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Waste Metal For Improving Concrete Performance And Utilisation As An Alternative Of Reinforcement Bar

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ABSTRACT
Waste material disposal is considered as a difficult issue to adopt in current world. Waste metal, which has been recognised as a major problem in the environment and resource deficiency, could have important implications in the concrete construction industries. Waste metal utilisation in construction of reinforced cement concrete (RCC) works is immerging in recent time. Construction industries are looking for cost effective structural materials and utilisation of renewable materials. Metal waste such as chips of tin, still and other metal fragments which is abandoned and spread in the environment could be utilize as a replacement of traditional steel reinforcement bar in the RCC. In this experiment, three different types of waste metal have been compared with commercial 40, 60 and 72 graded steel reinforcement bar. Compressive strength class of C25 concrete was used in the experiment and mechanical properties of concrete incorporating different waste metal were investigated in the first stage. Finally, three-point bend test on short beam was performed to compare their performances. Smaller metal fragments has shown better performance through micro crack bridging in concrete during loading stage and hence better than ordinary reinforcement concrete structure in some extent.

***Keywords* -** fiber reinforcement**,** metal waste, micro-crack bridging, reinforcement grade.

I. INTRODUCTION

Cementing materials combined with aggregate and reinforcement have great engineering property. Concrete that includes imbedded metal (usually steel) is called reinforced concrete or ferroconcrete. Reinforced concrete was invented in 1849 by Joseph Monier, who received a patent in 1867. Joseph Monier was a Parisian gardener who made garden pots and tubs of concrete reinforced with an iron mesh. Reinforced concrete combines the tensile or bendable strength of metal and the compression strength of concrete to withstand heavy loads. From this point forward, reinforced concrete structure becomes most popular and different scales of structure have been built with it. Typically, it is called reinforced cement concrete (RCC) where different standard grades of steel bars are used as reinforcement. However, reinforcement can be provided in cement concrete in different ways, such as different types of fibers which can provide the functionality of reinforcement in cement concrete. This type of fiber reinforced cement concrete (FRCC) is become more popular in last two decade. As additional benefits, fibers such as PE and PVA can possess chemical polarity, which significantly increases the self-healing capacity of cracks due to pre-loading. A little amount of fibers, such as 1.5 % is sufficient for processing healing action [1,2]. Although graded and commercial steel and PVA fibers are greatly beneficial, there is a great potential for different kinds of west metal and plastic to be categorised and used as an alternative of traditional expensive reinforcement bars or fibers.

Having that in mind, Venu Malagavelli and Neelakanteswara Rao Paturu (2011) has investigated the impact of cement bags waste (High Density Polyethylene (HDPE)) on concrete, and found that when the percentage of fibre in concrete was 3.5%, compressive and tensile strength increased considerably [3]. Zainab and Enas have observed that the mixture of iron filings and plastic waste materials could be used successfully as partial substitutes for sand in concrete composites [4]. Kandasamy and Murugesan have added 0.5% by volume of polythene (domestic waste polythene bags) fiber in concrete and reported compressive strength increment by 5.12% in 28 days [5]. This shows the structural integrity potential of waste materials with concrete for improving its mechanical property at micro structural level.

This research investigates different grade of traditional waste metal performance in concrete and as reinforcement compared to commonly used 40, 60, and 72 graded commercial steel reinforcement bars. It was hypothesized that waste metal could be used as an alternative of traditional reinforcement bar in some extant and both system could be used together to reduce the amount of steel bar necessary in the RCC structures to avoid honeycomb scenario.

II. MAERIALS AND METHOD

2.1 Materials

Waste metal was collected from a typical metal waste collector hawker in Sylhet City of Bangladesh. They normally have a labor squad survey around the city, collect free expose waste metal and also buy cheap metal give away by people for recycling. Most of the collected metal is iron. Metal wastes have been arranged in three different category (Fig. 1) based on their shape, size and metal type as; Chips of Metal (CM): metal waste down 80 mm (Nut bolt, steel sheet, pieces of steel rod etc.); Chips of Angle (CA): metal waste down 20mm (Fragments of angle, steel wire etc.); Chips of Tin (CT): metal waste down 150mm (Various types of tin)

Four different concrete mixes, i.e, control (C25), and control with CM, CA, and CT metal mixes were prepared for comparing waste metal impact after mixing with concrete. Three different grades of reinforcement bars were selected as common construction practice in Bangladesh (Table 1). Ordinary Portland cement (OPC) was used as the common binder materials and C25 concrete as per BNBC 2012 [6] was standard control mix. Concrete prepared mixing OPC, sand, stone with 0.50 w/c ratio as illustrated in Table 2. Than short beams were prepared with waste metal concrete, and traditional reinforcement bar with control mix short beams were prepared for comparison.

