CRUMB RUBBER CONCRETE FORMATION BY PARTIAL REPLACEMENT OF FINE AGGREGATES WITH CRUMB RUBBER AND CEMENT WITH SILICA FUMES

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Abstract - *The paper presents the study based on the utilization of crumb rubber and silica fumes in concrete. In this study, compressive strength of concrete was determined with partial replacement of fine aggregate with crumb rubber and cement with silica fumes. There is need to protect the environment by using the waste materials in construction industry. The disposal of waste tire becomes an important issue. The compressive strength of M30 grade concrete with partial replacement of fine aggregate with crumb rubber and cement with silica fumes were investigated as per IS10262-2009.*

Key Words: ***Crumb rubber, Silica Fumes, aggregate, concrete, Environment***

1.INTRODUCTION

Disposal of waste tyres has become an environmental issue now a days. With the increasing demand of vehicles, use of rubber tyre is increasing. Consequently, disposal of waste tyres is becoming a major environmental issue. There is lot of requirements of natural aggregates in construction industry. Due to huge demands of natural aggregates in construction industry, lot of environmental problem are being faced worldwide. Hence, there is need to protect the environment by using the waste material like rubber tyre, silica fumes, fly ash etc. as an alternate construction material.

Now a days, waste materials are used as a alternative materials used in construction. Lots of research have been done and techniques have been developed to use waste materials in construction industry. Crumb rubber which is obtained from waste tire and silica fumes as partial replacement of fine aggregates and cement are also being used as an alternate material in construction industry. Crumb rubber which is obtained from waste tire and silica fumes as partial replacement of fine aggregates and cement are also being used as an alternate material in construction industry.

In previous study, compressive strength of M30 grade concrete was investigated by using crumb rubber by 5%, 10%, 15% and 20% as partial substitute of the fine aggregate as per IS 10262-2009. It was found that compressive strength of M30 was the highest when 10% crumb rubber is used as partial replacement of fine aggregates. It has been observed that compressive strength of concrete is reduced by using waste tire. By using silica fume in the concrete mix, strength of concrete may be regained.

Silica fume is used in concrete mix to improve the compressive strength, abrasion resistance and bond strength. Improvement of properties of concrete mix are achieved due to pozzolanic reactions. Concrete mix prepared using crumb rubber and silica fumes may be used for interior construction, as a shock wave absorber for earthquake, architectural application, etc.

Erhan Güneyisi et.al. (2004) examined the properties of concrete mix by addition of crumb rubber and silica fumes and compare the results with rubberized concrete without adding silica fumes. The strength was decreased with the increase in rubber content. Kaloush et al. (2005) observed that the tensile strength of concrete is decreased with increasing the rubber content, but the strain at failure increased. Kumaran et al. (2008) has found that properties of rubberized concrete like tensile and compressive strength can be improved by doing partial replacement of cement with super plasticizers and industrial waste. Kotresh and Belachew (2014) observed that strength of rubberized concrete can be achieved by improving the bond properties. Use of rubber aggregates in concrete helps in enhancing bond properties. Shah et al. (2014) investigated the thermal properties of concrete using crumb rubber as partial replacement of coarse aggregates in different proportions. It has been observed that rubberized concrete can be used in energy efficient buildings. Sivakumar and Venkata Krishnaiah (2015) has found that concrete mix crumb rubber has less bonding strength as compared to normal concrete. Sivakumar et. al. (2016) examined the properties of concrete by adding of silica fume (SF). It was found that durability of concrete is improved if silica fumes and crumb rubber are uses in concrete mix. Gayathri and Seyon raja (2020) conducted a study to determine the properties of concrete M20 grade with replacement of cement with silica fume and replacement of fine aggregate with crumb rubber.

It was found that if the % of silica fume is increasing, compressive strength of rubberized concrete will be decreased.
This study presents the effect partial replacement of fine aggregates with crumb rubber and cement with silica fumes on compressive strength of concrete were investigated. In this experimental study, the compressive strength of concrete 10% partial replacement of fine aggregate with crumb rubber and various proportion of cement with silica fumes for M30 grade concrete is obtained as per IS10262-2009.

