Strengthening of RC Beams with M-Sand using external bonding of steel plates

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Abstract. Various techniques are initiated for the strengthening of RCC beams to overcome flexural and shear. RCC beams are important load-bearing components in any building structure, but we should strengthen beams when material deterioration, defective design and accidental disasters occurred. In recent years the external bonding of steel plate technique is used for strengthening reinforced concrete beams, which is an effectual way to ameliorate the strength of the RCC beam. In this research 5mm thick Mild steel plate is used for external bonding, M30 grade of concrete is used with various proportions of Manufacture and Natural sand. The research paper aims to differentiate the compressive, Split tensile and flexural strength of RCC beams with & without steel plates. From comparative results, it was found that the plate bonded beam observes more strength than no plate bonded beam at 50% replacement of M-sand.

1. Introduction
In any building structure, RC beams are important load-bearing elements. But, due to material deterioration and natural disasters they needed retrofitting. Therefore the common method for build up the strength and renovate of the RC beams is the side plating bonding technique [1]. Comparing the other methods the external plate bonding is relatively best method for upgrading the flexural strength and load bearing capacity of RC beam because it is convenience to adding, utilised less cost materials, and limited disruption to the structural activities. In this external plate bonding mild steel plate is used because it having good ductile behaviour and less-carbon content. So the external plating contributes their properties to external plated beam, that’s why it is the one of the good way to strengthening and retrofitting RCC beam [1-4]. The side steel plate bonding is one of the steel jacketing technique. In this method steel anchored plates to the sides of RCC beams. Flexural strength and ductility of RCC beam is increased at the same time without increasing any tension and compression reinforcement. The shear capacity and stiffness of RC beam is also increases because steel plates are bonded on side faces of same plane to the shear force [1-4].

Concrete is a combination of two types of material, one is binding material and the second is filler material. Cement and water are used as a binding agent while aggregate is used as filler material [5].
For the preparation cement mortar and concrete natural sand is an important filler material. In recent years construction field is increases at the same time the raw material consumption also increases. Due to consumption of raw material mainly standard natural sand paucity is occurring and also environmental effects due to extraction of natural sand from the river crust. To overcome all the problems, different research institutions are study to identify another material can replace natural sand without influencing the properties. After getting different study results they are identifying different materials are slag sand, M-sand and Pond Ash are substation, but the performances of these substitutions in cement mortar crystal clear. Finally they are identifying the some similar properties in M-sand same as Natural sand so the M-sand is suitable to occupy as he fine aggregate in cement concrete and cement mortar composition [6].

Aggregates are the major ingredients in concrete volume, 60-70 percentage in concrete is engaged by the aggregates. Coarse aggregate give the strength to the concrete while fine aggregate fills the space between particles. One of the alternative for natural sand is replacement of M-sand. Due to increased construction activities and also depletion of natural resources the availability to supply natural sand in time, M-sand plays a vital role as an ingredient in concrete making [7].

2. Methodology
This research paper deals improve the strength of the RCC beam by using the plate bonding. First, we are selecting and collection of materials for project activities. Then conducting the tests as per IS codes on the material to get properties. Then we go mix design (M30) and RCC beam design. To casting the cubes, Cylinders and beams as per mix design. To assign the external plates to strengthening beams with mechanical devices. Next we are conducting the test on specimens and comparing the test values. Finally, we write conclusion of this research investigation.

3. Materials

3.1. Cement
In this experimental study OPC 53 grade of cement is utilized. The cement was tested before going to work must conforming the IS code standards (see table 1 & 2).

| S.NO | Property                          | As per IS: 12269-1987 | value |
|------|----------------------------------|-----------------------|-------|
| 1.   | Normal Consistency               | -                     | 35    |
| 2.   | Setting time ( in minutes )      |                       |       |
|      | Initial Setting time(IST)        | < 30 min.             | 28    |
|      | Final Setting time(FST)          | > 600min.             | 244   |
| 3.   | Specific Gravity(SG)             | -                     | 3.14  |
| 4.   | Fineness of Cement               | >10%                  | 1.67  |
| 5.   | Compressive Strength             | 3 Days                | 27.0 N/mm² | 34.98 |
|      |                                  | 7 Days                | 37.0 N/mm² | 45.27 |
|      |                                  | 28 Days               | 53.0 N/mm² | 56.05 |
Table 2. Chemical properties of cement.

