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# Comparative Evaluation of Partial Substitution Mixture of Fine and Coarse Aggregates with Brick Kiln Powder and Recycled Coarse Aggregates in Rigid-pavement Based Cement-concrete Roads

**Nayeem Nazir Bhat[1], and Brahmjeet Singh[2]**

[1]M. Tech Scholar, Department of Civil Engineering, RIMT University Mandi Gobingarh, Punjab, India
[2]Assistant Professor, Department of Civil Engineering, RIMT University Mandi Gobingarh, Punjab, India

Correspondence should be addressed to Nayeem Nazir Bhat; nayiemnazir@gmail.com



**ABSTRACT-** Fine and coarse aggregates are the most common materials used in construction of cement concrete roads, alternate substitutes to coarse and fine aggregates like recycled aggregates and brick kiln powder have a prospect to replace fine and coarse aggregates in road constructions leading to effective cost-cutting, low pollution and comparable material strength. This work aimed to study the cost reduction of the cement concrete road and pollution caused by brick kiln powder and crushed aggregates and to see the strength properties of rigid pavement upon partial replacement. We achieved the study purpose by partially replacing the fine and coarse aggregate with brick kiln powder and recycled coarse aggregates. Subsequent analysis was performed by measuring various properties of brick kiln powder, admixture, fine aggregates, coarse aggregates, and recycled aggregates. Compressive strength and flexural strength tests were employed on the recycled coarse aggregates and brick kiln powder concrete mix. The results suggested the fact that a combination of brick kiln powder and recycled coarse aggregate as a replacement against conventional material is an effective material combination nearly as equivalent to the conventional concrete at replacements of 8% and 15%.

**KEYWORDS-** Brick Kiln Powder, Recycled Aggregates, Compressive Strength, Fine Aggregate, Coarse Aggregate, Concrete Mix, Flexural Strength, Rigid Pavement, Crushed Aggregate

## I. INTRODUCTION

Huge number of research works have been carried out globally regarding the recycling of different construction materials and found reasonably effective. The cost of construction materials is very high, so it is essential for civil engineers to adopt the recycled concrete ingredient and they need more research to look beyond the conventional sources in construction to make the work economical as well as durable. Keeping such important considerations in mind, the study was designed to work on comparing the strength and other parameters of Fine Aggregate (sand) & Coarse Aggregate compared to substitution with Brick Kiln Powder & Recycled coarse aggregate in High Strength concrete. The Rigid pavement or cement concrete roads are usually made from either Plain cement concrete or Reinforced cement concrete and the pavement behaves like a rigid reinforced slab to resist the wheel loading and deformation but in rigid pavements, many common problems have been observed such as Settlement of subgrade, Pumping out failure caused by the expulsion of water from beneath subgrade i.e. from the water table, the spelling of joints because of less strength or due to improper design mix of concrete, thermal stress, and shrinkage, etc [1]. Ultimately leading to failure or complete deterioration of rigid concrete roads. To reduce such problems to a greater extent, we carried out a brief analysis from previously done research in the field and devised a hypothesis to do a comparative analysis between conventional materials and recycled materials used.

This study focuses on improving the performance of rigid pavement by increasing its strengthening properties, such as Flexural strength, Compressive strength, Tensile strength of Cement concrete roads, and minimizing the expansion of pavement by resisting tensile stresses.

An admixture of Sodium Silicate would be used to improve the Compressive and flexural strength of concrete. sand would be replaced by fine brick kiln powder to improve the impermeability of subgrade to the top surface course of pavement. This powder is considered finer than sand which results in filling most of the small voids putatively, making pavement more durable and water-resistant.

In this study, conventional aggregates would be substituted with recycled aggregates. That comprises crushed and beneficiated mortar material previously used in constructions or rigid pavements.

### A. *Recycled Coarse Aggregate*

Recycled aggregates are crushed concrete or asphalt from construction debris that is reused widely in civil engineering, like in rigid cement concrete pavements, framed structures, and other construction works. In this investigation work recycled coarse aggregate has been obtained from Baramulla Kashmir. In the present study, recycled coarse aggregate has been used to replace conventional coarse aggregate. The properties of fresh and hardened concrete made of partial/full replacement of recycled coarse aggregate are found and the results are compared with conventional concrete.

