Preparation of low cost concrete bricks by replacing coarse aggregate with ceramic tile waste and fine aggregate with quarry dust

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ABSTRACT

The most of the building material for construction of houses is the normal brick. The rapid growth in today's construction industry has obliged the civil engineers in searching for more efficient and durable alternatives far beyond the limitations of the conventional brick production. This project presents the experimental investigation of partial replacement of tile waste as coarse aggregate and quarry dust as replacement of fine aggregate in the preparation of concrete bricks. In this study M10 grade of concrete was made for concrete bricks. Concrete mix of 10%, 20%, 30%, 40% & 50% ceramic tile waste as coarse aggregate and 50% replacement of quarry dust as fine aggregate constant replacement were made. The brick specimen was Casted a size of 100mm x 100mm x 100mm and the Shape and size test, Compression test, water absorption test, fire ignition, Soundness test, drop test, Efflorescence test, Color test and Structure test were conducted to analyze their suitability as a construction material.

Keywords: M10 grade of concrete, Quarry dust, ceramic tile waste, Shape and size test, Compression test, water absorption test, fire ignition, Soundness test, Drop test, Efflorescence test, Color test, Structure test.

1. INTRODUCTION

1.1 General

Shelter is a basic human need and owing a house becomes a life long struggle as majority of Indians find housing costs prohibitively expensive. This problem becomes even more acute when considering the low - income families who accounts for about 60-70% of Indian population. This brings out the need to reduce the cost of the housing and make it affordable for the booming population. Burnt clay bricks are being used extensively and the most important building material is the construction industry. In India the building industry consumes about 20000 million bricks and 27% of the total natural energy consumption for their production. The higher water absorption, high efflorescence, etc. which have forced engineers to look for better materials capable of reducing the cost of construction. In this contest search for an alternative building material to clay bricks, various government agencies and research institutions have repeatedly recommended the use of waste materials such as Fly Ash, Red Soil, Quarry Dust etc., as an alternative building material in making bricks, blocks and tiles etc. Logically the unlimited use of clay is harmful to the society, as all the conventional clay bricks depend on good quality clay available from agriculture fields. Presuming a weight of 2kg per brick, the total clay is taken out from agriculture lands per year for such brick works out to over 300 million tons.

About180 billion tons of clay brick production per year consumes 540 million tons of clay, makes 26305 hectares of land barren, and consumes 30 million tons of coal equivalent, generates 26 million tons of Carbon Dioxide. A 10% switchover to fly ash bricks will use 30 million tons of fly ash every year, save environment and coal. There has been impressive increase in the power generation in India from a low-capacity of 1362 MW in 1947 to about 112050 MW in 2004. Indian coal has high ash content around 35-45% and low calorific value 35004000 K. Cal/Kg as a result of which huge quantity of ash is generated. A typical 200 MW unit produce around 50-60 M. Tons of ash per hour in India. Generally 0.40-hectare land is needed per M.W. of power production. Power being considered as an engine of growth, has always been a focus area for most of the developing countries including India. The power generation in India has increased from 1362 MW in 1947 to 200000 MW in 2012 and ash generation will reach a figure of around 200 M. Tons per year. This would require about 40000 hectares of land for the construction of ash ponds.

Further, Government of India has planned for enhancement of installed capacity to 3, 00,000 MW by 2017 (Vimal et al. 1995). Coal based power plants not only produce of millions of megawatts of power but also millions of tons of fly ash. Most of the coal-based power plants were set-up with sole aim of power generation (Dhar, 2001). Environmentally safe disposal of large quantity of fly ash is not only problematic but also expensive. Keeping in view the gravity of the fly ash disposal problem, global efforts are mooted to utilize fly ash in bulk quantities.

