Replacement of Coarse Aggregate with Waste Marble

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Abstract: ***Now a days we are faced with an important consumption and a growing need for aggregates because of the growth in industrial production, this situation has led to a fast decrease of available resources. On the other hand, a high volume of marble production has generated a considerable amount of waste materials; almost 70%of this mineral gets wasted in the mining processing and polishing stages which have a serious impact on the environment. The processing waste is dumped and threatening the aquifer. Therefore, it has become necessary to reuse these wastes particularly in the manufacture of concrete products for construction purposes. This experimental study presents the variation in the strength of concrete when replacing aggregates by waste marble from 0% to 100% in steps of 25%, 50%, 75% & 100%. M25 grade of concrete were taken for study of slump value is reducing for more % of replacing the stone dust. The compressive strength of concrete cubes at the age of 7, 14 and 28 days were obtained at room temperature. From test result it was found that the maximum compressive strength is obtained only at 50% replacement of coarse aggregate by waste marble at room temperature. This result gives a clear picture that waste marble can be utilized in concrete mixtures as a good substitute for coarse aggregate giving higher strength.***

Keywords: Coarse Aggregate, Waste Marble, Compressive Strength, Reusing Materials, Sustainable, Waste Stone

1. Introduction

1.1 General

At present no construction activity is possible without using concrete. It is the most common material used in construction worldwide. The main reason behind this is because of its high strength, durability and workability. The total world consumption of concrete per year is about one ton for every living human being. Man consumes no materials except water in such tremendous quantities. Due to privatization and globalization, the construction of important infrastructure projects like Highways, Airports, Nuclear plants, Bridges, Dams etc. in India is increasing year after year. Such developmental activities consume large quantity of precious natural resources.

This leads not only faster depletion of natural resources but also increase the cost of construction of structures. In view of this, people have started searching for suitable other viable alternative materials which could be used either as an additive or as a partial replacement to the conventional ingredients of concrete so that the existing natural resources could be saved to the possible extent, and could be made available for the future generation. In this process, different industrial waste materials such as fly ash, blast furnace slag, quarry dust, tile waste, brick bats, broken glass waste, waste aggregate from demolition of structures, ceramic tiles, electronic waste of discarded old computers, TVs, refrigerators, radios, waste paper mill pulp, iron filling, waste coconut shell, rice husk ash, marble aggregate, dust powder, hypo sludge, machine crushed animal bones, chicken feather, eggs shell, granite quarry sludge, palm oil fuel ash, copper dust, human hair etc. Have been tried as a viable substitute material to the conventional materials in concrete.

Because of continual depletion of quarries aggregates, construction materials are more and more judged by their ecological characteristics. The lack of technology and unscientific methods of quarrying marble in Algeria has generated a huge quantity of waste of this valuable mineral; leaving the waste materials to the nature directly can cause serious environmental problems. In addition, the marble cutting industry generates a high volume of wastes. Recent studies showed that marble waste can be used as aggregates for assorted construction materials.

India possesses a wide spectrum of dimensional stones that include granite, marble stone, sandstone, limestone, slate, and quartzite, spread out all over the country. India is also amongst the largest producer of raw stone material and the sector is quite developed and vibrant in the South, as well as in Rajasthan and Gujarat, with a dedicated resource of entrepreneurs.

Stone are the natural, hard substance formed from minerals and earth material which are present in rocks. Rock is the portion of the earth’s crust having no definite shape and structure. Almost all rocks have a definite chemical composition and are made up of minerals and organic matter. Some of the rock - forming minerals are quartz, felspar, mica, dolomite, etc. The various types of rocks from which building stones are usually derived are granite, basalt, trap, marble, slate, sandstone and limestone.

Stone have still remained a major base in construction industry in India, as there are being used extensively in public buildings, hotels, and temples.

Use of stone in building construction is traditional in the places where it is produced, through its high cost imposes limitations on its use. Stone has been used in the construction of most of the important structures since prehistoric age. Most of the fort’s world over, the Taj Mahal of India, the famous pyramids of Egypt and the Great Wall of China are few examples.

Stone has also been extensively used in almost all the elements of building structures, as load carrying units as well as for enhancing the beauty and elegance of the structure. As building material stone has gradually lost importance with the advent of cement and steel. Secondly, the strength of the structural elements built with stones cannot be rationally analysed. Other major factors in overshadowing its use are the difficulties in its transportation and dressing which consume a lot of time resulting in slow pace of construction.

1.2 Aggregates

One of the most particular and general but most important material used for making concrete is AGGREGATE. Aggregates are used as filler with binding materials in production of concrete. Aggregates occupy about 72 - 75% of volume of concrete and they greatly influence the strength of concrete. These are cheaper than cement and admixtures. The aggregate impart density to concrete. Aggregates may be fine or coarse. The coarse aggregates form the main matrix of concrete and fine aggregate form the filler matrix between coarse aggregates. They may be available naturally or made artificial.

1.3 Marble

Marble is a non - foliated metamorphic rock composed of recrystallized carbonate minerals, most commonly calcite or dolomite. Geologists use the term "marble" to refer to metamorphosed limestone however; stonemasons use the term more broadly to encompass unmetamorphosed limestone. Marble is commonly used for sculpture and as a building material.

Figure 1: Marble aggregates

1.3.1 Rolling Through History

Believe it or not, but no one really knows where marbles originated. They've been found in the ashes of Pompeii and in the tombs of ancient Egyptians, and they were played with by Native American tribes, so it's impossible to pin down a precise country of origin. The earliest examples were simply stones that had been polished smooth by a running river, but for centuries artisans made them by hand from clay, stone, or glass.

Mass production became possible in 1884, when Sam Dyke of Akron, Ohio, created a wooden block with six grooves, each of which held a lump of clay. An operator would roll a wooden paddle over all the clay balls at once, with a back - and - forth and slightly lateral motion, creating six marbles. With around 350 employees, Dyke's factory was cranking out five train carloads, or about one million marbles, every day. Mass production made marbles much cheaper to make, allowing the price to drop from about one penny each to a bag of 30 marbles for the same price. Other businessmen jumped on the bandwagon and Akron soon became the marble capital of late - 19th century America.

In 1915, mass production of glass marbles began, thanks to a machine invented by Akron's M. F. Christensen. His machine consisted of a screw conveyor made up of two grooved cylinders spun next to each other. A "slug" of molten glass was placed between the cylinders on one end and it was gradually carried down to the opposite side, simultaneously cooled and shaped into a sphere by the rolling grooves. The design worked so well, it has remained essentially unchanged and is still the most common way to make marbles today.

Marbles were really popular throughout the early part of the 20th century, but World War II rationing, plus the utter chaos of the European Theatre, put a damper on the sport. It enjoyed a brief resurgence in the 1970s, and continues to be played today, but it has never been able to reclaim its title as a childhood institution.

1.3.2 Sculpture

White marble has been prized for its use in sculptures since classical times. This preference has to do with its softness, which made it easier to carve, relative isotropy and homogeneity, and a relative resistance to shattering. Also, the low index of refraction of calcite allows light to penetrate several millimetres into the stone before being scattered out, resulting in the characteristic waxy look which gives "life" to marble sculptures of any kind, which is why many sculptors preferred and still prefer marble for sculpting.

1.3.3 Construction Marble

Construction marble is a stone which is composed of calcite, dolomite or serpentine which is capable of taking a polish.

More generally in construction, specifically the dimension stone trade, the term "marble" is used for any crystalline calcific rock useful as building stone. For example, Tennessee marble is really a dense granular fossiliferous Gray to pink to maroon Ordovician limestone that geologists call the Formation. Ashgabat, the capital city of Turkmenistan, was recorded in the 2013 *Guinness Book of Records* as having the world's highest concentration of white marble buildings.

