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Experimental Study on Reactive Powder Concrete Replacing Aggregates with Industrial Waste

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ABSTRACT: To develop a Green Concrete for utilizing the available copper slag (Industrial Waste) to replace the river sand in concrete and to achieve ultra-high strength and high durability which will minimize the cost of construction material and produce High Strength Concrete, which even reduces the size and volume of the member used and the depth of the horizontal members can be reduced. Different materials such as Silica Fume, Fumed Silica and Quartz Powder have been added in various percentages. Here fine aggregate is totally replaced by an Industrial waste (Copper Slag) which is a by Product. Also that, Coarse Aggregate is completely neglected thus making a concrete comprising of only fine particles, which improves the matrix properties by addition of pozzolanic admixtures like silica fume. Thus granular mixture is optimised which enhances the compacted density. Due to these fine particles voids can be reduced to a greater extent. The various mix proportions are to be tried to achieve the exact percentage variations of the materials to be used. From the selected trial mixes mechanical and chemical properties of the optimized mix are to be carried out. These tests were carried out according to IS Codes. The aim of this study is to find the suitability of Reactive powder concrete. The first step of this project is to characterize the material property of RPC mix. Suggested by CSIR-SERC, Chennai, was taken into consideration for preparing the RPC mix. In addition, the mechanical property of the RPC structural components prepared from the recommended mix proportion was studied. The characteristics of the material to be used is studied, properties and chemical composition of the material is studied and the tests are carried out for materials to be used in concrete. The second phase involves the compression test on cubes, flexural strength test, split tensile strength, Rapid chloride permeability test and Acid resistance test are to be studied experimentally.

KEYWORDS: Copper slag, Micro steel fiber, Compressive strength, durability, Tensile, Deflection

I. INTRODUCTION

At present, across the world around 33 tons of slag is generated while in India three copper producers namely Sterlite, Birla Copper and Hindustan Copper produce around 66.5 tonnes of slag at different sites. Used copper slag is the largest source of waste from shipyards and refineries. A single copper industry produces 4 lakh ton/year of copper and during the process, around 8 lakh ton of copper slag is generated in a year, for every ton of a metal, 2.2 tons of slag is obtained. The copper is being produced from a copper concentrate containing around 30 - 35% of copper, iron and sulphur each along with around 12% of silica and 5% of calcium. While producing copper the anode, a slag with rich iron and moderate silica content is also generated. In copper industry about 30% production goes as waste, which is not being recycled at present making it a viable alternative to be used as a coarse aggregate. Use of hazardous industrial wastes in concrete-making will lead to a greener environment. Current options of management of this slag are Sand Blasting, recycling, recovering of metal, Replacement of sand as a fine aggregate, production of value added products and disposal in slag dumps or stockpiles.

A fine, glass powder recovered from the gases of burning coal during the production of electricity is fly ash. These micron sized earth elements consist primarily of silica, alumina and iron. The combustion of powdered coal in thermal power plants produces fly ash. The high temperature of burning coal turns the clay minerals present in the coal powder into fused fine particles mainly comprising of aluminium silicate. Fly ash produced thus possesses both ceramic and pozzolanic properties. When pulverized coal is burnt to generate heat, the residue contains 80 percent fly ash and 20 percent bottom ash. The ash is carried away by flue gas collected at economizer, air pre-heater and ESP hopper.

II LITERATURE REVIEW

Davoud Tavakoli., in 2013 studied and investigated the simultaneous use of nano-SiO₂ and silica fume in concrete. In order to such a purpose, silica fume in measures of 5 and 10 percent and nano-SiO₂ in measures of 0.5 and 1 percent were replaced with cement and totally eight mixture plans for doing the compressive strength and water absorption experiments. Finally, the results showed that using such materials improves the qualities of concrete. Test results showed that Silica fume and nano-SiO₂ can lead to the improvement of concrete strength.

Dr. A. Jagannathan., Mr.Iyappan., in 2014 studied replacement of Nano silica. There was three different replacement percentages of Nano silica (0%, 2%, 4%, 6%) is used in the study. Use of 2% Nano silica in SCC, it increased the compressive strength, flexural strength, Split tensile strength about 11.93%,10.51%,13.09% respectively. Use of 4% Nano silica in SCC, it increased the compressive strength, flexural strength, Split tensile strength about 18.88%,16.01%,23% respectively. But the use of 6% of nano silica in SCC, it decreased the compressive strength, flexural strength, split tensile strength 0.4%,1.29%,14.4% compared with 4% addition of Nano silica in SC respectively.