The development of the infrastructure the need of concrete has been increased at high rate. Concrete is important construction materials that have been widely used all over the world. The use of concrete has been increasing day by day. Due to this some negative impacts are there in production of concrete such as coarse aggregate extraction from natural resources, scarcity of river sand it leads to depletion of materials and ecological imbalance. Various researches have been found that replacement for coarse aggregate. The use of plastic, paper and pulp industry waste, textile waste, rice ash, recycled rubber tires, broken bricks are some examples for replacing aggregate in concrete. Coconut shell is an agricultural by product which can be used as coarse aggregate in concrete. According to report made in 2016 India is the third largest coconut producers in world. India produces of about 119 million tons of coconut every year. The coconut shells are accumulated in land and get degraded around 100-120years. Due to this, a serious environment problem of disposal of coconut shells occurs. So to minimize this coconut shell can be used as aggregate in concrete. The use of Fly Ash and other Agricultural wastes for making bricks is ecologically advantageous since apart from saving precious top agriculture soil, it meets the social objective of disposing industrial wastes otherwise are pollutants and nuisance.

1.2 Quarry stone dust

Igneous and metamorphic rocks cover about 90-95% of the earth's surface. In earth's crust, most abundantly available type of rock is igneous and due to its wide range of physical and chemical properties, enables its use in all different sectors of construction purposes. Most of the high-rise mountains, hills, plateaus and surface of the earth, even in oceanic crust consist of igneous rock. The leading manner of extracting rock or stone is through digging, quarrying and blasting. In India, most of the rocks are extracted through quarrying. Quarrying is the process of extracting rock using explosives. 15 The pieces of rock or stone obtained in quarrying are used in either stone masonry or aggregate in building or road construction. In this blasting process of rock, numerous small or fine particles of stones are transformed into dust particles in the atmosphere. These dust particles surround the environment throughout the quarry and get settled on the leaves and bark of trees, thereby killing the tissues of the tree. Hence to reduce air pollution, this quarry dust is used for construction purposes. It is used as a substitute for fine aggregate in concrete either partially or fully. As it is originated from rock, it offers better strength when compared with sand as fine aggregate in concrete. It can also be used in road construction and manufacturing of bricks and tiles. It is the cheap and best material available in the market for construction purposes.

2. LITERATURE SURVEY

Venkatakrishnan and Rajkumar, (2013) studied the properties of waste plastic fiber reinforced concrete when quarry dust is used to replace natural sand. The maximum workability and strength values were recorded when 30% of quarry dust used to replace sand. Meanwhile, after 30% replacement of quarry dust the strength values decreased. Therefore, by 50% and 30% replacement of sand by quarry dust is the optimum percentage for hollow concrete blocks and waste plastic fiber concrete respectively.

Suresh Chandra *et al.,* (2014) studied the effect of replacement of sand by quarry dust in hollow concrete block for different mix proportions. The objective of the study is to indicate the properties of hollow concrete blocks produced by the quarry dust as sand replacement. The results showed the hollow concrete blocks sand production can be replaced partially by 50% by quarry dust instead of complete replacement. It seemed that the blocks with 50% replacement performs better than blocks which are conventionally prepared using natural sand. Moreover, the hollow concrete blocks can be used in load bearing masonry structures as other option in construction industry.

Shruti *et al.,* (2016) the mechanical behaviour of M20 grade concrete was studied with quarry dust as sand replacement by 25%, 50%, 75% and 100%, ground granulated blast furnace slag (GGBS) as cement replacement by 20%, 30%, 40%, 50% and 60% with plain cement concrete. The optimum replacement of sand by quarry dust recorded from the findings was at 50%. The split tensile strength carried out on specimen with 50% quarry dust replacement on sand and 60% GGBS replacement of cement gave an increase value linearly. Besides, the flexural strength conducted with the same proportion showed an increase value but it did not show the linear value of increased. From the outcome, the 50% or quarry dust and 60% of GGBS by replacement were selected to be incorporated in the concrete in order to achieve maximum mechanical properties.