1.3.4 Production

According to the United States Geological Survey, U. S. domestic marble production in 2006 was 46, 400 tons valued at \$18.1 million, compared to 72, 300 tons valued at \$18.9 million in 2005. Crushed marble production (for aggregate and industrial uses) in 2006 was 11.8 million tons valued at \$116 million, of which 6.5 million tons was finely ground calcium carbonate and the rest was construction aggregate. For comparison, 2005 crushed marble production was 7.76 million tons valued at \$58.7 million, of which 4.8 million tons was finely ground calcium carbonate and the rest was construction aggregate. U. S. dimension marble demand is about 1.3 million tons. The DSAN World Demand for (finished) Marble Index has shown a growth of 12% annually for the 2000–2006 period, compared to 10.5% annually for the 2000–2005 period. The largest dimension marble application is tile. Marble production is dominated by 4 countries that account for almost half of world production of marble and decorative stone. Italy is the world leader in marble production, with 20% share in global marble production followed by China with 16% of world production. India is third ranking with 10% of world production, followed by Spain in fourth ranking position with 6% of world production; all other countries, combined, account for the remaining half of world marble production.

1.3.5 Occupational Safety

Dust produced by cutting marble could cause lung disease but more research needs to be carried out on whether dust filters and other safety products reduce this risk.

1.3.6 United States

The Occupational Safety and Health Administration (OSHA) has set the legal limit (permissible exposure limit) for marble exposure in the workplace as 15 mg/m^3 total exposure and 5 mg/m^3 respiratory exposure over an 8 - hour workday. The National Institute for Occupational Safety and Health (NIOSH) has set a recommended exposure limit (REL) of 10 mg/m^3 total exposure and 5 mg/m^3 respiratory exposure over an 8 - hour workday.

1.3.7 Classification of Aggregates Based on Size, Shape &Others

- Based on unit weight of aggregates
- Based on geological origin
- Based on parent roc
- Based on shape Based on size

1.4 Natural Basaltic Aggregates

Natural basaltic aggregate consists of rock fragments that are used in their natural state or used after various mechanical processing such as crushing, sizing, washing etc. Normal weight natural aggregates can be used in all type of work. The specific gravity of these aggregates' ranges from 1.5 to2.7. The concrete having density of 2300 kg/m3 to 2600 kg/m3 is produced.

1.4.1 Classification Natural Basaltic Aggregate Based on Weight

- Normal Weight Aggregates
- Light Weight Aggregates
- Heavy Weight Aggregates

1.4.2 Physical Properties of Natural Aggregates

Figure 2: Physical properties of N. A

1.4.3 Chemical Properties of Natural Aggregates

Chemical properties of natural aggregates are varying and generally depending on source of product. Natural aggregates generally used for construction purpose includes basalt. Basalt is an igneous rock. The aggregate formed from this rock are hard tough and dense. Other rocks like basalt are granite and dolerite. Most often basalt aggregates are used in construction field as aggregates in concrete mix. Moreover, basalt is hard and dense rock, normally undergoes very little creep or no creep. The modulus of elasticity of naturally occurring hard aggregates is one of the important factors influencing creep. Out of all - natural aggregate basalt is more preferred.

1.4.4 Chemical Composition of Marble, Granite and Kota stone

Table 1: Chemical Composition

Chemical Composition	Marble	Granite	Kota Stone
Lime	28 - 32%	1 - 4%	37 - 39%
Silica	3 - 30%	72 - 75%	24 - 26%
MgO	20 - 25%	05 - 1%	4 - 6%
$FeO+Fe_2O_3$	1 - 3%	-	-
Loss of ignition	20 - 45%	5 - 10%	32 - 35%

It is found that stream materials, crushed stones and artificial aggregates have been used in concrete aggregate in the world. It is unquestionable and more suitable material than other aggregate types. Same units can make stone grit and chips, but currently chips are more in demand. The demand for stone chips is directly linked with the volume of construction activity. Stone chips are used in concreting, along with cement and sand and inroad pavement work. Looking at the decreasing economic costs involved with storage while preventing possible environmental negative impacts it can be considered as a future pre - requisite to use crushed stone chips for construction in countries having scarce resource.

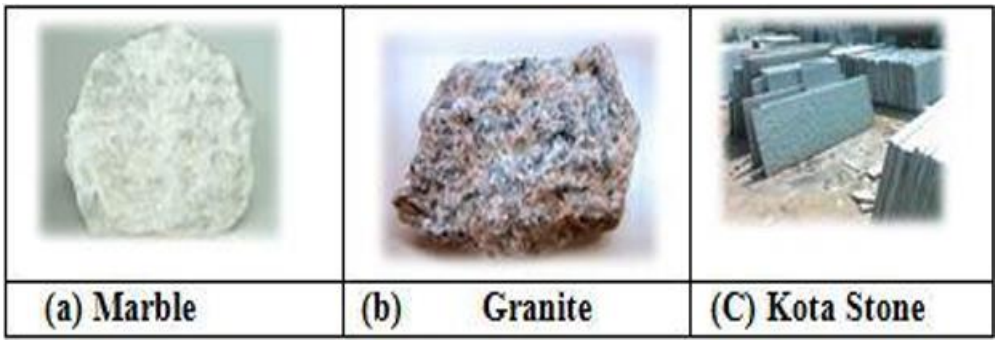

Figure 3: Types of aggregates

2. Litrature Review

Binici et. al. have studied some mechanical properties of concrete containing marble and limestone dusts; mixes were modified to 5%, 10% and 15% marble and limestone dusts instead of fine sand aggregates and their compressive strengths were compared. Binici et. al. investigated in another study the durability and the fresh properties of concrete made with granite and marble as recycled aggregates. In the specimens containing marble and granite there is a much better bonding among the additives, cement and aggregates. Furthermore, it may be said that marble and granite replacement rendered a good condensed matrix. The increased durability of concrete can be attributed to the glass content and chemical composition of the granite. The results of this study showed that the marble and granite waste aggregates can be used to improve the mechanical properties, workability and chemical resistance of the conventional concrete mixtures.

Corina desi et. al. showed that 10% substitution of sand by the marble powder has provided maximum compressive strength at about the same workability; mixtures were evaluated based upon cement or sand substitution by the marble powder. The marble wastes are not only substitutes or additives to concrete; they can also be used for other kinds of building materials. Saboya et al. have shown that the use of 15–20% of powder marble content in red ceramic raw material could be considered the best proportion to enhance the properties of brick ceramic.

Akbulut and Gurer demonstrated that the physical properties of the marble waste aggregates are within specified limits and these materials can potentially use as aggregates in light to medium trafficked asphalt pavement binder layers. A very limited number of studies has been conducted to understand the rheological and mechanical properties of marble waste aggregates concrete. In addition, it is difficult to make comparisons between concrete results because the few existing studies have not always the same concerns. We have undertaken this experimental campaign to review and develop the results of studies already carried out by our team.

In this paper, we study the marble waste of Fil - Fila quarry (wilaya of Skikda in the north - east of Algeria); the marble waste recycling is processed before use. The natural and recycled aggregates were characterized. Concrete mix designs with 25%, 50%, 75% and 100% of aggregates substitution was formulated. The performances of the ‘‘recycled aggregates” concrete was measured through tests of density, air content, workability and compressive and tensile strength.

Dr. Haider K. Ammash, et. al. studied on the possibilities Waste Glass of size up to 5mm as a fine aggregate in concrete. The waste glass was used as a partial weight replacement of sand with percentages of 10, 20, 30 and 40 %. They found that, waste glass aggregate can be satisfactorily substituted for natural fine aggregate at replacement levels up to 20%

M. Iqbal Malik, et. al. studied the use of Waste Glasses partial replacement of fine aggregates in concrete. Fine aggregates were replaced by waste glass powder as 10%, 20%, 30% and 40% by weight for M - 25 mix. The concrete specimens were tested for compressive strength, splitting tensile strength; durability and density at 28 days of age and the results obtained were compared with those of normal concrete. They discovered that 20% replacement of fine aggregates by waste glass showed 15% increase in compressive strength at 7 days and 25% increase in compressive strength at 28 days. Fine aggregates can be replaced by waste glass up to 30% by weight showing 9.8% increase in compressive strength at 28 days. With increase in waste glass content, percentage water absorption decreases. With increase in waste glass content, average weight decreases by 5% for mixture with 40% waste glass content thus making waste glass concrete light weight. Splitting tensile strength decreases with increase in waste glass content.

