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EXPERIMENTAL INVESTIGATION OF BENDING BEHAVIOR OF RC BEAM REINFORCED WITH BRAIDED ARAMID FRP BAR & PARTIAL REPLACEMENT OF CERAMIC WASTE POWDER FOR CEMENT

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ABSTRACT - *Concrete has been proved to be aleading construction material for more than a century. This paper deals with the bending behavior of RC beams strengthened with aramid fiber reinforced plastic (AFRP) reinforcing bars. The newly developed AFRP reinforcing bars were woven in the shape of braid and then were impregnated in a thermosetting resin. The braided-bars provide better mechanical bond to the surrounding concrete. The newly developed AFRP reinforcing bars were woven in the shape of braid and then were impregnated in a thermo setting resin. The braided-AFRP reinforcing bars in diameter of 13mm is 24.2% higher than that of RC beam reinforced with an equivalent area of deformed steel bars. Construction and Demolition (C&D) wastes contribute the highest percentage of wastes worldwide (75%). Furthermore, ceramic materials contribute the highest percentage of wastes within the C&D wastes (54%). The results proved that temperatures used in the manufacturing of these tiles (about 900^{0}C) are sufficient to activate pozzolanic properties of clay. They also showed that, after optimization (11-14% substitution); the cement blend performs better, with no morphological difference between the cement blended with ceramic waste, and that blended with other pozzolanic materials.*

Key Words: Braided Aramid FRP bar, Ceramic Wastepowder, compression test, Split tensile test, Flexural test.

1. INTRODUCTION

Concrete is the most important component used in the construction industry. Due to the increasing demand for cement, ceramic powder is used as a partial replacement for cement. Ceramic waste is one of the most active research areas that encompass a number of disciplines including civil engineering and construction materials.

FRP materials have been used in concrete structures for alternative of conventional steel reinforcements. FRP is an excellent choice for strengthening due to high strength and stiffness, higher ratio of strength to weight, inherent resistance to corrosion and non-magnetism. Fiber composites, such as carbon fibers having inherent higher strength and higher modulus, have been widely used in industries as vehicle, railways, aerospace, shipbuilding and construction. The demand of construction materials for project is increasing. Therefore there is a need to explore alternative building materials from industrial waste materials that can be recycled. Ceramic tiles are often discarded as waste after defined as useless. But it can be recycled and can be used as a construction material in present world which is seeking for alternative construction materials which are economical, environment friendly as well as provides same quality as that of a normal aggregate made of regular aggregates. Ceramic wastes can be used safely with no need for dramatic change in production and application process.

1.1 OBJECTIVES OF STUDY

This study is conducted to achieve the following objectives:

1. To study the bending behavior of aramid bars using for reinforcement steel bars.
2. To study the properties of industrial wastes and their suitability in the concrete.
3. To study the behavior as well as properties of concrete in fresh and harden state.
4. To find the optimum proportion(10%, 15%, 20%) of ceramic waste powder that can be used as a replacement substitute material for cement in concrete
5. To determine the mechanical properties such as compressive strength, split tensile strength, flexural strength of concrete with ceramic waste powder as partial replacement material of cement.

1.2.SCOPE OF STUDY

1. Flexural Strength of structural members can be improved.
2. Proper usage of waste materials from environment can be made.
3. Basic strength characteristics, such as Compressive strength, Flexural strength, Tensile strength, Density and durability studies of concrete are the main focuses in this project in order to study the quality and performance of concrete.

2. LITERATURE REVIEW

The usage of industrial by-products especially industrial wastes in making of concrete is an important study of worldwide interest. Many researchers have investigated the possible use of braided aramid FRP bar, Ceramic Tiles Waste powder For this investigation, some of the important literatures were reviewed and presented briefly.