Jitendra Patil., and Dr. Umesh Pendharkar., in 2016 studied the significance of nanomaterial for construction industry is emphasized and reviews of redevelopments and present state of the application of nano alumina, nano titanium dioxide, nano zinc oxide and nano-silica for sustainable development of concrete industry. The test results obtained are, Compressive strength of Cement by using nano Alumina as cement replacement 10 % is reduced by 27.27% for 7 days samples as compare to normal 53 grade cement. Compressive strength of Cement by using nano Titania as cement replacement 10 % is reduced by 45.45 % for 7 days' samples as compare to normal 53 grade cement. Compressive strength of Cement by using nano Silica as cement replacement 10 % is reduced by 66.67 % for 7 days' samples as compare to normal 53 grade cement.

Khadiranaikar R.B., and Murali S. M., in 2012 studied Reactive Powder Concrete (RPC) is an ultra-high strength and high ductile composite material with advanced mechanical properties. The test results obtained are, during the production process, it was found that an extended mixing time up to 20-30 min. is required to obtain a consistent and homogeneous mix. The maximum compressive strength of RPC obtained in the present study is 146 MPa at w/b ratio of 0.2 with accelerated curing. In the production of RP the optimum percentage addition of silica fume is found to be 15% (by weight of cement) with available super-plasticizer. The addition of quartz powder increased the compressive strength of RPC up to 20%. The high temperature curing is essential for RPC to achieve higher strength It increased the compressive strength up to 10% when compared with normal curing.

A.A. Maghsoudi., in 2010. This paper investigates the effect of nano-silica as an addition on new concrete generation called self-consolidating concrete, (SCC) and high strength SCC. The results were compared with SCC specimens without nano-silica addition. In order to investigate the development on the microstructure of SCCS, the scanning electron microscopy (SEM) imaging on specimens were also performed. The test results obtained are, the higher rate of strength gain from 28 to 90 days at curing condition, "W" may be due to rapid drying and crystallisation of lime in the pore structure of concrete. Overall, SCC mixes containing nano-silica showed better hardened properties than mixes without nano-silica. The addition of nano-silica in SCC mixes, consisting of micro silica causes to increase the compressive, flexural strength and modulus of elasticity up to the age of 90 days.

Rajkumar R., in 2016. In this paper an attempt has been made to improve the strength characteristics of concrete with the addition of Nano-silica which not only acts as a filler to improve the microstructure but also as an activator to promote pozzolanic reaction thereby resulting in the enhancement of the mechanical properties of the concrete mix. It is also cost effective when compared to the life cycle cost of concrete structures. The test results obtained are, With the addition of nS in concrete, several unexplored potentials in the field of concrete technology can be achieved. However, the technology in the conventional concrete has remained rather empirical and there are yet various aspects of concrete behaviour that are beyond our comprehension. The results obtained from 3rd day and 28th day compressive and tensile strength tests prove that the nS concrete attains high initial and final strength compared to the conventional concrete. The percentage increase in strength of nS concrete after 28 days was found out to be 35 for compression and 45 for tensile.

R.Sakthivel., in 2016. Nana-Silica is used as a partial replacement for cement in the range of 2.5%, 3%, and 3.5% for M25 mix. Specimens are casted using Nana-Silica concrete, the test results show that, the compressive strength of concrete initially increased up to 3% of Nana-Silica and with further increase in the Nana-Silica content the compressive strength of concrete decreased. Concrete containing lower percentages (3%) of Nana-Silica possess higher values of compressive strength than that of controlled concrete. A considerable increase in flexural strength and split tensile strength of Nana-Silica concrete was observed compared to controlled concrete. It is concluded that the permeability of concrete decreased with the increase in the percentage of Nana-Silica up to 3% due to the effect of Nana-Silica filling the voids in concrete. The initial and final setting times of cement mortar containing Nana-silica was found to decrease with increase in the replacement percentage. Use of Nana - silica in the concrete reduces the CO₂ emission.

