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Exploration of physical properties of brick waste and stone dust and its utilization as aggregates in concrete

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Abstract
Concrete is a blend of aggregates, cement and water and plays a dynamic role on development of infrastructure. Now a days we face the problem of growing need and more consumption of aggregate due to industrial production which quickly leading to decrease or shortage of aggregates. This condition pinched the attention of researcher to discover new replacements for concrete. Stone powder/dust produced from stone crushing zones appears as a problem for effective disposal. Also the quantities of clay bricks in our nation have been on the increase significantly without consideration for potential reuse or recycling increasing the risk to public health due to the scarcity of waste landfill. In this research the performance of stone dust and brick waste as partial replacement of sand and gravel in concrete mix is studied. Concrete samples and beams having partial replacement of fine and coarse aggregate with 0%, 10%, 20%, 30%, 40% and 50% of stone dust and brick waste were casted and then cured for 3, 7 and 28 days. After completion of the curing period, concrete specimens were tested for compressive strength. While flexure test was done on concrete beam specimen having no and 20% replacement of fine and coarse aggregate by stone dust and brick waste after 28 days curing period. Results shows that y adding stone dust and brick waste in concrete decrease the workability. Maximum compressive strength after 3 days curing was achieved at 10% replacement level. The increase in strength compared to strength of control mix was 14.13% and the maximum compressive strength after 7 and 28 days strength were 2.34% and 4.93% respectively. Similarly the increase in flexure strength at 28 days was found as 1.27% at 20% replacement level. Hence it is recommended that stone dust and brick waste can be replaced up to 20 % with fine and coarse aggregate in concrete mix.

Keywords: Brick waste, stone dust, aggregates, physical properties, mechanical properties,