G. Murali, et. al. Concluded that the concrete with Steel Powder as waste material was found to be good in compression which had the compressive strength of 41.25% more than the conventional concrete. Better split tensile strength was achieved with the addition of the steel powder waste in concrete. The strength has increased up to 40.87% when compared to that of the conventional concrete specimen. In flexure the specimen with soft drink bottle caps as waste material was found to be good. While adding the soft drink bottle caps the flexural strength increased by 25.88% that of the conventional concrete.

Dr. G. Vijayakumar et al. conducted and experiment concrete prepared by partial replacement of cement by waste Glass Powder of particle size 75µm. The waste glass powder was replaced by 10%, 20%, 30% and 40% of the binder and the mix design was prepared. Before adding glass powder in the concrete, it had to be powdered to desired size. In this studies glass powder ground in ball/pulverize for a period of 30to 6o minutes resulted in particle sizes less than size 150 µm and sieved in 75 µm. The concrete mix design was proposed by using Indian Standard for control concrete of grade M20. The mixture was prepared with the cement content of 330kg/m3 and water to cement ratio of 0.53. At 28 days the glass powder shows a compressive strength of 41.96 N/mm2, strength at 30% cement replacement. The pH value observed from the alkalinity test showed that the specimen tested found to be more alkaline and hence more resistant towards corrosion.

Ali N. Alzaed observed that Iron Filings are very small pieces of iron that look like a light powder. He used four different percentage of iron filing and was added to concrete mix to measure the variation 0% (control), 10%, 20%and 30% which may be obtained in compression and tensile concrete strengths after 28 days. Ordinary locally - available Portland cement having a specific gravity of 3.15, Locally available sand having a fineness modulus of 2.54 and a specific gravity of 2.62 was used. Crushed granite coarse aggregate of 20 mm maximum size having a fineness modulus of 7.94 and specific gravity of 2.94 was used. Water conforming to the requirements of water for concreting and curing as per IS: 456–2000. He concluded that compressive strength of concrete was increased by 17% when 30% of iron filling added to the concrete mix. Concrete tensile strength had a minor effect if the percentage of iron filing used more than 10%. Concrete tensile strength increased by 13% when 10% of iron filling added to concrete mix.

Kabiru Usman Rogo and Saleh Abubakar They studied on the Coconut Shell which can be a substitute for aggregates. The shell of the coconut is mostly used as an ornament and as a source of activated carbon. The powdered shell is also used in the industries of plastics, glues, and abrasive materials. The use of coconut shells can also help the prevention of the environment and also help economically. The coconut shells are obtained from a local coconut field. They were sun dried for 1 month before being crushed manually with particle sizes of the coconut shell range from 5 to 20mm. They prepared about 72 concrete cubes size 150x150x150 mm with different mixed ratios 1: 2: 4, 1: 11/2: 3 and 1: 3: 6 was casted and tested. They concluded that compressive strength in N/mm2 of coconut shell at 7, 14 21, and 28 days with mix ratios of 1: 2: 4, 1: 1.5: 3 and 1: 3: 6 are (8.6, 8.9, 6.4), (9.6, 11.2, 8.7), (13.6, 13.1, 10.7) and (15.1, 16, 5, 11) respectively for gravel (19.1, 18.5, 9.6) (22.5, 23.0, 10.4) (26.7, 24.9, 12.9) and (28.1, 30.0, 15) respectively. Since the concrete strength of coconut shell with mix ratio1: 1.5: 3 attained 16.5 N/mm2 at 28 days it can be used as plain concrete. Hence cost reduction of 48% was obtained.

Mohd Monishet. Al. They investigated that huge quantities of construction and demolition wastes are generated every year in developing countries like India. The disposal of this waste is a very serious problem because it requires huge space for its disposal and very little demolished waste is recycled or reused. The paper deals with the effect of partial replacement of coarse aggregate by demolished waste on workability and compressive strength of 7 and 28 days. The concrete mix design was done in accordance with IS: 10262 (1982). The cement content in the mix design was taken as380 kg/m3 which satisfies minimum requirement of 300 kg/m3. Three specimens each having 0%, 10%, 20%, and 30%demolished wastes coarse aggregate replacement for mix of 1: 1.67: 3.33 were cast and tested after 7 and 28 days in order to have comparative study. They concluded that up to 30% replacement of coarse aggregate with recycled aggregate concrete was comparable to conventional concrete.

P. Krishna Prasanna and M. Kanta Rao They carried out an experimental study by utilizing E - waste particles as coarse aggregates in concrete with a percentage replacement from 0% to 20% i. e. (5%, 10%, 15% and 20%). Similarly, conventional specimens were also prepared for M30 grade concrete without using E - waste aggregates. By conducting tests for both the specimens the hardened properties of concrete were studied.

The e - waste contents were calculated on weight basis as coarse aggregate in the conventional mix. The fineness modulus of coarse aggregate with various E - waste contents was observed as 6.937. Compressive strength test was conducted to evaluate the strength development of concrete containing various E - waste content sat the age of 7, 14, 28 days respectively. It was also observed that the compressive strength of concrete was found to be optimum when coarse aggregate was replaced by 15% with E - Waste. Beyond it the compressive strength is decreasing.

Dr. A. M. Pande and S. G. Makarand investigated that rice Husk Ash (RHA) which are the waste products of agricultural industry can be use as materials in concrete which not only improves the strength of concrete but also leads to the proper disposal of these materials, resulting in reducing the impact of these materials on environment. The investigation was to make the concrete with targets of 28 - day Compressive strength of at least 40 MPa. Proportion of mixtures was selected basing on these targets. The RHA was trailed replace for cement with various ratios, namely 0, 12.5, 25, and 37.5 % by mass of cement. They concluded that replacement of 12.5% of cement with rice husk ash in matrix causes reduction in utilization of cement and expenditures. Also, it can improve quality of concrete at the age of 90 days. Results indicated that pozzolanic reactions of rice husk ash in the matrix composite were low in early ages, but by aging the specimens to 90 days, considerable effect has been seen in strength.

Olaoye, R. A. et**.** Al. Jute, Oil palm and Polypropylene fibres were used as complement in concrete and its suitability, durability and influence on the properties of concrete were assessed by them.

The percentages of fiber used were 0.25 and 0.5 of cement content by weight. A total of 84 concrete cube specimens were prepared for standard tests which include compression test, slump test and compaction factor test. Concrete cube size of 150 x 150 x 150 mm was used to conduct the compressive test. The specimens were differentiated with respect to the type of fiber used and the fiber content by weight of cement. Specimen's which contain zero percentage of fiber were used as control specimen. A total of 84 test cubes were prepared. They concluded that with the addition of Jute, oil palm and Polypropylene fibers, the compressive strength increases greatly from the 7th - 28th day compared to the control mix.

Soman K and Dr. K. A. Abu baker they found that Granite Quarry Sludge is the waste from rock processing in quarries and crusher units and it is disposed by filling in barren land causing serious environmental issues. This paper deals with an experimental investigation on strength properties of concrete made with 2.5%to 20% replacement of cement by quarry dust of less than 75micron particle size.

The tests were carried out to find the compressive strength, splitting tensile strength and flexural strength on specimens. Based on this experimental study, they conclude that compressive strength remains unchanged for a replacement of granite sludge up to 7.5% of cement. The tensile strength and flexural strength are also not affected for replacement of cement by quarry dust up to 7.5%.