1) Applications of Recycled Coarse Aggregate

Making use of recycled aggregates over virgin materials can save money, as they are less expensive to produce. [2]Recycled aggregates are often referred to as 'Green construction material'.Local availability of recycled materials reduces transportation costs. Rendering it economical, less taxable, and cost-effective than sending them to landfills. Using recycled aggregate reduces the amount of virgin aggregates which are created and therefore means less use of natural resources.
Recycled aggregates can be used for different functions, suitable for use with construction projects, landscaping, and in-home improvement applications.

### *B. Brick kiln powder*

Brick kiln Powder used in this investigation has been obtained from chadoora in budgam. Brick dust kiln is a fine powder composed of pulverized red clay and is obtained from the burning of sun-dried bricks at high temperatures of about 700-1100 degrees Celsius. It can also be obtained by crushing old bricks. It contains silica, alumina, lime, and iron oxide. Red Brick kiln powder is a powder composed of pulverized red clay bricks which are used in the practice of hoodoo/rootwork/conjure. Some practitioners may add extra ingredients to the red brick dust to strengthen it, in a magical sense. Line Sprinkling is the common method for Redbrick dust deployment in entrances and doorways.

### *C. Advantages of Brick Kiln Powder*

- Use of brick kiln powder is environmentally friendly as the waste materials from industries are effectively being used to create quality building materials
- Brick kiln powder can be used as a partial replacement of fine aggregate because of its binding properties.
- Brick kiln powder has a good reactivity property when it is used as a partial replacement with fine aggregate.
- Brick kiln powder can be replaced with fine aggregate up to 30% easily.
- Brick kiln powder is resistant to acid and sulphate attacks.
- The shrinkage of brick kiln concrete is very less.
- The use of brick kiln powder gives concrete good workability, durability and finish.
- It was observed that the compressive strength of all the mortar mixes with 50% replacement of BKBD was higher, when compared to the compressive strength of normal mortar for immersion in water for 28 days

### *D. Admixture (Sodium Silicate)*

The compound sodium metasilicate, Na2SiO3, is also known as water glass or liquid glass, and is commonly referred to as sodium silicate.It's utilized in cements, passive fire protection, refractories, textile and lumber processing, and vehicles, and it's available in aqueous solution and solid form.When sodium carbonate and silicon dioxide are melted, sodium silicate and carbon dioxide are formed: Anhydrous sodium silicate comprises a chain polymeric anion made out of shared SiO4 tetrahedral corners and not a discrete SiO32− ion.

o Advantages of Sodium Silicate

It reduces the initial setting time of concrete mix

- It is used to give early strength concrete
- It is a high corrosion inhibitor and anti-scaling agent
- It can be used as filler in concrete

o Uses of Sodium Silicate

- To reduce the initial setting and strengthen the concrete
- Drilling fluids Concrete and general masonry treatment
- Corrosion inhibitors and anti-scaling agents
- Concrete and general masonry treatment
- Adhesives and sealant chemicals
- Adsorbents and absorbents