Table 01: Reinforcing steel bar used in experiment.

ASTM (A615)-Reinforcing bars	Minimum Yield Strength, (MPa)	Minimum Tensile Strength, (MPa)
Grade 40	275	420
Grade 60	415	620
Grade 72	500	690

Table 02: Mix design components of concrete.

Component		Mix design		
		Kg/m^3	Specific Gravity	Other properties
Control	OPC Cement	420	3.00	Initial and final setting time, 1hr 10 min, and 9hr 32 min
	Water	210	1.00	Normal tap water
	Sylhet Sand	680	2.65	Fineness modulus 2.56
	Crushed Stone	1428	2.70	Fineness modulus 6.45, Crushing strength 2.59 N/mm^2
	W/C	0.50	---	Adopted considering the optimum workability.
CM-mix		---		Control + 8% of control volume, CM
CA-mix		---		Control + 8% of control volume, CA
CT-mix		---		Control + 8.5% of control volume, CT

Figure 1: a. Chips of Metal, b. Chips of Angle, and c. Chips of Tin.

2.2 Experimental methods

Slump tests were conducted to measure the workability or consistency of concrete. Workability is the relative ease or difficulty of placing and consolidating concrete. The measure of the workability or consistency of concrete is its slump, which is a design consideration that is inversely proportional to the stiffness of the mix. The slump should never exceed 152.4 mm. Slump test was performed according to ASTM C 143 [7] as illustrated in Fig. 3a.

In the experimental stage mechanical strength behaviors were compared using compressive strength, split tensile strength, static modulus of elasticity (Fig. 3) and flexural strength. Therefore, Cubes of size 150mm X150mm X150 mm, cylinders with 150mm diameter X 300mm height and short beams of size150mm X 150mm X 600mm were prepared using the standard moulds. In the flexural strength experiment, six different set of short beam were prepared. Three sets of beam with three different commercial graded reinforcement bar (40, 60, and 72) and the rest three sets of beams with three different categories of waste metal chips (CM, CA, and CT). The design of short beam is illustrated in Fig. 4 and three different graded (40, 60 and 72) reinforcement bar were arranged similarly.

