The beam specimen with the dimension 100mm x 100mmx 500mmwere casted from concrete mix with and without fibers for the determination of flexural strength at 28 days according to the Indian standard codes IS-516-2000 & IS-1199-1959. The beams were demolded after 24 hours of casting and curing in steel mould. Thereafter, the demolded specimens were marked for the identification and kept submerged in Water curing at room temperature for 28days. The rate of loading was 30 N/sec. flexural strength of beam was determined as per Indian standard method of testing as shown in Fig. 2.6

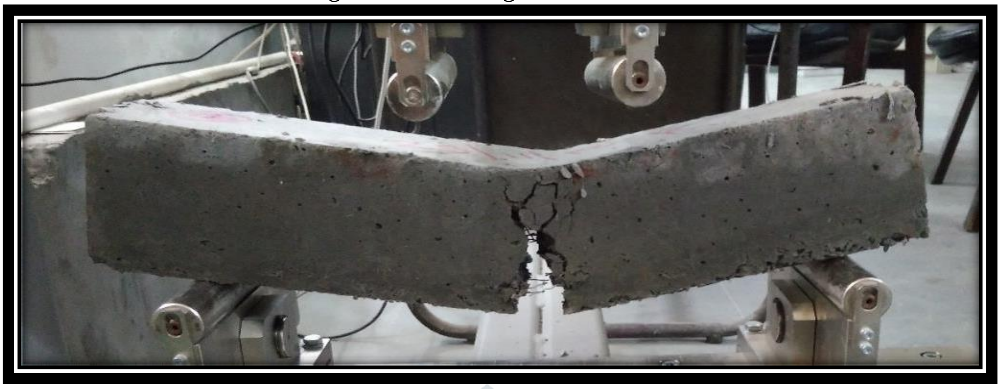

Fig. 2.6 Flexural strength test in progress

2.3.3 Abrasion resistance of concrete

- ***Horizontal slab method (ASTM C 779)*** - Since concrete pavement are subjected to dynamic load due to the vehicular movement therefore this abrasion resistance test of top surface of slab have a great importance, this test can be conducted in the laboratory as well as in the field. Slab with the dimension 400mm x 400mm x 100mm were casted from each concrete mix for the determination of abrasion resistance after 28days of curing according to the American standard ASTM Designation: C 779. The slabs were demolded after 24hours of casting and curing in steel mold. Demolded specimen were marked for identification and kept submerged in curing tanks for the age of 28days. Procedure for determination of abrasion resistance of concrete slab is briefly described below. The abrasion machine consists of three discs, which rotates along the vertical axis at the same time also revolves at the speed of 12 rev/min as shown in Fig 3.12 during the rotation of discs silicon powder fall from the cup (attached at the top of the shaft) at the rate of 4 to 6 gm/min. which helps to abrade the slab surface. After the 5 min initial charge, the abrasion depth is measured with the help of micrometer, total 20 readings are taken in the two perpendicular directions in a circle. Again Abrasion charges are applied for 60mins on final abrasion depth is measured in the same directions as previous (in mm) as shown in the Fig 2.8 & 2.9. Difference between the average initial and average final depth gives total abrasion of horizontal slab in mm.

Fig. 2.8 Abrasion resistance test on concrete in slab

Fig. 2.9 Slab after abrasion test

- ***Sand blasting method (IS 9284- 1979)*** -Abrasion resistance was also measured on concrete cubes of dimension 100mm x 100mm x 100mm by sand blasting method as shown in the Fig 2.10. Abrasive sand blasting is the operation of forcibly propelling a stream of abrasive material against the concrete surface under high pressure of to smooth a rough surface, roughen a smooth surface. A pressurized fluid, typically compressed air is used to propel the blasting material. This procedure simulates the action of waterborne particles and abrasives under traffic on concrete surface. Controlling the pressure and the type of abrasive allows varying the severity of abrasion. The blast cabinet is equipped with an injector type blast gun with high velocity air jet (Fig 2.10). The adjusting parameters are gradation of sand, air pressure, rate of feed of the abrasive charge.

Fig. 2.10 Sand Blasting Test Apparatus **Fig. 2.11 Sample under Sand Blasting**

Fig. 2.12 Sample after Sand Blasting

3. RESULTS AND DISCUSSION

This section describe result of various test carried out in this study on concrete mixes for the evaluation of fresh properties hardened state properties concrete containing fibers and without fibers. Results of tests discussed above are presented below.