Deepak T. J. et. Al. they studied that Palm Oil Fuel Ash is the by - product of burnt palm oil husk and palm oil shell in the boiler of palm oil mill. The paper deals with the experimental work done on the behaviour of Palm Oil Fuel Ash (POFA) in concrete. Specimens containing 5, 15, 25, 35 and 45% POFA were prepared at constant water - cement ratios of 0.5 with super plasticizer content of 0.5% with cement. Workability in terms of slump and strength properties were studied, and compared with control specimen. They determined that the ultimate compressive strength of concrete could be improved by using up to 25 % of POFA to replace Portland cement in the concrete mix. Compressive strength of shows its optimum compressive strength when the cement is replaced with 15% POFA giving a higher compressive strength than OPC. The flexural strength of POFA is slightly higher than that of OPC by replacing cement with 15% POFA

Sumit A. Balwaik and S. P. Raut They investigated the use of Paper - Mill Pulp in concrete as an alternative to landfill disposal. The cement has been replaced by wastepaper sludge accordingly in the range of 5% to 20% by weight for M - 20 and M - 30 mix. By using adequate amount of the waste paper pulp and water, concrete mixtures were produced and compared in terms of slump and strength with the conventional concrete. The concrete specimens were tested in three series of test as compression test, splitting tensile test and flexural test. Based on the results they conclude that the slump increased up to 5% replacement of cement, above 5% the slump decreased as the paper pulp content in the concrete mixtures was increased.

The compressive, splitting tensile and flexural strength increased up to 10% addition of waste paper pulp and further increased in waste paper pulp reduces the strengths gradually. The most suitable mix proportion is the 5to 10% replacement of waste paper pulp to cement.

Dr. A. S. Kanaga Lakshmi et. Al. they observed the potential use of both agricultural and industrial wastes namely RHA (Rice Husk Ash) and CD (Copper Dust) as raw material in production of concrete. They perform an experimental investigation on replacement of copper dust and rice husk in cement concrete.

3. Methodology

3.1 Introduction

Marble is a non - foliated metamorphic rock composed of recrystallized carbonate minerals, most commonly calcite or dolomite. Geologists use the term "marble" to refer to metamorphosed limestone; however, stonemasons use the term more broadly to encompass UN metamorphosed limestone. Marble is commonly used for sculpture and as a building material.

3.2 Collections of materials

All materials are collected from marble quarries in Prakasam.

Materials are:
- Cement
- Fine aggregates
- Coarse aggregates
- Water

Waste Marble are collecting from marble estate.

3.2.1 Material testing in laboratory: -

Tests are conducted for materials
- Cement
- Fine aggregate
- Coarse aggregate
- Marble aggregates

Experimental testing for the above materials:
- Fineness of cement
- Specific gravity of cement
- Standard consistency
- Initial setting time
- Final setting time
- Specific gravity of Waste Marble aggregates
- Flakiness index
- Elongation index
- Compaction factor test
- Impact test on Waste Marbles
- Fineness modulus of Waste Marbles
- Specific gravity of Coarse Aggregates
- Impact test on Coarse Aggregates
- Fineness modulus of Coarse Aggregate
- Fineness Modulus of Fine Aggregate

- Bulking of Fine Aggregate
- Crushing strength of (marble and coarse aggregate)

3.2.2 Cement

Cement is a binder, a substance used in construction that sets and hardens and can bind other materials together. The most important types of cement are used as a component in the production of mortar in masonry, and of concrete which is a combination of cement and an aggregate to form a strong building material.

Cements used in construction can be characterized as being either **hydraulic** or **non - hydraulic**, depending upon the ability of the cement to set in the presence of water.

Figure 4: Cement

Portland cement is the most common type of cement in general use around the world, used as a basic ingredient of concrete and most non - speciality grout. It was developed from other types of hydraulic lime in England in the mid - 19th century and usually originates from limestone. It is a fine powder produced by heating materials in a kiln to form what is called clinker, grinding the clinker, and adding small amounts of other materials. Several types of Portland cement are available with the most common being called ordinary Portland cement (OPC) which is grey in colour, but a white Portland cement is also available.

Figure 5: Fineness of cement

Weight of cement taken (w1) = 100g
Weight of residue (w2) = 8gms
Percentage of residue = w2/w1 x 100
= 8/100 x 100 = 8%

Standard Consistency Test

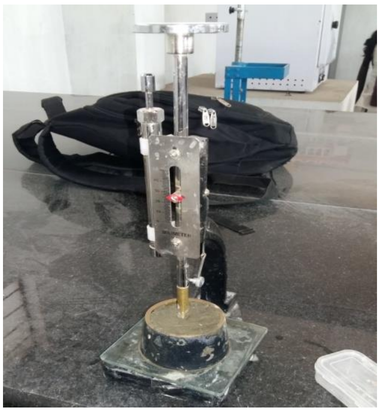

Figure 6: Standard consistency test

For finding out initial setting time, final setting time and soundness of cement, and strength a parameter known as standard consistency has to be used. It is pertinent at this stage to describe the procedure of conducting standard consistency test.

The standard consistency of a cement paste is defined as that consistency which will permit a Vicat plunger having10 mm diameter and 50 mm length to penetrate to a depth of 33 - 35 mm from the top of the mould shown in fig.3. The apparatus is called Vicat Apparatus. This apparatus is used to find out the percentage of water required to produce a cement paste of standard consistency. The standard consistency of the cement paste is some time called normal consistency (CPNC).

The following procedure is adopted to find out standard consistency. Take about 500gms of cement and prepare a paste with a weighed quantity of water (say 24 per cent by weight of cement) for the first trial. The paste must be prepared in a standard manner and filled into the Vicat mould within 3 - 5 minutes. After completely filling the mould, shake the mould to expel air. A standard plunger, 10 mm diameter, 50 mm long is attached and brought down to touch the surface of the paste in the test block and quickly released allowing it to sink into the paste by its own weight.

Take the reading by noting the depth of penetration of the plunger. Conduct a 2nd trial (say with 25 per cent of water) and find out the depth of penetration of plunger. Similarly, conduct trials with higher and higher water/cement ratio still such time the plunger penetrates for a depth of 33 - 35 mm from the top. That particular percentage of water which allows the plunger to penetrate only to a depth of 33 - 35 mm from the top is known as the percentage of water required to produce a cement paste of standard consistency. This percentage is usually denoted as 'P'. The test is required to be conducted in constant temperature (27° + 2°C) and constant humidity (90%).

Initial Setting Time

Lower the needle (C) gently and bring it in contact with the surface of the test block and quickly release. Allow it to penetrate into the test block. In the beginning, the needle will completely pierce through the test block. But after some time when the paste starts losing its plasticity, the needle may penetrate only to a depth of 33 - 35 mm from the top. The period elapsing between the time when water is added to the cement and the time at which the needle penetrates the test block to a depth equal to 33 - 35 mm from the top is taken as initial setting time.

Final Setting Time

Figure 7: Final setting time

Replace the needle (C) of the Vicat apparatus by a circular attachment (F) shown in theFig.5 The cement shall be considered as finally set when, upon, lowering the attachment gently cover the surface of the test block, the centre needle makes an impression, while the circular cutting edge of the attachment fails to do so. In other words, the paste has attained such hardness that the centre needle does not pierce through the paste more than 0.5 mm.

Table 2: Properties of Cement

S. no	Properties	Test Results	IS: 12269 - 1997
1	Normal consistency	32%	31%
2	Initial setting time	130min	Minimum of 30 Min
3	Final setting time	253min	Maximum of 600 Min
4	Specific gravity	3.15	2.85

3.3 Fine Aggregate

The river sand and crushed sand was used in combination as fine aggregate conforming to the requirements of IS: 383. The river sand was washed and screened, to eliminate deleterious material and over size particle. Different tests are conducted to find out the properties of fine aggregate (sand) and for the replacement of stone dust.