Gonzalez and Etxeberria prepared high performance concrete mixes using mixed recycled aggregate from construction and demolition treatment plant as partial substitution of gravel with replacement levels 20%, 50%, and 100%, in addition to preparing mixes incorporating fine ceramic aggregate as partial replacement of sand with levels 15%, and 30%. They reported that concrete mixes with fine ceramic aggregate have higher compressive and flexural strengths than conventional concrete. While concrete mixes incorporating ceramic mixed aggregates with replacement levels higher than 20% have lower compressive and flexural strengths than conventional concrete.

Paulo cachim experimented on use of waste ceramic tile aggregates, collected from ceramic industrial waste from different sources water absorption was 15.81 and 18.91 percent respectively. The more value of water absorption influenced the workability of concrete. In first 2 minutes 75 percent of total absorption takes place and after 5 minutes at least 91 percent of the total absorption occurred. Medina et al concluded that use of ceramic tile wastes with 4 mm and lower size as fine aggregates in concrete and density of concrete was 2.41 g/cm3 and compressive strength and split tensile strength were increased due to lower fraction of ceramic waste usage in to the concrete composition.

Pancheco-Torgail and said jalali experimented the strength and durability of ceramic tile waste concrete as compared to natural aggregate ceramic aggregates have higher value of water absorption. Medina concluded on utilization of ceramic tile waste as an alternative material of coarse aggregates. It was produced by crushing of sanitary ware and shape curve is same as that of natural aggregates. Irregular shape provided that superior surface area and better bonding was observed in experimentation.

Atul Uniyal et al. They replaced the aggregates with tile powder by 5%,10%,15% and 20. From there tests they concluded the following: They found the most optimal percentage for the replacement of ceramic tile powder with cement was 15 %. Above this percentage the compressive strength of their concrete decreases.

Parminder Singh et al. They prepared three different concrete mix designs M 20, M 25 & M30 to find the effect of tile aggregates on strength of concrete and they replaced it with natural aggregates by proportion of 0%,5%, 10% & 20%. They found limited use of tile aggregate in concrete due to its flaky nature. After performing various tests they concluded that: Tile aggregate shows similar mechanical properties to that of normal aggregates but not completely same. They found out that the water absorption, crushing value and impact value, were higher than natural coarse aggregate without compromising the strength we can substitute 20% of normal 20mm aggregates in M20 grade concrete.

The literature review shows that a lot of work has been carried out on the mechanical properties of concrete with the partial replacement of quarry dust and Cermaic tile waste with different percentages ratios individually. The literature survey reveals that very little work has been carried out on the M10 grade based concrete bricks with tile waste as coarse aggregates and quarry dust as fine aggregates replacement in the possible extent. The performance of the concrete is increased when it is added with the optimum percentage of ceramic tile waste and quarry dust.

3. OBJECTIVE AND METHODOLOGY

3.1 Aim

The aim of study is to evaluate the performance and suitability of replacement of Tile waste with coarse aggregate and fine aggregate with quarry dust in concrete bricks manufacturing.

3.2 Objective

The objectives of experimental study are:

- Study on strength characteristics of M10 grade concrete bricks with replacement of 50% fine aggregate by quarry dust and replacement of 10%, 20%, 30%, 40%, and 50% coarse aggregate by Tile waste.
- To determine the Shape and size test, Compression test, water absorption test, fire ignition, Soundness test, Drop test, Efflorescence test, Color test and Structure test for concrete bricks.

3.3 Methodology

The present study requires preliminary investigations in a systematic manner

- Selection of type of grade of mix, mix design by an appropriate method, trial mixes, final mix proportions.
- Estimating total quantity of concrete required for the whole project work.
- Estimating quantity of cement, fine aggregate, coarse aggregate, tile waste, quarry dust required for the project work.
- Preparing the concrete bricks with partial replacement of fine aggregate by quarry dust, coarse aggregates by tile waste and cement, water-cement ratio kept constants.
- Prepared bricks cure for 7days by sprinkling of water daily 2times.

Concrete bricks tested and concluded optimum dosage of waste material replacement.

4. EXPERIMENTAL INVESTIGATIONS

4.1 Materials Used

For the preparation of concrete bricks we are used Cement, tile waste, quarry dust, Coarse aggregates, Fine aggregates and water.