2. MATERIALS REQUIRED FOR MIX DESIGN

Following materials are used for concrete mix in this study.
- Ordinary Portland cement (OPC 33) is used and investigated as per IS: 269-1989.
- Fine sand having size 75 micron to 4.75 mm is used as fine aggregate.
- Crushed stone having maximum size of 20mm is taken as coarse aggregate.
- Water should be conformed to IS: 456-2000.
- Crumb rubber of size 0.075 mm to 4.75mm is used.
- Silica fume having diameter less than 1µm is used.

3. EXPERIMENTAL STUDY

In this study, compressive tests are conducted to determine the compressive strength of concrete mix in which 10% replacement of coarse aggregates with crumb and 5%, 10%,15%, 20% replacement of cement with silica fumes are considered. For making the mix design for M30 grade of concrete, cement (OPC33 ultra tech), 20mm size of aggregate and silica fume of 96 Grade are taken. Water content (maximum) and cement ratio (minimum) are taken as 0.5 and 300 kg/m3 respectively as per IS456:2000. Value of slump 100 mm, moderate exposure condition pumpable method of transporting is considered. Maximum cement content is taken as 450 kg/m3 as per IS456:2000. Specific gravities of fine aggregate, coarse aggregate, cement are calculated as per IS 2386-1963 PART 3.

3.1 Determination of Specific gravity and water absorption of fine aggregates

These are calculated using the relation (1) and (2)

Specific Gravity=D/[A-(B-C)] (1)

Water Absorption= (100(A-D))/D (2)

Where, A is the weight of saturated surface dry sample and it is obtained 500.9 gram. The sum of Weight of pycnometer, water and fine aggregate is denoted as B and obtained in the test as 1866gram. The sum of weight of pycnometer and water is denoted as C and obtained in test as 1554gram. The Weight of oven dried sample is denoted by D and obtained its value in the test as 496 grams.

After getting the values of A, B, C and C by conducting the test as per standard procedure, are substituted in Eq. (1) and (2)

$$\text{Specific Gravity} = \frac{D}{[A-(B-C)]} = \frac{496}{[500.9-(1866-1554)]} = 2.63$$

$$\text{Water Absorption} = \frac{100(A-D)}{D} = \frac{100(500.9-496)}{496} = 1\ \%$$

3.2 Determination of specific gravity and water absorption of coarse aggregates

These are determined by as per IS 2386-1963 PART 3 method 2 which is suitable for size 10mm to 40mm and calculated by Eq.(3) and (4).

Specific Gravity=D/[C-(A-B)] (3)

Water absorption=(100(C-D))/D (4)

Where,

A = weight in gram of vessel containing sample and crammed with water= 4470g
B = weight in gram of vessel crammed with water only =3824g
C = weight in gram of saturated surface-dry sample=1000g
D = weight in gram of oven dried sample only =996g
After getting the A,B,C and D for coarse aggregates, These are obtained as:

$$\text{Specific Gravity} = \frac{D}{[C-(A-B)]} = \frac{996}{[1000-(4470-3824)]} = 2.81$$

$$\text{Water absorption} = \frac{100(C-D)}{D} = \frac{100(1000-996)}{996} = 0.4\%$$

3.3 Determination of Specific gravity of Cement

$$\text{Specific Gravity} = \frac{W_1}{V_2 - V_1} \qquad (5)$$

After getting values of w_1, v_2.v_1 from the test, it is calculated as:

$$\text{Specific Gravity} = \frac{W_1}{V_2-V_1} = \frac{60}{169-150} = 3.15$$

4. DESIGN OF CONCRETE MIX

In this this study, compressive strength of M30 grade concrete mix is determined in which fine aggregates partially replaced by crumb rubber and cement is partially replaced by silica fumes.

In the previous study, Concrete mix was prepared by partial replacement of fine aggregate with crumb rubber in proportion of 5% 10% 15% and 20%. It was found that compressive strength of concrete gives best result when 10% fine aggregate replaced by crumb rubber. In this study different combination of concrete mix in which 10% partial replacement with rubber and varying the partial replacement of cement with silica fume in proportion of 5%, 10%,15%,20%. These are given below:

- Mix design for 10% partial replacement of fine aggregate with crumb rubber with 5% Silica fumes in M30 concrete. It is designated as MCS1.
- Mix design for 10% replacement of fine aggregate with crumb rubber with 10% Silica Fumes in M30 concrete. It is designated as MCS2.
- Mix design for 10% replacement of fine aggregate with crumb rubber with 15% Silica Fumes in M30 concrete. It is designated as MCS3.
- Mix design for 10% replacement of fine aggregate with crumb rubber with 20% Silica Fumes in M30 concrete. It is designated as MCS4.