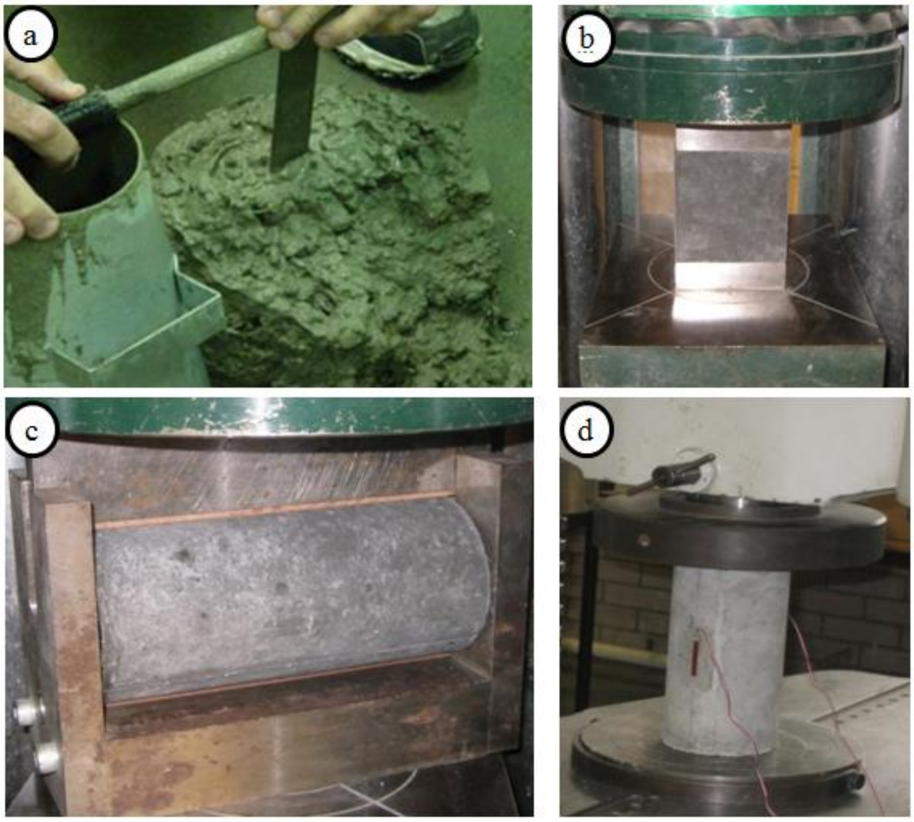

Figure 3: Typical a. Slump, b. compressive, c. tensile and d. modulus of elasticity test setup

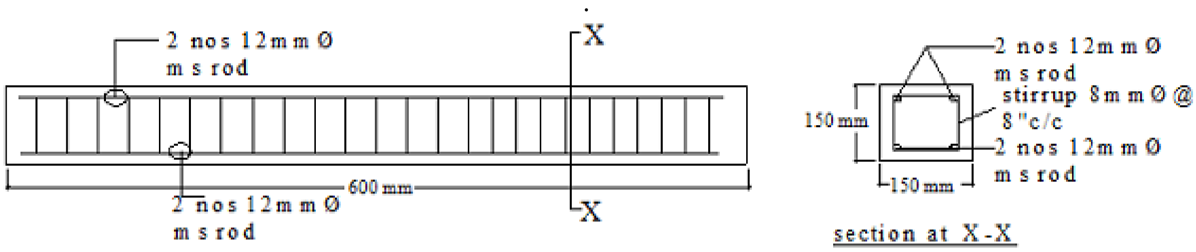

Figure 4: Long and Cross section of Beam.

Short beams with three different waste metal grades were also casted and equivalent weight of reinforcement bars as designed for beam was replaced with different waste metal chips. This requires around 8% (of total concrete volume) metal waste to be added in concrete with CM and CA, and around 8.5% with CT containing beams. Although the total amount of reinforcement bars (40, 60 and 72 grade) were 6.265% volume of concrete, due to the different shape and void spaces different chips required little higher amount of volume in consideration with the equivalent weight reinforcement. This equivalent weight replacement in the concrete allows a direct comparison between impacts of traditional reinforcement bars with equivalent weight of waste metal. Beam sample preparation and experimental setup is illustrated in Fig. 5.

Finally in the mixing stage, concrete mixes were vibrated using a vibrator to attain maximum possible density. Each sets of mix had triplicate sample. The samples were demoulded after 24 hours from casting and kept in a water tank for 28 days curing. BSEN 12390-3:2009 [8] Standard was used in conducting compressive tests, BSEN12390-6:2000 [9] Standard was used for the split tensile strength tests, and Young's Modulus tests on cylinders were conducted in accordance with the requirements of BS 1881-

121:1983 [10]. Three-point bend test was arranged following BSEN 12390-5 [11] (Fig. 6) where flexural strength was calculated using equation 1 below.

$$\sigma_f = \frac{3PL}{2bd^2} \quad \text{...........(1)}$$

In this equation, σ_f = Stress in outer surface at midpoint (MPa), P = Maximum failure load (N), L= Support span (mm), b = Width (mm), and d = Depth (mm) of the beam. Experimental beam setup arrangement is illustrated in Fig. 6.

Figure 5: Short beam preparation and three-point bend test setup.

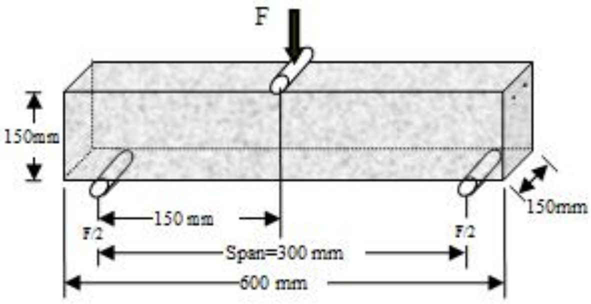

Figure 6: Three-point bend test beam arrangement.