Sanga Kranthi Kumar., in 2015. In this work 40MPa self-compacting concrete is developed using modified Nan-Su method of mix design. Slump flow, J-Ring, V- funnel tests are conducted to justify the fresh properties of SCC and are checked against EFNARC (2005) specifications. The Test results are, there is a steep increase in the compressive strength at 28days of about 45.2% and 41.13% with the addition of 1.5% Nano silica of XLP grade and XTX grade respectively. Hence 1.5% addition of nano silica is said to optimum. The addition of nano silica improves the hydrated structure of concrete. The percentage compressive strength loss is more for 1.5% Nana Silica-XLP and is about 56.02 % and 18.74% with 5% H₂SO₄ and 5% HCl respectively after 28 days of immersion. This may be due to higher pozzalonic content.

Saurav., in 2012. In this paper, application of nanotechnology in building materials for various civil engineering works is discussed. The test samples show that the compressive strength increases with nano-ZrO₂ particles chemical up to 1.0% replacement (N2) and then it decreases, although the results of 2.0% replacement (N4) is still higher than those of the plain cement concrete (CO). It was shown that the use of 2.0% nano-ZrO₂ particles decreased the compressive strength to a value which is near to the control concrete.

Nageh N. Meleka., and Alaa A. Bashandy., in 2013. In this paper, mechanical properties were investigated and evaluated by studying the effects of using different cement and silica fume contents and new steel fibres aspect ratios as reinforcement for this concrete. A compressive strength of about 154MPa, indirect tensile strength of 12MPa, modulus of elasticity of 45GPa and flexural strength of 30MPa have been achieved for reinforced RFC contains 800 kg/m³ cement content and silica fume content 30% of cement weight, The test results are, increasing of the studied properties of the reactive concrete samples at the 28 days results with respect to that of 7 days age was very small except in the case of samples that have no silica fume content it has a positive effect. Increasing silica fume contents improves the compressive strength, modulus of elasticity, tensile strength and flexural strength values at different RPC ages.

Hasan Sahan Arel., in 2016. In this paper, Ultrahigh-performance fibre-reinforced concrete (UHPFRC) is produced by combining various fibres and high-performance concrete (HPC) with a low water/cement (w/c) ratio. The test results are, Under the effect of standard curing, samples produced using SFI display results that are 45.7% lower and 10% lower in comparison to those displayed by samples produced using SF2 and SF3 silica fumes,

respectively. Under all curing conditions, the compressive strength increased by 1.5-2% with increasing fibre content. Sample SF3-1 mm, when subjected to steam curing for 90 days, produces better results in terms of compressive strength (177 MPa) than the other samples.

SREELAKSHMI S., and NIVIN PHILIP., in 2016. This paper described the development of High-Performance Fibre Reinforced Concrete (HPFRC) with very high strength and durability properties. The test results are, by the addition of steel fibres there is up to 12% increased the compressive strength of the specimens- The 1.25% fibre content has given the maximum compressive strength out of the three fibre contents. A considerable increase in Split tensile strength (up to 63%) was observed for the HPFRC. 1.25% content steel fibres shows considerable increase in tensile strength. The maximum value of flexural strength was obtained for 1.25% fibre content. The average weight loss due to sea water attack is more for 1.25% fibre content. Addition of fibres up to 1.25% gives best results in all strength parameters compare to other fibre contents. While 0.75% fibre contents shows better durability properties.

Ki Nam Hong., and Sn Tae Kang., in 2001. This study investigated the material properties of air-cured ultra-high-performance fibre-reinforced concrete (UHPFRC) at early ages. The test results are, the compressive strength and modulus of elasticity of air-cured UHPFRC increased rapidly after 1.25 days, following the concrete casting. Based on the compressive test results, model equations for predicting the compressive strength and modulus of elasticity of UHPFRC at early ages were proposed. The non-notched three-point flexural tests verified that, the flexural strength of UHPFRC manifested rapidly until the age of 3 days, and the strength at 7 days was almost equal to the strength at 28 days. The compressive strength and modulus of elasticity of air-cured UHPFRC were about 64 and 84 respectively, of those of high-temperature-cured UHPFRC, which is a substantial difference depending on the curing method.

Sudarsana Rao.Hunchate., in 2014. This Paper discusses about the production HPC with normal ingredients we use mineral admixtures like Silica fume, fly ash and metakoline and workable agents, Super-plasticizers are also used. The compressive strength is investigating finding the optimum use of mineral admixture Silica fume of levels 0, 5, 10, 15, 20 and 25% at 7 days and 28 days of curing). The present investigation aims to give design mix for HPC by using silica fume and super-plasticizers. As the silica fume content increases the compressive strength increases up to 15% [HPC4] and then decreases. Hence the optimum replacement is 15%. The 7 days and 28 days' cube compressive strength ratio of HPC is 0.84 to 0.9. The percentage replacement of cement by silica fume increases, the workability decreases.