2.1. BRAIDED ARAMID FRP BAR

Fei Yan, Zhibin Lin, Mijia Yang (2016): Althoughmuch research has showed that different factors respond for the different bond performance of GFRP bars in concrete and accordingly yield the different bond strength, current design codes cannot accurately account for the bond strength with respect to transverse reinforcement. On the other hand, several models have been developed to construct the bond stress-slip relations and each of them may be derived under certain assumptions. So far, no unified model is available that can be applied to general bond behavior of GFRP bar. Thus it is necessary to review the existing bond models and their applicability, for assisting engineers to select desirable models.

Dr. G. Nandini Devi (2015): Fiber-reinforcedpolymer (FRP) rebar won't rust or corrode, so it's ideal for periodic or long-term immersion in fresh water or brine in applications such as retaining walls, piers, jetties, quays, caissons, decks, pilings, bulkheads, canals, offshore platforms, swimming pools and aquariums. It's also immune to road salt and other deicing chemicals, making it a more durable and less maintenance-intensive choice for roadways and bridges, parking structures, airport runways, Jersey barriers, retaining walls and foundations, curbs, parapets, and slabs on grade. The tensile strength of FRP rebar is typically 1.5 to 2 times higher than steel, so it's a good counterbalance to concrete's high compressive strength. It also provides excellent fatigue resistance, making it suitable for cyclic loading situations (such those on roads and bridges).

David Tse Chuen Johnson (2014): Anexperimental program was conducted consisting of24 large-scale beams reinforced with various types of GFRP and steel bars complying with CSA certification standards. The results of which show that the stress in the bent bar stirrups at beam failure exceeded minimum code-prescribed values for design (CSA S6, CSA S806, ACI440). An alternative bend-less system of shear reinforcement using straight double headed bars was successful as shear reinforcement but did however result in significant reductions to member deformability. A critical review of the various design provisions incorporating GFRP shear reinforcement, it was found that many of the design codes use conservative shear reinforcement strengths coupled with un conservative values of either the angle of inclination of the compression strut or the concrete contribution to shear resistance.

Saptarshi Sasmal, Balthasar Novák, K. Ramanjaneyulu, Constanze Roehm, V. Srinivas, N. Lakshmanan, Nagesh R. Iyer (2011): In the study, twotypes of FRP viz., braided aramid and pre-formed glass-aramid were used. It was reported that flexural strength and ductility were enhanced by the use of FRP confinement. Geng et and Mosallam used composite overlays to strengthen simple models of beam–column joints and reported increase in the strength, stiffness, and ductility of the specimens. Mosallam brought out the effectiveness of polymer composites for retrofit and up gradation of reinforced concrete joints subjected to seismic loading. Pantelides studied the behaviour of RC bridge bents strengthened using CFRP sheets in the cap beam–column joints under quasi-static lateral load. It was observed that the composite wrap increased the shear capacity of the joints by almost 35%. Tsonos and Stylianidis performed a simulated seismic load test of an exterior joint model strengthened with FRP. Considerable increase in strength, energy dissipation and stiffness characteristics compared to the control (un strengthened) specimen were observed. Gergely tested a series of scaled exterior beam–column joints strengthened with CFRP sheets. Main variables in this investigation were the concrete surface preparation and the fiber orientation. It was concluded that FRP composites provided a viable solution in improving the shear capacity of exterior RC joints.

2.2 CERAMIC WASTE POWDER

Dr.M.Swaroopa Rani (2016): Ceramic waste maycome from two sources. The first source is the ceramics industry, and this waste is classified as non-hazardous industrial waste (NHIW). According to the Integrated National Plan on Waste 2008-2015, NHIW is all waste generated by industrial activity which is not classified as hazardous in Order MAM/304/2002, of the 8th February, in accordance with the European List of Waste (ELW) and identified according to the following codes:10 Waste from thermal processes.10 12 Waste from the manufacture of ceramic products, bricks, roof tiles and construction materials.10 12 08 Ceramic, brick, roof tile and construction materials waste (fired).