A standard UTM machine was used for three-point bending test. Beam clear span was adjusted to 300mm and displacement transducers were attached at the mid span during the test. Applied load were gradually increased until the beams reached to failure conditions and applied load verses deflections data were recorded for analysis.

III. RESULTS AND DISCUSSION

3.1 Waste metal impact on concrete mechanical property

Bulk density of different concrete mixes was changed as presented in Fig. 7.

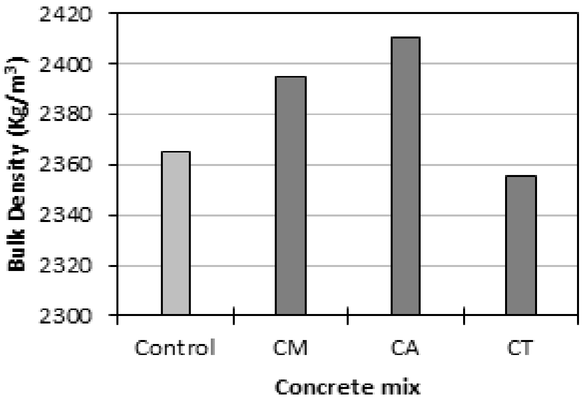

Figure 7: Relationship between waste metal content in mix and bulk density.

Density of concrete was found increased with lower waste metal size, shape and higher specific gravity which results CA>CM>Control>CT in this experiment.

The Compressive and split tensile strength of the concrete on 28 days is illustrated in Fig. 8. Concrete mix with chips of metal and angle (CM ad CA) shows higher strength compared to control (only cement concrete) mixes. This strength increases were due to the strong interlocking between metal ships and cement concrete. Compressive strength increment resembles findings of Alwaeli et al. experiment with recycled scale and steel chips waste [12]. Size and shape of the metal chips also influence the strength. Hence, CA concrete shows greater strength following by CM, control and CT.

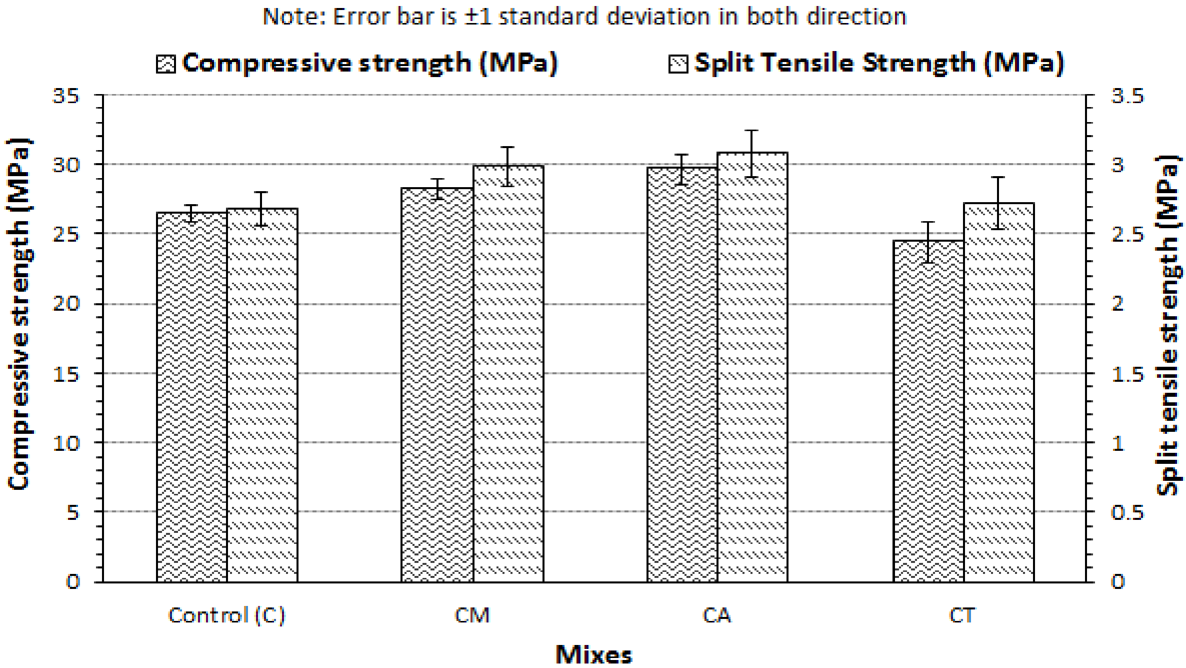

Figure 8: Compressive and split tensile strength of different concrete.