R. Yu., and P. Spiesz., in 2013. This paper addressed the mix design and properties assessment of Ultra-High Performance Fibre Reinforced Concrete (UHPFRC). The design of the concrete mixtures is based on the aim to achieve a densely compacted cementitious matrix, employing the modified Andreasen & Andersen particle packing model. The test results show that, Using the Andreasen & Andersen particle packing model, it is possible to produce a dense and homogeneous skeleton of UHPC using a relatively low binder amount (about 650 kg/m³). In this study, the maximum compressive and flexural strengths at 28 days of the obtained UHPFRC (with steel fibre 2.5 vol.%) are about 150 MPa and 30 MPa, respectively.

Doo-Yeol Yoo et al., in 2015. They investigated the effect of the reinforcement ratio on the flexural behaviour of ultra-high-performance fibre-reinforced concrete (UHPFRC) beams under impact loading, a total of four large-sized (200 x 270 x 2900 mm) beams were fabricated and tested using a drop weight impact test machine. The incident kinetic energy and impact velocity were 4.2 kJ and 5.6 m/s, respectively. A higher reinforcement ratio exhibited lower maximum and residual deflections and better deflection recovery. A nonlinear analytical model for predicting the impact behaviour of a UHPFRC beam was developed using multi-layer sectional analysis and single-degree-of-freedom analysis, and the model was verified through comparison with the experimental results.

Sn-Tae Kang, Jeong-II et al., in 2015. This study experimentally investigated the effect of hybrid combinations of straight 0.2 mm diameter steel fibre and various microfibers on the mechanical properties of UHPC. Four types

of hybrid fibre reinforced UHPCs including steel, basalt fibres, polyvinyl-alcohol, and polyethylene fibre were designed and then compressive strength, density, and tensile behaviour were investigated. Test results showed that combining a synthetic fibre with high strength, such as PE fibre, and steel fibre can improve the tensile behaviour of UHPC and basalt fibre was effective for improving the tensile strength of UHPC.

Luciano Ombres, The performances of plain concrete elements wrapped with PBO (short of Polypara-phenylene-benzo-bisthiazole) fiber meshes embedded into an inorganic stabilized cementitious matrix (Fiber Reinforced Cementitious Mortar, FRCM) are analyzed, both theoretically and experimentally, in the paper. Results of the comparison were presented and discussed in the paper. A simple semi-empirical model to predict axial peak strength and associated axial strain in PBO-FRCM confined concrete is also proposed.

A.M.T. Hassan, et al. In this study, attempts to design a novel testing method to measure the punching shear capacity of the concrete was carried out. The designed test arrangement was employed to carry out an extensive experimental study on UHPFRC slabs subjected to punching shear failure. From the results obtained, the relationship between the punching shear load and the angle of the shear plane, the critical value of the basic control perimeter and failure mode were studied. The experimental study undertaken here provides significant insight into the punching shear capacity of UHPFRC slabs. The results illustrated and highlighted many of the advantages of using UHPFRC compared to normal concrete in structural designs.

S.Sundararaman, S.Azhagarsami in 2013. Experimental investigation was carried out for two different UHPC mixes (Mix 1 and Mix 2) with different water cement ratio of 0.26 and 0.3 respectively. Both the UHPC mix had different values of steel fibre in terms of volume fraction (1%, 1.5% and 2%). At the end of 28 days it was found that the UHPC Mix 1 with water cement ratio of 0.26 showed 31.5% increase in compressive strength for 2% of steel fibre content. Also the UHPC Mix 1 showed a higher split tensile strength of about 6.36Mpa.

C. K. Sridhar, S. B. Vanakudre, explained the use of high performance concrete in present days is increasing as conventional concrete does not meet the requirement. This study aims at developing high performance concrete using Nano silica. Initially, M60 grade concrete (high strength concrete) is designed and prepared with and without Nano silica. Then it is proposed to make this concrete as high performance concrete by using high quality super plasticizer and a better packing of coarse aggregate (40% 10 mm downsize & 60% 20mm down size). The test results showed that slump higher than 210mm, strength 68.44 to 75.11MPa and better resistance to water absorption.