Table 4.1 Properties of Cement

Property	Values
Fineness of cement	5%
Standard consistency	35%
Initial setting time	40min
Final setting time	400min
Specific gravity	3.06

4.1.2 Water

According to IS 456: 2000, water used for mixing and curing shall be clean and free from injurious amounts of oils, acids, alkalis, salts, sugar, organic materials or other substances that may be deleterious to concrete or steel. Potable water is generally considered satisfactory for mixing concrete. The pH value of water shall be not less than 6.

4.1.3 Fine aggregates

It is the aggregate most of which passes 4.75 mm IS sieve and contains only so much coarser as is permitted by specification. According to source fine aggregate may be described as:

- Natural sand-it is the aggregate resulting from the natural disintegration of rock and which has been deposited by streams or glacial agencies.
- Crushed stone sand-it is the fine aggregate produced by crushing hard stone.
- Crushed gravel sand-it is the fine aggregate produced by crushing natural gravel.
- The specific gravity value is 2.43
- The water absorption value is 0.8%

4.1.4 Coarse aggregates

It is the aggregate most of which is retained on 4.75 mm IS sieve and contains only so much finer material as is permitted by specification. According to source, coarse aggregate may be described as:

- Uncrushed Gravel or Stone– it results from natural disintegration of rock
- Crushed Gravel or Stone– it results from crushing of gravel or hard stone.
- Partially Crushed Gravel or Stone– it is a product of the blending of the above two aggregates.
- Hard crushed granite stone, coarse aggregates confirming to graded aggregate of size,10mm as per IS:383-1970 was used in the study.
- The specific gravity value is 2.67
- The water absorption value is 1.2%

4.1.5 Quarry dust

Fine aggregate is described as crushed rock particles with a size of less than 4.75mm. It is further divided into coarse, medium, and fine categories. Coarse grains range from 4.75mm to 2mm, medium grains range from 2mm to 0.425mm, and fine grains range from 0.425 mm to 0.075 mm. According to source, quarry dust may be described as:

- The specific gravity value is 2.6
- The water absorption value is 1.2%

4.1.6 Ceramic tile waste

The ceramic tile waste collected from C&D waste. The collected waste crushed into small pieces with passed from IS sieve 10mm.

- The specific gravity value is 2.28
- The water absorption value is 1.0%

4.2 Mix design

Adopted Grade was **M10** for preparation of concrete bricks. **For 1 Brick making** (50% Replacement of fine aggregate with quarry dust and 0% to 50% replacement of coarse aggregates with Tile waste).

QD: Quarry dust & TW: tile waste

Table 4.2 Material weights requirement for making 1 brick

Mix No	QD – TW (%)	Cement (gm)	Water	Coarse aggregate (gm)	Tile waste (gm)	Fine aggregate (gm)	Quarry dust (gm)
M1	0 - 0	244	135	1830	0	813	0
M2	50 - 0			1830	0	406.5	406.5
M3	50 – 10			1647	183		
M4	50 -20			1464	366		
M5	50 – 30			1281	549		
M6	50 – 40			1098	732		
M7	50 - 50			915	915		

4.3 Sample Production

Control mix: The cement, fine and coarse aggregates were weighted according to mix proportion of M_{10}. All are mixed together in a bay until mixed properly and water was added at a ratio of 0.55. The water was added gradually and mixed until homogeneity is achieved. Any lumping or balling found at any stage was taken out, loosened and again added to the mix.

Quarry dust based Concrete bricks: The cement, quarry dust (50% of sand weight replacement), fine and coarse aggregates were weighted according to mix proportion of M_{10}. All are mixed together in a bay until mixed properly and water was added at a ratio of 0.55. The water was added gradually and mixed until homogeneity is achieved. Any lumping or balling found at any stage was taken out, loosened and again added to the mix.