4.1 Mix design -MCS1 (10% Crumb Rubber with 5% Silica Fumes M30 concrete)

- To design any grade of concrete, target strength is found according to IS10262 -2009 given as -

$Fck_t = Fck_c + 1.65*S$; where S is standard deviation.

Where Fck_t is the target strength and Fck_c is the characteristic strength.

Target strength = 30 + 1.65* 5 =38.25 N/mm^2

Here Standard deviation S is taken as 5 for M30 grade concrete given in Table 1 of IS 10262-2009 and it is also given in Table 8 of IS 456-2000.

- For moderate exposure conditions in reinforced concrete minimum cement content is 300 kg/m3 and maximum water cement ratio is 0.5 [IS456-2000 Table 5]. In this study, water cement ratio is considered as 0.45.
  - Maximum water content for 20mm nominal size of aggregate is 186 kg for slump range 25 to 50 mm. [IS 10262 -2009 Table 2]. For slump range 75 to 100 mm the water content is increased as 3% for every 25 mm slump. i.e., for 75 to 100 mm range it is increased 6%.

Water content corrected for slump = 186 + 186*6/100 =197 kg or liter (specific gravity of water is one).

- Cement content is determined using w/c ratio 0.45.

Cement = 197/0.45 = 437.78 kg/m^3

Increasing cementious material by 10 % i.e., =437.78 *1.1 = 481.6 kg/m^3

Now Silica fumes for 5 % replacement of cement = 481.6 * 0.05 = 24.08 kg/m^3

So, cement content is = 481.6 – 24.08 = 457.52 kg/m^3

- Proportion of coarse aggregates out of total aggregates for 20 mm. max nominal size of aggregates and zone 2 is 0.62. [As per table 3 of IS 10262-2009]. This value is applicable for 0.5 w/c ratio. For every 0.05 decrease in w/c ratio, this proportion is increased by 0.01 and for every 0.05 increase in w/c ratio this proportion is decreased by 0.01. In this present study, it is increased by 0.01 as we have taken w/c ratio as 0.45.

So , coarse aggregate fraction is 0.63 .

Now, for pump able concrete this fraction is reduced by 10 %

So final coarse aggregate content is = 0.63*0.9 = 0.567

Therefore, fine aggregates fraction = 1- 0.567 = 0.433

As fine aggregate replace by 10% Crumb Rubber = 0.433*10/100= 0.0433

And hence the fine aggregate fraction = 0.3897

4.2 Estimation of quantities for 1 m3 of concrete.

Volume of concrete = 1 m^3

Volume of cement = 457.52/ (3.15*1000) = 0.1452 m3

Volume of water = 0.197 m3

Volume of Silica Fumes = 24.08/(2.2*1000) = 0.0109 m3

Volume of aggregates = 1 – 0.1452 - 0.197 - 0.0109

= 0.647 m^3

Coarse aggregates content = 0.647*0.567*2.83*1000

= 1038.2 kg/m^3

Fine aggregates content = 0.647*0.3897*2.61*1000

= 658.07 kg/m^3

Crumb Rubber content = 0.647*0.0433*0.95*1000 = 26.61 kg/m3

Similarly Quantity of material used for making Mix Design MCS2 (10% Crumb Rubber with 10% Silica Fumes M30 concrete), Mix Design MCS3((10% Crumb Rubber with 15% Silica Fumes M30 concrete) and Mix Design- MCS4 (10% Crumb Rubber with 20% Silica Fumes M30 concrete) are calculated. Quantity of material used for making Mix Design are shown in Table1.