Fineness modulus of fine aggregate

Fineness modulus is generally used to get an idea of how coarse or fine the aggregate is, more fineness modulus value indicates that the aggregate is coarser and small value fineness modulus indicates that the aggregate is finer.

Fineness modulus is an empirical factor obtained by adding the cumulative percentages of aggregates retained on each of the standard sieves ranging from 4.75mm to 90 microns. Fineness modulus of different type of sand is as per given below:

Table 3: Different types of sand

Type of sand	Fineness Modulus of Range
Fine Sand	2.2 - 2.6
Medium Sand	2.6 - 2.9
Coarse Sand	2.9 - 3.2

Table 4: Sieve Analysis for Sand

IS Sieve sizes	Weight Retained (g)	Individual Weight retained (gm)	% retained	Cumulative Retained
4.75mm	0.016	99.4	0.016	0.5
2.36mm	0.038	98.2	0.054	1.8
1.18mm	0.16	92.87	0.21	7.13
600microns	1.36	61.7	1.5	38.3
425microns	0.440	47	1.59	53
300microns	0.95	15.4	2.54	84.6
150 microns	0.28	5.8	2.828	94.2
90microns	0.018	5.2	2.846	94.8

Fineness of sand $= \frac{\textbf{sum of cumulative percentage Weight retained}}{\textbf{100}}$

$= \frac{3.743}{100}$

$= 3.743$

Specific Gravity of Fine Aggregate

Figure 8: Specific gravity of sand

Empty weight of pycnometer (W1) = 0.562 kg

Empty weight of pycnometer + 1/3rd height of dry sand (W2) = 1.134 kg

Empty weight of pycnometer+1/3rd height of dry sand + Remaining height of water (W3) = 1.744 kg

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Empty weight of pycnometer +full height water (W4) = 1.392 kg

$$\frac{(w2 - w1)}{(w4 - w1) - (w3 - w2)}$$

$$\frac{(1.134 - 0.562)}{(1.392 - 0.562) - (1.744 - 1.134)}$$

Specific Gravity of Fine Aggregate = 2.6

Bulking of Fine aggregate

The volume increase of fine aggregate due to presence of moisture content is known as bulking. Fine sand bulks more as compared to coarse sand.

The moisture presents in aggregate forms a film around each particle. These films of moisture exert a force, known as surface tension, on each particle. Due to this surface tension each particle gets away from each other. Because of this no direct contact is possible among individual particles and this causes bulking of the volume.

Bulking of aggregate is dependent upon two factors,
Percentage of moisture content.
Particle size of fine aggregate.

Bulking increases with increase in moisture content up to a certain limit and beyond that the further increase in moisture content results in decrease in volume. When the fine aggregate is completely saturated it does not show any bulking. Fine sand bulks more as compared to coarse sand i. e., percentage of bulking is indirectly proportional to the size of particle.

Due to buckling, fine aggregate shows completely unrealistic volume. Therefore, it is absolutely necessary that consideration must be given to the effect of buckling in proportioning the concrete by volume

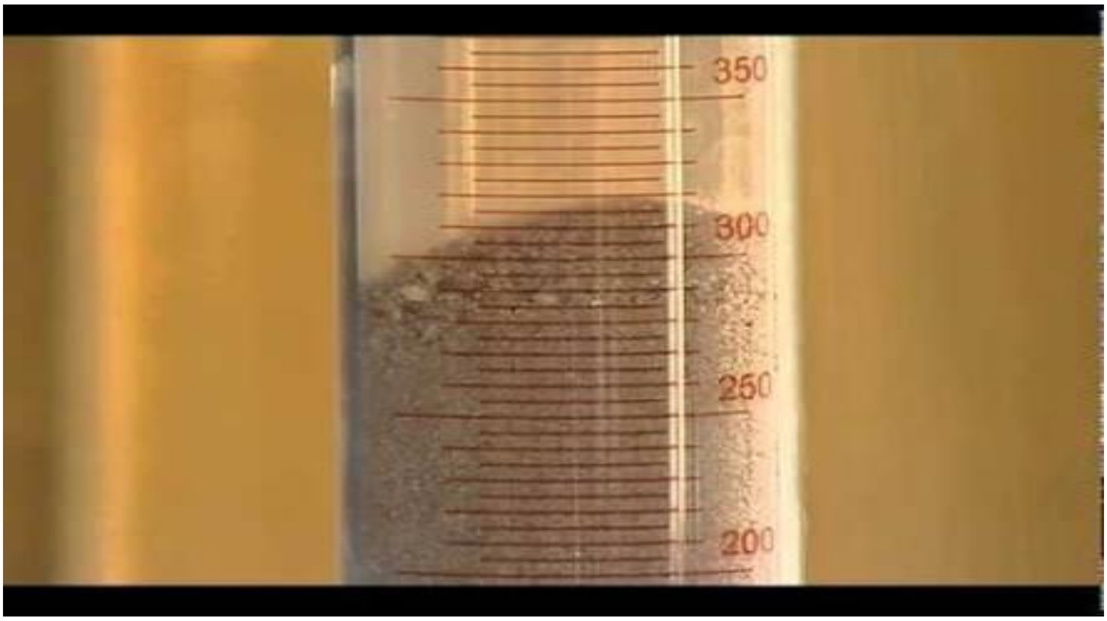


Figure 9: Bulking of sand

S. no	Original height of sand (h1) cm	% of water added	Final height (h2) cm	Increase in height (h2 - h1) cm	Percentage bulking $\frac{(h2-h1)}{h1}$*100
1	9	0	9	0	0
2	9	1	10.2	1.2	13.33
3	9	2	11.2	2.2	24.4
4	9	3	10.7	1.7	18.89
5	9	4	10.2	1.2	13.33
6	9	5	9.7	0.7	7.7
7	9	6	9.2	0.2	2.2
8	9	7	8.7	0.3	3.33

3.4 Aggregates

A crushed granite rock with a maximum size of 12 mm was used as a coarse aggregate. The individual term absorption of the aggregates.

Specific Gravity of Coarse Aggregate

Figure 10: Specific gravity of coarse aggregate

Empty weight of pycnometer (W1) = 0.565kg
Empty weight of pycnometer + 1/3rd height of coarse aggregate (W2) = 1.014kg
Empty weight of pycnometer + 1/3rd height of coarse aggregate +
Remaining height of water (W3) = 1.675kg
Empty weight of pycnometer + total height of water (w4) = 1.388kg

$$\frac{(w2 - w1)}{(w4 - w1) - (w3 - w2)}$$
$$\frac{(1.014 - 0.565)}{(1.388 - 0.565) - (1.675 - 1.014)}$$

Specific Gravity of Coarse Aggregate = 2.88

Specific gravity of waste marbles
Empty weight of pycnometer (W1) = 0.565kg
Empty weight of pycnometer + 1/3rd height of coarse aggregate (W2) =1.014kg
Empty weight of pycnometer + 1/3rd height of coarse aggregate +
Remining height of water (W3) = 1.675kg

Empty weight of bottle + water (W4) =1.388kg

$$\frac{(w2 - w1)}{(w4 - w1) - (w3 - w2)}$$
$$\frac{(1.014 - 0.565)}{(1.388 - 0.565) - (1.675 - 1.014)}$$

Specific Gravity of Coarse Aggregate = 2.88

Aggregate Impact Value
With respect to concrete aggregates, toughness is usually considered the resistance of Material to failure by impact. Several attempts to develop a method of test for aggregates impact value have been made. The most successful is the one in which a sample of standard aggregate kept in a mould is subjected to fifteen blows of a metal hammer of weight 14 Kgs. falling from a height of 38 cms. The quantity of finer material (passing through 2.36 mm) resulting from pounding will indicate the toughness of the sample of aggregate. The ratio of the weight of the fines (finer than 2.36 mm size) formed, to the weight of the total sample taken is expressed as a percentage. This is known as aggregate impact value IS 283 - 1970specifies that aggregate impact value shall not exceed 45 per cent by weight for aggregate used for concrete other than wearing surface and 30 per cent by weight, for concrete for wearing surfaces, such as run ways, roads and pavements.