Quarry dust & Tile waste based concrete bricks: The cement, quarry dust (50% of sand weight replacement), fine aggregates, coarse aggregates and tile waste (0% - 50% with interval of 10% replacement of coarse aggregates) were weighted according to mix proportion of M_{10}. All are mixed together in a bay until mixed properly and water was added at a ratio of 0.55. The water was added gradually and mixed until homogeneity is achieved. Any lumping or balling found at any stage was taken out, loosened and again added to the mix.

A standard 100×100×100 mm brick specimens were casted for all above various types of concrete mixes. The samples were then stripped after 24hours of casting and are then be sprinkling of water for curing 7days (daily 2 times). As casted, a total of (40) 100x 100 × 100mm bricks specimens were produced.

Fig.4.7: mixing of all ingredients (quarry dust + tile waste)

Fig.4.9: Demoulded concrete bricks

4.4 Concrete Bricks Testing

4.4.1 Compression Test

- Brick specimen to be tested is placed on a horizontal surface and the specimen is to be centered between the plates on Compression testing machine.
- Apply the load at a uniform rate till the failure occurs.
- Note down the maximum load at failure.

Fig 4.10 Compression Test

4.4.2 Water Resistance Test

In this the bricks first weighted in dry condition and they are immersed in water for 24 hours. After that they are taken out from water and they are wipe out with cloth. Then the difference between the dry and wet bricks percentage are calculated. The less water absorbed by bricks the greater its quality. Good quality bricks don't absorb more than **20%** water of its own weight.

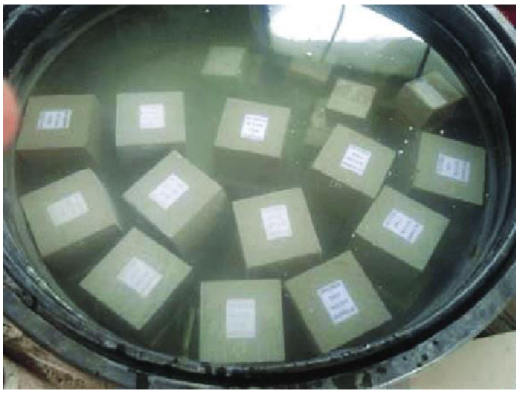

Fig 4.12 Water absorption Test

4.4.3 Efflorescence test

The presence of alkalies in bricks is harmful and they form a gray or white layer on the brick surface by absorbing moisture. To find out the presence of alkalis in bricks this test is performed. In this test, a brick is immersed in fresh water for 24 hours and then it's taken out of the water and allowed to dry in shade. If the whitish layer is not visible on the surface it proofs that absence of alkalis in brick. If the whitish layer visible about 10% area of the brick surface then the presence of alkalis is in the acceptable range. If that is about 50% of surface area then it is moderate. If the alkali's presence is over 50% of the brick surface area, then the brick is severely affected by alkalies**.**

4.4.4 Shape and Size Test

Shape and size of bricks are very important consideration. All bricks used for construction should be of same size. The shape of bricks should be purely rectangular with sharp edges. Standard brick size consists length x breadth x height as 100mm x 100mm x 100mm.

4.4.5 Color Test

A good brick should possess bright and uniform color throughout its body.

4.4.6 Fire Resistance Test

The external fire, applied on brick to test the fire resistance test. Concrete bricks all materials are act like insulation. If there is no change in the structural properties of bricks up to 180^0 above which visible cracks are seen and the bricks deteriorate with increase in temperature.

4.4.7 Soundness test

Soundness test of bricks shows the nature of bricks against sudden impact. In this test, 2 bricks are chosen randomly and struck with one another. Then sound produced should be clear bell ringing sound and brick should not break. Then it is said to be good brick.

Fig 4.15 Soundness test of brick

4.4.8 Hardness test

A good brick should resist scratches against sharp things. So, for this test a sharp tool or finger nail is used to make scratch on brick. If there is no scratch impression on brick then it is said to be hard brick.

Fig 4.16 Hardness test of brick

4.4.9 Drop test

When bricks are dropped from the height of 1 to 1.2m (4 feet), it should not crack or break. This ensures the durability and quality of bricks.

