Utilization Of Corn Cob As A Partial Replacement Of Coarse Aggregate In Concrete Blocks

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Abstract:

Demand for construction activity is on a steep rise due to an increase in population, which has led to a growth in industrialisation and urbanisation in the country by marshalling the way for infrastructure development resulting in heavy usage of natural resources. To implement such ventures concrete must be used which require an immense quantity of non-renewable resources such as Fine aggregates, Coarse aggregate, and Cement. Corn is one of the widely used grain all around the world, its impulsive nature towards wastage generation of about 50-70% as corncob has concerned a lot due to waste accumulation. Keeping in view of the availability of natural resources, rise in environmental pollution and waste deposition by construction industry, has motivated us to work on this aspect. In this paper, discussion is carried out on the influence of using corncob as a partial replacement to the coarse aggregate in the concrete mix. It aims at finding out the optimum percentage replacement for natural coarse aggregates, which can give us the similar or more strength and has the same amount of workability as compared to nominal concrete. Moulds were casted using cement, sand, coarse aggregate, corncob, and marble paste. Cubes were casted and tested for 7-days, 14-days & 28-days against compression loads to determine its compressive strength.

1. Introduction:

Increasing population has resulted in an increase in industrialization and urbanization in the country, setting up the stage for infrastructure development resulting in heavy usage of natural resources as a result for construction activity. To cater for the general needs of the people like shelter and food, development activities like construction of high-rise buildings, storage units and roads are to be carried out. To implement such ventures concrete must be used, manufacturing of concrete majorly requires natural resources which are non-renewables such as Fine aggregates, Coarse aggregate and Cement. There is a dire need to come up with innovative and eco-friendly materials which can be used in the concrete to meet up the demand.

Corn(Maize) is one of the widely used grain all around the world with USA being one of leading consumer and largest producer of corn, with about 96,00,000 acres (i.e., 39,000,000 hectares) of land being reserved for corn production. USA’s economy is even influenced by the production and
export volumes of corn, as approximately 13% of corn produced is being exported to other countries. India is also a good producer of corn, in 2019-2020 maize production estimate was around 28.70 million tonnes. In India, Andhra Pradesh is the largest contributor in maize production, with its share being about 20.09% to India. Maize production in AP is almost as equal to the USA market. Whilst about 1,060,247,727 tonnes of corn is produced annually worldwide, its impulsive nature towards wastage generation as corn cob (cob of corn) is what has concerned more. For each cup of corn produced, percentage of corn cob generation as a wastage varies from two-quarters of a cup to three-quarters of a cup, depending on the quality of corn crop production. At an average it is considered as for every one cup of corn produced, we get half-cup of corn cob as a wastage.

If the corn cob generated is not deposited properly or reused decently, then it will become an issue for environment, resulting in pollution. If corn cob encounters water, then it creates bad odour, contaminate the area and also acts as a colony for germs and bacteria. Various methods have been developed to reuse them in various fields of environment preservation. One among them is using of corn cob ash. Ash produced from burning of corn cob is also used for various purposes like concrete, energy production, etc. A recent study carried out on the use of corn cob ash in the manufacturing of lightweight concrete, by Polat[1] has shown that the use of corn cob ash has resulted in change of unit weight to about 800 - 1520 kg/m³ and the heat transmissibility coefficient values ranged between 0.19 - 0.34 Kcal/m.h.°C. Another research work by Parameswaran[2] has also provided great insights on construction materials.

Previously many research works have been carried out to reduce the self-weight of concrete by replacement of aggregates with various alternatives having lower unit weight. It was also observed that many such works have quoted that the replacement has not only reduced the self-weight of the concrete but has also elevated its other characteristics such as compressive strength, workability, etc. In this study coarse aggregates have been partially replaced in the concrete mix with corn cob to reduce the self-weight as well as to reduce the construction cost, as the waste (by-product) of corn industry is being used. Discussion about the method of using corn cob in the concrete mix by incorporating them into it is also specified here, thereby safeguarding natural aggregates and preserving the environment. Marble dust (a residue from marble quarry/fabricators) has also been used in the work as an additive, to increase the strength of concrete by addition of it in suitable proportion. As per the study carried out by Ranjan Kumar[3].