Table -1: Quantities of material for Mix Design

S.N.	Material	MCS1	MCS2	MCS3	MCS4
1	Cement	457.5 kg/m³	433.4 kg/m³	409.3 kg/m³	385.2 kg/m³
2	Crumb Rubber	26.61 kg/m³	26.47 kg/m³	26.34 kg/m³	26.17 kg/m³
3	Water	197 kg/m³	197 kg/m³	197 kg/m³	197 kg/m³
4	Fine aggregates	658 kg/m³	654.5 kg/m³	651.1 kg/m³	647 kg/m³
5	Coarse aggregates	1038.2 kg/m³	1032 kg/m³	1027 kg/m³	1020 kg/m³
6	Silica Fumes	24.08 kg/m³	48.16 kg/m³	72.24 kg/m³	96.32 kg/m³
7	Water Cement ratio	0.45	0.45	0.45	0.45

4.2 Calculation for the amount required for making 9 cubes of each mix

The size of cube is 15 cmx15cmx15cm, volume of 9 cubes will be 0.030375 m3. For proper filling of the cubes extra 25 % material is made. Material required for MSC1 concrete mix as:

The weight of cement is = 457.52 * 0.030375 * 1.25

= 17.3715 kg.

The weight of water is = 197 * 0.030375 * 1.25 = 7.48 kg.

The weight of crumb rubber is = 26.61*0.030375*1.25

= 1.0 kg

The weight of fine aggregates = 658.07 * 0.030375 * 1.25

= 24.98 kg.

The weight of coarse aggregates = 1038.2 *0.030375 * 1.25

= 39.42 kg.

The weight of Silica Fumes = 24.08 *0.030375 * 1.25

= 0.92 kg.

Similarly amount of material required for design M2, M3, M4 are calculated. Total material is required for making concrete cube is shown in Table 2:

Table -2: Total amount of required material

S.N.	Material	Weight for MCS1 mix	Weight for MCS2mix	Weight for MCS3 mix	Weight for MCS4 mix
1	Cement	17.37 kg	16.46 kg	15.54 kg	14.63 kg
2	Crumb rubber	1.0kg	1.0kg	1.0kg	1.0kg
3	Water	7.48 kg	7.48 kg	7.48 kg	7.48 kg
4	Fine aggregates	24.98 kg	24.85 kg	24.72 kg	24.57 kg
5	Coarse aggregates	39.42 kg	39.20 kg	39.0 kg	38.76 kg
6	Silica Fumes	0.92 kg	1.83 kg	2.74 kg	3.66 kg

5. METHOD OF CUBE PREPARING

- Preparation of cubical moulds is done by proper cleaning them and oil is applied at the jointed sections so that no concrete water leaves the cube and then proper tightening of the cubes is done. After this a thin layer of oil as lubricant on all the faces of the cube is applied.
- Materials (without water) were weighed for 9 cubes accordingly from above table and putted into the batch mixture and mixed in dry state for 2 to 4 minutes. Then water is poured gradually from above after dry mixing and the mixing is done for suitable time not less than 3-4 minutes. Then this mix is dropped into a big tray by rotating the handle of the batch mixture and transported near the moulds and shaking table.
- Then slump test is performed. The slump of MCS1 mix was 7.6 cm i.e. 76 mm, the slump of MCS2 mix was 62 mm and slump of MCS3 mix was 54 mm slump of MCS4 mix was 48 mm slump. The slump values for different mix are shown in Fig.1. It is clear

from the figure that slump value is decreases with the %of silica fumes increases.

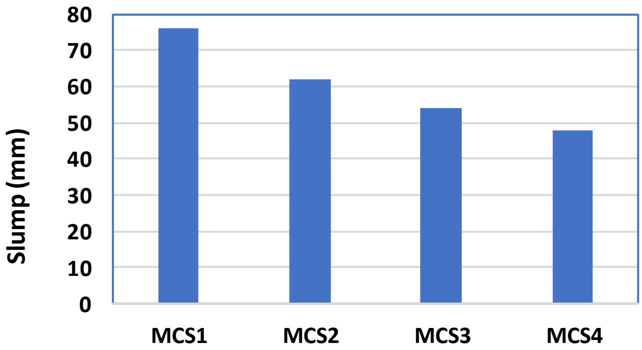

Fig.1: Slump Value of Concrete Mix (mm)

After the mix is prepared i.e., water is mixed to the materials it should be filled into the moulds. To ensure full compaction, shaking table was used and to ensure that segregation not takes place the moulds was filled in 3 to 4 layers starting from 5 cm each and then compacting by vibration on shaking table as shown in Fig.2. After complete filling and finishing of cube moulds are shown in Fig.3.