Fig 4.17 drop test of brick

4.4.10 Structure of Bricks

To know the structure of brick, pick one brick randomly from the group and break it. Observe the inner portion of brick clearly. If there are any flaws, cracks or holes present on that broken face then that isn't a good quality brick.

Fig 4.18 Structure test of bricks

5. RESULTS AND DISCUSSIONS

As per experimental programmed results for different experiments were obtained. They are shown in table format or graph, which is to be presented in this chapter.

5.1 Brick Test Results

5.1.1 Compression Test

Table 5.1 Compression test results

Mix No	QD – TW (%)	Compressive strength (Mpa)
M1	0 - 0	7.8
M2	50 - 0	9.8
M3	50 – 10	9.6
M4	50 -20	9.4
M5	50 – 30	9.0
M6	50 – 40	8.5
M7	50 - 50	8.0

The compressive strength is decreasing with increasing in the tile waste as coarse aggregate replacement in the concrete brick's preparation. The replacement of sand with quarry dust (50%) and coarse aggregate with tile waste (Up to 50%), the incremental concrete compressive strength comparison is mentioned below:

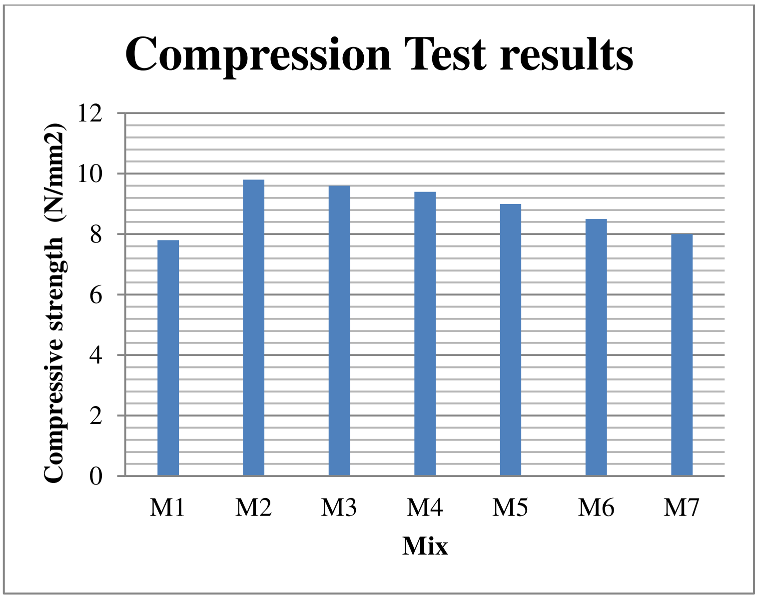

Fig 5.1 Compressive strength test results graph

Table 5.2 Compression test results comparison

Mix No	QD – TW (%)	Compressive strength (Mpa)	Increment / Decrement (%)
M1	0 - 0	7.8	0 (control mix)
M2	50 - 0	9.8	+ 25.64
M3	50 – 10	9.6	+ 23.07
M4	50 -20	9.4	+ 20.51
M5	50 – 30	9.0	+ 15.38
M6	50 – 40	8.5	+ 8.97
M7	50 - 50	8.0	+ 2.56

The compressive strength is higher for all different mixes from M2 to M7 as compare to the control mix of M1. The optimum dosage of QD – TW (%) is 50 – 10 (%).

5.1.2 Efflorescence test

No efflorescence visible on all bricks. All the bricks are good quality bricks.

5.1.3 Shape and Size Test

For all bricks are rectangular shape and size 10 cm x 10 cm x 10 cm. Proper shaped or uniformly shaped all the casted and cured concrete bricks. Then these bricks are good quality bricks.