Figure 11: Impact testing machine

Aggregate impact value (%)	Quality of aggregate
≤10	Exceptionally strong
10 - 20	Strong
20 - 30	Satisfactory for road surfacing
≥ 35	Weak for road surfacing

The impact strength for aggregate = $\frac{\mathbf{WB}}{\mathbf{WA}}$ X 100

Where: -
$\mathbf{W_B}$ is the material passed through 2.36mm sieve
$\mathbf{W_A}$ is the total weight of the material taken.

Impact value for coarse aggregate: -
Weight of mould (w1) =1.814 kg
Weight of mould + weight of aggregate passed through 13.5mm sieve and
Retained on 10mm sieve (w2) =2.446 kg
$\mathbf{W_A}$=$w2 - w1$ = 2.446 - 1.814
= 0.632 gms.
Weight of aggregate passed through 2.36mm sieve after compaction ($\mathbf{w_B}$) = 0.058gms
$\frac{\mathbf{WB}}{\mathbf{WA}}$ **X** 100 = $\frac{0.058}{0.632}$ X 100
= 9.2%

Impact value for waste marbles: -
Weight of mould (w1) =1.814 kg
Weight of mould + weight of aggregate passed through 13.5mm sieve and
Retained on 10mm sieve (w2) =2.468 kg
$\mathbf{w_A}$=$w2 - w1$ = 2.468 - 1.814
= 0.654 gms.

Weight of aggregate passed through 2.36mm sieve after compaction ($\mathbf{w_B}$) = 0.082 gms
$\frac{\mathbf{WB}}{\mathbf{WA}}$ X 100 = $\frac{0.082}{0.654}$ X 100
= 12.5%

Fineness modulus of coarse aggregate
A crushed granite rock with a maximum size of 12 mm was used as a coarse aggregate. The individual term absorption of the aggregates

Sieve Size	Weight retained (kg)	Individual weight Retained	Cumulative% Weight retained (x)	Cumulative% Passing (100 - x)
80 mm	_	-	-	100
40 mm	_	0	0	100
20 mm	3.040	3.040	60.8	39.2
16mm	1.390	4.43	88.6	11.4
13.2 mm	0.408	4.838	96.76	3.24
10 mm	0.128	4.966	99.32	0.68
6.3 micron	_	4.966	99.32	0.68
4.75 micron	_	4.966	99.32	0.68

Fineness modulus of coarse aggregate: -

$$\frac{sum\ of\ cumulative\ percentage\ weight\ retained}{100}$$

$\frac{544.12}{100}$= 5.44

Fineness modulus of waste marbles

sieve size	Weight retained (kg)	Individual weight Retained	Cumulative% Weight retained (x)	Cumulative% Passing (100 - x)
80 mm	_	-	-	100
40 mm	_	0	0	100
20 mm	1.24	1.24	62	38
16mm	0.55	1.79	89.5	10.5
13.2 mm	0.174	1.964	98.2	1.8
10 mm	0.026	1.99	99.5	0.5
6.3 micron	_	1.96	98	2
4.75 micron	_	1.96	98	2

Fineness modulus of waste marbles: -

$$\frac{sum\ of\ cumulative\ percentage\ weighe\ retained}{100}$$

$\frac{545.2}{100}$ = 5.452

3.5 Mixing

3.5.1 Mix Ratio

We are using the grade of concrete is M25

Table 6: Mixing proportion

Grade	Proportion	w/c ratio	Slump
M25	1: 1: 2	0.4; 0.45; 0.5	True; shear; collapse

Material calculation:

0% coarse aggregates replacing
Cement = 6.33kgs
Sand = 6.33kgs
Aggregates = 12.66kgs

25% coarse aggregates replacing
Cement = 6.33kgs
Sand = 6.33kgs
Aggregates = 3.126kgs
Marble aggregates = 9.495kgs

50% coarse aggregates replacing
Cement = 6.33kgs
Sand = 6.33kgs
Aggregates = 6.33kgs
Marble aggregates = 6.33kgs

75% coarse aggregates replacing
Cement = 6.33kgs
Sand = 6.33kgs
Aggregates = 9.495kgs
Marble aggregates = 3.126kgs

100% coarse aggregates replacing
Cement = 6.33kgs
Sand = 6.33kgs
Aggregates = 0kgs
Marble aggregates = 12.66kgs

Total quantities of materials used:
Total cement quantity = 31.65kgs
Total sand quantity = 31.65kgs
Total aggregate quantity = 31.611kgs
Total Marble aggregates quantity = 31.581kgs

3.5.1.1 Mixing

Thorough mixing of the materials is essential for the production of uniform concrete. The mixing should ensure that the mass becomes homogeneous, uniform in colour and consistency. There are two methods adopted for mixing concrete:

- Hand mixing
- Machine mixing

We are choosing the hand mixing

Figure 12: Mixing of concrete

3.5.1.2 Hand Mixing

Hand Mixing: Hand mixing is practised for small scale unimportant concrete works. As the mixing cannot be thorough and efficient, it is desirable to add 10 per cent more cement to cater for the inferior concrete produced by this method. Hand mixing should be done over an impervious concrete or brick floor of sufficiently large size to take one bag of cement. Spread out the measured quantity of coarse aggregate and fine aggregate in alternate layers. Pour the cement on the top of it, and mix them dry by shovel, turning the mixture over and over again until uniformity of colour is achieved. This uniform mixture is spread out in thickness of about 20 cm. Water is taken in a water - can fitted with a rose - head and sprinkled over the mixture and simultaneously turned over. This operation is continued till such time a good uniform, homogeneous concrete is obtained. It's of particular importance to see that the water is not poured but it is only sprinkled. Water in small quantity should be added towards the end of the mixing to get the just required consistency. At that stage, even a small quantity of water makes difference.

3.5.1.3 Measurement of Workability

It is discussed earlier that workability of concrete is a complex property. Just as it eludes all precise definition, it also eludes precise measurements. Numerous attempts have been made by many research workers to quantitatively measure this important and vital property of concrete. But none of these methods are satisfactory for precisely measuring or expressing this property to bring out its full meaning. Some of the tests measure the parameters very close to workability and provide useful information. The following tests are commonly employed to measure workability.

- Slump Test
- Compacting Factor Test

3.5.1.4 Slump Test:

Figure 13: Slump test

The result for the slump test of the fresh concrete is shown in Figure 5. The slumps obtained are in the medium range (35– 70mm). The highest slump was obtained with concrete made with river gravel. River gravel has a relatively smooth surface and round in shape, being water - worn due to the action of running water and thereby enhanced the workability of fresh concrete. This aggregate requires less amount of paste to coat its surface and thereby leave more paste for lubrication so that interactions between aggregate particles during mixing are minimized (Mindless, Young, and Darwin, 2003). Quartzite and granite aggregates are crushed from rock fragments and this gives the aggregate a characteristic rough and fairly angular in shape. Aggregate of this nature requires more amount of water when used for concrete work to provide for aggregate coating and lubrication (ACI Committee 211.1 - 91). The concrete containing crushed quartzite and granite aggregates therefore shows lower workability compared to concrete made with river gravel.

Table 7: Slump test results

Test no	% of marble aggregates	Slump value (mm)	Type of slump
1	0% marble aggregates	70	Shear slump
2	25% marble aggregates	15	True Slump
3	50% marble aggregates	10	True slump
4	75% marble aggregates	75	Shear slump
5	100% marble aggregates	92	Shear slump

3.5.1.5 Compacting Factor Test:

The compacting factor test is designed primarily for use in the laboratory but it can also be used in the field. It is more precise and sensitive than the slump test and is particularly useful for concrete mixes of very low workability as are normally used when concrete is to be compacted by vibration. Such dry concrete is insensitive to slump test. The compacting factor test has been developed at the Road Research Laboratory U. K and it is claimed that it is one of the most efficient tests for measuring the workability of concrete. This test works on the principle of determining the degree of compaction achieved by a standard amount of work done by allowing the concrete to fall through a standard height. The degree of compaction, called the compacting factor is measured by the density ratio i. e., the ratio of the density actually achieved in the test to density of same concrete fully compacted.