## II. REVIEW LITERATURE

- Investigated brick waste for its use as a replacement of cement and sand in cement mortar as it behaves as a pozzolana. It may make an important contribution towards decreasing the adverse effect of the production, disposal and the dumping of brick waste on the environment. His findings show that richer mixes give the lower values of bulk density and higher values of compressive strength for sand replacement with brick waste up to 40%.
- Investigated an optimal methodology for determining whether given brick dust will produce a pozzolanic reaction when combined with lime. Pozzolanicity will be used to describe this property.
- Investigated the feasibility of using waste bricks powder of Gachsaran Company in concrete. Cement is replaced by waste bricks powder in different proportions until 40% by weight. Pozzolanic properties of the brick powder and compressive strength of concrete were investigated. His findings demonstrated that the brick powder showed pozzolanic properties.
- "In this study, the mechanical and physical properties of local recycled coarse aggregate have been investigated through detailed laboratory tests.Local coarse RCA materials were combined with natural coarse aggregate (rounded) and crushed natural coarse aggregate in various proportions of 0, 25, 50, 75, and 100%. When mixed with natural coarse aggregates (rounded) and high compressive strength (similar to the ordinary RCA free mix), the results showed a decrease in density and an increase in compressive strength, as well as a decrease in flexural strength with an increasing percentage of RCA when mixed with crushed natural coarse aggregate.New relationships have been developed for calculating the flexural strength and modulus of elasticity of concrete containing RCA using non-destructive tests with a high level of confidence."
- "The results of a test program to study the use of recycled concrete aggregate (RCA) in high-strength, 50 N/mm$^2$ or greater, concrete are described. The effects of coarse RCA content on the ceiling strength, bulk engineering and durability properties of such concrete have been established. The results showed that up to 30% coarse RCA had no effect on concrete strength, but thereafter there was a gradual reduction as the RCA content increased.The consequences of high RCA content are accommodated by a simple

adjustment to the water/cement ratio mix. It is shown that high-strength RCA concrete will have equivalent engineering and durability performance to concrete made with natural aggregates, for a corresponding 28-day period".

- It was observed that the compressive strength of all mortar mixes with 50% replacement of BKBD were higher, when compared to the compressive strength of normal mortar for immersion in water for 28 days

## III. ABBREVIATION

NCA: Natural Coarse Aggregate
RCA: Recycled Aoarse Aggregate
BKP: Brick Kiln Powder
FA: Fine Aggregate
CA: Coarse Aggregate

## IV. METHODOLOGY

The properties of different constituent materials used for making the specimens in the experimental studies were tested in the laboratory. Various tests were performed on: Cement, Fine aggregate, Coarse aggregates, Brick Kiln Powder, and Glass fiber Admixture (Sodium Silicate)

### *A. Cement (OPC-43 Grade)*

The Ordinary Portland cement (43) grade was used as the main binding material, which is sulphate resistant with an average heat of hydration. The characteristic resultant properties of cement are shown in Table 1

Table 1: Characteristic resultant properties of cement in experiment

| **S.No** | **Test performed** | | **Experimental** | **Specified value as per** |
|---|---|---|---|---|
| | | | | |
| | | | **Value** | **IS:8112-1989** |
| **1.** | Consistency of cement (%) | | 32.25 | ------ |
| **2.** | Specific gravity | | 3.21 | 3.15 |
| **3.** | Initial setting time (minutes) | | 28 | >30 |
| **4.** | Final setting time (minutes) | | 370 | <600 |
| **5.** | Compressive strength | | | |
| | | (N/mm² ) | 23.90 | >23 |
| | 1. | 3 days | 35.80 | >33 |
| | 2. | 7 days | 65.90 | >43 |
| | 3. | 28 days | | |
| **6.** | Soundness (mm) | | 2.01 | 10 |
| **7.** | Fineness of cement | | 1.8 | 10 |

### *B. Fine Aggregate*

Fine aggregate is defined as soil particles that pass through a sieve of 4.25 mm. River sand or machine sand is the most common fine aggregates. The fine aggregate used In this investigation was clean sand collected from river Jhelum Baramulla, Kashmir with a maximum size (4.75mm) conforming to zone I. The specific gravity of the fine aggregate was 2.47, water absorption capacity was 0.166 and free moisture content was 2%. The sieve analysis of fine aggregate used in the experiment is mentioned in Table 2.

Table 2: Sieve Analysis of Fine Aggregate used in experiments

| S. No | IS sieve Designation | Weight retained on sieve (gm) | Cumulative weight retained (gm) | Cumulative %age Retained | %age Passing | IS 383-1970 Requirements for zone II |
|---|---|---|---|---|---|---|
| 1 | 4.75mm | 19 | 19 | 1.9 | 98.1 | 90-100 |
| 2 | 2.36mm | 131 | 150 | 15.0 | 85 | 75-100 |
| 3 | 1.18mm | 102 | 252 | 25.2 | 74.8 | 55-90 |
| 4 | 600µ | 349 | 601 | 60.1 | 39.9 | 35-55 |
| 5 | 300µ | 293 | 894 | 89.4 | 10.6 | 8-30 |
| 6 | 150µ | 88 | 982 | 98.2 | 1.8 | 0-10 |
| 7 | Pan | 18 | 1000 | | ∑F=310.2 | |
| **Fineness modulus of sand=3.102** | | | | | | |

### *C. Coarse Aggregate*

The coarse aggregate is an inert material that is retained on 4.75mm sieve. They are usually dolomite aggregates used widely in the construction industry. The aggregates are mainly categorized based on size rather than their chemical and mechanical properties.