I. Introduction

As the time is passing, the construction industry is growing rapidly and in the last decade we are seeing relatively huge constructions. With this rapid growth, a concern of its waste management also growing with the same speed every annum. This problem is not of some specific region but it is a global problem and raising his head high very fast. Dozens of materials are common in the construction industry and one of the materials is brick. Regular bricks are used in the construction of buildings either as main walls, partition walls or some other purposes. When we see the perspective of its manufacturing we find a lot of waste in the form of over burnt bricks. In every batch of brick manufacturing, a high number of over burnt bricks are produced which acts as a waste. (Recycling is a process to change materials (waste) into new products to prevent waste of potentially useful materials, reduce the consumption of fresh raw materials, reduce energy usage, reduce air pollution(from incineration) and water pollution (from land filling) by reducing the need for "conventional" waste disposal, and lower greenhouse gas emissions as compared to plastic production). The brick which are near the fire in the kiln subjected to high heat more than 1000 degree centigrade. Ultimately shrink and loose its shape, color becomes reddish and its appearance like reddish to blackish gradient stone. This over burnt brick serves as waste in the construction industry and has to accumulate somewhere in the process of recycling. Concrete is a solid, hard material produced by combining Portland cement, coarse and fine aggregate (sand and stone), water and sometimes admixtures in proper proportions. It is one of the most widely used construction material and has a long history of use. Its constituent ingredients derive from a wide variety of naturally occurring materials that are readily available in the most parts of the world. Approximately 60 to 80 percent of concrete is made up of aggregates .The cost of concrete and its properties are directly related to the aggregates used. In aggregates, the major portion is of coarse aggregate i.e. stone or gravel which are obtained naturally either from river bed or by crushing rocks mechanically up to the required size. According to general definition concrete is a composite material so by taking advantage of the situation for the people, this paper presents the overview and research that is carried out on the concrete when natural coarse aggregate is partially replaced by over burnt brick aggregate. No construction activity can be imagined without using concrete. Concrete is the most widely used building material in construction industry. The main reason behind its popularity is its high strength and durability. Today, the world is advancing too fast and our environment is changing progressively. This has created what we call the biggest problem of the world, industrial waste and debris accumulation. Hence there is a need to recycle these waste into something more useful and environment friendly. To achieve this, major emphasis must be laid on the use of waste from various industries. Research into new and innovative use of waste materials being undertaken world-wide and innovative ideas that are expressed are worthy of this important subject. Research concerning the use of by-products to augment the properties of concrete has been going on for many years. Many highway agencies, private organizations and individuals have completed or are in the process of completing a wide variety of studies and research projects concerning the feasibility, environmental suitability and performance of using waste materials in construction. The potential applications of industry by-products in concrete are as partial aggregate replacement or as partial cement replacement, depending on their chemical composition and grain size. The use of these materials in concrete comes from the environmental constraints in the safe disposal of these products. These studies try to match societal need for safe and economic disposal of waste materials with the help of environmental friendly industries, which needs better and cost-effective construction materials. In civil engineering the mixture of cement and fine aggregate gives the product Mortar. In which water is added to make mixture. Water is added to make mixture, and when we add water to mixture cement activate which act as a binding material. Mortar works as a matrix in concrete. Mortar is different from concrete. Mortar basically made by cement and fine aggregate and concrete is made by mixture of cement, coarse aggregate and fine aggregate with proper proportion. Concrete acts in a similar way of mortar but which contains coarse aggregate which is bound together by the cement. Also mortar is an integral part of masonry wall systems. Now a day's people needs alternatives, new innovation. Mortar with stone dust gives them new technology. Mortar also provides protection to the outer part of structural concrete from detrimental effect, consisting the outer layer. When water mixed in cement it react with cement and form harsh, stiff paste that is unworkable and becoming hard very quickly. Some Portland cement assists the workability and plasticity of the mortar. It also provides early strength to the mortar and speeds setting. Sand is the general component of mortar which gives its distinctive color, texture and cohesiveness. In mortar Sand plays important part as cement. Sand which is used for concrete and mortar it must be free of impurities, such as salts, clay or other foreign materials. The three key characteristics of sand are particle shape, gradation and void ratio. Sand is mainly used as inert material to give volume in mortar for economy. The strength of mortar is largely affected by the fine aggregates the main constituents of mortar is sand are mainly natural resources Stone dust, fly ash, silica fume, wheat husk etc are the waste materials. Exchange of normal sand by stone dust will assist both solid waste minimization and waste recovery. Stone dust is such materials which is easily available in large quantities from crusher units. Diminishing natural sand resources have increased and the efforts to identify substitutes for natural sand as a constituent of Portland cement concrete. The use of crusher stone dust in making concrete and mortar by partial/full replacement of Natural River sand not only provides economy in the cost of construction but at the same time solves the problem of disposal of stone dust.