T.Chandra Sekhara Reddy, J.K.Elumalai, studied the macro mechanical properties of ultra-high strength concrete (UHSC) in the recent revolution of concrete. The major difference between ultra-high strength concrete and conventional concrete is that no coarse aggregate is involved in ultra-high strength concrete, but quartz sand, quartz powder is used instead, with high dosage of silica fume. The results showed marked difference in compressive strength ranging from 187 Mpa to 142 Mpa. The samples cured under normal water only produced strength of 116 Mpa with the mix considered. It is observed from the study that quartz powder, quartz sand, duration of temperature affects the compressive strength; hot air temperature curing increased the compressive strength up to 40% nearly when compared with the specimen under normal water curing only.

Swati Choudhary et al., discuss in their paper the focus on High Performance concrete (HPC) has immensely increased due to utilization of large quantity of concrete, thereby leading to the development of infrastructure Viz., Buildings, Industrial Structures, Hydraulic Structures, Bridges and Highways etc. This paper includes the detailed study on the recent developments in High Performance Concrete, stressing more on the earthquake prone areas. It highlights the advantages and importance of High Performance concrete over conventional concrete and includes effect of Mineral and Chemical Admixtures used to improve performance of concrete.



III EXPERIMENTAL PROGRAM

Material Properties

Ordinary Portland Cement : Ordinary Portland Cement (OPC) is the most common type of cement in general usage. It is a key ingredient of concrete, mortar and plaster. It consists of a mixture of oxides of calcium, silicon and aluminium. The Ordinary Portland cement is classified into three grades namely 33, 43 and 53 grade cement depending upon the strength of the cement at 28 days. We have used Cement used in the investigation was 53 grade Ordinary Portland cement.

Quartz Powder : It has a hexagonal crystal structure and is made of trigonal crystallized silica. It is most varied in terms of varieties, colours and forms. The most important distinction between the types of quartz is that one is of macro crystalline. His discoveries states that no matter how distorted a quartz crystal is, the long prism faces always made a perfect 60-degree angle.

Fumed Silica : Fumed silica has a very strong thickening effect. Primary particle size is 5-50 nm. The particles are non-porous and have a surface area of 50-600 m²/g. The density is 160-190 kg/m³. Fumed silica serves as a universal thickening agent and an anticaking agent (free-flow agent) in powders. Like silica gel, it serves as a desiccant.

Silica Fume : Silica fume consists primarily of amorphous (non-crystalline) silicon dioxide (SiO₂). The individual particles are extremely small, approximately 1/100th the size of an average cement particle. Because of its fine particles, large surface area, and the high SiO₂ content, silica fume is a very reactive pozzolana when used in concrete. The quality of silica fume is specified by ASTM C 1240 and AASHTO M 307.

Basalt Fibre : The manufacture of basalt fibre requires the melting of the crushed and washed basalt rock at about 1,500°C (2,730°F). The molten rock is then extruded through small nozzles to produce continuous filaments of basalt fibre. The basalt fibres typically have a filament diameter of between 10 and 20 µm.

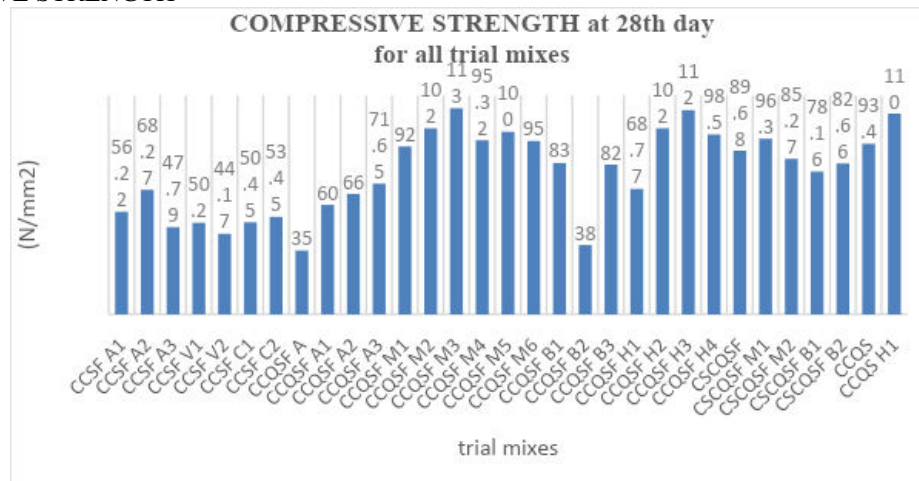
Micro- Steel Fiber : The ultimate tensile strength of the micro steel fibre is 2000MPa and length and diameter are 13 mm and 0.16 mm, respectively. Figure shows the micro steel fibre used in this investigation, various percentages were added in the trial mixes. Table shows the properties of micro-steel fibre used in this investigation.