3.1 Effect of Fiber on fresh properties

3.1.1 Compaction Factor **-** Workability of concrete in term of compaction factor was determined following standard procedure described in chapter 3. The result obtained showing the effect of synthetic fiber and its hybridization on workability are presented in table 3.1

Table 3.1: Compaction factor of all mixes

Mix	M30	M40	M60
Control Mix	1	0.89	0.95
Synthetic fiber Concrete	0.92	0.85	0.83

A result shows that the addition of fibers reduces workability of concrete but does not effect in the ease of compaction because water absorption of the fibers are almost zero. From the result it observed that reduction in workability synthetic fiber is more than control concrete.

3.1.2 Fresh Density **-** It can be seen from the table that all the concrete mix had a fresh density varying between 2511-2619 kg/m^3. Concrete containing hooked end steel fiber has maximum density and control concrete has a minimum density. The density of the concrete containing steel fiber is more due to more unit weight of the steel fiber. From the result it was observed that on addition of the fiber, fresh density of concrete increase insignificantly. This may be due to addition of the fiber in the concrete without any alteration / modifications in control concrete. Due to addition of the fiber variation in individual density of the concrete cube is may be due to the following reasons.

1. Randomly distribution of the fiber so number of the fiber effect on the weight of the concrete cube.
2. Errors in the dimension of the cube mould.

3.2 Effect of fiber on hardened property - The most common property of concrete for the durability of the pavement is abrasion resistance. In addition to it compressive strength, flexural strength, Dry Density tests were determined concrete containing fiber and without fiber. The results have been discussed in the following section.