II. Literature Review

It was reported that rock dust due to its higher surface area consumes more cement in comparison to sand which increases workability. Study concluded the effect of rock dust and pebble as aggregate in cement and concrete and found that crushed stone dust could be used to replace the natural sand in concrete. It was also examined that the effect of rock dust as fine aggregate in cement mixes and they suggested a method to proportion the concrete using rock dust as fine aggregate. It is investigated that the basic properties of conventional concrete and concrete made using quarry dust have compared. They have studied M20 (1:2:4) and M30 (1:4:8) concretes. Equivalent mixes are obtained by replacing stone dust partially/fully. Test results indicate effective usage of stone dust with same compressive strength, comparable tensile strength and modulus of rupture. It was concluded that workability of 40% replacement of stone dust with 2% Super plasticizer is equal to the workability of conventional concrete. Workability is increased by the addition of Super plasticizer. The purpose of study was to investigate the possibility of using crushed stone dust as fine aggregate partially or fully with different grades of concrete composites. The suitability of crushed stone dust waste as a fine aggregate for concrete has been assessed by comparing its basic properties with that of conventional concrete. Two basic mixes were chosen for natural sand to achieve M25 and M30 grade concrete. The equivalent mixes were obtained by replacing natural sand by stone dust partially and fully. The test results indicate the crushed stone dust waste can be used effectively to replace natural sand in concrete. In the experimental study of strength characteristics of concrete using crushed stone dust as fine aggregate it is found that there is increase in compressive strength, flexural strength and tensile strength of concrete. Owing to increased construction activities for different regions and utilities scaring of natural resources is being forced due to over exploitation. Depleting natural resources posed threat to the environment. Hence conservation of natural resources is great challenge for civil engineers since construction activities cannot be diminished as it is intimate able. The only way is to search alternatives material which can fully or partially replaced naturally available material in construction. Stone dust is such an alternative material which can be effectively being used in construction as partial replacement of natural sand. In the present investigation an experimental program was carried out to study the suitability and potential use of stone dust as partial replacement of fine aggregate in concrete. To accomplish this specimen were cast for different replacement level at an interval of 10 percent to determine workability and compressive strength of concrete at different level of fine aggregate with stone dust. The concept of replacement of natural fine aggregate by quarry dust which is highlighted in the study could boost the consumption of quarry dust generated from quarries. By replacement of quarry dust, the requirement of land fill area can be reduced and can also solve the problem of natural sand scarcity. The availability of sand at low cost as a fine aggregate in concrete is not suitable and that is the reason to search for an alternative material. Quarry dust satisfies the reason behind the alternative material as a substitute for sand at very low cost. It even causes burden to dump the crusher dust at one place which causes environmental pollution. From the results of experimental investigations conducted, it is concluded that the quarry dust can be used as a replacement for fine aggregate. It is found that 40% replacement of fine aggregate by quarry dust gives maximum result in strength than normal concrete and then decreases from 50%. The compressive strength is quantified for varying percentage and grades of concrete by replacement of sand with quarry dust. It was studied that the concrete properties with over-burnt bricks as aggregates and inferred that compressive strength of concrete with over-burnt bricks as aggregates can be increased by decreasing the W/C ratio. The concrete properties with crushed bricks as partial substitute for gravel as coarse aggregate and found the mechanical properties of concrete and inferred that, for up to 15% replacement of aggregates with burnt bricks, the mechanical properties of concrete is almost similar to that of normal concrete. It is studied that properties of brick aggregates and compares the properties of concrete with brick aggregates and the concrete with stone aggregates and inferred that there is no reduction in strength of concrete for up to 20% replacement of stone aggregates with brick aggregates. The thermal properties of brick aggregates and inferred that the brick aggregates performed better than gravel at elevated temperature. The properties of higher strength concrete made with crushed brick as coarse aggregate and found that higher strength concrete (fcu = 31.0 to 45.5 N/mm2) with brick aggregate is achievable whose strength is much higher than the parent uncrushed brick implying that the compressive strength of brick aggregate concrete can be increased by decreasing its water-cement ratio. Bricks are a versatile and durable building and construction material, with good load-bearing properties. Various researches have been carried out on porosity, permeability and absorption of bricks. The properties of concrete which use crushed bricks as natural coarse aggregate partial substitute. Experimental investigation has also been done to achieve higher strength concrete using crushed brick aggregate. It has been found that even recycled brick can also be used as coarse aggregate in concrete. It have showed that concrete can be successfully produced by using recycled aggregates that have been produced from demolition and construction waste. The specific gravity and water absorption of over burnt brick is found out to be 1.71 and 6.502 % respectively.

III. Research Approach

This research aimed to find physical properties of brick waste and stone dust as coarse and fine aggregate. And then replacement of coarse and find aggregate in concrete are done. Coarse aggregate was replaced by brick waste and fine aggregate was replaced by stone dust respectively. Concrete cylindrical and beam specimen with 10%, 20%, 30%, 40% and 50% replacement of coarse aggregate and fine aggregate by brick waste and stone dust respectively will be casted, tested and compared with control concrete cylindrical and beam specimen with no replacement.