IV. EXPERIMENTAL RESULTS

Compressive strength

40 x 40 x 40mm cube specimen was prepared for all the trial mixes and is tested at 7, 14, 28th day. Three identical specimen were tested for one batch and the average value of the obtained value is noted. Specimen were placed in the UTM of 1000KN capacity. For the finalised mix, the specimen is casted for 70.6 x 70.6 x 70.6mm and is tested at 7, 14, 28th day. Load is gradually applied on the specimen until the specimen got crack

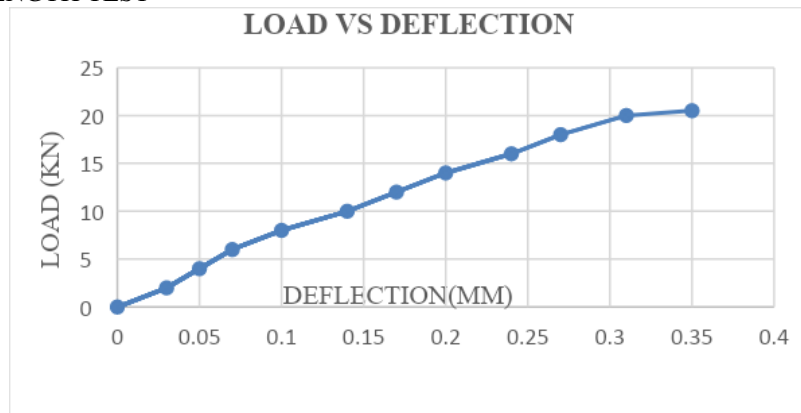
COMPRESSIVE STRENGTH



Flexural strength of Cylinder

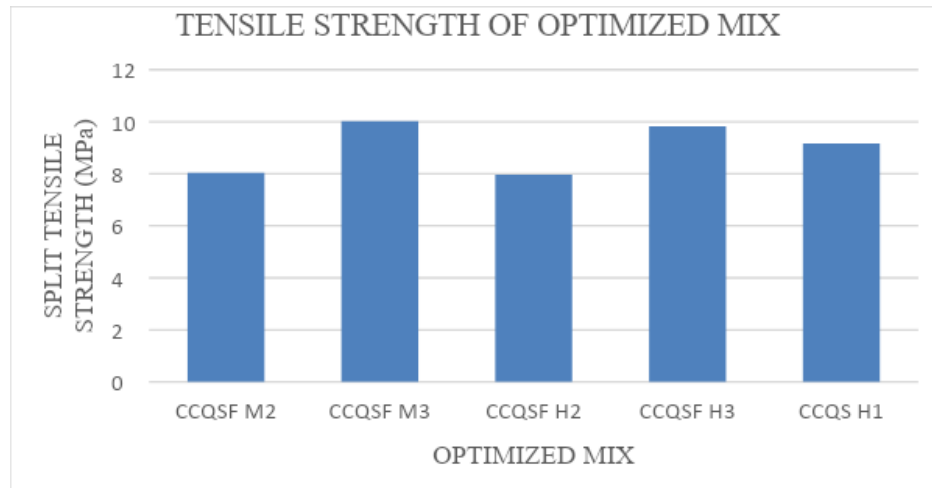
From all the 31 trial mixes compression values, the mixes which gives more than 100MPa MPa at 28th day test are taken for flexural test and the details about the specimen are given below.

FLEXURAL STRENGTH TEST



Split Tensile Strength of beams

The tensile test is carried out in UTM with a cylinder specimen of size 150 x 300mm. These specimens were placed in the UTM and the load is applied to it. The specimen is tested under UTM with capacity of 400KN.



V. CONCLUSION

From the above literatures, it is seemed that the usage of fine aggregate in concrete is reduced only to a certain extent and is not completely avoided. Hence, in this thesis the fine and coarse aggregate is completely neglected and is replaced by Industrial waste to achieve ultra-high strength concrete.

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