Compressive and split tensile strength of the CT concrete was found reduced compared to all. This was because of the incompatible surface area of the tin which not suitable for making samples of 150mm cubes for compressive strength test. In addition, there was void space in the tin chips which makes it unsuitable to interlock with cement and aggregate.

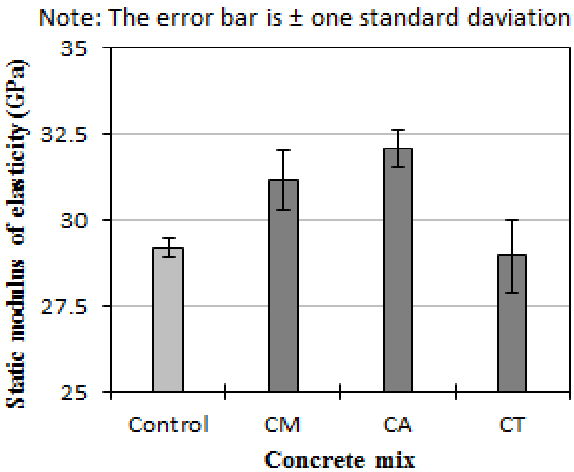

Figure 9: Static modulus of elasticity of concrete.

Likewise compressive and tensile strength, static modulus of elasticity shows similar response (Fig.9). This further confirms, tin chips in CT concrete mix shows less structural integrity due to its shape and size ratios with typical cube, and cylinder samples.

3.2 Flexural strength performances of different reinforcing in the beam

Different types of reinforcement arrangements in beams showed apparently different flexural behaviors, although equivalent amount of reinforcement was provided (Fig.10). The deflection pattern and rotation at the mid-span of beams were different as presented in Fig. 11. Beams containing steel bars showed more deflection taking property i.e., ductility for the applied load compared to the beams with metal chips. One of the key reasons was the continuation of the steel bars across the beam cross-section. More ductile behavior of beams was prominent with Grade 72 of tensile bars as it was strongest reinforcement bar and forms strongest bond strength than other beams compared to those with Grade 40 and 60. Beams with grade 72 shows similar ductility behavior as grade 40 beams up to 40 KN load and it gains an extra exponential curve to reach its maximum failure point at around 62.5 KN.

On the contrary, beams with waste metal showed different failure and deflection behavior. Beams with chips of metal (CM) and chips of tin (CT) showed moderate ductility and reached up to 50 KN, whereas beams with chips of angle (CA) gained highest peak load at around 72.5 KN out of all types of beam. Beams with chips of angle also showed moderate ductility which is even better than beams with 40 and 60 grades steel bar containing beams. This might be caused because of the micro crack bridging by the smaller metal chips at micro level. Beams with chips of tin showed most brittle failure though it gained strength up to 50 KN which is better than 40 grade bar beams. This was because of the void and unsuitable shape of the tin chips which didn't had good compatibility with concrete. In case the metal wastes were grained in smaller size in fiber shapes, the compatibility between the waste metal and concrete may be improved as it is evident from Murali, et al, 2012 findings [13]. Hence, properties could be improved by grinding those metal chips in smaller pieces and preferably void less in particularly with the tin chips. This could be further investigated in future. Although, 72 grade beams showed most consistent result with promising ductility, chips of angle (CA) containing beams resists much higher load and its ductility is better than grade 60 and 40 beams.

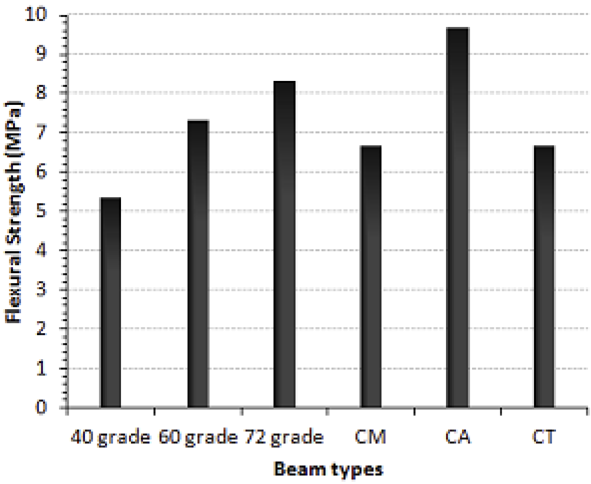

Figure 10: Flexural strength of beams.