3.2.1 Compressive strength – The variation in compressive strength of different grade of concrete are shown in fig. 3.1

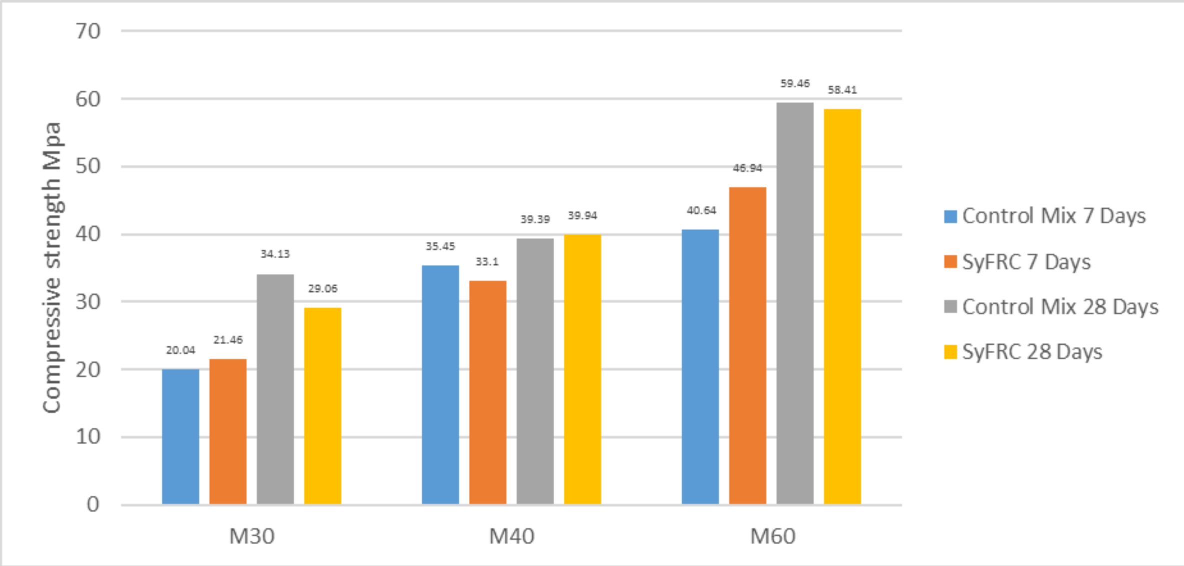

Fig 3.1: Influence of Synthetic Fiber on Compressive Strength

***3.2.2 Flexural strength* -** The variation in flexural strength of different grade of concrete are shown in fig.3.2

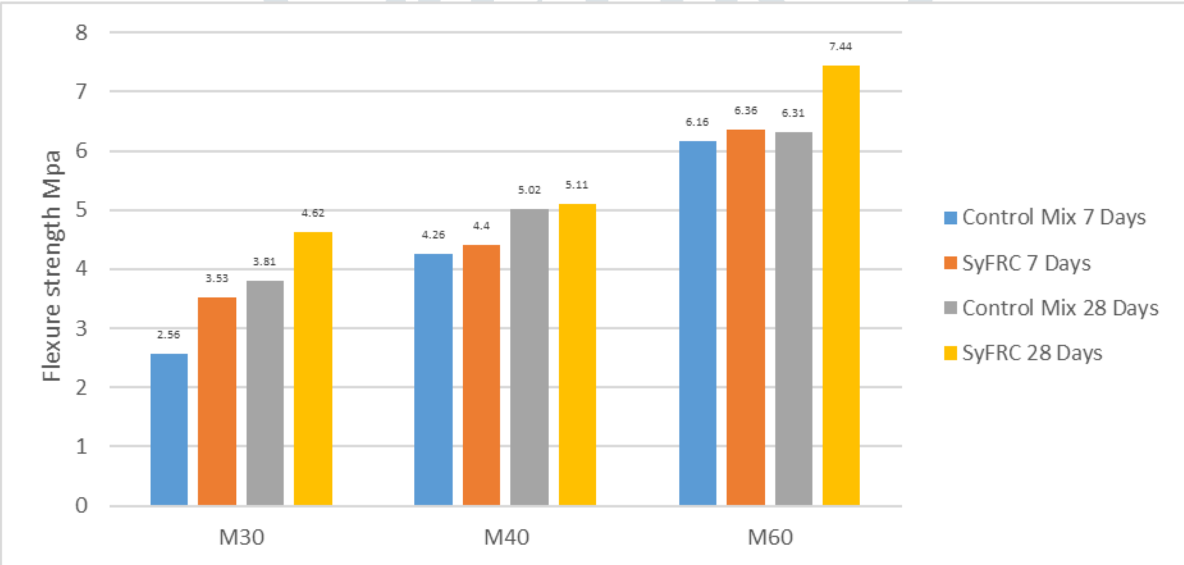

Fig 3.1: Influence of Synthetic Fiber on Compressive Strength

3.2.3 Abrasion resistance-

- ***Abrasion test by using horizontal slab* -** Abrasion resistance due to vehicular movement plays an important role in cement concrete pavement which is evaluated by performing abrasion resistance test on horizontal slab. Average abrasion resistances in term of abraded concrete surface, result obtained on duplicate specimens are shown in Fig.3.3