| Ingredients | Concentration (%) |
|-------------|------------------|
| CaO         | 66.67            |
| SiO₂        | 18.91            |
| Fe₂O₃       | 4.94             |
| Al₂O₃       | 4.51             |
| SO₃         | 2.5              |
| MgO         | 0.87             |
| K₂O         | 0.43             |
| Na₂O        | 0.12             |
| Loss of ignition (LOI) | 1.05          |

3.2. Aggregates
Aggregates used for the study are conventionally classified into coarse and fine.

3.2.1. Coarse Aggregates: Nominal size of 20 mm coarse aggregates are used and tests are conducted to determine their properties (see table 3).

Table 3. Physical Properties of Coarse aggregates.

| Property                  | Value |
|---------------------------|-------|
| Water Absorption %        | 0.81  |
| Specific gravity          | 2.74  |
| Aggregate Impact value    | 27.3% |

3.2.2. Fine Aggregates (Natural Sand): The fine aggregates utilised in this study must clearly pass through the 4.75 mm sieve. Natural sand available in some areas possess good quality. Tests on fine aggregates are conducted (see table 4).

Table 4. Properties of Fine aggregates.

| Property                  | Value   |
|---------------------------|---------|
| Fineness Modulus          | 2.7     |
| Specific gravity          | 2.6     |
| Bulk Density(Kg/m³)       | 1625    |
| Silt content              | 0.25%   |
| Zone                      | II      |

3.2.3. Fine Aggregates (M-Sand): The crushed fine aggregate is produced based on our purpose from source material called as M-sand. This M-sand is produced with different types of crushing machines like cone crusher, impact crusher, roll crushers etc., in this crushing process parent rock is a raw material for M-sand production. The mineral properties, chemical properties and texture of M-sand is based on parent rock. In this research work M-sand proportions of 0%, 50% and 100% replacement in concrete mix. Properties M-sand is listed in table 5.
Table 5. Properties of M-sand.

| Property           | Value   |
|--------------------|---------|
| Fineness Modulus   | 2.8     |
| Specific Gravity   | 2.70    |
| Bulk Density(Kg/m³)| 1633    |
| Silt content       | 5.5%    |
| Zone               | II      |

3.3. Super Plasticizer
The superplasticizer utilised in this research is Master Glenium, the purpose of this admixture were water reduction, slump retention, high early strength and durable properties.

3.4. Steel Plates
Mild steel plate having high resistance to breaking and contains low carbon. In this research to improve strength of RCC beam mild steel plate (5mm thickness) is used (see table 6).

Table 6. Properties of Mild Steel as per IS 6240:2008.

| Property          | Value     |
|-------------------|-----------|
| Yield strength    | 240N/mm²  |
| Ultimate strength | 350N/mm²  |
| Elongation        | 25%       |

3.5. Water
Water is an important ingredient to make concrete slurry with binding material and aggregates. Concrete get good strength properties when water must be conforming IS 456-2000.

4. Mix Design
Using IS: 10262:2009 Concrete mix is designed with moderate exposure condition and the proportion of ingredients is evaluated to yield concrete with strength of M30 Grade. The W/C ratios of mix design is 0.38, 0.43&0.50. The concrete mix is prepared by three mix proportions MIX-I, MIX-II and MIX-III. The three mixes represents the M-sand replacement quantity. In the mixes MIX-I having 0% M-sand, MIX-II having 50% M-sand and MIX-III having 100% M-sand replacement respectively. Proportions of ingredients (per m³) is listed in table 7.