5.1.4 Fire Resistance Test

There is no change in the structural properties of bricks up to 200°C above which visible cracks are seen and the bricks deteriorate with increase in temperature

5.1.5 Water Resistance Test

Table 5.3 Water Resistance Test results

Mix No	QD – TW (%)	Water absorption (%)
M1	0 - 0	2.2
M2	50 - 0	2.0
M3	50 – 10	2.6
M4	50 -20	2.8
M5	50 – 30	3.0
M6	50 – 40	3.3
M7	50 - 50	3.8

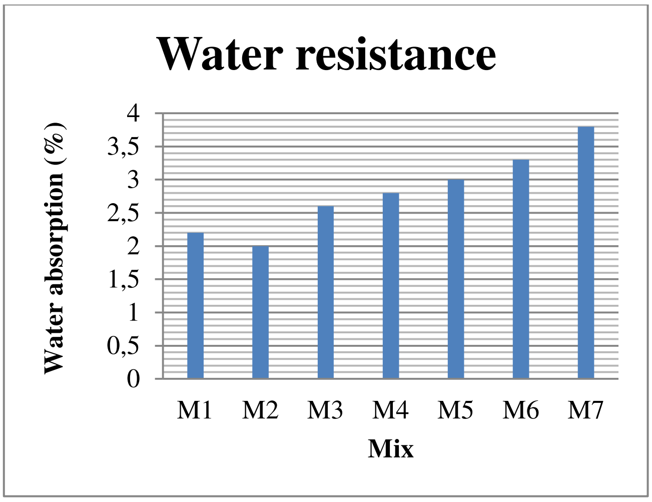

Fig 5.2 Water absorption test results graph

The water absorption value is going to increases with increasing the tile waste content in the preparation of concrete bricks**.**

5.1.6 Color Test

All the bricks having the uniform color for entire structure. Then these concrete bricks are good quality bricks.

5.1.7 Soundness test

For all the bricks ringing sound produced and bricks are un-broken. Then the bricks are good quality bricks.

5.1.8 Drop test

For all the bricks un-broken while performed drop test, then the bricks are good quality bricks.

5.1.9 Structure of Bricks

There are no flaws, cracks or holes present on that broken face then that is a good quality brick.

5.1.10 Hardness test

Little bit scratch visible on all bricks concrete bricks.

5.2 Advantages

1. The main advantage of this project is it is utilization of C&D waste and Industrial waste.
2. Using of Quarry dust reduce the amount of sand in the concrete brick's preparation and its giving good strength compare to normal concrete bricks.
3. This type of bricks can be used in all types of constructions because of it have less water absorption capacity, but it's under specified limit of water absorption for bricks (<20%).
4. As these bricks are constructed with waste materials like quarry dust, tile waste. this is considered a value product out of waste and economical (lesser cost).

6. CONCLUSIONS

1. The aggregates are vital elements in concrete Bricks. The usage of enormous quantities of aggregates results in destruction of hills causing geological and environmental imbalance. The environmental impacts of extracting river sand and crushed stone aggregates become a source of increasing concern in most parts of the Country. Pollution hazards, noise, dust, blasting vibrations, loss of forests and spoiling of natural environment are the bad impacts caused due to extraction of aggregates. Landslides of weak and steep hill slopes are induced due to unplanned exploitation of rocks.
2. Considering the depletion of natural sources and the effect on environment, the disposal problems involved in disposing Tile waste and quarry dust. This waste used in concrete bricks manufacturing gives good mechanical properties.
3. Trying to replace aggregate by tile waste partially to make concrete structure more economic along with good strength criteria. This can be useful for construction of low-cost housing society. Solves problems of disposal of C&D waste of tiles.
4. Up to 10% of coarse aggregate replaced by tile waste and 50% of sand replaced by quarry dust is good according to strength and cost wise.
5. Up to 10% of coarse aggregate replaced by tile waste and 50% of sand replaced by quarry dust gives higher compressive strength compare to control mix.
6. The water resistance value is increasing by increasing tile waste replacement by coarse aggregates. The structure test, soundness test, drop test, Color test, Size and shape test the properties are similar to good quality bricks. And these bricks are very lesser cost compare to normal concrete and fly-ash bricks.

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