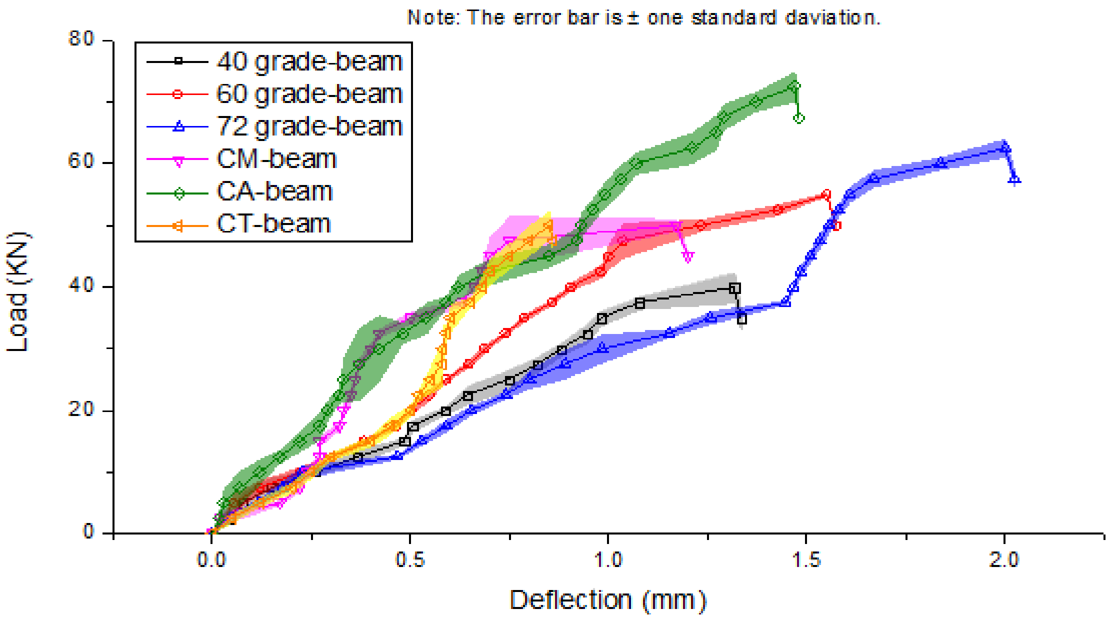

Figure 11: Three-point bend test on short beams, a. Load vs deflection graphs; b. Maximum flexural strength.

While analysisng flexural strength of different beams, it was clearly found that CA beams poses highest flexural strength followed by grade 72 beams and others. The trend was like CA >72 grade > 60 grade > CM = CT > 40 grade beams (Fig.10). Consistently increase in flexural strength in beams with higher grades reinforcement bar was obvious as it was proportional with the stronger reinforcement steel bars. Flexural strength in beams with different metal chips, was dominantly depends on the size, shape and probably the materials strength. Infatuate, metal waste categorizing with optimum size and shape could be attained for most consistent and better performance.

IV. CONCLUSION

Beams with different graded reinforcement bar showed consistent results as it was expected, however the metal wastes containing beams results were highly promising. Mechanical properties (compressive strength, split tensile strength, and modules of elasticity) of the concrete were improved with the addition of smaller metal chips CM, and CA, however it deteriorated a little with CT chips due to larger size and shape. Waste metal may have better performances if they were grinded in specific size and shape. Most of the waste metal was steel fragments; therefore it had better compatibility with concrete. Ductility of bar beams was higher as there were shear reinforcements and continuation of reinforcement tied end to end. Investigation on graded waste metal is ongoing and there is also potential for plastic waste materials. From current findings it could be concluded that waste metal in some extend showed better performance than traditional bar and could be used in the RCC structure as an alternative of traditional steel bars or as partial substitution for better performance. This will not only minimize the construction cost, but also impact on the environment positively by using the recycle waste metal.

V. Acknowledgements

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