The sample of concrete to be tested is placed in the upper hopper up to the brim. The trap - door is opened so that the concrete falls into the lower hopper. Then the trap - door of the lower hopper is opened and the concrete is allowed to fall into the cylinder. In the case of a dry - mix, it is likely that the concrete may not fall on opening the trap - door. In such a case, a slight poking by a rod may be required to set the concrete in motion. The excess concrete remaining above the top level of the cylinder is then cut off with the help of plane blade supplied with the apparatus. The outside of the cylinder is wiped clean. The concrete is filled up exactly up to the top level of the cylinder. It is weighed to the nearest 10 grams. This weight is known as "Weight of partially compacted concrete". The cylinder is emptied and then refilled with the concrete from the same sample in layers approximately 5 cm deep. The layers are heavily rammed or preferably vibrated so as to obtain full compaction. The top surface of the fully compacted concrete is then carefully struck off level with the top of the cylinder and weighed to the nearest 10 gm. This weight is known as "Weight of fully compacted concrete".

The Compacting Factor = Weight of partially compacted concrete

The weight of fully compacted concrete

Figure 14: Compaction factor test

Can also be calculated by knowing the proportion of materials, their respective specific gravities, and the volume of the cylinder. It is seen from experience, that it makes very little difference in compacting factor value, whether the weight of fully compacted concrete is calculated theoretically or found out actually after 100 per cent compaction. It can be realized that the compacting factor test measures the inherent characteristics of the concrete which relates very close to the workability requirements of concrete and as such it is one of the good tests to depict the workability of concrete. Weight of fully compacted concrete

Table 8: Compaction factor results for different ratios

Test No.	Ratio	Compaction Value
Test – 1	For 0%marbles & 100% aggregate	0.945
Test – 2	For 25%marbles & 75% aggregate	0.962
Test – 3	For 50%marbles & 50% aggregate	0.984
Test – 4	For 75%marbles & 25% aggregate	0.987
Test – 5	For 100%marbles & 0% aggregate	0.996

3.6 Casting of Cubes

After the sample has been mixed, immediately fill the cube moulds and compact the concrete, either by hand or by vibration. Any air trapped in the concrete will reduce the strength of the cube. Hence, the cubes must be fully compacted. However, care must also be taken not to over compact the concrete as this may cause segregation of the aggregates and cement paste in the mix. This may also reduce the final compressive strength.

3.6.1 Hand Compaction:

Hand Compaction: Hand compaction of concrete is adopted in case of unimportant concrete work of small magnitude. Sometimes, this method is also applied in such situation, where a large quantity of reinforcement is used, which cannot be normally compacted by mechanical means. Hand compaction consists of Roding, ramming or tamping. When hand compaction is adopted, the consistency of concrete is maintained at a higher level. The thickness of the layer of concrete is limited to about 15 to 20 cm. Roding is nothing but poking the concrete with about 2 metre long, 16 mm diameter rod to pack the concrete between the reinforcement and sharp corners and edges. Roding is done continuously over the complete area to effectively pack the concrete and drive away entrapped air. Sometimes, instead of iron rod, bamboos or cane is also used for rodding purpose. Ramming should be done with care. Light ramming can be permitted in unreinforced foundation concrete or in ground floor construction. Ramming should not be permitted in case of reinforced concrete or in the upper floor construction, where concrete is placed in the formwork supported on struts. If ramming is adopted in the above case the position of the reinforcement may be disturbed or the formwork may fail, particularly, if steel rammer issued.

Figure 15: Compacting the concrete in the cube mould (For 150 mm cube at least 25 tamps per layer)

Tamping is one of the usual methods adopted in compacting roof or floor slab or road pavements where the thickness of concrete is comparatively less and the surface to be finished smooth and level. Tamping consists of beating the top surface by wooden cross beam of section about 10 x 10 cm. Since the tamping bar is sufficiently long it not only compacts, but also levels the top surface across the entire width.

Figure 16: Finishing and casting cubes

3.6.2 Precautions to be taken while making of Cubes

While finishing off the surface of the concrete, if the mould is too full, the excess concrete should not be removed by scraping off the top surface as this takes off the cement paste that has come to the top and leaves the concrete short of cement. The correct way is to use a corner of the trowel and dig out a fair sample of the concrete as a whole, and then finish the surface by towelling.

Once a specimen has been compacted, it should not be left standing on the same bench as another specimen that is being compacted. If this is done, some vibration will be passed on to the first specimen and it will be more compacted than the other. In extreme cases some re - arranging of the particles may result and segregation will occur.

Figure 17: Removing the cubes

Table 9: Different % of M. A replacement and no of cubes casting

Marble aggregates Replacement	0%	25%	50%	75%	100%
No of cubes	3	3	3	3	3

3.6.3 Curing Of Cubes

Curing is the process in which the concrete is protected from loss of moisture and kept within a reasonable temperature range. The result of this process is increased strength and decreased permeability. Curing is also a key player in mitigating cracks in the concrete, which severely impacts durability.

Figure 18: Curing of cubes

3.7 Compressive Strength of Cubes:

Compressive Strengths the capacity of a material or structure to withstand loads tending to reduce size, as opposed to tensile strength, which withstands loads tending to elongate. In other words, compressive strength resists compression (being pushed together), whereas tensile strength resists tension (being pulled apart). In the study of strength, tensile strength, compressive strength, and shear strength can be analyzed independently.

Compressive strength can be measured by plotting applied force against deformation in a testing machine, such as a universal testing machine.

Some materials fracture at their compressive strength limit; others deform irreversibly, so a given amount of deformation may be considered as the limit for compressive load. Compressive strength is a key value for design of structures. Measuring the compressive strength of a steel drum.

Figure 19: Compression testing machine

Compressive strength is often measured on a universal testing machine; these range from very small table - top systems to ones with over 53 MNcapacity. Measurements of compressive strength are affected by the specific test method and conditions of measurement. Compressive strengths are usually reported in relationship to a specific technical standard.

When a specimen of material is loaded in such a way that it extends it is said to be in tension. On the other hand, if the material compresses and shortens it is said to be in compression.

On an atomic level, the molecules or atoms are forced apart when in tension whereas in compression they are forced together. Since atoms in solids always try to find an equilibrium position, and distance between other atoms, forces arise throughout the entire material which oppose either tension or compression. The phenomena prevailing on an atomic level are therefore similar.

The "strain" is the relative change in length under applied stress; positive strain characterises an object under tension load which tends to lengthen it, and a compressive stress that shortens an object gives negative strain. Tension tends to pull small sideways deflections back into alignment, while compression tends to amplify such deflection into buckling. Compressive strength is measured on materials, components, and structures.

By definition, the ultimate compressive strength of a material is that value of uniaxial compressive stress reached when the material fails completely. The compressive strength is usually obtained experimentally by means of a compressive test. The apparatus used for this experiment is the same as that used in a tensile test. However, rather than applying a uniaxial tensile load, a uniaxial compressive load is applied. As can be imagined, the specimen (usually cylindrical) is shortened as well as spread laterally. A Stress–strain curve is plotted by the instrument and would look similar to the following:

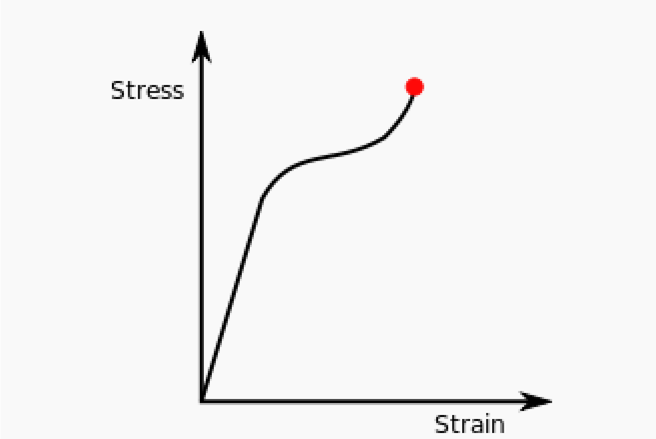


Figure 20: True Stress - Strain curve for a typical specimen

The compressive strength of the material would correspond to the stress at the red point shown on the curve. In a compression test, there is a linear region where the material follows Hooke's Law. Hence for this region $\sigma = E\epsilon$ where this time E refers to the Young's Modulus for compression. In this region, the material deforms elastically and returns to its original length when the stress is removed.