The conventional coarse aggregate used in this investigation was irregular machine-made collected from the Tangmarg crusher plant. The specific gravity of coarse aggregate was 2.54, water absorption capacity 01 and free moisture content was 0.0%. The sieve analysis of coarse aggregate used in the experiment is shown in Table 3

Table 3: Sieve analysis of Coarse Aggregate used in experiments

| S. NO | Sieve Designation (mm) | Wt. Retained on sieve (gm) | Cumulative wt. Retained (gm) | Cumulative %age retained | %age passing | IS:383-1970 |
|---|---|---|---|---|---|---|
| 1. | 80 | Nil | Nil | Nil | 100 | 100 |
| 2. | 40 | Nil | Nil | Nil | 100 | 100 |
| 3. | 20 | 00 | 00 | 00 | 100 | 85-100 |
| 4. | 10 | 3429 | 3429 | 68.58 | 31.42 | 25-55 |
| 5. | 4.75 | 1513 | 4942 | 98.84 | 1.16 | 0-10 |
| 6. | Pan | 58 | 5000 | 100 | 0.0 | ---- |
| | | | | ∑F=267.42 | | |
| **Fineness modulus of C.A=2.67** | | | | | | |

### *D. Recycled Coarse Aggregate*

The Specific gravity of Recycled coarse aggregate was 2.3 and bulk density was 1325.93 kg/$m^3$ Recycled coarse aggregate was produced after dismantling of the existing concrete. The physical properties of RCA & NCA are shown below in Table 4

Table 4: Physical properties of RCA & NCA

| S. No | Particular | Proportion | |
|---|---|---|---|
| | | NCA | RCA |
| 1 | Water absorption (%) | 1.56 | 6.4 |
| 2 | Specific gravity | 2.63 | 2.3 |
| 3 | Bulk density kg/$m^3$ | 1469.8 | 1325.93 |

### *E. Brick Dust Kiln*

Brick dust kiln composed of pulverized red clay was obtained from burning of sun-dried bricks at a high temperature of about 700-1100 °C. It could also be obtained by crushing old bricks. Its composition includes silica, alumina, lime, and iron oxide. The chemical composition of brick kiln powder is mentioned in table 5 below.

Table 5: Chemical Composition of Brick Kiln Powder

| S. No | Particular | Proportion |
|---|---|---|
| 1 | Calcium Oxide | 36-94% |
| 2 | Silicon dioxide | 0% |
| 3 | Aluminium | 0.1% |
| 4 | Calcium Oxide | 0.3-0.2% |
| 5 | Magnesium Oxide | 0.1% |
| 6 | Potassium Oxide | 2.15% |
| 7 | Ignition Oxide | 3.15-4% |

### *F. Admixture (Sodium Silicate)*

Admixture sodium silicate used in this investigation was purchased from Ahad Scientific Industries located at Srinagar Jammu & Kashmir. Sodium silicate, also known as water glass or soluble glass, is a compound containing sodium oxide and silica. In this research work sodium silicate crystals were used by 2% by weight of cement as per IS Code to decrease the initial setting time adhesive, sealant, absorbent and increase the strength of concrete. The chemical composition of sodium silicate(admixture) is shown below in Table 6

Table 6: Chemical Compositions of Sodium Silicate Used

| S. No | Particular | Proportion |
|---|---|---|
| 1 | MF | Na2O3Si.9H2O |
| 2 | MF | 284 |
| 3 | Chloride | Max 0.05% |
| 4 | Sulphate | Max 0.05% |
| 5 | Iron | Max 0.05% |
| 6 | Heavy Metals | Max 0.001% |