Table 7. Mix proportions.

| Mix No. | Cement Kg/m³ | Coarse aggregates Kg/m³ | Fine aggregates(Natural sand) kg/m³ | Fine aggregates(M-sand) kg/m³ | Water Kg/m³ | Superplasticizer kg/m³ | W/C ratio |
|---------|--------------|-------------------------|------------------------------------|-------------------------------|-------------|-------------------------|-----------|
| I       | 370          | 1302                    | 683                                | -                             | 140         | 2.96                    | 0.38      |
| II      | 370          | 1302                    | 342                                | 342                           | 160         | 2.96                    | 0.43      |
| III     | 370          | 1302                    | -                                  | 709                           | 185         | 2.96                    | 0.50      |

5. RCC Beam Design
In any constructional works reinforced concrete beams are important structural elements. The reinforced concrete beams are designed as per IS-456:2000, in this they are classified into three categories such as under, balanced and over reinforced sections. As per design code beam was designed balanced or under reinforced sections because the stresses with corresponding strains in concrete and steel similarly due to externally acted load. Mainly any structural element is designed for
serviceability, durability, safety and economy. Based on these all designed criteria RCC beams are abundant used in structural application. The dimensions of RCC beam is 1500 mm X 230 mm X 230 mm is casted and testing 28 days of curing shown in figure 1.

![Figure 1. Detailing of RCC beam.](image)

The reinforcement detail of beam is 3#12mm in at tension and 2# 12 mm in compression zones and 8mm @150mm c/c spacing as a shear reinforcement.

### 6. Casting and Curing

#### 6.1. Cube, Cylinder and plain concrete beams casting

After mix design of M30 grade concrete, we conducting trail mixes and the strength of concrete is reaches the target strength as per mix design. To starting the casting of cubes, cylinders and plain concrete beams with three mix proportions of M-sand. The dimensions of cube mould is 150mm X 150 mm X 150 mm, cylinder mould is 300 mm X 150 mm and plain concrete mould is 100 mm X 100 mm X 500 mm shown in figure 2 to 5.

![Figure 2. Casting of cubes.](image)

![Figure 3. Mixing of concrete.](image)
6.2. Beam Casting
The RCC beam is casted with M30 grade of concrete with three proportions of M-sand. The beam mould of size 1500mmX230mmX230mm before placing the concrete we must prepare the clean and oiling the inner faces of mould and reinforcement is kept clearly on cover blocks shown in figure 6. After we proceed to placing of concrete. The ingredient quantities are listed table 8.

M-sand have a better bonding strength, less permeability, and fineness modulus properties makes having good homogeneity mix in preparing the mix.

Table 8. Mix proportions of beam.

| Mix No. | Cement Kg | Coarse aggregates kg | Fine aggregates (river sand) kg | Fine aggregates (M-sand) kg | Water lit | Superplasticizer Lit |
|---------|-----------|----------------------|---------------------------------|-----------------------------|-----------|---------------------|
| 1       | 38.48     | 135.44               | 71                              | -                           | 14.56     | 0.307               |
| 2       | 38.48     | 135.44               | 35.52                           | 35.52                       | 16.64     | 0.307               |
| 3       | 38.48     | 135.44               | -                               | 73.77                       | 19.24     | 0.307               |
6.3. Curing
After casting of specimens to demoulding from the moulds. The cube, Cylinder and Plain concrete beam specimens are placed in water 7 days and 28 days. The beam specimens are watering 28 days. After curing period is completed to conducting the tests on specimen shown in figure 7.

Figure 7. Curing of specimens.

7. Assigning the Plates to Beams
The plates are assigning at sides of beams after curing of 28 days. The thickness of steel is 5mm. The beams placed at side by side and to take drilling machine to drilling the holes at sides of beams. After getting holes cleaning the surfaces with clean and smooth. The bonding agent is mixed with proper portion and to apply the sides of beams. After some time to take plates assemble the side with proper fixing [8-9]. The dimensions of plate is 5 mm X 190 mm X 1500 mm. The plated beam is tested after 7 days.

8. Testing Results of Specimens

8.1. Testing Of Cubes, Cylinders and Plain concrete beams
After completing of curing period the cube and cylinder specimens are testing in CTM to get compression strength and tensile strength values of concrete. The plain concrete specimens are testing Flexural testing machine with 2-point loading system shown in figure 8 and 9

Figure 8. Compression testing machine.  
Figure 9. Testing of Cubes.
The compressive strength, Split Tensile strength and Flexural strength of respective specimens obtained after testing 7 days and 28 days curing period the mix-II specimens are getting more strength compared to other two mixes and 28 days curing period shown in figure 10 to 14.