This linear region terminates at what is known as the yield point. Above this point the material behaves plastically and will not return to its original length once the load is removed.

There is a difference between the engineering stress and the true stress. By its basic definition the uniaxial stress is given by:

$$\sigma = \frac{F}{A}$$

Where, F = Load applied [KN],
A = Area [mm^2]

Figure 21: Testing of cubes

Table 10: Compression test results

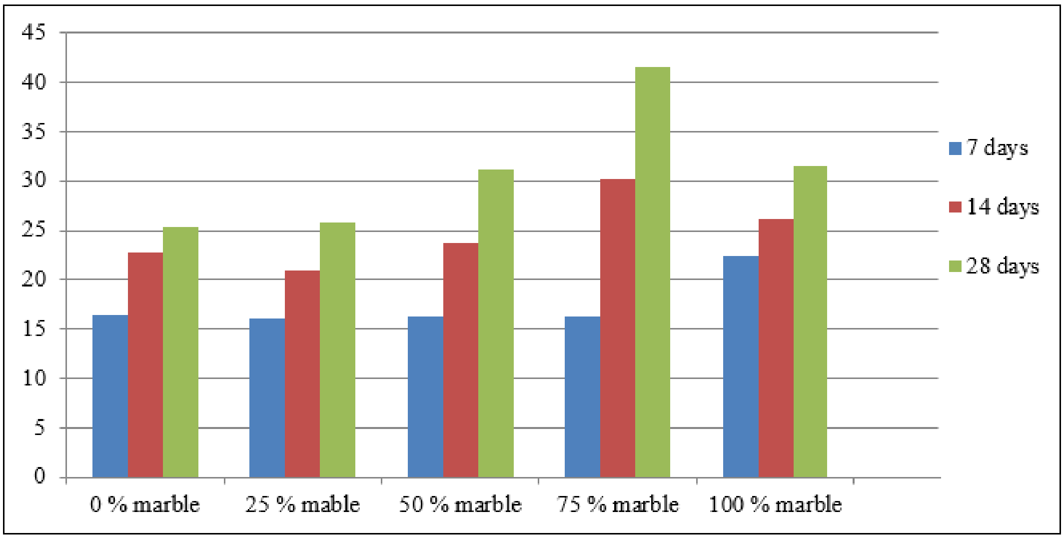
Marble aggregates Replacement	0%	25%	50%	75%	100%
No of cubes	3	3	3	3	3
Compressive strength of cubes (N/mm2)	7 days: 16.4 14days: 22.67 28 days: 25.3	7 days: 16.05 14 days: 20.91 28 days: 25.79	7 days: 16.2 14 days: 23.7 28 days: 31.20	7 days: 16.30 14 days: 30.27 28 days: 41.51	7 days: 22.37 14 days: 26.20 28 days: 31.53

4. Results

4.1 Results

Compression test results

0% replacement of marble aggregates compressive strength[at]7 days 16.4 N/mm2
0% replacement of marble aggregates compressive strength[at]14 days 22.67 N/mm2
0% replacement of marble aggregates compressive strength[at]28 days 25.3 N/mm2
25% replacement of marble aggregates compressive strength[at]7 days 16.05 N/mm2
25% replacement of marble aggregates compressive strength[at]14 days 20.91 N/mm2
25% replacement of marble aggregates compressive strength[at]28 days 25.79N/mm2
50% replacement of marble aggregates compressive strength[at]7 days 16.2 N/mm2
50% replacement of marble aggregates compressive strength[at]14 days 23.7 N/mm2
50% replacement of marble aggregates compressive strength[at]28 days 31.20 N/mm2
75% replacement of marble aggregates compressive strength[at]7 days 16.30 N/mm2
75% replacement of marble aggregates compressive strength[at]14 days 30.27 N/mm2
75% replacement of marble aggregates compressive strength[at]28 days 41.51 N/mm2
100% replacement of marble aggregates compressive strength[at]7 days 22.37 N/mm2
100% replacement of marble aggregates compressive strength[at]7 days 26.20 N/mm2
100% replacement ofmarble aggregates compressive strength[at]28 days 31.53 N/mm2



Graph 1: Compression strength vs different % with bar chart

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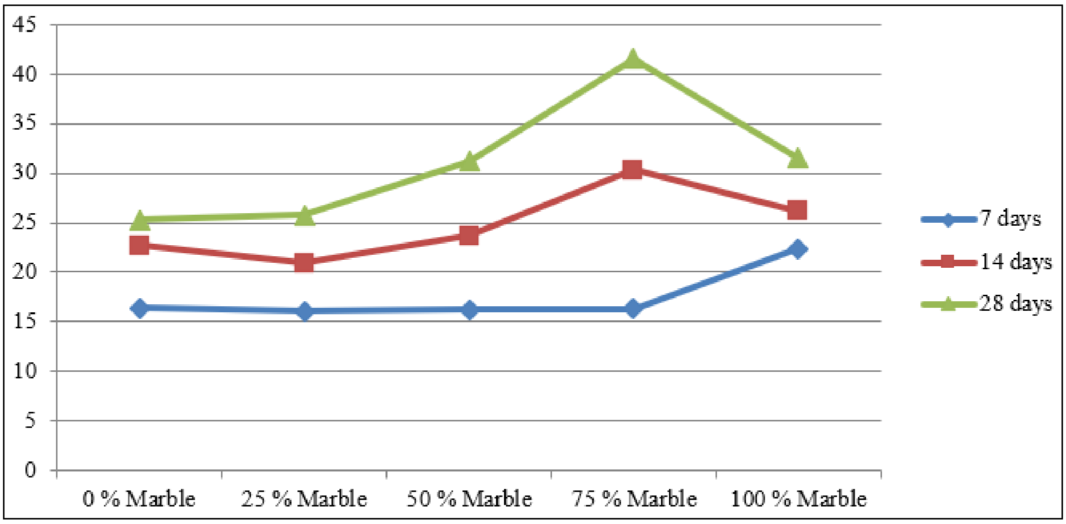

Graph 2: Compression strength vs different %

5. Conclusion

This research is an experimental approach to substitute natural aggregates by the waste marble aggregates; the concern is more scientific than economical and environmental. The results obtained demonstrated the performance of various concrete mixtures which may help to understand the behaviour of these marble aggregates. Therefore, the orientation of this research has shown that setting certain parameters has identified the best percentage of substitution for each type of aggregate. From our project we have obtained the maximum compressive and tensile values for 50 % replacement of aggregate with marble. Analysis of these results has revealed that the appropriate incorporation of marble waste aggregates can lead to interesting characteristics in terms of strength, indeed the use of marble aggregates resulted in a considerable increase in the compressive and tensile strength. The enhancement in resistance is very significant for 25%, 50%, 75%and 100% of substitution. The concrete workability can be improved by the correct quantity of water and the correct proportioning and grading of the ‘‘sand” and the ‘‘gravel” which can provide practical formulations. The marble waste can be used as alternative aggregates for concrete and for many other purposes such as bricks manufacturing, road construction and landfills.

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