Hardik Patel, Dr. N.K. Arora (2015): Indianceramic production is 100 Million ton per year. In the ceramic industry, about 15% -30% waste material generated from the total production. This waste is not recycled in any form at present. However, the ceramic waste is durable, hard and highly resistant to biological, chemical, and physical degradation forces. The Ceramic industries are dumping the powder in any nearby pit or vacant spaces, near their unit although notified areas have been marked for dumping. This leads to serious environmental and dust pollution and occupation of a vast area of land, especially after the powder dries up so it is necessary to dispose the Ceramic waste quickly and use in the construction industry. As the ceramic waste is piling up every day, there is a pressure on ceramic industries to find a solution for its disposal. The advancement of concrete technology can reduce the consumption of natural resources. They have forced to focus on recovery, reuse of natural resources and find other alternatives. The use of the replacement materials offer cost reduction, energy savings, arguably superior products, and fewer hazards in the environment.

Qu Shuying, Zheng Bin, Sun Chen and Li Jin (2014): In the study of ceramic waste instead of fineaggregate, pieces of ceramic waste are always reprocessed firstly, which will be polished to become the fine aggregate as the particle with maximum size of 4mm. Spanish Hanifi Binici [21] and V. Lopez [22], using different substitution rate of 40% ~ 60% and 10% ~ 50% did mechanics experiment respectively, their experimental conclusion showed: In wear resistance, workability and resistance of the chloride ion penetration, the concrete group of substitution is better than traditional concrete, and with the increase of replacement ratio, the compressive strength increased, and was higher than that of conventional concrete. At present, the research on ceramic concrete of domestic scholars is not much, and the beginning of reusing research is relatively late. The gap of current technology exist between our country and the international advanced countries, mainly on the utilization of waste products.

D. Tavakoli, A. Heidari, and M. Karimian (2013): Moreover, a good strategy to achieve the two purposes of removing the wastage material and also obtaining the positive qualities of concrete. Tile and constructive ceramics are among the most commonly used materials in structures. The global production of ceramic tiles in the world is about 8500 million square meters, this amount is about 400 million square in Iran, which make Iran the fifth ceramic tile producer in the world [4]. This huge amount of productions has caused them to be among the most commonly-consumed materials in the world. Usually, The wastage related to tile, ceramic and sanitary ware are created in different forms some of which are produced in companies during and after production process due to errors in either construction, human activities, and also inappropriate raw materials. Some others are produced in transportation and distribution procedures and finally, the most bulk of them are created as a result of destroying constructions. It is predicted that almost 3 to 7 percent of daily production of ceramic in Europe change into wastage and this amount reaches to millions ton per year. The properties of these materials are in a way that they are unusable in other cycles of production. Therefore, they are useless in practiced and cause damages to environment. All in all, the hard physical structure of these materials and also their chemical structure make them a good and suitable choice to be used in concrete.

2.4 LITERATURE SUMMARY

From all the above literature reviews, it was evident that Braided Aramid FRP bar can be used as a reinforcement replacement, Ceramic Tile waste powder can be used as a cement replacement, individually in a concrete mix.

From the above all reviews it is explained clearly how aramid bar & ceramic waste powder are used and the optimum percentage of replacement is identified in each material replacement and physical & chemical properties are explained.

Hence it is planned to use Ceramic Tile Waste powder as cement replacement, braided aramid FRP bar as reinforcement replacement respectively together as an ingredient of the concrete.

3. MATERIAL USED

The materials used for the project is collected and made sun dried before as initial testing and for further usage. The amount of material to be used should be noted in advance based on the preparation of mix design. From the results of mix design the quantity of each component such as cement, FA, CA and water will be finalized, then the collection of materials to be done and to be stored in a specified place free from impurities. Based on the availability of the materials and its condition the following tests were performed.