### *G. Strength tests*

Tests were done as per the codes of Bureau of Indian Standards. The test for compressive strength on cubes was measured at 7,14 and 28 days of curing as per IS: 516 1959 test for flexural strength on beam was measured at 28 days of cure period as per IS 516 19

1) Compressive Strength Test

For the M45 concrete grade, cube samples of 150 x 150 x 150 mm were made. Different proportions of cement, recycled coarse aggregates, and brick kiln powder were used to fill the moulds.
Vibration was given to the moulds using a table vibrator. The specimen's top surface was finished and levelled.
After 24 hours the specimens were remoulded and transferred to the curing tank wherein they were allowed to cure for 7 and 28 days. After 7 and 28 days curing, these cubes were tested on manual compression testing machines as per I.S. 516 1959. The failure load was recorded. Three cube replicates were tested to reduce statistical error and the average result value was obtained. The quantity of material required to check the crushing/compressive strength of the sample is shown in Table 7.

Table 7: Quantity of materials Required Crushing strength Test

| Mix Design | CEMENT % | RCA % | BKP % | ADMIXTURE By 2% C/w | FA In Kg | CA In Kg |
|---|---|---|---|---|---|---|
| MIX 0 | 100 | 0 | 0 | 0% | 2.586 | 3.861 |
| MIX 1 | 100 | 8 | 4 | 0.02 | 2.482 | 3.552 |
| MIX 2 | 100 | 15 | 8 | ----- | 2.379 | 3.282 |
| MIX 3 | 100 | 25 | 12 | ----- | 2.276 | 3.869 |
| MIX 4 | 100 | 30 | 16 | ----- | 2.172 | 2.703 |
| MIX 5 | 100 | 35 | 20 | ----- | 2.068 | 2.509 |

2) Flexural Strength Test

The standard sizes of beam specimens were 15x15x70 cm. The beam moulds conform to IS: 10086 1982. Compacting of concrete was done by proper vibration as per IS: 516 1959. Curing: Test specimens were stored in water at a temperature of $24^0$ & 34 $^0$c for 48 hours before testing. The specimens were analysed as soon as they were removed from the water, while they were still wet. The Flexural test was performed on a two-point loading system. The quantity of material used to make a specimen cube to check the flexural strength is shown in Table 8.

Table 8: Quantity of materials Required for Flexural Strength Beam

| Mix Design | CEMENT % | RCA % | BKP % | ADMIXTURE By 2% C/w | FA In Kg | CA In Kg |
|---|---|---|---|---|---|---|
| MIX 0 | 100 | 0 | 0 | 0 | 10.864 | 18.051 |
| MIX 1 | 100 | 8 | 4 | 0.02 | 10.429 | 16.606 |
| MIX 2 | 100 | 15 | 8 | ----- | 9.995 | 15.334 |
| MIX 3 | 100 | 25 | 12 | ----- | 9.560 | 13.539 |
| MIX 4 | 100 | 30 | 16 | ----- | 9.125 | 12.636 |
| MIX 5 | 100 | 35 | 20 | ----- | 10.429 | 11.734 |

# V. RESULTS AND DISCUSSION

## *A. Compressive Strength After 7 days*

The compressive strength of specimen after 7 days are as shown in Table 9.

Table 9: Compressive strength after 7 days

| S .No | Mix designation | Average compressive Strength | % increase average compressive strength |
|---|---|---|---|
| 1 | MX0 | 32 | |
| 2 | MX1 | 31.10 | -3% |
| 3 | MX2 | 29.13 | -10% |
| 4 | MX3 | 27.14 | -17% |
| *5* | MX4 | 24.18 | -32% |
| 6 | MX5 | 20.00 | -55% |

The experimental investigations show that by the partial replacement of recycled coarse aggregate at (8%) and brick kiln powder (4%). The compressive strength decreased by 3%. At compositions (15%) and (8%) respectively it decreased up to 10%. At compositions (25%) and (12%) respectively compressive strength decreases by 17%. At compositions (30%) and (16%) respectively compressive strength decreases by 32% and At compositions (35%) and (20%) respectively compressive strength decreases by 55%.