In this paper, M25 grade concrete moulds/blocks were studied. It aims at finding out the optimum percentage replacement for natural coarse aggregates, which can give us the more strength and has the same amount of workability as compared to nominal concrete. Moulds were casted using cement, sand, coarse aggregate, corn cob and marble paste. Percentages of replacement were carried using volume batching of 10%, 20%, 30%, 40% and 50% to the total coarse aggregate content. Tests were carried out on coarse aggregate, fine aggregate, cement, and corn cob to determine their physical property. Cubes of sizes 0.15 m x 0.15 m x 0.15 m were casted and tested for 7-days, 14-days & 28-days against compression loads to determine its compressive strength. In total about 54 moulds were casted for this purpose.

2. Research Methodology and Design

2.1. Objective

- To find the properties of cement, coarse aggregates, and fine aggregates.
- To evaluate the physical properties of Corncob.
- To evaluate the physical properties of marble dust.
- To calculate mix design proportion using IS 10262:2009.
- Casting of concrete moulds.
- To study the compressive strength of cubes at 10%, 20%, 30%, 40% and 50% replacement of corn cob for coarse aggregate with the addition of marble dust.
2.2. Materials

Materials used in this research work were tested for various physical and mechanical properties as they can influence the performance of the samples.

2.2.1. Cement:
- Ordinary Portland Cement (OPC) of Grade 53 by Ultratech Cement was used for casting of cubes for all concrete mixes. Laboratory tests were performed conforming to IS 4031:1988 on cement whose results are shown in table 1.

| Physical Property          | Value      | Test Carried Out                        |
|----------------------------|------------|-----------------------------------------|
| Specific Gravity           | 3.15       | Specific Gravity Bottle (IS:4031 Part - 4) |
| Density                    | 1440 kg m$^{-3}$ | Le-Chatelier Flask (IS:4031 Part -11) |
| Initial Setting Time       | 39 minutes | Vicat Apparatus (IS:4031 Part - 5)     |
| Final Setting Time         | 570 minutes|                                         |
| Fineness                   | 2.6%       | Siege Test (Sieve No.9) (IS:4031 Part – 2) |
| Compressive Strength       | 28.15 N/mm$^2$ | Compression Test (IS:4031 Part – 6)   |
| (7, 14, 28 days)           | 39.05 N/mm$^2$ |                                         |
|                            | 55.87 N/mm$^2$ |                                         |

Figure 1(a)  Figure 1(b)

Figure 1. OPC Cement of 53 Grade
2.2.2. Fine Aggregate
- Fine Aggregate(sand) which passes through 4.75mm IS sieve has been used here. Assessment of various physical properties and their results are specified in table 2.

Table 2: Physical Properties of Fine Aggregate

| Physical Property         | Value                  |
|---------------------------|------------------------|
| Specific Gravity          | 2.70                   |
| Density                   | 1748 kg m\(^{-3}\)     |
| Water absorption          | 1.0%                   |
| Grading                   | IS:383-1970 conforms zone-II |
| Size                      | <4.75 mm               |
| Fineness Modulus          | 2.427%                 |

![Figure 2. Sieving of Fine Aggregates](image2)

![Figure 3. Coarse Aggregate](image3)

2.2.3. Coarse Aggregate
- A Type of coarse aggregate used here has been assessed for various aspects of physical properties and the results has specified.

Table 3: Physical & Mechanical Properties of Coarse Aggregate

| Physical Property          | Value                  |
|---------------------------|------------------------|
| Specific Gravity          | 2.66                   |
| Density                   | 1456 kg m\(^{-3}\)     |
| Water absorption          | 0.6%                   |
| Flakiness Index           | 13                     |
| Elongation Index          | 11                     |
| Max size                  | 20 mm                  |
| Fineness Modulus          | 6.548%                 |
| Aggregate Impact value    | 19.78%                 |
2.2.4. Water
- Water used in this research is as per IS 3025 Part 22 & 33, portable water free from organic substances whose pH value is greater than 6.5 is used for both curing and as well as mixing.