3.1 CEMENT

Ordinary Portland cement of 53 grade having specific gravity of 3.1 and fineness modulus of 4.62% was used. The Cement used has been tested for various proportions as per IS 4031-1988 and found to be confirming to various specifications of IS 12269-1987

Table 3.1 Physical Properties of cement

SL. NO.	PROPERTY	VALUE
1	Specific Gravity	3.1
3	Initial Setting Time	45 min
4	Final Setting Time	385 min
5	Fineness Modulus	6%
6	Bulk density (Dense)	1.56 g/ cm^3
7	Bulk density (Loose)	1.16 g/ cm^3

3.2 FINE AGGREGATE

Fine aggregates are termed as "filler" which fills the voids in concrete. The fractions of aggregates less than 4.75mm are known as fine aggregates. The river sand is used as fine aggregate conforming to requirements of IS: 383-1970 comes under zone II.

Table 3.2 Physical Properties of Fine Aggregate

Materials	Specific Gravity	Finess Modulus (%)	Bulk Density (Kg/m^3)	Water Absorption (%)
Fine Aggregate	2.55	3.9	1736.67	1.69

3.3 COARSE AGGREGATE

Aggregates fractions are larger than 4.75mm are termed as coarse aggregates. The fraction of aggregates used in the experimental work passed in 20mm sieve and retained on 10mm IS sieve comes under Zone II aggregates conforming to IS: 383-1970.

Table 3.3 Physical Properties of coarse Aggregate

Materials	Specific Gravity	Finess Modulus (%)	Bulk Density (Kg/m^3)	Water Absorption (%)
Coarse Aggregate	2.71	3.18	1612.67	0.33

3.4 BRAIDED ARAMID FRP BAR

1. FRP materials have been used in concrete structures for alternative of conventional steel reinforcements.
2. FRP is an excellent choice for strengthening due to high strength and stiffness, higher ratio of strength to weight, inherent resistance to corrosion and magnetism.
3. Many researchers currently investigate the Application of glass fiber reinforced plastic (GFRP) reinforcing bars to Aramid fiber-reinforced plastic (AFRP) reinforcing bars may be better choice on higher resistance to alkaline environments and are more economical than CFRP Reinforcing bars.

Fig no 3.1 Braided Aramid FRP bar

Table 3.4 Characteristics of braided –AFRP reinforcing bars

specification	Units	Braided aramid bar		Steel deformed bar
		ARD13	ARD11	
c/s area	mm^2	145.27	95.03	126.68
Unit weight	g/m	184.20	121.30	994.50
Yield stress	N/mm^2	-	-	361.00

3.5. CERAMIC TILE WASTE POWDER

The principle waste coming into the ceramic industry is the ceramic powder, specifically in the powder forms ceramic wastes are generated as a waste during the process.

It is estimated that 15 to 20% waste are produced of total raw material used, and although a portion of this waste may be utilized on-site, such as for excavation pit refill.

The disposals of these waste materials acquire large land areas and remain scattered all around, spoiling the aesthetic of the entire region. Ceramic waste can be used as a partial replacement of cement or as a partial replacement of fine aggregate sand as a supplementary addition to achieve different properties of concrete.

Fig.No.3.2 ceramic tile waste powder

4. TESTING AND RESULT

Experimental Investigation comprises of test on cement, Fine aggregate and Coarse aggregate, concrete with partial replacement of Cement with ceramic tile waste powder, Braided aramid FRP bar replacement of conventional reinforcement.

4.1 MIX DESIGN

The mix proportion was done as per the IS 10262:2009 the target mean strength was 43.25 Mpa (35) for the OPC control mixture. Mix design is a term used for determining quantities of different constituents, which in our experiment was done with Indian standard method. The quantities of cement, fine aggregate, coarse aggregate, Ceramic Tiles Waste powder were found out with help of this method. The proportions for normal mix of M35 Normal Mix were: - Cement: Sand: Coarse Aggregate: Water. After calculating the quantity, all constituents were weighed using electronic weighing machine.

Starts from cement and Ceramic Tiles Waste powder were thoroughly mixed in dry state, fine aggregate were later added to the mixture. To the above mixture coarse aggregate are added. Now the whole mixture was mixed manually. Water was finally added to the dry mixture.

After mixing operation, moulding was done and as the moulds were filled tamping was done simultaneously for compaction. After 24 hours de moulding was done and the specimen was placed in curing tank for 7, 14 and 28 days.