A. Physical Properties of Brick Waste and Stone Dust

A.1 Fineness modulus Brick Waste

Arrange the sieves in descending order and put the arrangement on mechanical shaker. It is suggested that, to know the exact value of fineness modulus for coarse aggregate, mechanical shaker will give better value than hand shaking because of more no. of sieves and heavy size particles. After proper sieving, record the sample weights retained on each sieve and find out the cumulative weight of retained particles as well as cumulative % retained on each sieve. Finally add all cumulative percentage values and divide the result with 100. Then we get the value of fineness modulus.

A.2 Fineness Modulus Stone Dust

Take the sieves and arrange them in descending order with the largest sieve on top. If mechanical shaker is using then put the ordered sieves in position and pour the sample in the top sieve and then close it with sieve plate. Then switch on the machine and shaking of sieves should be done at least 5 minutes. If shaking is done by the hands then pour the sample in the top sieve and close it then hold the top two sieves and shake it inwards and outwards, vertically and horizontally. After some time shake the 3rd and 4th sieves and finally last sieves. After sieving, record the sample weights retained on each sieve. Then find the cumulative weight retained. Finally determine the cumulative percentage retained on each sieves. Add the all cumulative percentage values and divide with 100 then we will get the value of fineness modulus.

B. Fresh Properties of concrete having Brick waste and Stone Dust

B.1 Slump Test

Clean the internal surface of the mould and apply oil. Place the mould on a smooth horizontal non- porous base plate. Fill the mould with the prepared concrete mix in 4 approximately equal layers. Tamp each layer with 25 strokes of the rounded end of the tamping rod in a uniform manner over the cross section of the mould. For the subsequent layers, the tamping should penetrate into the underlying layer. Remove the excess concrete and level the surface with a trowel. Clean away the mortar or water leaked out between the mould and the base plate. Raise the mould from the concrete immediately and slowly in vertical direction. Measure the slump as the difference between the height of the mould and that of height point of the specimen being tested. The above operation should be carried out at a place free from Vibrations or shock and within a period of 2 minutes after sampling.

C. Mechanical/Hardened Properties of concrete having Brick waste and Stone Dust

C.1 Compression test- 28 Days of Curing age (ASTM C-39/39M)

Concrete cylindrical samples were tested after taking out from curing. The compression test shall be performed as soon as possible after removal from water. Before testing the concrete cylindrical samples their respective heights and diameter is to be measured and recorded with the help of scale. Upper and lower plates of universal testing machine was cleaned with a cloth. Now place the concrete cylindrical sample in universal testing machine. Switch on the universal testing machine and apply load at constant loading rate. After failure of concrete cylindrical sample record the load. Compressive strength is obtained by dividing maximum load by cross sectional area of the specimen.

Total 18 concrete cylindrical specimens were casted to study mechanical properties of control concrete and concrete having partial replacement of sand (fine aggregate), gravel (coarse aggregate) by stone dust and brick waste. Stone dust and brick waste were replaced up to 0%, 10%, 20%, 30%, 40% and 50% respectively. Detail number of concrete cylindrical samples is shown in Table 1

Table 1: Number of concrete cylindrical specimen

Mix	Percentage of Stone Dust and Brick Waste	Compressive Test Samples
		28 Days
M0	0%	3
M1	10%	3
M2	20%	3
M3	30%	3
M4	40%	3
M5	50%	3
Total Concrete Cylindrical Samples		18

Flexural strength test- 28 Days of Curing age (ASTM C-293/C293M-10)

To determine the dimensions of the specimen section for use in calculating modulus of rupture, take measurements across one of the fractured faces after testing. The width and depth are measured with the specimen as oriented for testing. For each dimension, take one measurement at each edge and one at the center of the cross section. Use the three measurements for each direction to determine the average width and the average depth. Take all measurements to the nearest 1 mm [0.05 in.]. If the fracture occurs at a capped section, include the cap thickness in the measurement.

Calculation

Calculate the modulus of rupture as follows:

$$R=\frac{3PL}{2bd^2}$$

Where

R = modulus of rupture, MPa [psi]

P = maximum applied load indicated by the testing machine, N [lbf], L = span length, mm [in.]

b = average width of specimen, at the fracture, mm [in.]

d = average depth of specimen, at the fracture, mm [in.]