2.2.5. Marble Dust:
- Marble belongs to the metamorphic rock family, it’s a sedimentary rock that got burnt deep in the earth crust for millions of years, the heat and pressure can change it into a metamorphic rock. Marble dust is leftover waste which is obtained during cutting, shaping and polishing of marbles. It is collected from construction or fabrication sites. It constitutes about 15-25% of the total marble used and is available in the semi-liquid form.

Table 4: Physical Properties of Marble Dust

| Physical Property  | Value                      |
|--------------------|----------------------------|
| Specific Gravity   | 2.71                       |
| Bulk Density       | 1257 kg m\(^{-3}\)         |
| Water absorption   | 0.95%                      |
| Colour             | White                      |
| Form               | Powder                     |
| Sieve              | 90µm                       |
| Moisture Content   | 0.62%                      |

Figure 4. Marble Dust

Figure 5. Corn cob

2.2.6. Corn cob / Cob of Corn:
- It is an important residue of corn processing and consumption.

Table 5: Physical Properties of Corn cob

| Physical Property        | Values                          |
|--------------------------|---------------------------------|
| Specific Gravity         | 0.957                           |
| Bulk Density             | 271.64 kg m\(^{-3}\)           |
| Moisture Content         | 4.51%                           |
| Porosity                 | 46.54%                          |
| Size of Aggregates       | 20mm = 100% Passing             |
|                          | 9.5mm = 100% Retained           |
2.3. **Sample Proportions**

Following are the coarse aggregate replacement proportions which were used for the study. Here proportioning was carried out using volume, as the weight proportioning resulted in higher quantity of corncob due to its lower density.

- **M1**: Gravel : Corncob = 0.90 : 0.10
- **M2**: Gravel : Corncob = 0.80 : 0.20
- **M3**: Gravel : Corncob = 0.70 : 0.30
- **M4**: Gravel : Corncob = 0.60 : 0.40
- **M5**: Gravel : Corncob = 0.50 : 0.50

2.4. **Material Preparation:**

- Collection of Corncob, followed by cleaning it and slicing it down to about 10mm – 20mm sizes. It is then placed under sunlight to remove moisture. Oven dry, can also be carried out as per the availability and convenience.
- Now that the corncob is ready for use, Dry mixing is carried out initially with cement and sand, which is then followed by addition of course aggregates both granite and corn.
- After obtaining a homogeneous mixture water is added in parts to carry out wet mixing.
- Once mixing is completed, moulds are prepared, and casting is done.

2.5. **MIX DESIGN**

2.5.1. **Parameters**

- Workability = 100mm (slump)
- Zone of Fine aggregate = Zone-II
- Size of Coarse aggregate = 20mm
- Size of Corncob = 20mm
- Water Cement ratio = 0.5

2.5.2. **Target mean strength**

\[ F'_{ck} = F_{ck} + 1.65 \times S \]
\[ F'_{ck} = 25 + 1.65 \times S \]
\[ F_{ck} = 25 + 1.65 \times 5 \]
\[ F_{ck} = 33.25 \text{ N mm}^{-2} \]

2.5.3. **Selection of water cement ratio**

- Water cement ratio = 0.5
- Cement content = 380 kg m\(^{-3}\)

2.5.4. **Selection of water content**

- For 20mm of coarse aggregates = 186 litres (for 50mm of slump)
- For every 25mm increased water content 3%
- Water content = 191 litres

2.5.5. **Calculation of cement content**

- Water content/water cement ratio
- Cement content = 191/0.5 = 382.3 kg
- Since 382 kg > 320kg (min cement content)

2.5.6. **Aggregate volume**

- Coarse aggregate = 0.62 m\(^{3}\) (as per zone-II)
- Fine aggregate = 0.38 m\(^{3}\)