**Figure 10.** Testing of Cylinders.

**Figure 11.** Testing of pain concrete beams.

**Figure 12.** Average Compressive Strength of concrete.
8.2. Testing of Beams

The RCC beams are completed curing period they are tested under the loading frame machine capacity of 2000 kN. In this research study mainly comparing the flexural strength results of controlled beams and strengthening beams. First we are testing the controlled beams then after testing the strengthening beam.

8.2.1. Test Set Up: As shown in Figure 15, the flexural test setup of RCC beam with simply supported and two point loading was applied on the beams. The two point loading system is arranged by placing of two loading cells at a distance of L/3, above these cells I girder was placed and on that girder at the centre load was applied in table 9. The load was applied constantly. Linear variable displacement transformer (LVDT) was placed at the centre bottom of the test beam for knowing the deflection of beam at different loadings shown in figure 15 [10].

| Table 9. Specifications of Loading Frame. |
|------------------------------------------|
| **Name of Company** | Milenium Technologies (I) Pvt.Ltd. |
| **Capacity** | 2000 kN |
| **Rate of Loading** | 4 kN/sec |
| **Colour of Frame** | Yellow |
| **Material** | Mild Steel |
| **Brand** | Milenium |
| **Accessories** | 4-Strain Channels, 2-LVDT Channels & 2-Load Channels |

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**Figure 13.** Average Split Tensile Strength.

**Figure 14.** Average Flexural Strength.

**Figure 15.** Testing of Beams.
From the above figure 16, the ultimate load of RCC beam is improved by bonding of side plate and m-sand also contributes the improve the strength of RCC beam.

From figure 17 & figure 18, the Ultimate Load Vs Deflection mix-II RCC beams carrying more load at less deflection compared to other two mixes RCC beams [11, 12]

9. Conclusion
1. In this research study we observed that from the results of compression strength, Split tensile and Flexural strength of concrete M-sand is replaceable by N-sand in concrete mix. The value of 50% M-sand gives better strength compared to nominal mix of concrete and fully replacement M-sand also gives equal strength to nominal mix of concrete strength.
2. The compressive strength of concrete at 28 days is increased 16.37% by 50% M-sand replacement(MIX-II) and 2.6% increase by 100% M-sand replacement (MIX-III) compared with Nominal mix(MIX-I) respectively and 7 days compressive strength is increased 11.11% by 50% M-sand replacement(MIX-II) and 0.6% increase by 100% M-sand replacement (MIX-III) compared with Nominal mix(MIX-I) respectively.

3. The Split Tensile strength of concrete at 28 days is increased 1% by 50% M-sand replacement(MIX-II)and 0.28% increase by 100% M-sand replacement (MIX-III) compared with Nominal mix(MIX-I) respectively and 7 days Split tensile strength is increased 0.96% by 50% M-sand replacement(MIX-II) and 0.06% increase by 100% M-sand replacement (MIX-III) compared with Nominal mix(MIX-I) respectively.

4. The Flexural strength of concrete beams at 28 days is increased 2.03% by 50% M-sand replacement(MIX-II)and 0.1% increase by 100% M-sand replacement (MIX-III) compared with Nominal mix(MIX-I) respectively and 7 days Flexural strength is increased 1.56 % by 50% M-sand replacement(MIX-II) and 0.09 % increase by 100% M-sand replacement (MIX-III) compared with Nominal mix(MIX-I) respectively.

5. The strength of RCC beam is improved by M-sand replacing, it is overcome the defects occurring in concrete such as voids, segregation and honeycombs. The M-sand properties like fineness modules Index, bulk density and specific gravity etc., were played a main role in getting more strength in RCC beams.

6. Compared to concrete mix of M-sand replacement consume more water to normal mix concrete .M-sand is preferable for replace of Natural sand in concrete mix at certain ratios.

7. The Strength of RCC beam is increased with bonding of plates is 20%, 25.6% & 24.01% and the RCC beam of load carrying capacity is more at 50% M-sand replacement (mix-II) concrete mix. The steel plate bonding is valid to increase the strength of RCC beams and to increase the load baring capacity of beams.

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