Total 6 concrete cylindrical specimens were casted. 3 Samples were casted for control concrete having no replacement. After studying the compressive strength it was concluded that on 20% level replacement concrete gives optimum compressive strength. So for 20% replacement of stone dust and brick waste were casted and tested for flexure.

Table 2: Number of concrete beam specimen

Mix	Percentage of Stone Dust and Brick Waste	Flexure Test Samples
		28 Days
M0	0%	3
M2	20%	3
Total Concrete Beam Samples		6

IV. Results/Discussion

Physical Properties of Brick Waste and Stone Dust

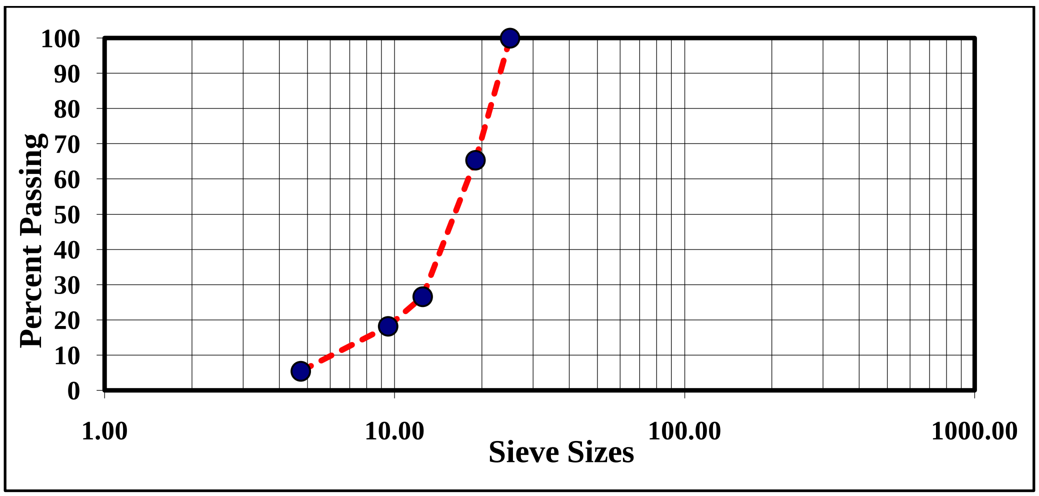

Figure 1: Sieve analysis of Brick Waste

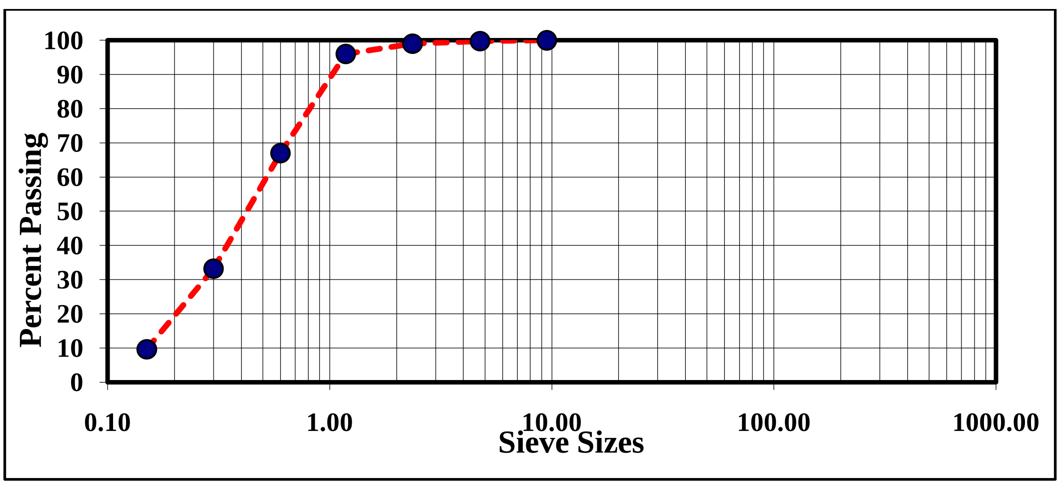

Figure 2: Sieve analysis of stone dust

Fresh Properties of concrete having Brick waste and Stone Dust

Slump Test

Slump test results is shown in Figure 3

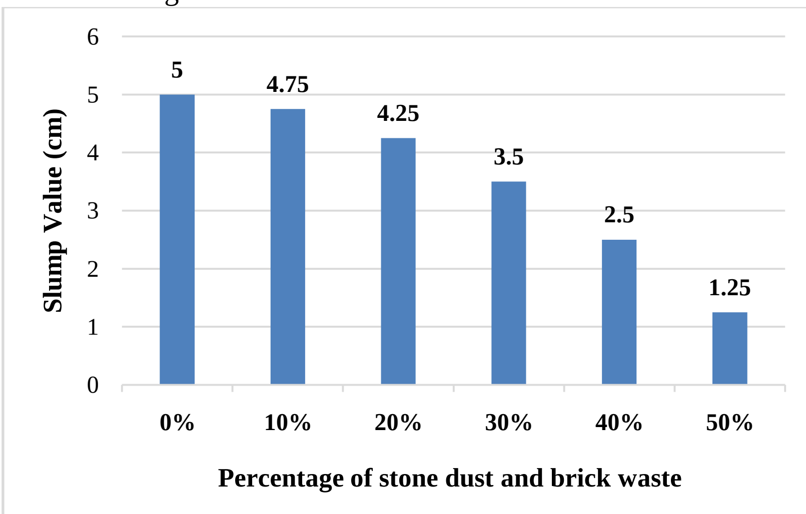

Figure 3: Slump test result

Discussion: To check the workability of fresh concrete slump test was conducted. Slump test was conducted for each batch of concrete. Each batch of concrete was having percent replacement of fine aggregate and coarse aggregate by 10%, 20%, 30%, 40% and 50% stone dust and brick waste respectively. Slump test was also performed for control concrete. Results shows that the control/ordinary concrete give slump up to 5 cm, while on 10%, 20%, 30%, 40%, and 50% replacement of stone dust as fine aggregate gives slump up to 4.75cm, 4.25cm, 3.50cm, 2.50cm and 1.25cm. By results discussed above it can be concluded that by replacing stone dust and brick waste in concrete, slump value gradually decreases hence lesser workability. The main reason behind decrease of workability is greater water absorption of brick waste.

Mechanical/Hardened Properties of concrete having Brick waste and Stone Dust

Compression test- 28 Days of Curing age (ASTM C-39/39M)

Concrete cylindrical samples having partial replacement of fine and coarse aggregate with 0%, 10%, 20%, 30%, 40% and 50% of stone dust and brick waste were casted and then cured for 28 days. After completion of 28 days curing period the concrete cylindrical specimens were tested, the compressive test result for 28 days of curing period is shown in Table 4.