2.5.7. **Design mix ratio** :- Cement : Fine Aggregates : Coarse Aggregate = 1 : 1.6 : 3.24
Table 6: Mix Proportions

|                        | 0 % Replacement | 10 % Replacement | 20 % Replacement | 30 % Replacement | 40 % Replacement | 50 % Replacement |
|------------------------|-----------------|------------------|------------------|------------------|------------------|------------------|
| Volume of Concrete (m³)| 1               | 1                | 1                | 1                | 1                | 1                |
| Volume of Cement (%)  | 0.121           | 0.121            | 0.121            | 0.121            | 0.121            | 0.121            |
| Cement Content (kg)   | 382.3           | 382.3            | 382.3            | 382.3            | 382.3            | 382.3            |
| Total Aggregate Volume| 0.688           | 0.688            | 0.688            | 0.688            | 0.688            | 0.688            |
| Actual Volume of Course aggregate (%) | 0.45408 | 0.45408 | 0.45408 | 0.45408 | 0.45408 | 0.45408 |
| Course Content (kg)   | 1244.18         | 1244.18          | 1244.18          | 1244.18          | 1244.18          | 1244.18          |
| Coarse Content after replacing with corncob (kg) | - | 1119.76 | 995.34 | 870.93 | 746.51 | 622.09 |
| Corncob Content (kg)  | -               | 124.42           | 248.84           | 373.25           | 497.67           | 622.09           |
| Volume of Fine Aggregates (%) | 0.23392 | 0.23392 | 0.23392 | 0.23392 | 0.23392 | 0.23392 |
| Fine Aggregates Content (kg) | 619.9 | 619.9 | 619.9 | 619.9 | 619.9 | 619.9 |
| Marble Dust Content (kg) | 3.8 | 3.8 | 3.8 | 3.8 | 3.8 | 3.8 |
| Volume of Water (%)   | 0.191           | 0.191            | 0.191            | 0.191            | 0.191            | 0.191            |
| Volume of Water Litres| 191             | 191              | 191              | 191              | 191              | 191              |

3. Laboratory Investigation

Laboratory tests carried on the freshly prepared concrete and hardened concrete moulds are as follows

3.1. Test for Workability

Slump test is carried out to assess the workability of the design mix. It was observed that the degree of workability is medium as per IS:456-2000. It can also be noted that as the percentage of corncob increases the workability has decreased resulting in lower slump value and stiffer concrete.

Figure 9. Slump Test Results
3.2. Test for Compressive Strength

Compressive strength test is the common test carried out on concrete to understand its overall qualitative characteristics, since many attributes of the concrete are related to its compressive strength.

To evaluate the compressive strength of concrete, cubical specimens were tested as per the IS 516-1959 procedure using Compression Testing Machine (CTM). Specimens were tested after 7, 14 and 28 days of curing.

Cubes are removed from tank and kept aside for few hours under shade (not under direct sunlight or oven) to remove moisture from its surface. Specimens were then placed in Compression Testing Machine and load was applied gradually, the peak load at which the specimen fails was noted. This test was repeated for two more specimens similarly and the average load value was taken as the mean strength.