Fig.2: During vibrating of moulds on Vibration Table

Fig.3: Casting of Cubes

- These cubes might be covered from top by putting plate over them for no loss of water or they might be stored in moist air of at least 90 +/- 0.5 percent humidity for 23 hours +/- 15 min. After 24 hours the cubes as shown in Fig.4 are put into curing Tank.

Fig.4: After 24 hours the cubes are ready to be putted in curing tank

6. METHOD OF COMPRESSION TEST ON CONCRETE CUBES

After curing of concrete cubes, the compression test is carried in the laboratory. At least 3 specimens from different mixes are to be tested. The average of compressive strength of the specimen is considered as compressive strength of concrete mix. The specimens after curing for concrete mix MCS1 are shown in Fig.5.

Fig. 5: Surface dried samples ready for testing in CTM

These specimens are put into compressive testing machine to determine the compressive strength of concrete mix as shown in Fig. 6. The compressive strength is taken when the cracks are visible as shown in the Figure.

Fig.6: Cube samples after completion of test with visible cracks

7. RESULTS AND DISCUSSION

According to the procedure and process of experiment, Compression strengths of concrete mix were determined for the Crumb rubber Concrete with the silica fumes and the testing of the sample has been executed for the 7 and 28 days. The results of compressive strength for concrete mix (MC) without using crumb rubber and silica fumes is shown in Table 3.

Table -3: Compressive strength for normal concrete (MC)

S.No.	Days	Specimen No.	Load (KN)	Compressive strength (N/mm²)	compressive strength (Avg.)
1	7 days	1	464.8	20.66	19.81 N/mm²
2		2	445.7	19.81	
3		3	411.2	18.95	
4	28 days	1	702.4	31.21	31.79 N/mm²
5		2	734.5	32.61	
6		3	710.7	31.55	

The results compressive strength for concrete mix (MCS1) with 10 % partial replacement of crumb rubber of coarse aggregates and 5% partial replacement of silica fumes of fine aggregates for 7 and 28 days are shown in Table 4.

Table -4: Compressive strength for Concrete mix (MCS1)

S.No.	Days	Specimen No.	Load (KN)	Compressive strength (N/mm²)	compressive strength (Avg.)
1	7 days	1	421.3	18.72	18.37 N/mm²
2		2	407.8	18.12	
3		3	411.2	18.27	
4	28 days	1	589.4	26.19	26.67 N/mm²
5		2	635.1	28.22	
6		3	576.6	25.62	

The results compressive strength for concrete mix (MCS2) with 10 % partial replacement of crumb rubber of coarse aggregates and 10% partial replacement of silica fumes of fine aggregates for 7 and 28 days are shown in Table 5.

Table -5: Compressive strength for Concrete mix (MCS2)

S.No.	Days	Specimen No.	Load (KN)	Compressive strength (N/mm²)	compressive strength (Avg.)
1	7 days	1	405.3	18.01	18.89 N/mm²
2		2	411.3	18.28	
3		3	458.9	20.39	
4	28 days	1	659.1	29.29	28.59 N/mm²
5		2	628.4	27.93	
6		3	641.7	28.52	

The results compressive strength for concrete mix (MCS3) with 10 % partial replacement of crumb rubber of coarse aggregates and 10% partial replacement of silica fumes of fine aggregates for 7 and 28 days are shown in Table 6.

Table -6: Compressive strength for Concrete mix (MCS3)

S.No.	Days	Specimen No.	Load (KN)	Compressive strength (N/mm^2)	compressive strength (Avg.)
1	7 days	1	387.2	17.21	16.91 N/mm^2
2		2	361.9	16.08	
3		3	392.7	17.45	
4	28 days	1	568.2	25.26	31.79 N/mm^2
5		2	547.9	24.35	
6		3	562.7	25.01	

The results compressive strength for concrete mix (MCS4) with 10 % partial replacement of crumb rubber of coarse aggregates and 20% partial replacement of silica fumes of fine aggregates for 7 and 28 days are shown in Table 7.