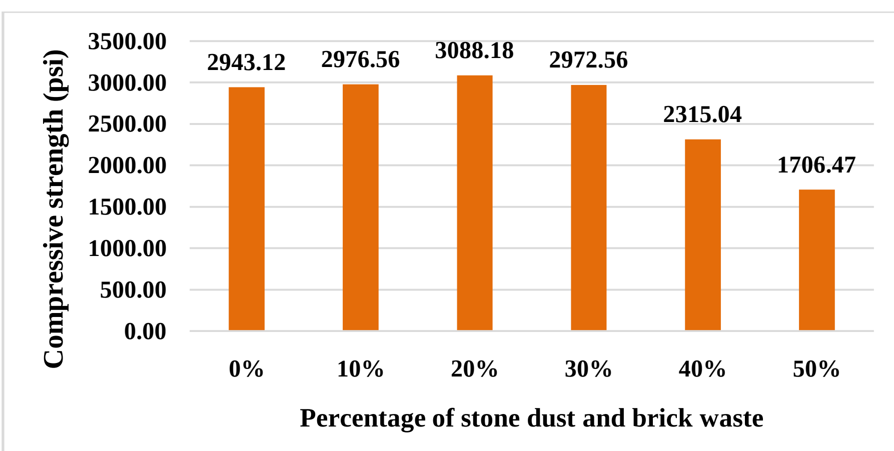

Figure 4: Compressive strength 28 Days

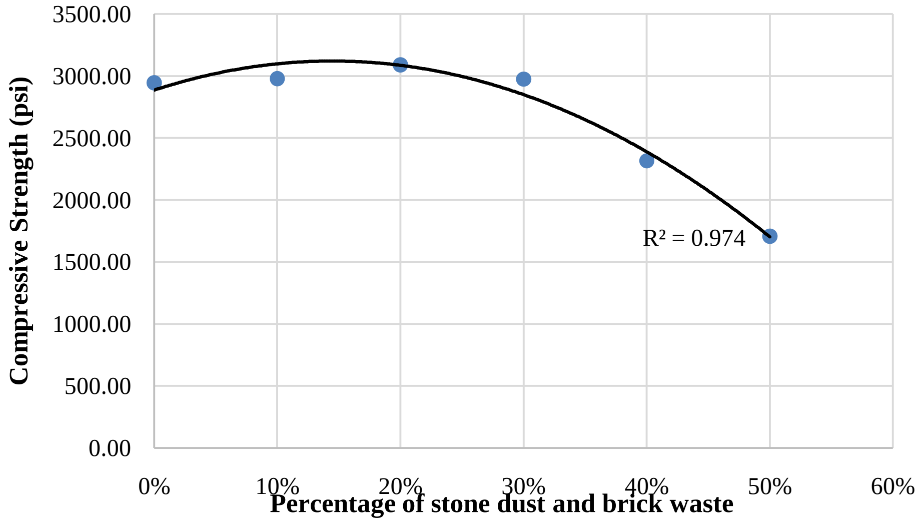

Figure 5: Trend Line Compressive Strength-28 Days

Discussion: Compressive test was conducted on concrete cylindrical samples having partial replacement of fine aggregate and coarse aggregate by stone dust and brick waste and then compared with control concrete for 28 days of curing age. Results shows when fine and coarse aggregate were replaced by stone dust and brick waste at 10%, 20%, 20%, 30%, 40% and 50% it gives the compressive strength 2943.12, 2976.56, 3088.18, 2972.56, 2315.04 and 1706.47 psi respectively Hence it is concluded that optimum compressive strength (peak value) for 28 days of curing period is on 20% replacement ie- 3088.18 psi.

Flexural strength test- 28 Days of Curing age (ASTM C-293/C293M-10)
Concrete beam samples having partial replacement of fine and coarse aggregate with 20% of stone dust were casted and related to control concrete beam samples after 28 days. The flexure test result for 28 days of curing period is shown in Table 3

Table 3: Flexure strength (28 days age)

Mix Type	Percentage of stone dust and brick waste	Flexure strength (psi)			Average (psi)	Percent Increase in Strength
		28 Days				
		Sample 1	Sample 2	Sample 3		
M0	0%	793	773	788	785	0%
M20	20%	801	804	779	795	1.27%

Discussion: The Flexure test was conducted on concrete cylindrical samples having partial replacement of 20% fine and coarse aggregate by stone dust and brick waste and then compared with control concrete having no addition. Results shows that there is an increase in the strength of 1.27%.

V. Conclusion

By adding stone dust and brick waste in concrete decrease the workability. Optimum compressive strength (peak value) for 28 days of curing period is on 20% replacement ie- 3088.18 psi The Flexure strength of 20% replacement when compared with control concrete having no addition increases the strength to 1.27%.

VI. Recommendations

It is recommended that stone dust and brick waste can be replaced up to 20 % with fine and coarse aggregate in concrete mix.

VII. Acknowledgement

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