Compressive strength = P/A

Where P = load in KN
A = Area of cross section

Figure 10. Compression Testing Machine

Figure 11. Specimen Under Loading

Figure 12. Specimen after failure
4. Results

Table 7: Results Obtained for various specimens

| S.No | Percentage Replacement | 7 days | 14 days | 28 days |
|------|------------------------|--------|---------|---------|
|      |                        | Weight (Kg) | Strength (kN) | Stress (N/mm²) | Weight (Kg) | Strength (kN) | Stress (N/mm²) | Weight (Kg) | Strength (kN) | Stress (N/mm²) |
| 1    | 0%                     | Sample 1 | 8.24    | 384     | 17.07    | 8.21    | 509     | 22.62    | 8.19    | 584     | 25.96        |
|      |                        | Sample 2 | 8.31    | 341     | 15.16    | 8.33    | 521     | 23.16    | 8.26    | 603     | 26.80        |
|      |                        | Sample 3 | 8.19    | 375     | 16.67    | 8.16    | 505     | 22.44    | 8.11    | 565     | 25.11        |
| 2    | 10%                    | Sample 1 | 8.21    | 352     | 15.64    | 8.15    | 491     | 21.82    | 8.02    | 534     | 23.73        |
|      |                        | Sample 2 | 8.16    | 368     | 16.36    | 8.11    | 529     | 23.51    | 7.91    | 557     | 24.76        |
|      |                        | Sample 3 | 8.07    | 349     | 15.51    | 8.04    | 513     | 22.80    | 7.72    | 546     | 24.27        |
| 3    | 20%                    | Sample 1 | 8.02    | 373     | 16.58    | 7.87    | 501     | 22.27    | 7.77    | 598     | 26.58        |
|      |                        | Sample 2 | 7.92    | 427     | 18.98    | 7.66    | 552     | 24.53    | 7.56    | 638     | 28.36        |
|      |                        | Sample 3 | 8.12    | 398     | 17.69    | 7.91    | 537     | 23.87    | 7.86    | 627     | 27.87        |
| 4    | 30%                    | Sample 1 | 7.84    | 442     | 19.64    | 7.5     | 588     | 26.13    | 7.56    | 693     | 30.80        |
|      |                        | Sample 2 | 7.995   | 416     | 18.49    | 7.82    | 527     | 23.42    | 7.8     | 623     | 27.69        |
|      |                        | Sample 3 | 7.85    | 431     | 19.16    | 7.62    | 559     | 24.84    | 7.62    | 671     | 29.82        |
| 5    | 40%                    | Sample 1 | 7.79    | 385     | 17.11    | 7.44    | 498     | 22.13    | 7.34    | 671     | 29.82        |
|      |                        | Sample 2 | 7.84    | 369     | 16.40    | 7.76    | 506     | 22.49    | 7.58    | 629     | 27.96        |
|      |                        | Sample 3 | 7.68    | 348     | 15.47    | 7.53    | 472     | 20.98    | 7.14    | 607     | 26.98        |
| 6    | 50%                    | Sample 1 | 7.58    | 371     | 16.49    | 7.4     | 442     | 19.64    | 7.32    | 502     | 22.31        |
|      |                        | Sample 2 | 7.69    | 293     | 13.02    | 7.52    | 387     | 17.20    | 7.35    | 471     | 20.93        |
|      |                        | Sample 3 | 7.65    | 338     | 15.02    | 7.48    | 415     | 18.44    | 7.4     | 492     | 21.87        |

Table 8: Average Results Obtained for various specimens

| Percentage Replacement | 7 days Strength (kN) | Stress (N/mm²) | 14 days Strength (kN) | Stress (N/mm²) | 28 days Strength (kN) | Stress (N/mm²) |
|------------------------|----------------------|----------------|------------------------|----------------|------------------------|----------------|
| 0%                     | 366.67               | 16.30          | 511.67                 | 22.74          | 584.00                 | 25.96          |
| 10%                    | 356.33               | 15.84          | 511.00                 | 22.71          | 545.67                 | 24.25          |
| 20%                    | 399.33               | 17.75          | 530.00                 | 23.56          | 621.11                 | 27.60          |
| 30%                    | 429.67               | 19.10          | 558.00                 | 24.80          | 662.33                 | 29.44          |
| 40%                    | 367.33               | 16.33          | 492.00                 | 21.87          | 635.67                 | 28.25          |
| 50%                    | 334.00               | 14.84          | 414.67                 | 18.43          | 488.33                 | 21.70          |
Use of Corncob as a replacement for coarse aggregate has increased its strength by keeping the workability about the same, following conclusions have been made from the test results obtained:

- For 10% replacement, the compressive strength obtained is none the less about the same as standard concrete block.
- For 20% replacement, the compressive strength obtained is about 6% more than the standard concrete block.
- For 30% replacement, the compressive strength obtained is about 12% more than the standard concrete block.
- For 40% replacement, the compressive strength obtained is about 8% more than the standard concrete block.

5. Conclusion
• For 50% replacement, the compressive strength obtained is about 19% lower than the standard concrete block.
• The trend followed here shows that the strength has increased till about 30% replacement, after that there is a drop in it.
• Use of waste material will lead to sustainable development in the construction industry

6. References

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