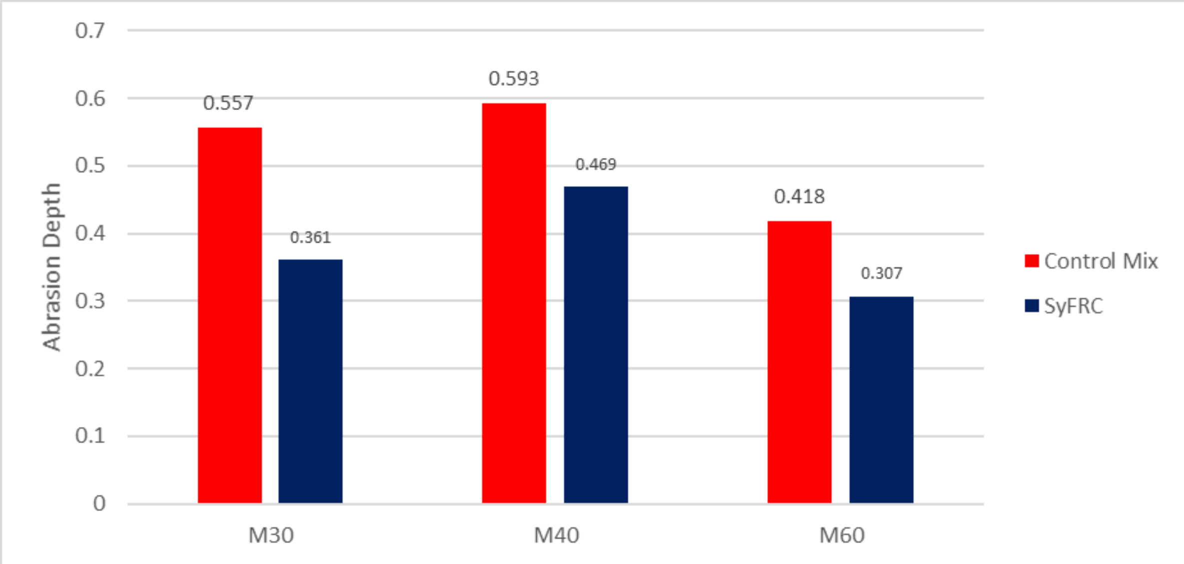

Fig. 3.3 Abrasion Depth of M30, M40 & M60 Grade Concrete

It is observed that, fibers have an important role in abrasion resistance of concrete. It is observed from the study that, abrasion resistance of concrete increase drastically on addition of synthetic fibers this may be due to mechanical bonding between the fiber and the matrix, fibers did not allow the particle to move away during the abrasion testing. Addition of synthetic fiber results 35%,20% and 26% improvement in abrasion resistance of M30, M40 and M60 grade of concrete respectively.

- **Abrasion by sand blasting -** Abrasion resistance due to vehicular movement plays an important role in cement concrete pavement which is evaluated by performing sand blasting test on cube. Abrasion resistance of M30, M40, and M60 concrete cube was determined at 28 days following the standard procedure described in chapter 3. Average abrasion resistances in term of percentage weight loss, result obtained on duplicate specimens are shown in Fig. 3.4

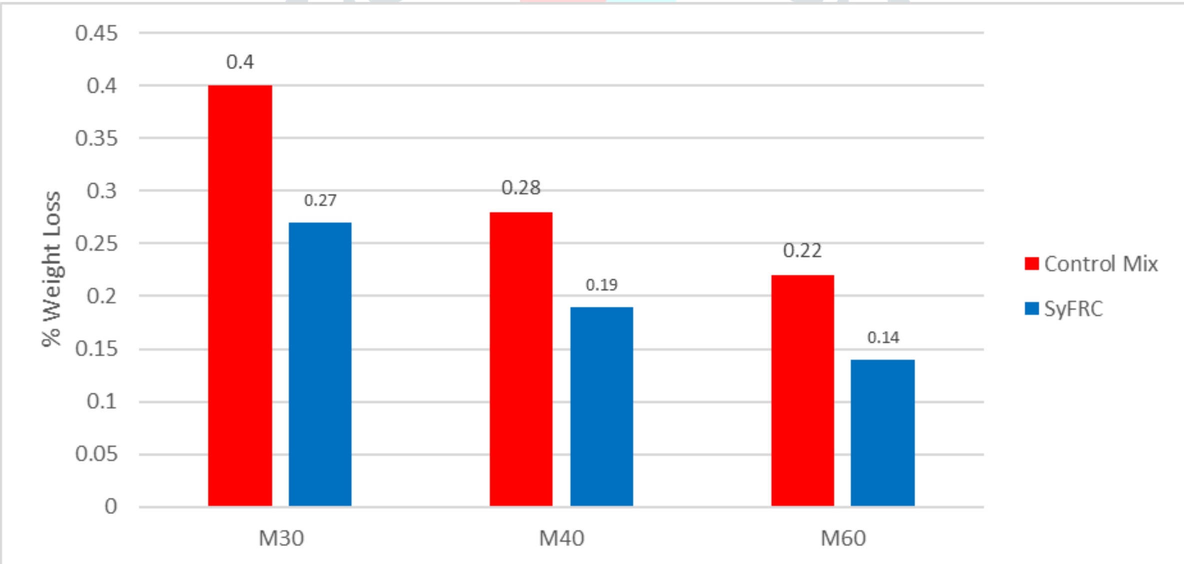

Fig. 3.3 % Weight loss of M30, M40 & M60 Grade Concrete

Results shows that addition of synthetic fiber 32% ,32% and 36% improvement in abrasion resistance of M30,M40 and M60 grade of concrete respectively.

5. CONCLUSIONS

The following conclusion can be drawn from the present study.

1. The compressive strength has no significant influence with the addition of synthetic fiber.
2. Flexural strength of concrete has been improved significantly with the addition of synthetic fiber.
3. Addition of synthetic fiber also enhances the workability of fresh concrete.
4. Concrete containing synthetic fiber shows up to 36% more abrasion resistance with respect to control concrete. Which shows that synthetic fibers can drastically improve the abrasion resistance of concrete.

5. ACKNOWLEDGEMENTS

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