Table 7: Compressive strength for Concrete mix (MCS4)

S.No.	Days	Specimen No.	Load (KN)	Compressive strength (N/mm^2)	compressive strength (Avg.)
1	7 days	1	367.8	16.34	15.88 N/mm^2
2		2	344.9	15.32	
3		3	359.6	15.98	
4	28 days	1	528.9	23.50	23.39 N/mm^2
5		2	517.3	22.99	
6		3	533.1	23.69	

The compressive strength of different concrete mix for 7 days are compared and is shown in the form of bar chart as shown in Fig.7. It is clear from the trend of bar chart that compressive strength decreases with the % of silica fumes increases. But it gives the best result of compressive strength when 10% fine aggregate replaced by silica fumes.

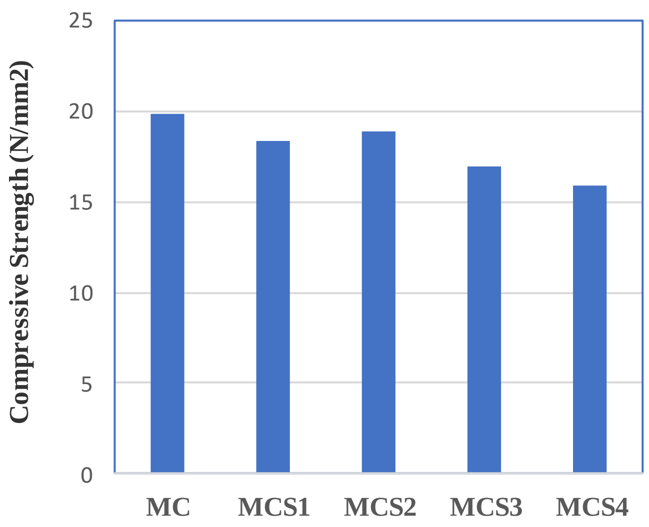

Fig-7: Comparison of compressive strength of different concrete mix for 7 days

The comparison of compressive strength of different concrete mix for 28 days is shown in the form of bar chart as shown in Fig.8. It is clear from the trend of bar chart that compressive strength for 28 days also decreases with the % of silica fumes increases. But it also gives the best result of compressive strength when 10% fine aggregate replaced by silica fumes.

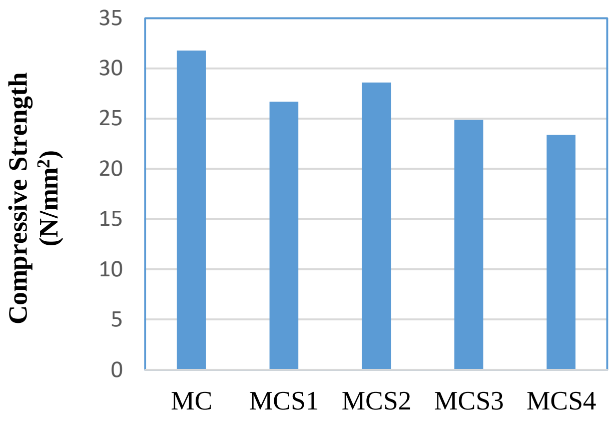

Fig-8: Comparison of compressive strength of different concrete mix for 28 days

8. CONCLUSIONS

Following conclusions were made from this study:

1. The strength of the concrete reduces with the increment of the amount of crumb rubber used in the concrete. However, the optimal results were observed with the 10% crumb rubber sample by attaining approximate 80% of the standard strength of M30.

2. The strength parameter of crumb rubber concrete shows a positive response when silica fume have been added as a binding product in the mixture by partial replacement of the cement with the amount 5% , 10% , 15% and 20%.

3. The strength which is measured is Compressive strength and the new mix gives a considerable result as with use of 5% silica fume content the compressive strength attained is approximate 90% of the standard strength of M30.

4. The strength obtained with the use of 10% silica fume content provided the compressive strength of approximate 95% of the standard strength of M30.

5. The strength obtained with the use of 15% silica ume content provided the compressive strength of approximate 85% of the standard strength of M30.

6. The strength obtained with the use of 20% silica fume content provided the compressive strength of approximate 80% of the standard strength of M30.

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