## *B. Compressive Strength After 28 days*

The compressive strength after 28 days is shown in Table 10

Table 10: Compressive strength after 28 days

| S .No | Mix designation | Average compressive strength | % increase average compressive strength |
|---|---|---|---|
| 1 | MX0 | 63.25 | |
| 2 | MX1 | 61.14 | -4% |
| 3 | MX2 | 62.32 | -1.5% |
| 4 | MX3 | 58.17 | -9% |
| 5 | MX4 | 55.66 | -45.50% |
| 6 | MX5 | 52.10 | -60% |

The experimental investigations show that by the partial replacement (8%) coarse aggregates and (4%) of brick kiln powder. Compressive strength decreased by 4%, and at replacements of (15%) and (8%) respectively, it decreased up to 1.5%, at replacements of 25 % and with 12% it decreases the compressive strength by 9%, at replacements of 30% and 16%, compressive strength decreases by 45.50% and at replacements of 35% and 20% of, The compressive strength decreases by 60%

### *C. Flexural Strength After 7 days*

The flexural strength after 7 days is shown in Table 11 below

Table 11: Flexural Strength after 7 Days

| S .No | Mix designation | Average flexural strength | % increase average flexural strength |
|---|---|---|---|
| 1 | MX0 | 4.20 | |
| 2 | MX1 | 4.01 | -5% |
| 3 | MX2 | 5.08 | 20% |
| 4 | MX3 | 4.25 | -1% |
| 5 | MX4 | 3.61 | -30% |
| 6 | MX5 | 3.10 | -35% |

Study results depict that with the partial replacement of (8% recycled coarse aggregate) and (4% brick kiln powder) respectively, the flexural strength decreases by 5%. At (15%) and (8%) respectively, it increased up to 20%. At 20% and 12%, it decreases by 1%. At replacements of 30% and 16%, it decreases by 30%. At replacements of 35% and 20%, it decreases by 35%.

### *D. Flexural Strength After 28 Days*

The flexural strength after 28 days is shown below in Table 12.

Table 12: Flexural Strength after 28 Days

| S .No | Mix designation | Average flexural strength N/mm² | % increase average flexural strength |
|---|---|---|---|
| 1 | MX0 | 9.76 | |
| 2 | MX1 | 8.56 | -11% |
| 3 | MX2 | 9.96 | 2% |
| 4 | MX3 | 8.22 | -20% |
| 5 | MX4 | 7.11 | -35% |
| 6 | MX5 | 7.00 | -40% |

Study results depict that by the partial replacement of (8% recycled coarse aggregate) and (4% brick kiln powder), the flexural strength decreases by 11%. At replacements of (15%) and (8%) respectively, it increases by up to 2%. At replacements of 25% and12%, it decreases by 20%. At replacement of 30% and 16%, it decreases by 35%. And at replacements of 35% and 20%, it decreases by 40%

## VI. CONCLUSION

- The experimental study depicts that the combination of brick kiln powder and recycled coarse aggregate as a replacement of conventional material is an effective combination and provides nearly equivalent strength to the conventional concrete at replacement rates of 8% and 15% respectively.
- The analysis provides useful conclusions in classifying the cement sand, coarse aggregate**,** brick kiln powder, and glass fibre. These results also confirm the right type and proportion of the material substitute.
- The study inferences that the combination of brick kiln powder and recycled coarse aggregates has the potential to reduce the cost of the cement concrete roads
- The study inferences towards the methods to minimise the pollution caused by the demolition of building and hence conceptualizes an eco-friendly approach towards the environmental preotection.
- The experimental study indicates that the compressive strength increase with the increasing percentage of brick kiln powder and recycled coarse aggregates upto the replacement rates of 8% brick kiln powder and 15% recycled coarse aggregates, upon the further increase in proportion the strength decreases gradually.
- The maximum flexural strength is obtained usually after 28 days at the partial replacement of 8% brick kiln powder and 15% recycled coarse aggregates.

## CONFLICTS OF INTEREST

The authors declare that they have no conflicts of interest.

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