4.2 TESTING

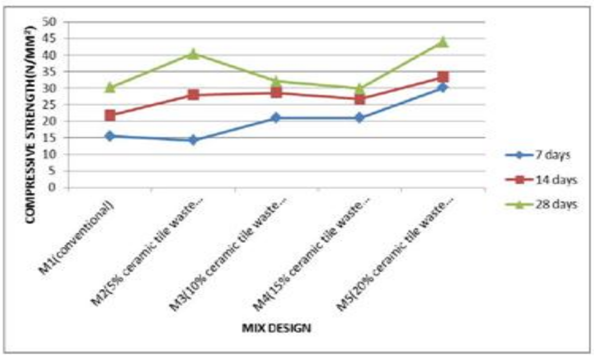
Compressive Strength: To examine the compressiveStandard cubical moulds of size 150mm × 150mm×150mm made of cast iron were used to cast concrete specimens to test compressive strength of concrete.

To determine the compressive strength we casted cubes with different percentage of Ceramic tiles waste powder in the concrete. After that the specimen are tested at 7, 14 and 28 days at compression testing machine (CTM) as per I.S. 516-1959. The optimum percentage of ceramic tiles waste powder was again casted and tested at 7, 14 and 28 days.

Table 4.1: Compressive Strength Result

MIX DESIGN	Compressive Strength (N/mm^2)		
	7 days	14 days	28 days
M1(conventional)	15.52	21.77	30.22
M2(5% CWP)	14.23	28.01	40.45
M3(10% CWP)	21	28.55	32.11
M4(15% CWP)	21.05	26.72	29.88
M5(20% CWP)	30.2	33.40	44

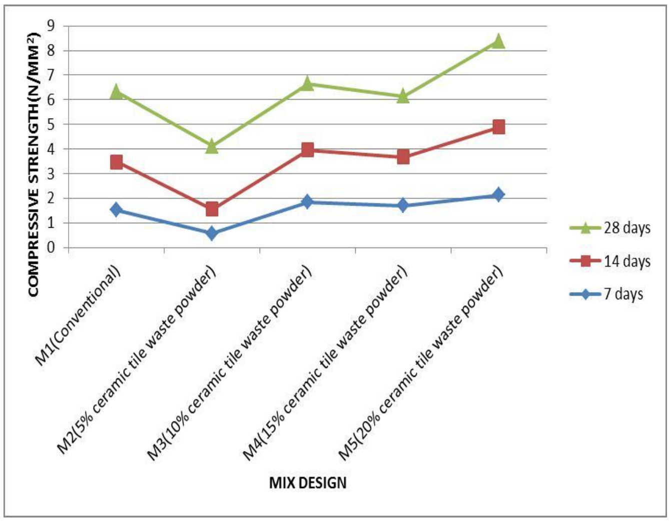
Chart.4.1 Compressive strength result of different % of CWP



- **Split Tensile Strength:**

To examine the split tensile strength of plane mortar and mortar of various percentages of steel slag and crushed pebbles stones contents in concrete has been investigated by testing cylinders of 300mm x 150mm under CTM of 2000kN capacity.

Chart.2 split tensile strength result of different % of CWP



- **Flexural strength**

To determine the flexural strength of the beam of mould size 150mm×150mm×1000mm. the beam is under reinforced in which two numbers of 13mm dia aramid bar at bottom, 2 numbers of 12mm dia steel bars at top, 8mm dia stirrups are placed at 150mm centre to centre.

5. CONCLUSION

Based on the results of the laboratory tests, the following conclusions can be drawn:

1. The compressive strength & split tensile strength increases by replacing the cement at optimum percentage of (20%) ceramic tile waste powder.

2. The ultimate moment of RC beam reinforced with two braided-AFRP reinforcing bars in diameter of 13mm is 24.2% higher than that of RC beam reinforced with an equivalent area of mild steel deformed bar.

3. The flexural strength of the AFRP reinforced beam at 28 days is on process.

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